Maine Stormwater Best Practices Manual

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Introduction

The use of this manual helps address the following common impacts of development:

- Altered site hydrology
- Increased stormwater runoff
- Increased flooding of rivers and streams
- Warming of water resources by heated runoff
- Reduced ground - water recharge and baseflow to rivers and streams
- Increased pollutant loadings to receiving waters

Mount Katahdin is one of Maine's many natural areas available for recreation and enjoyment. Valuable resources such as these must be protected from the negative impacts of human activities to ensure their availability and use for future generations.

Maine's inland and coastal waterbodies are among the state's most valuable resources and have historically been a source of pride for Maine's residents and visitors. Rivers, streams, lakes, wetlands, and coastal waterbodies complement our natural environment and provide a valuable resource for human use and enjoyment. To ensure that these resources are available for future generations to enjoy, we must collectively cooperate to preserve and protect them from the negative impacts of human activities.

Development opens up stable vegetated landscapes and increases impervious area, which in turn increases the amount and quality of stormwater runoff that leaves an area. The increased runoff contributes to flash flooding and reduces the amount of rainfall that would normally recharge groundwater to maintain baseflows. Development also increases pollutant concentrations in runoff, as pollution associated with development is deposited onto disturbed surfaces and carried by runoff into nearby waterbodies. Such pollutants include sediment, suspended solids, nutrients, pesticides, herbicides, heavy metals, chlorides, hydrocarbons, other organics and bacteria.

EPA has identified stormwater as a major contributor of pollution to surface waters and has established regulations to control its impacts.

Manual Contents:

Volume I: Stormwater Management Manual

Volume II: Phosphorous Design Manual

Volume III: BMPs Technical Design Manual

Regulatory Overview

Since the early 1970's, point sources of discharge (i.e., direct discharges of wastewater from municipal and industrial facilities) have become generally regulated under the National Pollution Discharge Elimination System (NPDES) by the U.S. Environmental Protection Agency (EPA). Since 2003, this program has been administered by the Department of Environmental Protection in Maine.

Point source discharges have measurably improved over the past 30 years, but the continued degradation of waterways led EPA to examine non-point sources of pollution (landscape based runoff, including stormwater). The 1987 Section 319 amendments to the Clean Water Act directed EPA to focus on the contribution of non-point sources of pollution and begin regulation of stormwater.

Section 6217 of the Coastal Zone Act Reauthorization amendments of 1990 calls for states to develop and implement non-point source pollution control plans for the coastal watershed. Other federal efforts to control non-point source pollution include:

- the National Estuary Program (Clean Water Act Section 320),
- Groundwater Protection programs (Safe Drinking Water Act Amendments and others),
- the Wetland Protection Program,
- the NOAA Coastal Zone Management Program (also Section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990), and
- several USDA programs specifically geared towards reducing non-point source pollution from agricultural production.

In addition to the regulatory programs listed above, the 303d Section of the Clean Water Act requires states to develop a '303d' list of all waterbodies that do not meet water quality standards. States are then required to develop a 'TMDL Report' or Total Maximum Daily Load for all waterbodies on the 303d list. A TMDL analyzes the source of the degradation, defines pollution limits and describes a path to achieve compliance with water quality standards. Stormwater is the cause of pollution for many waterbodies on Maine's 303d list. Maine DEP expects the implementation of the BMPs described in this document will help prevent future problems and reverse past degradation.

DEP Urban Streams Program

During its first fifteen years, the MDEP's Biological Monitoring Program primarily monitored the water quality of rivers and streams impacted by point source discharge. More recently, biological monitoring has expanded to include streams impacted by nonpoint source (NPS) pollution. Under this monitoring program, a number of rivers and streams have been identified as impacted by development.

In 2003, MDEP collected biological, physical, and chemical data in four urban streams to better understand the impact of development. In these streams, toxics were rated as the top stressor. Other stressors included degraded in stream habitat, increased sedimentation, and altered hydrology. The urban sources of impairments include: a high percent of impervious surfaces, industrial operations, road runoff, input of winter road sand/road dirt, spills and dumping, CSO input and channelizations.

A full report can be found at: www.state.me.us/dep /blwq/docmonitoring/ stream/index.htm

Objective of This Manual

Maine DEP has developed this manual to provide Professional Engineers, developers and municipalities with information to improve the management of stormwater and its impacts. The manual provides information on selecting, designing and installing **Best Management Practices (BMPs)** for stormwater management in the State of Maine. The manual has three volumes as follows:

Volume I – Stormwater Management Manual
This volume provides general information on the impacts of development, common problems with standard BMP designs and what can be done to control stormwater runoff and associated pollutants. It is intended for the general public, municipalities, watershed groups, developers, engineers and designers.

Volume II – Phosphorus Design Manual
This volume outlines Maine's phosphorus standards, which limit the amount of phosphorus that new development can add to a lake. It also outlines methods for reducing phosphorus loadings to meet the established standards.

Volume III – BMPs Technical Design Manual
This volume provides technical information to assist in the selection and design of BMPs to control stormwater runoff and its impacts.

BMP DEVELOPMENT & PERFORMANCE

The information included in this handbook is drawn from state-of-the-art technology or currently recognized practices cited in recent literature. The purpose of estimating removal efficiencies is to provide both designers and reviewers with consistency in developing stormwater plans. Also, new BMPs may be added as applicable new technologies are developed.

A BMP is a structure or practice designed to minimize the discharge of one or more pollutants to the land surface and their wash-off by stormwater, or to temporarily store or treat urban stormwater runoff to reduce flooding, remove pollutants, and provide other amenities.

Engineers and designers are encouraged to use the information contained in this manual in developing stormwater management programs. All practices should be based on sound engineering and environmental judgment, and should be specifically adapted to the sites to which they are applied. Some technical assistance and services may also be available from the Department of Environmental Protection and the state's Soil and Water Conservation Districts to help prepare and to review stormwater management plans.

This manual is not intended to be an all-inclusive source of information, as stormwater management is an evolving and developing science, and the conditions of each site are unique. New stormwater management methods may be available and the engineer is encouraged to use alternative approaches. However, to provide satisfactory and consistent results, all designers should adhere to the basic principles and guidelines of stormwater management.

Chapter 1
Introduction

Pollution from Stormwater can Cause:

- Destruction of fish, wildlife and aquatic habitats
- Beach closures
- Loss in aesthetic value
- Higher cost for, or loss of, drinking water supply

Stormwater runoff has been identified as a leading cause of pollution to surface water bodies. As precipitation falls onto land, some of it infiltrates into the ground to recharge groundwater, while a portion of it flows across the land (runoff) where it is directly discharged into surface water bodies. As the level of development increases, impervious areas generally increase. With greater imperviousness comes greater stormwater runoff. Pollutants on the land are then carried by the stormwater runoff into nearby surface waters.

Photo courtesy of Center for Water Protection.

Health risks associated with stormwater pollution have forced the closure of many beaches and waterways like the one shown above.

The Maine Department of Environmental Protection (DEP) recognizes the importance of controlling stormwater to preserve the State's natural resources. This manual was developed to assist communities, watershed groups, individuals, engineers and developers in understanding stormwater impacts and to select appropriate Best Management Practices (BMPs) to control stormwater from development in accordance with Maine DEP's Stormwater Management regulations, Chapter 500.

Volume I of this manual provides background information on the effects of urbanization and stormwater runoff and outlines Maine DEP's objectives and some techniques that can be implemented by anyone to control stormwater runoff.

Section Contents:

1.1 Past Stormwater Management Practices

The design of stormwater management has evolved over the last 100 years. The first efforts at controlling stormwater, often previously called "drainage", were made by engineers and farmers with the goal of draining wet areas to make them more useable. While it must have seemed practical at the time, this was the first step in creating the current dilemma of excess stormwater and flooding. In addition fill adding took up flood plain and flood storage volume, pushing flood flows downstream.

As flooding increased, early piped drainage systems simply rerouted runoff 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.

Flood control projects grew in size as the population grew. As development occurred, larger and larger pipes, canals and lined concrete channels were needed to move the water out as quickly as possible.

Under the authority of the Clean Water Act, point sources of pollution such as industrial discharges and municipal waste treatment plants were increasingly more stringently regulated, yet fishable/swimmable water quality goals set in 1972 were not met within the original twenty year timeframe. In the late 1980s, federal and university scientists began to understand the water quality problem that had been created by past drainage engineering and land use practices. 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 clearly recognized that flooding and other water quantity issues such as groundwater declines and losses in stream baseflow are also due to how stormwater is managed.

Urbanization causes changes in the hydrology of an area's:

- Peak flow characteristics,
- Total runoff volume,
- Water quality,
- Aesthetic character of the hydrologic system.
- Drainage areas because of land grading, and
- Base flow.

As urbanization and suburbia spread, major changes in stormwater quantity and quality occur. Developed areas reduce groundwater recharge by dramatically increasing imperviousness. Impervious surfaces prevent water from infiltrating into the groundwater, and cause water to rapidly flow off surfaces, picking up pollutants as it travels to the nearest surface water. The pollutant concentrations in stormwater are also much higher along with the greater volume of runoff.

1.2 Water Quantity

Development interferes with the natural hydrologic cycle. In a natural hydrologic cycle, a portion of the precipitation goes back into the atmosphere through evaporation and transpiration (evapotranspiration); a portion infiltrates into the ground, where it is able to recharge groundwater flows and provide baseflows for streams, and lastly a portion runs off over the surface of the land and is discharged into nearby surface waters. In urbanized areas, these three components still occur but the runoff portion is greatly increased at the expense of the infiltration portion. Figure 1-1 illustrates the effects of development on the water budget.

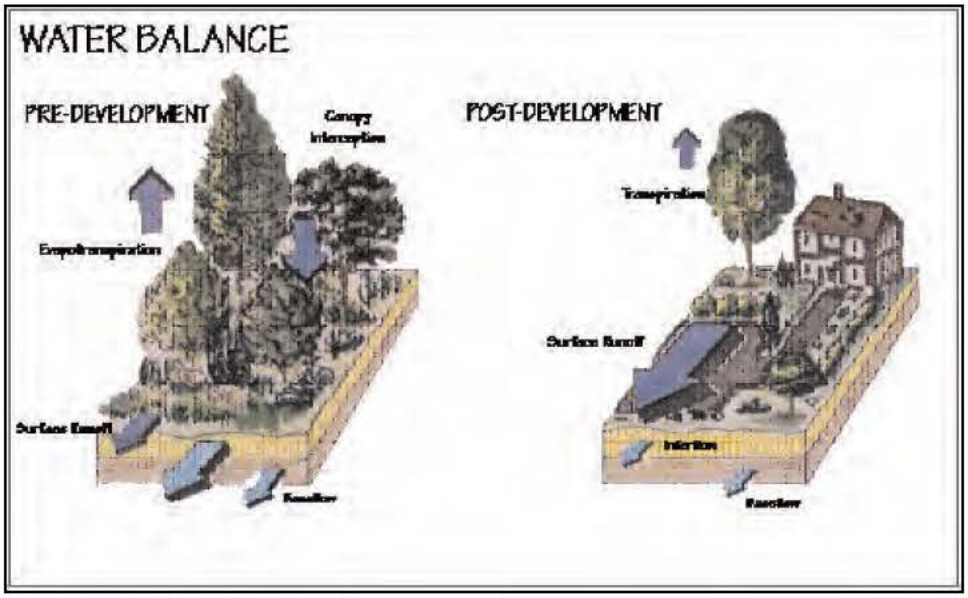


Figure 1-1. Effects of Development on the Water Budget

As the land is covered with impervious surfaces such as roads, buildings, and parking lots, the amount of rainfall that can infiltrate into the soil is reduced, thereby increasing the volume of surface runoff from the watershed. Typical impervious cover percentages are shown in Table 1-1. Impervious surface also reduce evapotranspiration, as the trees and vegetation that contribute to this process are removed and replaced with paved surfaces. Figure 1-2 shows the relationship of runoff, infiltration, and evaporation for watersheds with varying degrees of impervious cover.

Table 1-1
Typical Impervious Area Percentages
(MPCA, 1989 modified by Maine DEP)

LAND USE	% IMPERVIOUS COVER
Business District or Shopping Center	95-100
Residential, High Density (lots 1/2 acre or less)	30-60
Residential, Medium Density (lots less than 3 acres but greater than 1/2 acre)	10-40
Residential, Low Density (lots greater than 3 acres)	8-15
Open Areas	0-5

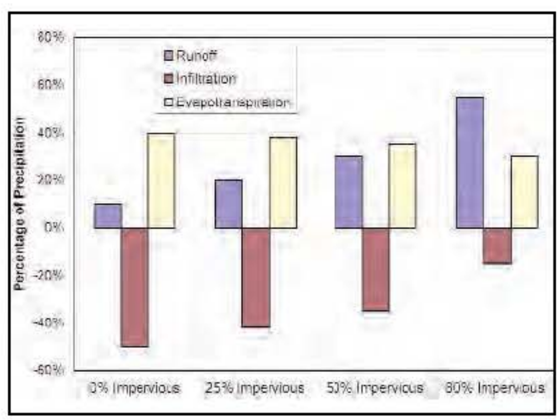


Figure 1-2. Relationship Between Infiltration, Runoff, Evapotranspiration and Imperviousness

As urban areas develop, natural drainage patterns are modified, with runoff channeled into road drainage ditches, storm sewers, and paved channels. These modifications increase the velocity of runoff, which decreases the time required to convey it to the nearest surface water. Greater volumes of water reach streams and rivers faster, resulting in excessive peak volumes and floods. Figure 1-3 shows typical pre- and post-development hydrographs. As shown on the figure, natural pre-development runoff slowly seeps into the ground over a period of days, with slow release to surface waters. The post-development peaks are much higher since the water turns into surface runoff and hits the receiving water body at once.

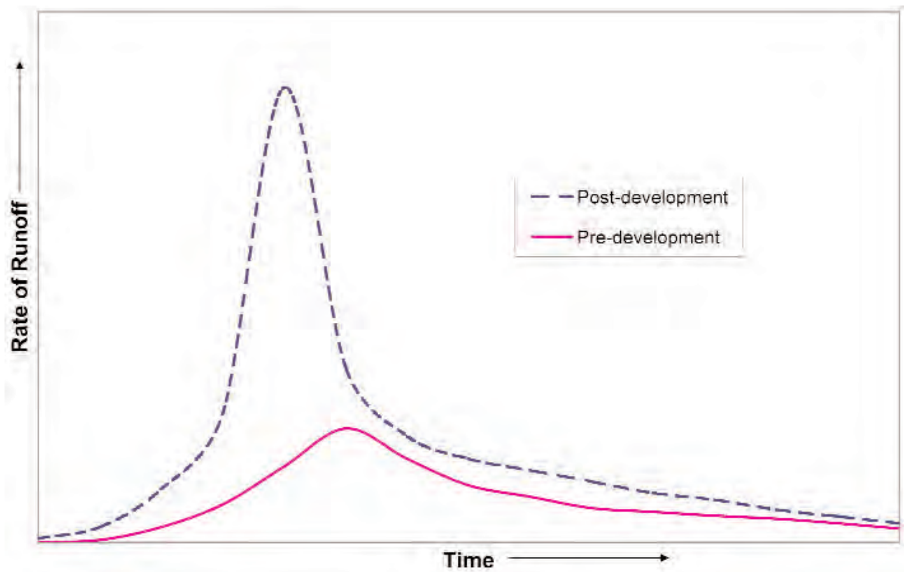


Figure 1-3. Typical Stormwater Runoff Hydrograph Pre and Post Development

Figure 1-4 shows the impacts of development on flooding frequencies. A developed watershed can increase flows from 550 cfs in a forested state to over 3000 cfs in a developed, highly impervious state, a dramatic and frightening increase. Increased streamflows also leads to erosion of natural streambanks and widening of the stream channel to handle the larger flow volumes during frequent storm events. This increases sediment loadings to the streams and exposes plant roots along the banks.

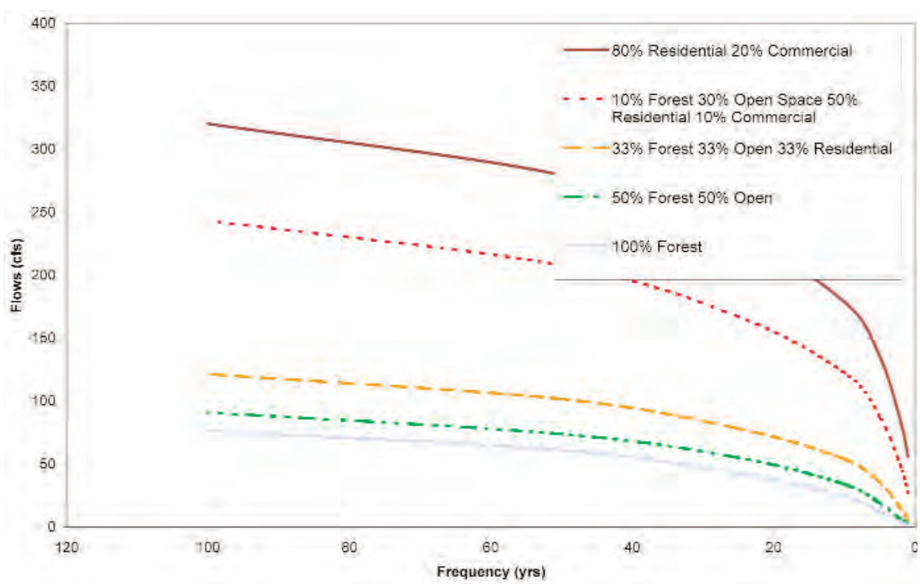


Figure 1-4. Effects of Development on Flooding Magnitude and Frequency

In addition to flooding, increased runoff due to development can tax the hydraulic capacity and stability of downstream channels and structures, and cause the lowering of the groundwater table. The stream channel is exposed to erosive and destabilizing flows much more frequently than under natural conditions, thus resulting in loss of bottom dwelling organisms with longer life cycles that rely on relatively stable habitat. The groundwater table decline can affect the yield of drinking water supplies and also reduces the discharge of clean water to streams (baseflow). Baseflow is needed to maintain streamflows during summer periods, when there is less precipitation. These changes in hydrology, combined with increased pollutant loading, can have a dramatic effect on the aquatic ecosystem in urban streams.

Increased streamflow volumes and velocities associated with urban impacts have resulted in significant erosion of streambanks, as shown here in Bangor, Maine.

1.3 Water Quality

The photo above shows runoff from a developed area entering a municipal storm drain system. If not managed properly, increased runoff can flood local roads and waterways, as the capacity of drainage structures and natural channels are taxed.

Development also impacts the water quality of streams, ponds, lakes and wetlands. As impervious area increases, the volume and velocities of stormwater increase, often resulting in erosion of soils. Pollutant deposits on the land surface also increase as the intensity of land use increases. In a forested or other undeveloped area, many ongoing physical, chemical, and biological processes interact to trap, immobilize, decompose or otherwise alter most of the dissolved and suspended materials found in the runoff. As human land use intensifies, these natural biological and chemical processes are disrupted and pollutants build up as more are added to the land surface (i.e., pesticides, fertilizers, animal wastes, oil, grease, heavy metals). These materials are then washed off by rain and runoff, increasing the pollutant load to receiving waters. Figure 1-5 shows the increase in sediment and phosphorus loadings in agricultural and urban settings compared to a forested setting.

Some of the typical urban pollutants and their impacts are summarized in Table 1-2 and discussed further below.

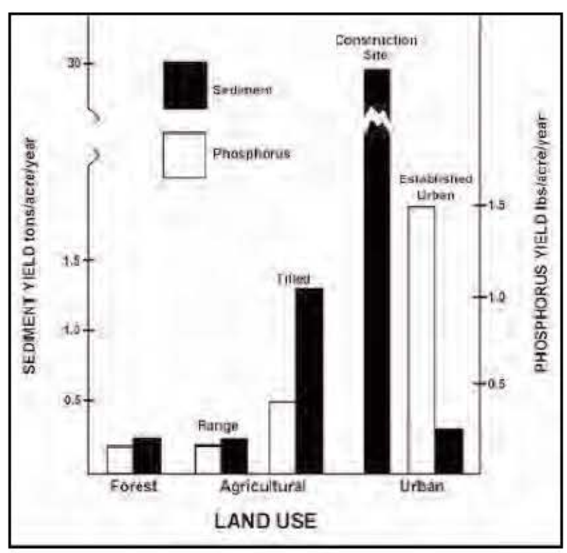


Figure 1-5. Land use affects on the quality of runoff water

Table 1-2. Summary of Urban Non-point Source Pollutants

	Contaminants	Sources	Impacts
Nutrients	• Phosphorus • Nitrogen	• Urban landscape runoff (fertilizers, detergents, plant debris, sediment, dust, gasoline, tieres, septic system effluent) • Agricultural runoff (fertilizers, animal waste)	• Increased algal growth & turbidity • Decreased dissolved oxygen (DO) • Limited recreational values • Reduction of animal habitat
Solids	• Sediment • Floatables	• Construction sites & other disturbed/non-vegetated lands • Road & parking lot sanding • Agricultural lands • Eroding stream banks • Animal waste	• Decreased storage capacity • Destruction of benthic habitat • Interference with animal respiration & digestion • Reduced aesthetic value
Pathogens	• Bacteria • Viruses	• Septic systems • Illicit sewage connections	• Shellfish bed closures • Beach closures • Contamination of drinking water
Thermal Impacts	• Temperature changes from urbanization	• Paved & open areas that absorb heat • Reduction of shade trees • BMPs (shallow ponds and swales	•Reduced sensitive stream insects and fish species
Hydrocarbons	• Oil & grease • Polycyclic aromatic hydrocarbons (PAHs)	• Parking lots & roadways • Spills, Oil leaks & auto emissions • Illicit sewage connections • Illegal dumping of waste oil	• Degraded appearance of water surfaces • Lowered DO • Degradation of fisheries
Toxic Organics	• Pesticides • Polychlorinated biphenyls	• Indoor & outdoor use • Industrial activities • Illicit sewage connections	• Loss of sensitive animal species and fisheries • Reproductive & behaviorial problems from accumulation in food chain
Acids	• Nitrate (NO_3) • Sulfite (SO_2) • Anions HNO_3, HSO_2/H_2SO_4 that form in the air	• Incomplete combustion process coupled with atmospheric reactions (acid rain)	• Loss of sensitive animal species and fisheries • May affect mobility, availability & toxicity of metals & other toxins
Humic Substances	• Plant materials (grass clippings & leaves)	• Urban & surburban landscapes	• Degraded fisheries
Salt	• Sodium • chloride	• Road salt storage areas • Roadway & parking areas	• Loss of sensitive animal species and fisheries • Contaminated surface and ground waters
Metals	• Heavy metals (lead, copper, cadmium, zinc, mercury & chromium)	• Industrial activities & waste • Illicit sewage connections • Asphalt & atmospheric deposition • Automobile wear & exhaust & fluid leaks • Leaching water supply and stormwater delivery systems	• Accumulation in animal tissue that could be ingested by humans

Nutrients

Water quality is largely impacted by nutrient inputs, particularly nitrogen and phosphorus. Phosphorus is typically the primary nutrient of concern in freshwater systems, with nitrogen a secondary concern. Nitrogen is usually more important in saltwater systems. These key nutrients are largely responsible for eutrophication of waterbodies – the gradual increase in nutrient inputs to a waterbody over time, causing excessive plant growth (algae). The increased algal growth can also contribute to greater turbidity and lower dissolved oxygen concentrations, which can promote the release of other substances (pollutants) into the water column. In some cases, algal blooms may occur causing the growth of billions of algae to color the water green and release strong odors as they decay. Phosphorus is readily removed if filtered through soils, as it has a tendency to stick to particles. However, carried by stormwater either in a dissolved form or attached to small particles, it quickly enters the waterbody and accelerates eutrophication.

This waterway is experiencing excessive algae blooms due to nutrient inputs from stormwater.

Solids   Sediment and Floatables

Solid contaminants include sediment and floatable wastes. Large deposits of sediment are often seen with construction sites, where erosion controls are not properly installed. High velocity stormwater easily erodes and picks up sediments from disturbed areas. It also comes from sanding practices and is carried through the storm drain network. Sediment deposits can fill in the waterbody, smother benthic invertebrates, increase turbidity (which in turn affects fish and other organisms), and contribute other pollutants in that many pollutants have a tendency to stick to sediment particles. Floatables are also a concern as they may be collected and deposited into waterbodies from street litter and careless disposal practices.

The best approach to control sedimentation is to implement erosion controls to prevent the production and transport of sediment to waterways. Sediment can also be intercepted in stormwater and allowed to settle.

This parking area contributes sediment to the storm drain network, where it will be carried to the nearest surface water. The sediment contains many pollutants that are deposited through air pollution or directly by cars, as these have a tendency to stick to the sediment particles. Sediments fill in waterbodies, providing a substrate for aquatic weed growth, and can have an adverse effect on fish and other organisms.

Pathogens

Pathogens are responsible for many beach closures, shellfish bed closures and the contamination of drinking water. Pathogens are often associated with storm events, due to bacteria that enters the water course from runoff over land that has deposited pet and livestock wastes, septic overflows, sewer surcharges or exfiltration and wastes from other animals. Testing over the years has shown huge quantities of pathogenic bacteria, viruses and protozoans often rivaling those found in slightly diluted sewage. Pathogens can cause human diseases, including gastroenteritis, giardiaris and cryptosporidiosis, among others. Filtration through soils is generally the best method to remove pathogens from stormwater.

Thermal Impacts

Pavement and other impervious surfaces tend to absorb substantial amounts of heat in summer due to their dark coloring and typically a lack of shade. This heat is transferred to runoff passing over the surface, resulting in runoff that is dramatically warmer than natural groundwater inflow would have been under a natural hydrologic cycle. Some BMPs, such as shallow ponds and swales, can also increase the temperature of runoff before it is discharged, as it is quickly warmed on hot summer days before being discharged. Temperature changes can be stressful and even lethal to many coldwater organisms. A rise in water temperature of just a few degrees Celsius over ambient conditions can reduce or eliminate sensitive stream insects and fish species such as stoneflies, mayflies and trout (Schueler, 1987).

Hydrocarbons

Hydrocarbons are a common contaminant associated with development. They are generally related to transportation in that they are washed off roadways, parking lots and other impervious surfaces after being deposited there by auto emissions, oil leaks and spills. Hydrocarbons are toxic to animal species at low concentrations and can degrade fisheries habitats.

This oil sheen, left by parked vehicles, makes its way towards this catch basin and storm drain network. Without proper treatment, the oil will enter the nearest surface water, where it will degrade fisheries habitats.

Toxic Organics

Toxic organics, such as pesticides and polychlorinated biphenyls (PCBs), may be found in stormwater due to industrial activities and illicit sewage connections. Toxic organics may cause the loss of sensitive animal species and fishery resources, and often accumulate through biomagnification in the food chain causing reproductive and behavioral problems that can ultimately affect human health through ingestion of the fish and animal species.

Acids

Acids may enter stormwater through incomplete combustion processes coupled with atmospheric reactions (acid rain). Acidic contamination can cause loss of sensitive animal species and fishery resources, and may increase the mobility, availability, and toxicity of metals and other toxins.

Humic Substances

Humic substances include decomposing plant materials such as grass clippings and leaves that can be picked up in stormwater and carried into a waterbody. Increased loading of organic materials into water bodies uses oxygen to finish the decomposition of the materials. This lowers dissolved oxygen levels, which can in turn cause the release of other substances (pollutants) into the water column. Oxygen concentrations may ultimately be reduced below levels needed to support aquatic life. These contaminants can degrade fishery resources and reduce fish populations.

Leaves that enter the storm drain network are carried into receiving waters, where they use dissolved oxygen to decompose. Reduced dissolved oxygen levels in the water threaten aquatic life that need the oxygen to live.

Uncovered salt piles can be picked up by runoff and carried to surface waters, where it is toxic to freshwater organisms.

Salt

Salt is often contained in stormwater due to winter salting practices and road salt storage.

Salt is toxic to freshwater organisms and can reduce fishery resources. Salt can also stress plant species. Normal application of salt to roads for deicing is unlikely to create toxic conditions due to elevated chloride levels; however, there have been numerous documented cases of surface and ground water contamination caused by runoff from inadequately protected stockpiles of salt and sand salt mixtures (MPCA, 1989). Contamination of wells due to salt application on roads is well documented.

Metals

Metals are commonly seen in stormwater due to industrial activities, atmospheric deposition and from transportation related activities (i.e., asphalt, automobile wear, exhaust). The most abundant heavy metals in stormwater are lead, zinc and copper, which together account for about 90% of the dissolved heavy metals and 90-98% of the total metal concentrations. Metals increase toxicity of runoff and accumulate in the food chain. Many metals can be removed from stormwater through settling of sediments, as they tend to stick to sediments.

Selected References

MPCA, 1989. *Protecting Water Quality in Urban Areas: Best Management Practices for Minnesota.* Minnesota Pollution Control Agency, Division of Water Quality, St. Paul, Minnesota.

Schueler, T.R. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs.* Metropolitan Washington Council of Governments, Washington, D.C.

Chapter 2
DEP Stormwater Management Objectives

Four Stormwater Management Objectives:

- Effective Pollutant Removal
- Cooling
- Channel Protection
- Flood Control

2.1 Problems with Traditional BMP Designs

The Department recognizes that some of the traditional stormwater management standards that have been applied in the past to new developments, are either inadequate or may actually be causing problems in the resources to which they drain. The current philosophy is now built around insuring that stormwater management systems for new developments meet the following four objectives: effective pollutant removal, cooling, channel protection, and flood control. In some instances, the latter three objectives are not necessary, such as for direct discharges to lakes, large rivers or some tidal waters; but stormwater management systems should always provide effective pollutant removal. These objectives will be discussed in detail later but first we will look at some of the shortcomings of traditional stormwater management.

Failure to Protect Stream Channel Integrity

As urban areas develop, the volume of runoff rises because of the increase in impervious area. Also, natural drainage patterns are modified, with runoff channeled into road drainage ditches or storm sewers. These modifications increase the velocity of runoff and decrease the travel time required for runoff to reach the receiving surface water. Stormwater rises much more rapidly to peak discharges that are much higher, often resulting in higher flood stages in the receiving water.

Figure 2-1 shows typical pre- and post- development hydrographs. The hydrographs represent the flow rates of stormwater discharges from the site before and after development. The area below each hydrograph represents the volume of runoff for that particular storm event. As shown on the figure, both the peak discharge flow rate and volume are lower under natural pre-development conditions since

Section Contents:

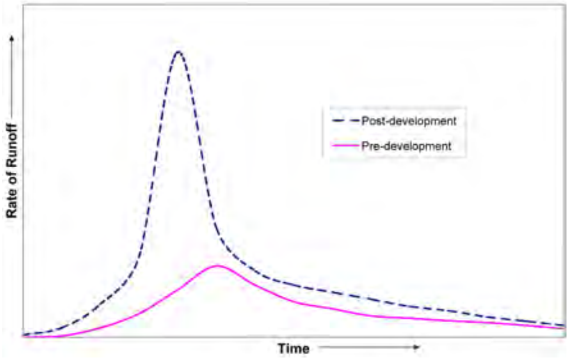


Figure 2-1. Pre and Post Development Hydrographs

stormwater is able to slowly seep into the ground with slow release to surface water over a period of days. The post-development peak flow rate and volume are much higher since the water turns into surface runoff and hits the receiving water body all at once.

As a result, the stream channel experiences higher flows more frequently and for longer durations. These higher velocity flows cause stream banks to erode and the channel to widen. Eroded sediment is deposited in slower downstream reaches. The frequency of these channel disturbances limits the quality of the habitat in the stream channel, especially for organisms with longer life cycles.

Peak flow attenuation, where stormwater is detained so that the post-developed peak flow does not exceed pre-developed peak flow, is the traditional way of dealing with this problem. While it may prevent flooding of downstream infrastructure, traditional peak flow attenuation does little to prevent stream channel degradation and downstream sedimentation, and may even exacerbate it. There are several reasons for this. Peak flow attenuation is usually applied only to relatively infrequent storms (i.e. 2-yr, 10-yr, 25-yr or greater). This type of detention usually has little or no effect on the exaggerated post-development hydrographs from the smaller, more frequent storms (i.e. 3-month, 6-month and 1-yr) that produce flows high enough to cause significant channel degradation. Also, since peak flow attenuation does not reduce the total volume of runoff, the peak flow is sustained over a much longer timeframe and the stream channel is therefore exposed to highly erosive flows for a longer period than it would have been without the peak attenuation. This is illustrated in Figure 2-2, which shows a typical hydrograph for a developed site where peak attenuation controls are used compared with hydrographs for undeveloped and uncontrolled developed sites. In fact, when viewed on a watershed-wide basis, studies have shown that peak attenuation alone can sometimes result in an increase in stream peak flows from pre-developed conditions due to a shift in the timing and duration of the peak flows. Peak controls on several different developed sites that before development were staggered, may cause the truncated peaks to overlap, thus increasing the stream flow. Also, detention of the peak from a developed site low in the watershed may cause it to coincide with the peak streamflow from the upper part of the watershed.

To effectively limit the negative impacts of development on stream morphology and habitat, stormwater management systems must do more than the traditional peak flow attenuation of large, infrequent storms. They must minimize exposure of the stream channel to erosive flows either through extended detention of the discharge or through reduction in the volume of the stormwater discharge for the more frequent, potentially channel shaping storms.

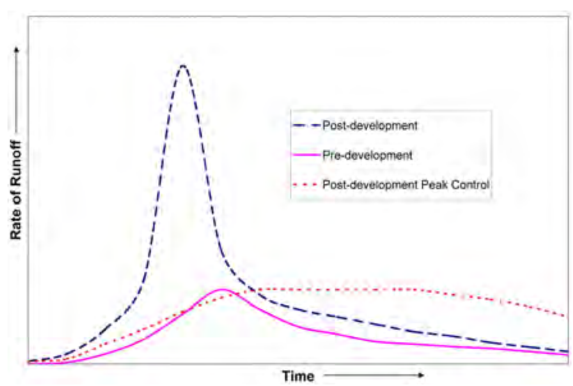


Figure 2-2. Pre and Post Development Hydrographs with Peak Control

Inadequate Pollutant Removal

The principal focus of traditional stormwater management has been avoidance of down-stream flooding, usually involving detention basins that truncate peak flows during large infrequent storms. These detention basins provide little if any pollutant removal because the majority of storm flows pass quickly through with little opportunity for loss of sediment. In Maine, the exception to this has been in lake watersheds where, for several decades, many developers have been required to incorporate measures such as wooded buffers or wet ponds to reduce phosphorus export from the developed site. In most stream and coastal watersheds, the pollutant removal requirements have either been absent or limited to a total suspended solids (TSS) removal requirement that in most situations result in the removal of only coarser, sand-sized particles that are easily removed by short term sedimentation processes. Unfortunately, the majority of nutrients, heavy metals and hydrocarbons in urban stormwater tend to be either dissolved or associated with the finer, silt-sized particles suspended in the stormwater. So, traditional management of stormwater has done little to prevent these pollutants from reaching streams and coastal waters, where they often have harmful effects on the biological communities. These pollutants will be effectively removed and the communities protected only if filtration, infiltration, long term sedimentation and/or biological processes are incorporated in our stormwater management systems

Inadequate Shading

Many of the organisms native to Maine streams cannot tolerate the high summer temperatures common in urban streams. The elevated temperatures are caused by reduced shading in developed riparian areas, warming of stormwater as it runs over hot roofs and pavement, and heating of water stored in stormwater management ponds. Traditional peak reduction outlet structures and simple spillway outlets do nothing to cool the water before discharge. To address this problem, alternative BMPs, such as buffers, infiltration or under-drained filters can be used, or, if ponds are required, under-drained outlet structures can provide effective cooling. Equally important to maintaining cool stream temperature is preservation and/or restoration of riparian trees and shrubs to provide shade.

The natural riparian buffer has been removed from this stream, reducing shade and increasing the temperature of the stream. Many native organisms cannot tolerate these higher temperatures.

Lack of Maintenance

Stormwater treatment units, also known as Best Management Practices or BMPs, can work well as long as they are maintained appropriately. Maintenance is a key criteria that needs to be incorporated into every BMP design and the maintenance burden needs to be as small as possible to ensure success of the BMP. In Maine's cold weather climate, sanding and salting of roads, driveways and parking lots is common practice and significantly increases the sediment loading to BMPs. If BMPs are not sized adequately to hold these sediments and to allow ease of maintenance, the BMP may fail prematurely. As a general rule of thumb, vegetated BMPs should be designed for no more than annual maintenance, or spring and fall. Anything else is likely too demanding for most owners/municipalities.

Additionally, some BMPs such as underground parking lot infiltration units may be designed with a bypass feature in the case of failure. This allows water to pass through the system untreated, without any outside indication that the system is failing. The end result is a greater maintenance burden and cost on the owner or significant water quality impacts, or more likely, both. Instead of a bypass for failure, BMPs should cause flooding or some other indication that they need attention.

Systems need to be designed with realistic maintenance goals (i.e., annual maintenance) and must be easily accessible for inspection and maintenance activities.

These culverts are preceded by a small detention area, which has filled in with sediment due to lack of maintenance. As a result, sediment is transported from this area further downstream during storms events. Improvements to increase the detention area could easily be made, however, periodic maintenance is crucial to the performance of the BMP.

Failures and Replacement

All drainage structures will eventually fail, even if religiously maintained and cared for. Although some types of BMPs, for example detention basins, may not need outright replacement, excavating and disposing of the sediments once it is completely full can be costly and difficult.

Underground parking lot units are particularly susceptible to unseen failure. Because they are not visible and sometimes not even readily accessible, they may quickly fail if not maintained. They are also expensive for the site owner to replace. Without maintenance, most will probably be useless within a few months or a year, with stormwater from the parking lot left to discharge completely untreated. Pretreatment and maintenance are essential to extend the life of a BMP.

Subsurface detention and infiltration galleries, where feasible, 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.

2.2 The Four Stormwater Management Objectives

The department has reviewed past stormwater management requirements and practices and has identified the following objectives as necessary for most stormwater management systems: effective pollutant removal, cooling, channel protection and flood control. These objectives may be met either directly by providing BMPs that manage and treat the runoff after it has been created, or indirectly by incorporating low impact development site planning concepts to minimize production and contamination of runoff by maximizing infiltration and evapotranspiration.

Traditional wet ponds like this one collect heated runoff from paved surfaces and allow it to heat up further in the hot sun before being discharged to a nearby stream. The incorporation of a principal spillway that discharges through an under drained gravel trench will provide adequate cooling of the stormwater before discharging and slower release of stormwater, while offering better pollutant removal efficiencies. The pond can also be designed to control peak flows, meeting all four of Maine DEP's objectives.

Effective Pollutant Removal
In order to deliver effective pollutant removal stormwater management systems should provide the following:

- Site planning and operation that minimizes contamination of stormwater;
- Stormwater treatment BMPs that effectively remove the fine particles that carry much of the nutrient and heavy metal load;
- Stormwater treatment BMPs that remove dissolved pollutants (phosphorus and metals); and
- Stormwater treatment BMPs that remove hydrocarbons.

Since all surface waters are vulnerable to the potential harmful effects of stormwater pollution, and most are vulnerable to sedimentation, effective pollutant removal is necessary everywhere, regardless of the receiving water.

Cooling
Unless the receiving water is a lake, major river or tidal water, stormwater management systems should either incorporate strategies to avoid heating of the stormwater or to effectively cool it down (22°C or cooler). These systems should incorporate the following:

- Site planning and operation that minimizes impervious areas, maximizes shading, and minimizes ponding;
- BMP systems that provide some cooling of runoff from hot pavement and roofs; and
- Pond principal spillways that discharge through under-drained gravel trenches or provide for some other means of cooling.

Channel Protection
Unless the receiving water is a lake, major river or tidal water, stormwater management systems should either incorporate strategies that minimize the magnitude and duration of enhanced stormwater discharge from the site to avoid destabilization and resulting sedimentation of receiving stream channels. These systems should incorporate the following:

- Site planning and operation that minimizes the volume and rate of discharge of stormwater by minimizing impervious area, maximizing infiltration and evapotranspiration, and maximizing time of concentration of storm flows; and

- BMP systems that provide storage and slow release of not only the very large, infrequent storms, but, more importantly, the relatively frequent moderate sized storms that happen several times each year and have the potential to cause significant stream channel erosion and destabilization.

Flood Control
For some projects, the traditional flood control detention for very large, infrequent storms will still be necessary to avoid flooding of downstream infrastructure. Such control is generally unnecessary when projects discharge directly to large bodies of water such as lakes, major rivers or tidal waters. It also may be unnecessary, and actually harmful, in developments near the bottom of a stream's watershed where detention to control peak flow may hold up the peak long enough so that it can coincide with the peak from the upper watershed, thus exacerbating rather than avoiding flooding. There is no existing rule of thumb or easy answer to evaluate whether an individual flood control project will help or hurt the downstream flooding situation. A comprehensive analysis of the contributing watershed and the detention structures contained within would be the most accurate analysis of downstream impacts, but requires a significant amount of information to generate.

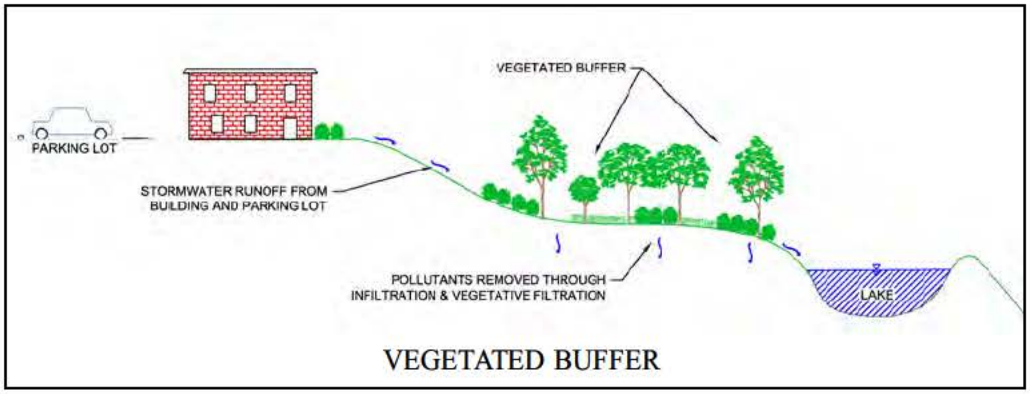
2.3 BMPs to Achieve Objectives

DEP is recommending four types of BMPs that if sized appropriately, will provide effective pollutant removal, cooling and channel protection. In some instances they may also provide flood control benefits without the need for a pond structure. A brief introduction to these BMP types is provided below, with details on their application and construction provided in Volume III. An alternative stormwater management system may be used if it will provide equivalent pollutant removal, cooling and channel protection.

Vegetated Buffers

Vegetated buffers consist of natural or planted strips of vegetation (non-lawn) located adjacent to and downgradient from a developed tract of land. They provide protection by allowing pollutants to filter out of stormwater runoff as it travels across the buffer and through the vegetation. Buffers are typically used to treat runoff from smaller developments and require minimal maintenance. DEP has established acceptable buffer lengths for various applications to meet the objectives previously outlined. Four types of buffers are included in DEP's regulation:

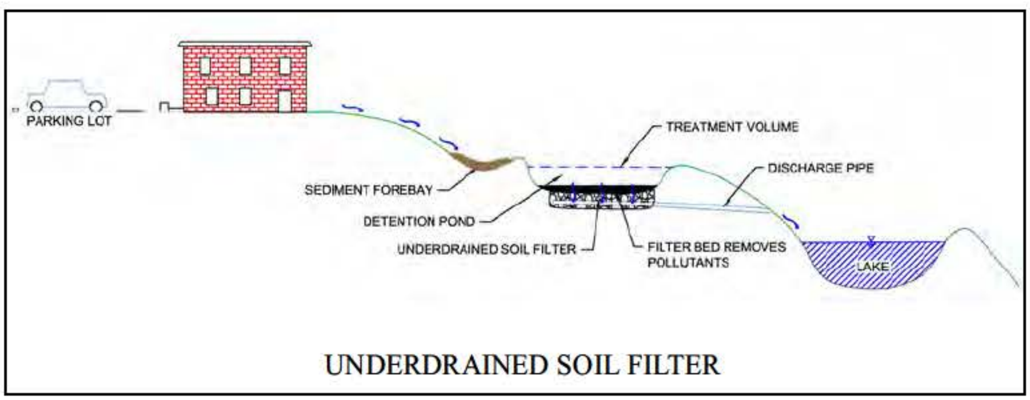
- Vegetated buffer with stone bermed level lip spreaders – this is for areas where stormwater flows may be concentrated and a level lip spreader is needed to uniformly distribute flows.
- Buffer adjacent to the down hill side of a road – this is to treat sheet runoff from a road and shoulder.
- Ditch turn-out buffer – this is to treat runoff collected in a ditch along the side of a road and use level lip spreaders to evenly disperse the runoff into the buffer.



Vegetated buffers remove pollutants through filtration as the stormwater runoff travels across the buffer and through the vegetation. The vegetative canopy also helps to cool the stormwater runoff and contributes to the natural cycle of evapotranspiration, minimizing the amount of stormwater runoff reaching the stream or lake. Buffers also provide for some infiltration due to the natural depressions found across the buffer, which allow some minor ponding to occur.

Underdrained Soil Media Filters

Underdrained soil filters consist of a loamy, coarse sand mix underlain by a gravel bedding and perforated pipe. Stormwater runoff is collected in a storage area above the soil filter, where the runoff passes through the soil and discharges through the underdrain piping. The soil media filters out particles and pollutants that bind to the soils, while also cooling the stormwater runoff. Underdrained soil filters are typically incorporated into a detention structure, or a proprietary filter system approved by the department may be used.

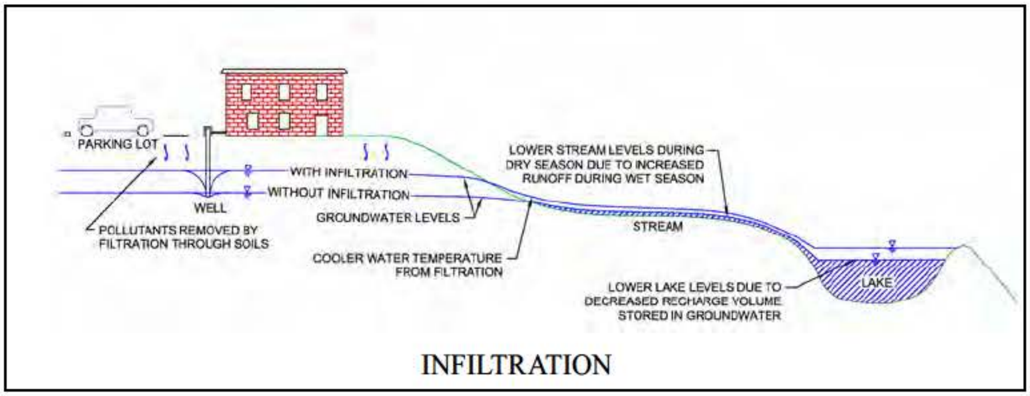


An underdrain soil filter works by discharging water through a constructed soil media, which is underlain by a perforated drainage pipe. The stormwater runoff is filtered through the soil providing cleaner, cooler water which is then collected into a drainage pipe and discharged to a nearby receiving water. The soil media can also act to absorb and release water through evapotranspiration when combined with vegetation. When combined with a detention basin, this BMP can be used to meet all four of DEP's objectives.

Infiltration

Infiltration involves discharging stormwater runoff into the ground. The runoff percolates through soils, which act as a filter to cleanse the stormwater before discharging it to the groundwater table. In addition to meeting DEP's objectives, infiltration also minimizes the volume of water reaching surface waters as runoff and increases stream baseflows.

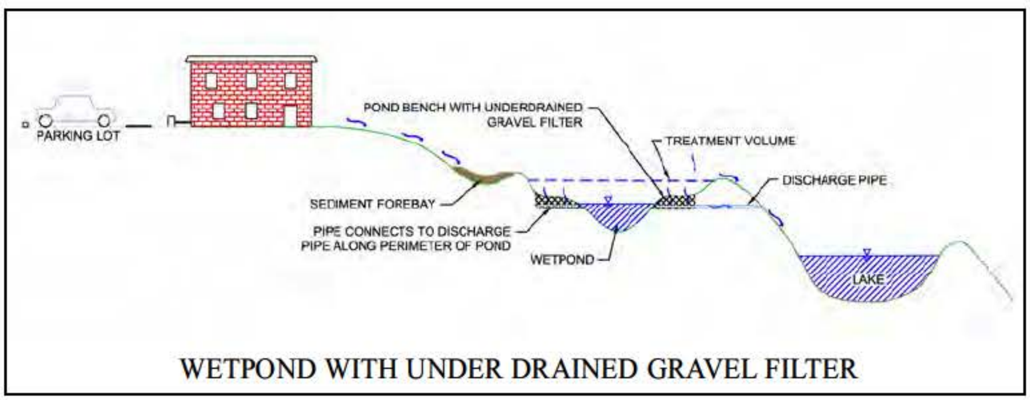
It is critical that adequate pretreatment be provided prior to discharge to an infiltration area to prevent the system from clogging.



Infiltration involves discharging stormwater runoff into the ground. The stormwater is filtered through natural soils, removing pollutants, before it reaches groundwater. It has many benefits including: cooler water temperatures reaching lakes and streams due to filtration through soils; higher groundwater levels for water supplies; higher summer stream levels; and cleaner water. It can also reduce flooding issues by imitating natural, pre developed conditions.

Wet Pond with Underdrained Gravel Filter

A wet pond consists of a detention structure with a permanent pool. The stormwater runoff is detained above the permanent pool and discharged through an underdrained vegetated gravel filter. The gravel filters are built on an elevated pond bench, set above the permanent pool and running the length of the pond. The gravel media filters out particles and pollutants that bind to the gravel, while also cooling the stormwater runoff. The treated stormwater discharges through a perforated pipe located beneath the gravel filter.



A traditional wetpond consists of a permanent pool with detention storage above the pool for stormwater runoff. Although wetponds can be beneficial in removing pollutants from stormwater, the pool itself heats up in the warm summer sun, discharging warm water to lakes and streams. A modification to the traditional design, incorporating an underdrained gravel filter forces the stormwater runoff to filtrate through the gravel filter to a perforated discharge pipe located at the bottom of the filter. This helps to remove the finer particles in the stormwater and cools the stormwater before it is discharged. The wetpond can also be sized to handle peak discharge, meeting all four of DEP's objectives.

References

Comprehensive Environmental Inc. March 2003. *City of Nashua, New Hampshire Alternative Stormwater Management Methods, Part 1 – Planning & Guidance.*

Chapter 3
Low Impact Development

Benefits of LID:

- Preserves the hydrologic cycle
- Protects streamflows
- Protects drinking water quantity
- Keeps drinking water pure
- Fish and wildlife benefits
- Promotes water conservation
- Reduces flooding and property damage from peak flows
- Saves communities money
- More attractive and diverse than traditional developments

Low Impact Development, known as LID, is the process of developing land while minimizing impacts on water resources and infrastructure. It is a site-based process, unlike Smart Growth and New Urbanism, which are community or regionally based and directed at minimizing sprawl and making developments more people-friendly. LID is geared to protecting the hydrologic cycle that is normally badly damaged during development. The benefits of LID are shown at left.

Photo courtesy of Maplewood Public Works Department.

This raingarden is located in Minnesota, where some communities have reduced the total stormwater load on their water resources by building connected raingardens at each home along the street. Where homeowners do not want a raingarden, they instead get a shallow grass swale that can be mowed. These projects have reduced flooding problems and are attractive. Maplewood, Minnesota, where this garden is located, has developed seven different designs with different looks and maintenance requirements.

LID can be applied to existing, as well as new developments. How? By retrofitting existing paved or otherwise impervious sites with infiltration or storage units. Dispersed units are better than single end-of-pipe treatment devices since they come closer to replicating the natural hydrology of the site. Reestablishing the hydrologic connection has many benefits, but of course it's more expensive than doing it right in the first place. Still, the benefits outweigh the costs in many cases, particularly since the costs can include repeated flooding events and groundwater decline.

Section Contents:

3.1 Problems LID Addresses

Many people are surprised to find out that today's traditional developments are causing so much harm to the environment. It wasn't intentional, but somewhere along the line, it became cheaper and easier to clear cut large swaths of land for new developments. Then topsoil began to be sold off, and just a little loam was left for the lawns. The extensive clearing of the lots also left little shade, so the poor soils and grass bake in the sun and create high water demand. Meanwhile, the runoff calculations, if there even were any, designed to protect communities from increased runoff never got significantly updated to reflect the new, more impervious lawns and wider streets, so runoff from these new developments may be significantly more than planned. LID addresses many of these issues.

Photo courtesy of the National Oceanic and Atmospheric Administration (NOAA).

The photo above shows a flooded road could be anywhere. Increased flooding is one of the most obvious problems caused by today's development practices. The water lost downstream should have recharged an aquifer that may now begin to decline a less obvious problem.

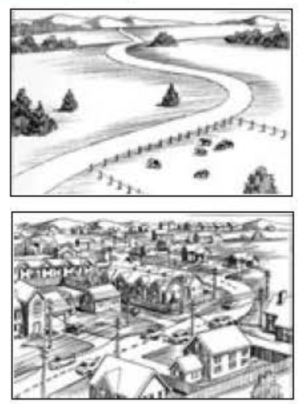
Why Developments Can Cause Environmental Harm and Flooding

- Farmland converted to suburbia or commercial and industrial development has more runoff. Some big box retailers, for example, have 30 acres or more of parking area
- Compacted lawns and playing fields have more runoff than the undisturbed woods
- Erosion during construction continues to be a major problem in many areas
- Undersized stormwater treatment units in older developments may demand high maintenance, and when they don't get maintained, they fail, leaving the site worse off than without them
- Peak flow controls focus on larger storms, passing smaller, more frequent storms through, which damage stream channels.

Results of Traditional Development

Low Impact Development (LID) focuses on replicating the natural hydrologic cycle as much as possible. The results of today's high impact development is damage to the hydrologic cycle, which can result in:

- Lower low flows in streams;
- Higher peak flows and flooding;
- Less clean recharge and dropping groundwater levels;
- Pollution of drinking water;
- Loss of wildlife habitat and damage to fisheries;



Drawing courtesy of NASA.

As farmlands are converted to residential areas in the developed parts of Maine, runoff volumes are multiplied.

New homes in suburban areas, with their massive lawns and sprinkler systems have a high water demand and high runoff.

3.2 LID Design Practices

There are several land planning and design practices that can be used to achieve LID. These focus on developing land in a manner that helps mitigate potential environmental impacts. Ideally, these planning and design practices should be incorporated at the design phase to be most cost-effective, but can also be used to redevelop sites. Specific technologies that can be used to implement these practices are discussed later in this section.

LID Principals

- **Minimize Impervious Areas**
- **Limit Areas of Clearing and Grading**
- **Minimize Directly Connected Impervious Areas**
- **Manage Stormwater at its Source**

Minimize Impervious Areas

Impervious areas increase the amount of runoff that leaves a site, as undeveloped lands that allow for natural infiltration of rain water are replaced with impervious surfaces such as buildings, sidewalks and pavement. Less impervious area equals less runoff from the site. Means to minimize impervious areas include:

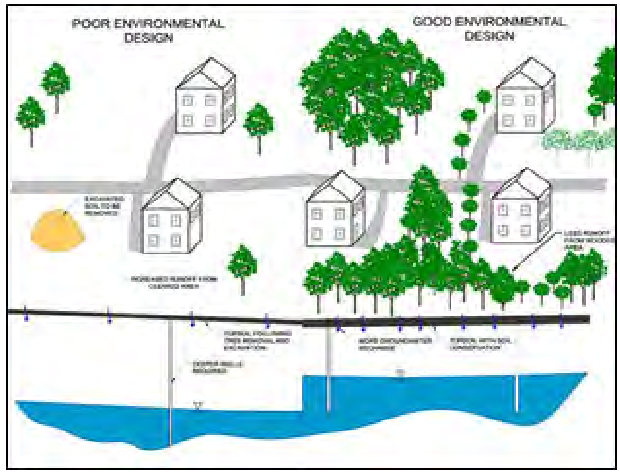
- Minimize building setbacks to reduce driveway lengths
- Use vertical construction over horizontal
- Incorporate smart growth concepts such as clustering
- Reduce unnecessary parking areas and aisle widths
- Design pervious overflow parking areas and emergency access ways
- Design narrower streets and driveways wherever possible• Design narrower streets and driveways wherever possible
- Keep sidewalks to one side of primary roads, preferably separated from the road by a vegetated or pervious buffer

Photo courtesy of Center for Watershed Protection.

This photo shows pervious pavement on an overflow parking lot.

Limit Areas of Clearing and Grading

One way to preserve pre-development conditions is to minimize land disturbance activities to the extent possible. Development should be located in areas that are less sensitive to disturbance (i.e., developing on clay soils will have less impact than developing on sandy soils). At a minimum, buffers to sensitive areas (i.e., waterbodies, floodplains, wetlands and steep slopes) should be left undisturbed. The limits can be applied through use of Landscape Design Guidelines or Standards referenced in the subdivision regulations or stormwater bylaws. The limits also need clear marking on development plans and in the field.



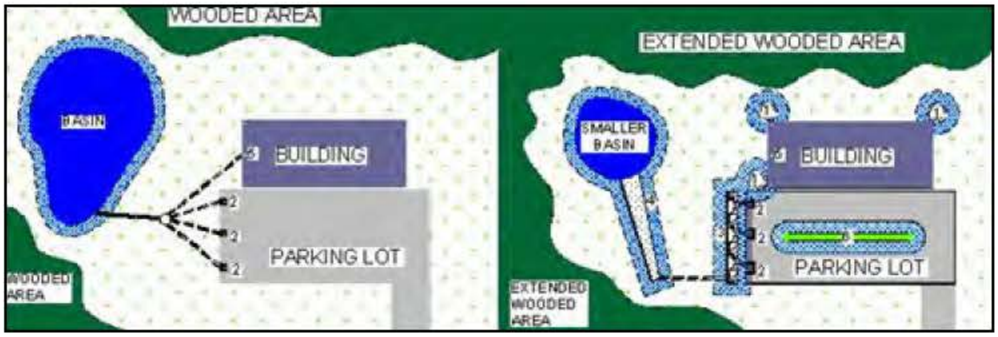
The drawing above shows how a site that is extensively cleared might affect groundwater recharge and aesthetics of the overall development. Leaving mature trees has also been shown to increase the value of the homes even though it may be resisted by onsite contractors, who may see it as a major inconvenience. Despite the inconvenience to some, it is a major benefit to the future homeowners, the community and the environment.

Common practice in urban areas is to deal with erosion problems by paving them over to protect the soil. This compounds the problem, and can be corrected using LID methods that disconnect roofs and other impervious areas from the street by diverting the roof leader to a dry well or the like away from the building.

Minimize Directly Connected Impervious Areas

Some impervious area is unavoidable, but the impervious areas can be separated from the discharge point by using low impact techniques such as dry wells, raingardens, level spreaders and others. These can be used to cut down on the Directly Connected Impervious Area or DCIA as coined by EPA. For example:

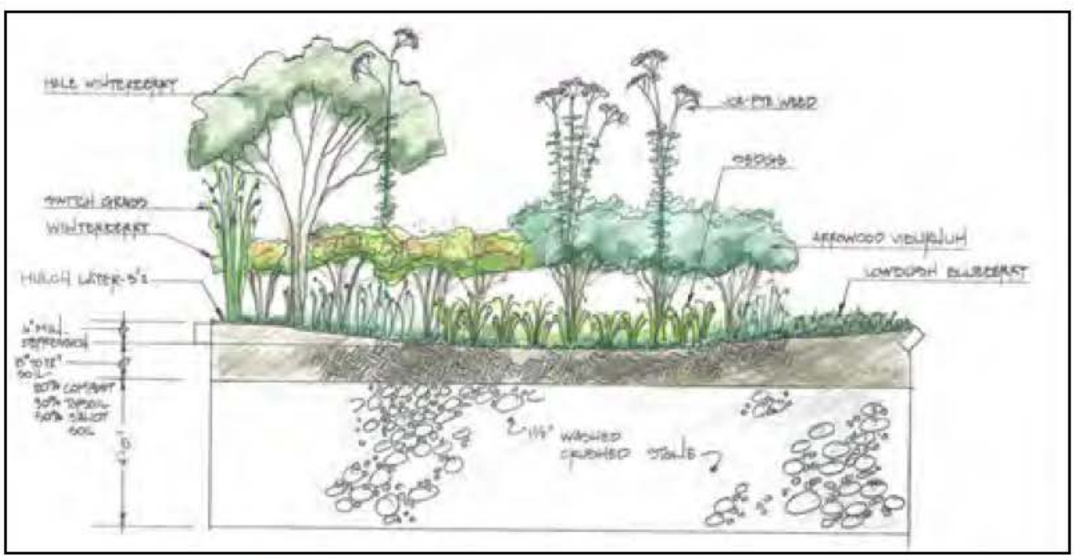
- Drain impervious areas as sheet flow to natural systems such as vegetated buffers.
- Break up flow directions from large paved surfaces to allow for on-site treatment of smaller flows.
- Avoid situations like that shown in the opposite photograph, where roof leaders are directly connected to streets by paving due to erosion problems created by the velocity of the roof leader discharge. Instead, collect roof leader water in dry wells or raingardens set 8 feet or more from the building.



The drawing above shows how a typical commercial site is usually drained (left), with some LID improvements to the same site shown on the right. On the right side, there is a) less clearing; b) the roof leaders are handled in dry wells; c) the emergency access way and some overflow parking are in pervious materials; and d) an infiltration divider is used in the parking lot to collect some of the drainage in a vegetated island. This reduces the size of the basin, but more importantly, small storms are almost completely collected and treated, resulting in a major reduction in the overall water quantity leaving the site via runoff and an accompanying improvement in water quality leaving the site.

Manage Stormwater at the Source

Although end-of-pipe treatment structures can be used to control peak-flows, they cannot mimic natural hydrologic conditions of a site. To most closely mimic the natural functions of a site, stormwater must be handled as close as possible to the source. This is best accomplished with numerous smaller systems that fit in with the site's natural topography and drainage conditions. Breaking up the drainage in this way results in much greater overall control of the runoff during smaller storms and for the "first flush" of each storm when most of the pollution occurs.



This commercial raingarden or bioretention island is a good way to keep stormwater at the source of its generation in a parking lot. It has heat and salt tolerant species and is low maintenance as well as beautiful. Many versions are also available for residential use, as described further in Chapter 6. LID Techniques.

3.3 Soil Considerations

Minimize Compaction

Soils play a key part in LID. It is important to minimize soil disturbance and compaction from heavy equipment during development to maintain pre-developed conditions. Compaction of soils reduces the natural infiltrating ability of the soils. It is also important to avoid steep slope development, as these can quickly erode and runoff into nearby waterways degrading water quality and wildlife habitat.

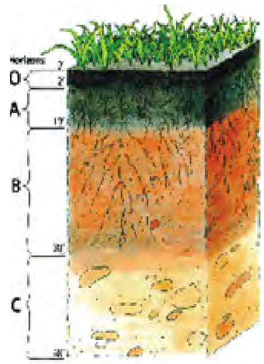
The site soils also help direct development activities. If possible, impervious surfaces and development disturbances should be directed towards the more impermeable soils of a site, leaving the pervious soils to continue infiltrating runoff. This will cost-effectively minimize the overall impacts to the hydrologic cycle reducing the cost of stormwater best management practices (BMPs). The types of soils available will also help with the selection, sizing and placing of LID techniques.

Increase Organic Content of Soils

When constructing many of the LID techniques, it is important to provide a sufficient soil and organic layer to optimize pollutant removal. The soil bed should consist of at least 20-30% organic material and 30% planting or top soils. The organic materials should consist of a mulch layer over compost type materials such as composted leaves.

This highly organic layer traps contaminants, absorbs more rainfall or runoff and provides a medium for biological activity that helps break down pollutants. Planting soil provides a healthy growing medium for vegetation by encouraging strong root growth. In addition, microbes found in healthy soils transform nutrients into forms that are essential for plant growth. Compost is a particularly attractive amendment because it is readily available, has trace minerals and micronutrients and recycles a waste product.

Most gardeners swear by compost as the best soil additive for healthy plant growth, minimizing disease and insect problems and retaining soil moisture. This goes even further in LID in that compost absorbs more rainfall, acting as a sponge, and keeping rain where it fell rather than running off as stormwater.



Drawing courtesy of Natural Resource Conservation Service (NRCS)

Typical soil profile.

LID calls for soils with a high organic content to absorb and cleanse rain and stormwater. Today's developments often lack adequate topsoil as it may be sold off during construction. This leaves little organic topsoil to support the growth of lawns and othervegetation, which may also increase irrigation use. Adding organic matter in the form of compost is relatively easy and effective.

Compost or other organic amendments can be added at the site preparation level, typically by the truckload. It is also available for little or no cost from many community leaf compost programs.

For raingardens and bioretention areas, compost addition is also valuable in absorbing and retaining moisture for plant life, filtering pollutants and providing an active layer for microorganisms to reside and reproduce. A healthy microorganism population is key to the decomposition of many pollutants, whether in the home raingarden or in a parking lot.

Avoid Pesticides

Healthy soil is alive with microorganisms that decompose and inactivate pollutants, but some of these microorganisms may be killed by the use of pesticides or excessive chemical fertilizers. Pesticides include herbicides that kill undesirable vegetation and insecticides that kill nuisance or pest insects and other similar organisms such as spiders. Although the soil microorganisms are not typically the target of these chemicals, many of them may fall victim to the use of pesticides. A loss of diversity of microorganisms in the soil and on the surface is the result, and the resulting soil can be "dead", with less pollutant removal capability. Additionally, insect species that prey on pests are also killed by pesticides. Since the predatory species tend to have slower reproduction than the pest species, a natural defense against insect pests may be lost.

3.4 LID Techniques

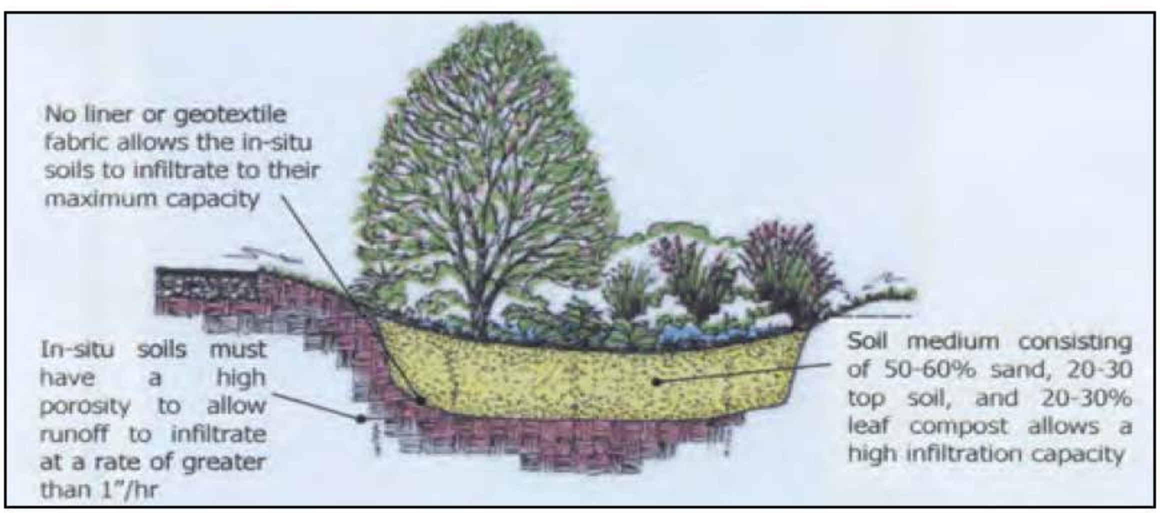
LID is a natural evolution of stormwater management, and as a result, some of the techniques are not new at all but have been used for years. For example, drywells for roof leaders are hardly new technology. Other techniques are relatively new, but no matter the age of the technique, all LID methods have one characteristics in common: keeping the rainfall or runoff as close to its point of generation as possible. The LID approach emphasizes multiple, dispersed on-site systems that mimic natural conditions as closely as possible. These are attractive, cost-effective solutions designed to retain and treat stormwater runoff at the source. Following are several LID techniques that can be used on a site:

Photo courtesy of Maplewood Public Works Department

A raingarden in Maplewood Minnesota blends in with the neighborhood, infiltrating rain while providing an attractive garden. This one is one of seven styles, called "Sunny Border Garden" and features hardy low maintenance species.

Bioretention Areas or Raingardens

A bioretention area is designed to collect, infiltrate, and treat moderate amounts of stormwater runoff using conditioned planting soil beds, gravel beds and vegetation within a shallow depression. These are typically placed close to runoff sources, such as parking lot islands or along roadside edges. The vegetation generally consists of native or naturalized species to the area and are capable of handling periodic wet conditions such as the ponding that often occurs during storm events. The plants, soils, and organic matter such as compost and a mulch layer all play an important role in treating runoff by naturally breaking down pollutants. The underlying gravel beds serve to temporarily store and infiltrate treated stormwater after percolating through the organic soil layer. Maine soils have relatively poor infiltration capacity, and these systems may need to be underdrained so their storage capacity is available for the next storm. Maintenance involves annual sediment and debris removal, mulch replacement and trimming and weeding as necessary. Raingardens are a more popular name for a bioretention area and have been used near streets and driveways in some communities. Appendix I-A provides examples of various raingarden layouts.



Drawing courtesy of Department of Environmental Resources, Prince George's County, Maryland

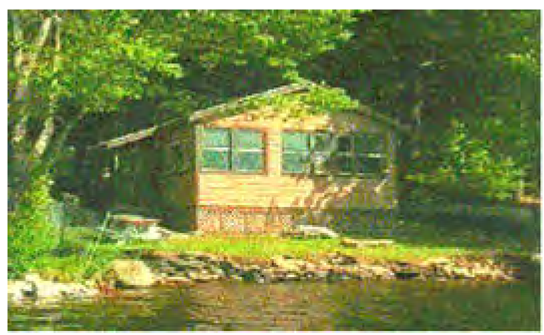
Filter Strips

Filter strips are shallow pitched vegetated areas placed between developed areas, such as parking lots and road edges, and downstream waterways. Filter strips are designed to disperse stormwater runoff velocities and capture moderate sediment loads by eliminating any channeled or piped outlets. Vegetation used in these areas is often grasses and low-lying groundcovers that allow recreational activities and pedestrian access between developed areas. Filter strips are often used to augment other stormwater treatment practices. The filter strip shown at right likely has limited usefulness in that it may be relatively compacted, but it still probably provides better infiltration than would a paved or otherwise completely impervious strip between the lanes.

Photo courtesy of the Milwaukee River Basin Partnership

Vegetated Buffers

Vegetated buffers are natural or planted vegetated areas between developed areas and waterways and other sensitive areas such as wetlands and vernal pools. Buffers serve to moderately infiltrate and disperse stormwater runoff. Native site-specific vegetation is used to duplicate natural site conditions if planting is necessary due to disturbances. Buffers serve as a crucial element in preventing runoff pollutants from entering into waterbodies. They should include several layers of vegetation as these multiple layers absorb more precipitation and provide better uptake of pollutants and water through the mixed root zones of trees, shrubs, possibly a herbaceous layer and groundcovers. The duff layer is also important. Duff consists of leaves, pine needles and other plant materials in various stages of decomposition. The duff layer acts as a sponge, absorbing water and filtering pollutants as well as providing habitat for microorganisms that help treat runoff. In manmade vegetated buffers, some type of mulch may be used for the duff layer until a natural one develops over time.



The above camp on a lake in Maine has little buffer zone between the human activity and the water.

The retouched photo simulates a shrubby buffer that can help filter pollutants despite its small size.

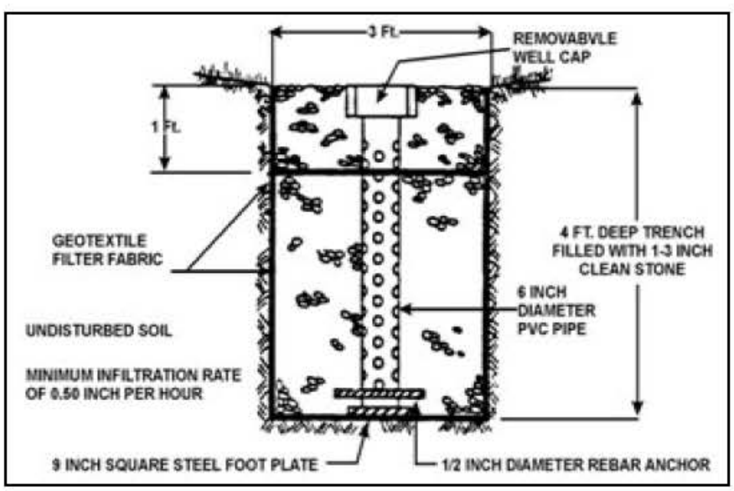
Vegetated Wet or Dry Swales

Swales are shallow pitched elongated depressions seeded with grass or other suitable vegetation that are designed to transport and infiltrate moderate amounts of runoff, and capture sediment loads. A wet swale is often designed in areas with high water table levels and utilizes wet tolerant plants. Dry swales can be as simple as a grassed depression or planted with a diversity of native vegetation and underlined with a gravel bed to improve infiltration rates. An underdrain may also be provided in tighter soils, as in Maine, which will provide the absorption and pollutant removal benefits of the soil, while allowing the water to drain from the site. Swales are used along roadside edges and medians and in areas with site constraints.

This dry swale is located in New Hampshire. It blends well with the landscaping and is low maintenance yet effective. It does have an overflow to the storm drain system that can be accessed once the water reaches more than halfway up the side slopes.

Infiltration Trenches

An infiltration trench is an in-ground usually crushed stone bed designed to capture and infiltrate stormwater in urban settings. All trenches should have some type of pretreatment to remove sediments from stormwater before it enters the trench, as they have been found to clog without this. Some types of appropriate pretreatment might include grass swales, deep sump catch basins, grassed areas after level spreaders, plunge pools or sediment forebays. Following the pre-sedimentation step, infiltration into the trench allows for the removal of most remaining pollutants. Collected stormwater may remain in the trench for several days depending on soil conditions.



This cross section of a typical infiltration trench shows some of the basics of the design. In addition, pretreatment is needed and in Maine, the bottom of the stone should reach below the frost line to keep the trench working during the winter. This section is from U.S. EPA.

Porous Pavement

Porous or permeable pavements are designed to allow some amounts of rainfall to infiltrate through the road surface into the underlying gravel beds and soils. There are basically three types of porous pavement, including:

- **porous asphalt** resembles typical asphalt but is made with many void spaces throughout the surface material allowing water to pass through.

- **block pavers** are interlocking blocks of material resembling a grid that are usually made out of concrete allowing runoff to infiltrate through the exposed areas.

- **plastic grid pavers** generally come in a honeycomb pattern and the voids are filled with stone, or loamed and seeded. The grid provides strength to allow vehicles to park on it without compacting the soils in between.

All three types of pavements are susceptible to clogging in cold climates due to sanding applications although the block pavers have the best attributes in this regard and have been used in Canada. Both plastic grid pavers and porous asphalt can be problematic for plowing, as can block pavers if not bedded properly. All three of these types of porous pavement do hold promise for some applications, and testing is ongoing at several New England sites, including University of New Hampshire Cooperative Extension and the University of Rhode Island Cooperative Extension. The use of these pervious pavements is particularly suited to overflow parking, emergency access ways, unplowed lots and areas where pretreatment can be incorporated to remove sand. The use of any porous pavement requires approval by the Maine Department of Environmental Protection.

Courtesy of University of Connecticut, NEMO website

Porous Asphalt

Courtesy of University of Connecticut, NEMO website

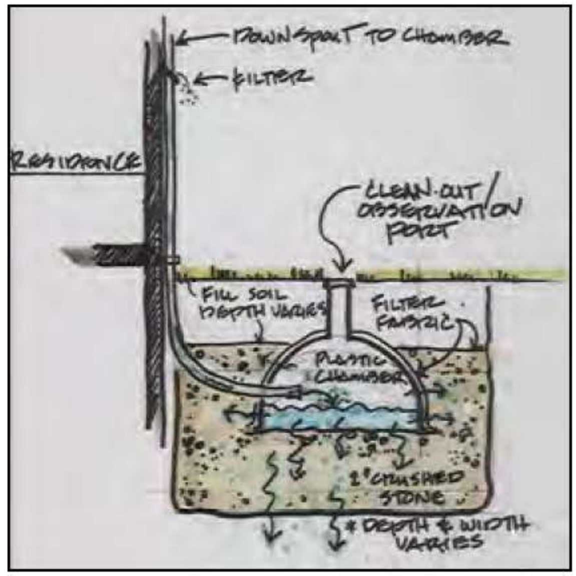
Block Pavers

Courtesy of University of Connecticut, NEMO website

Plastic Grid Pavers

Dry Well

A dry well is an in-ground chamber filled with stone that is typically used to collect and infiltrate "clean" roof runoff. Roof runoff is usually free from clogging materials that shortens the life-cycle of this type of system. Roof leaders are generally diverted directly into the dry well. Rooftops,particularly in urban areas, contribute to the amount of impervious surfaces causing significant increase in runoff amounts. Diverting the rainfall into drywells diminishes the amount of runoff occurring from a site, minimizing downstream flooding conditions and allowing downstream BMPs to operate more effectively. As with other infiltration BMPs, dry wells require soils with a good infiltration rate and adequate separation from bedrock and groundwater.



This is a typical dry well for a roof drain leader.

Rain Barrels & Cisterns

Rain barrels are simple collection devices, usually made out of plastic, that are designed to capture roof runoff. Like a dry well, roof leaders are diverted directly into the unit(s). Most barrel designs incorporate child resistant covers and mosquito screens. Rainwater is stored in a barrel or number of barrels for later reuse in the garden or the landscape. Weep holes or an intended leaky spigot are used to allow water to slowly seep into the ground and to ready the unit for the next storm. A cistern for LID usually refers to an underground irrigation storage unit that receives roof runoff, saving it for irrigation purposes.

The above photo shows a rain barrel used to collect and store roof runoff for later use.

Level Spreader

A level spreader is designed to disperse stormwater runoff over a level, shallow pitched area to prevent erosion and capture sediment. Some designs incorporate an underlying gravel bed and water bar to improve runoff infiltration and storage. Vegetation is not usually part of the design as it can impair sediment cleanup operations. This low cost technique is often used on road edges and in median strips. Several level spreaders are sometimes used in parallel along sloping terrain. They often disperse runoff evenly to a vegetated area for further treatment. Volume III contains standards for designing level spreaders for buffers and for simple distribution of runoff to avoid gullying.

The above photo shows a typical level spreader used to evenly disperse flows to a vegetated area.

Rooftop Greening

Rooftop greening is an innovative approach designed to temporarily store rainfall for vegetation on rooftops while simultaneously lowering the air temperature. It is particularly useful in urban areas that have become "heat sinks" with high summer temperatures creating uncomfortable, unhealthy microclimates because of vast amounts of imperviousness. Green roofs can improve local air quality and can absorb a significant volume of precipitation, depending on the depth of the soil profile provided. In new construction, green roof systems are generally installed on flat or shallow sloped roof tops that are engineered to withstand the added weight of vegetation and temporary water storage that occurs after a storm event. However, several vendors of green roofs also claim that they can be installed on existing buildings and they note the weight limits per square foot of saturated roof garden. Impervious layers are installed to prevent leaks. Benefits of the roofs include reducing solar damage of the roofing materials and providing additional greenspace, and of course reducing stormwater.

Photo courtesy of University of Connecticut, NEMO website.

Fencing Academy of Philadelphia, Roofscapes, Inc.

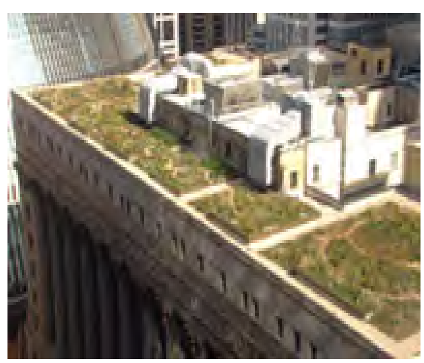


Photo courtesy of American Landscape Architects Association.

Green roof on Chicago City Hall

More Information

More detailed information on each of these techniques, including plant selections and layouts is included in Volume III, Chapter .

3.5 Getting Started

LID is a great concept that can be implemented by communities as well as individuals. A collective effort is needed to preserve and protect streams, lakes and water supplies. Every project helps to make a difference. Many communities and individuals may wonder where to start. The following tips are provided to help with LID implementation.

These children are learning about infiltration by building soil profiles and running liquids through them.

What Can Communities Do?

- Revise existing development controls through bylaws or subdivision and site plan review changes to promote retaining more total runoff on each site
- Minimize site disturbance through clustering and other methods and stake out clearing limits and stockpiles
- Review engineering calculations for overly optimistic pre and post runoff assumptions
- Adopt guidance and design criteria
- Set a good example on municipally owned properties
- Create a public education program and demonstration project

What Can Individuals Do?

- Review property's drainage and find out where it goes during large rainstorms
- Disconnect roof leaders and direct connections to the street and reroute these to drywells or other infiltration
- Build a raingarden using one of the many guides available
- Cut down on lawn size and plant shrubs and trees instead—look for hardy, low maintenance varieties that don't need a lot of water or pampering once established
- Keep a raingauge and try to keep all of the rain that falls on the property!

Chapter 4
Pollution Prevention

Benefits of Pollution Prevention:

- Cost savings by consuming and disposing of less
- Cleaner air and water
- Less solid waste in landfills
- Improved safety
- Reduction in liability
- Reduction in reporting and permitting

A combination of preventative and structural measures are necessary for optimal reduction of stormwater impacts to water bodies. Preventative measures focus on preventing pollutants from getting into stormwater, while structural measures, the topic of Volume III, focus on removing pollutants from stormwater. Once pollutants reach a water body, it is much more difficult and expensive to restore it to its pre-impacted conditions. Therefore, preventative measures are recommended to minimize the degradation of receiving waters using fewer, smaller structural measures, which will also reduce the overall costs of water quality protection.

This section focuses on preventative Best Management Practices (BMPs) intended to minimize or prevent the release of pollutants so they are not available for mobilization by runoff. These BMPs are not given specific credit for phosphorus removal, but should be considered for inclusion in an overall stormwater management plan. The measures described include:

- Long-Term BMP Maintenance
- Street Sweeping
- Sand and Salt Management
- Fertilizer Management
- Pesticide Management
- Materials Management

These BMPs are not given specific credit for phosphorus removal, but should be considered for inclusion in an overall stormwater management plan.

POLLUTION PREVENTION

Right From The Start

Section Contents:

4.1 Long-Term BMP Maintenance

Description

Structural BMPs have been used for many years to manage and treat stormwater runoff before it is released to surface waters. These BMPs are designed and sized with a specific performance criteria in mind to remove pollutants such as phosphorus and sediments from stormwater runoff. The maintenance of these systems is crucial for them to continue to perform as designed.

Failure to provide proper maintenance can reduce the pollutant removal efficiency and can impair the hydraulic capacity of the system. Lack of maintenance, especially with regard to vegetative systems or systems that accumulate sediment, can increase rather than decrease the pollutant load of stormwater discharges.

With this in mind, it is important for design engineers to incorporate realistic maintenance goals into BMP designs. For example, sediment removal is a common maintenance practice that is required to prevent infiltration and filter type BMPs from clogging and to prevent water quality storage areas from filling in. If sediments are not removed as needed, the effectiveness of the device will decrease, possibly to the point of failure.

Some devices are also designed with bypasses that allow flows to pass when the system is not maintained to prevent flows from backing up into parking lots and other areas. In these cases, the owner has no physical indication that the device is failing and stormwater runoff flows through the system untreated.

The key to effective maintenance is a combination of realistic maintenance goals, the clear assignment of responsibilities to an established agency (such as local government) or organization (for example, a homeowners association) and a regular schedule of inspections to determine maintenance needs. Maintenance considerations need to begin with the design. Stormwater management system designers should seek to make systems as simple, natural and maintenance-free as possible.

Lack of maintenance at this location has caused the structure to fill up with sediment and other debris. Maintenance is crucial to the overall performance of a BMP. Without it, the BMP is not performing as designed and in some cases can worsen conditions than if no BMP was present

Guidelines

1. **Size BMPs to hold a year's worth of sediment.**

2. **Use the Revised Universal Soil Loss Equation (RUSLE)** to calculate sediment deposits that would occur from pervious areas adjacent to the BMP.

3. **Account for sand deposits from winter storm applications** when designing pre-treatment/sediment removal. Calculate sediment loads using a sand application rate of 500 lbs/acre for sanding of parking areas and access drives, a sand density of 90 lbs/ft^3 and assuming a minimum frequency of ten sandings per year.

To obtain an annual sediment volume, perform the following calculation:

$$\text{Area to be sanded (acres)} \times 500\ \frac{\text{pounds}}{\text{acre-storm}} \div 90\ \frac{\text{pounds}}{ft^3} \times 10\ \frac{\text{storms}}{\text{year}} = \text{cubic feet of sediment/yr}$$

4. **Design BMPs to alert the owner when it is failing and maintenance is required.** Bypasses should not be used unless there is risk to public health or safety.

5. **The BMP should be easily accessible** to facilitate inspection and maintenance.

6. **Inspections shall be conducted by a person with knowledge of erosion and stormwater control**. General inspection standards are provided in Table 4-1. Actual inspection activities should follow the approved inspection and maintenance plan for the site. The maintenance needs for most vegetative and stabilization measures may be found in the Maine Erosion and Sediment Control BMPs manual as published in, 2003.

7. **Conduct maintenance in accordance with the approved inspection and maintenance plan** for the site. Detailed descriptions of maintenance activities for design purposes can be found in Volume III of this manual for each type of BMP.

References

Comprehensive Environmental Inc. November 2003. *Design Guidelines and Criteria for Stormwater Management.*

4.2 Street Sweeping

Description

Street sweeping involves the removal of grit, debris, and trash from impervious areas such as streets, parking lots, and sidewalks. It is commonly performed to remove trash and sediment buildup from curb gutters to improve aesthetics and reduce the export of sand to structural BMPs and/or to receiving waters. It is most effective at removing coarse particles, leaves, trash, and other similar materials and the pollutants bound to them. If these materials are removed from the paved areas where they are deposited, they are no longer available for transport as a pollutant in stormwater runoff. The specific pollutants generally reduced by street sweeping include sediment, some nutrients, oxygen-demanding substances, and non-biodegradable trash.

The effectiveness of street sweeping will depend on the equipment used and its ability to pick up fine particles. The majority of nutrient, oxygen-demanding and toxic substances reaching the streets is attached to fine particles. Therefore, street cleaning practices that can remove fine particles (less than 246 microns) will be most effective for nonpoint source pollution control. Recent improvements in technology have increased the efficiency of street sweepers, allowing them to pick up more of the fine grained sediment particles, which most of the pollutants are attached to, increasing the benefit to water quality.

New data shows that the newer dry vacuum sweepers can reduce nonpoint pollution by 35–80 percent compared to conventional mechanical broom and vacuum-assisted wet sweeper efficiency of 5–30 percent. Nutrient reduction with the newer dry vacuum sweepers is between 15–40 percent, compared to 0–15 percent with the conventional equipment (Runoff Report, 1998). The new vacuum assisted dry sweeper has also shown a potential reduction in annual sediment loading of 50–88 percent for a residential street, depending on sweeping frequency (Bannerman, 1999).

Other factors will also play a role in the overall effectiveness of street sweeping to remove pollutants from a given area. These include the frequency and location of sweeping and the ability to sweep on heavily traveled roads with on street parking.

Table 4-1 Inspection and Corrective Action for Structural BMPs			
	Inspection Schedule	What to Look For	Corrective Action
Vegetated Areas	• Annually early in the growing season • After heavy rains	• Active or potential erosion problems	• Replant bare and sparse areas • Armor erosion areas or divert the erosive flows
Ditches. Swales & Open Stormwater Channels	• Spring & late fall • After heavy rains	• Obstructions to flow • Accumulated sediments & debris • Erosion	• Remove obstructions to flow • Remove accumulated sediments & debris • Repair erosion of ditch lining • Repair sloping side slopes • Replace riprap on areas where underlying filter fabric or underdrain gravel is showing
Culverts	• Spring & late fall • After heavy rains	• Obstructions to flow • Accumulated sediments & debis • Erosion at inlet & outlet	• Remove obstructions to flow • Remove accumulated sediments & debris • Repair erosion
Catch Basins	• Annually early spring	• Accumulated sediments & debris • Floating debris & oils	• Remove accumulated sediment and debris • Remove floating debris & oils
Roadways and Parking Surfaces	• Annually early spring	• Accumulated sediments & debris	• Remove accumulated sediment and debris
Resource & Treatment Buffers	• Annually	• Erosion of downslope of spreaders & turn-outs & within the buffer • Concentrating flow • Encroachment by development	• Modify spreader's or turn-out's lip for better distibution of flow into buffer • Repair erosion • Clean out accumulated sediment within spreader bays or turn-out pools
Stormwater Detention Retention Areas	• Annually in fall • After heavy rains	• Obstructions to flow • Settlement and erosion of embankment • Damage to piping • Downstream swamping • Broken seals, obstructed orifices & plugged trash racks at the outlet structure • Accumulated sediment & debris	• Remove obstuctions to flow • Remove accumulated sediment & debris every 2-5 years • Repair eroded areas • Repair damage to trash racks or debris gurards • Mow to control woody vegetation • Replace riprap where underlying filter fabric, soil or underdrain filter is showing
Runoff Infiltration Facilities	• Spring & late fall	• Accumulated sediment & debris • Drainage within 72 hours	• Remove sediment & oils in pretreatment spring & late fall • Remove sediments in infiltration area every 2-5 years • Till & replant soil of vegetated basins every 2-5 years • Reconstruct rock basins or trenches by removing stones, replacing underlying filter fabric, & tilling underlying soil
Proprietary Treatment Devices	• Early spring & late fall	• Accumulated sediments, oils & debris	• Remove accumulated sediment, oil & debris

The following describes some of the most common street sweeping equipment used:

a. *__Mechanical sweepers:__* Mechanical sweepers basically consist of a gutter broom and a main broom which rotate at high speeds, forcing the debris from the street surface into a conveyer belt and subsequently into a hopper. Water is usually sprayed on the pavement surface for dust control.

The effectiveness of mechanical sweepers is recognized to be a function of a number of factors, including; (1) particle size distribution of accumulated surface contaminants; (2) sweeping frequency; (3) number of passes; (4) equipment speed; and (5) pavement conditions.

b. *__Vacuum Sweepers:__* These sweepers feature vacuum action over the entire path, assisted by a gutter broom. Regenerative air sweepers force air down onto the pavement, suspending particles, which are then picked up by the vacuum suction. Some types of vacuum sweepers can serve another municipal maintenance function. If the unit is equipped with a wandering hose attachment, it can be used for sewer and catch basin cleaning.

Guidelines

The majority of particulate contaminants which are deposited on streets are blown to the side by moving vehicles. An estimated 90% of street contaminants accumulate within 12 inches of the curbline of guttered streets (citation). Street cleaning operations should concentrate in cleaning curb and gutter lines for maximum pollutant removal efficiency. Other areas can also be swept periodically, probably on a less regular basis. Sweeping should be conducted immediately following spring snowmelt to remove sand and other debris. Pavement surfaces may be swept at other times, basically for aesthetic reasons, such as in the fall after leaves have dropped to remove accumulated debris.

Street sweepers such as this one remove sediment buildup on roadways, reducing the amount of sand that is deposited in catch basins and other structures, and ultimately into the receiving water.

References

Bannerman, R. 1999. Sweeping Water Clean. *American Sweeper Magazine*, Huntsville, AL. Volume 7, Number 1.

MPCA. 1989. *Protecting Water Quality in Urban Areas: Best Management Practices for Minnesota*. Minnesota Pollution Control Agency, Division of Water Quality, St. Paul, Minnesota.

EPA. 1983. *Results of the Nationwide Urban Runoff Program. Volume I — Final Report*. U.S. Environmental Protection Agency, Water Planning Division, Washington, D.C. NTIS Accession number PB 84-185552.

Pollution Prevention/Good Housekeeping for Municipal Operations, Parking Lot and Street Cleaning. (August 15, 2002). Retrieved March 29, 2005 from the World Wide Web: URL: http://cfpub.epa.gov/npdes/stormwater /menuofbmps/poll 10.cfm

A Clean Sweep Now Possible. Runoff Report. The Terrene Institute, Alexandria, VA. Vol. 6 No. 4, July/August 1998.

4.3 Sand and Salt Management

Description

Sand and salt is commonly used on roads during cold winters to make travel safer. The salt reduces the melting point of ice to prevent ice buildup, while the sand increases traction on the road. The two products are often combined and applied as a sand/salt mix.

Salt is very soluble in water. Contact with stormwater causes salt to dissolve into the water, allowing it to migrate into groundwater and surface water resources, where excessive salt levels contaminate these resources. Salt runoff and wind-carried spray may damage or kill plants and trees. Corrosion damage to motor vehicles is another side effect of salt use.

The proper application and storage of salt and sand/salt can minimize the negative impacts associated with its use and storage. Close control of salt spreading to avoid excessive application will not only save maintenance funds but will also minimize these harmful side effects. It may also be desirable to use ditching and storm drains to alter present runoff patterns to reduce contamination of wells and roadside vegetation. If this water can flow directly and quickly to reasonably sized streams or rivers, this damage can be minimized.

The proper storage of salt and sand/salt piles can minimize the impacts associated with bulk storage, which is responsible for many of the problems associated with contamination of local waterways. That is why the Maine Legislature enacted the storage facility program in 1987.

This salt pile is appropriately stored within a covered salt storage shed. Proper storage of salt under cover is essential to minimize leaching of salt into ground and surface waters. It also eliminates the loss of salt to precipitation and keeps it in a form that is easy to work with.

Because shallow wells, and maybe deep wells, can be polluted by salt, it is possible that a municipality could face unexpected expenses in providing fresh water or drilling new wells for certain buildings. A municipality should be aware of State law Title 23 MRSA 3659 on the "protection of private water supplies". This law details the procedure for handling well damage claims.

Guidelines

1. **Salt and Sand/Salt Storage**:
   a. All new sand/salt storage areas greater than or equal to 100 cubic yards of mixed sand/salt **must be registered** with the Maine Department of Environmental Protection and follow Chapter 574, "Siting and Operation of Road Salt and Sand-Salt Storage Areas."

2. **Handling and Application**:
   a. **Use sand/salt spreaders that are capable of adjusting application rates and routinely calibrate** to achieve an optimal application rate according to roadway characteristics (e.g., width and design).

   b. **Train existing and new employees** for effective application of deicing materials.

   c. **Use weather and roadway monitoring systems** to adjust de-icing activities to changing conditions and minimize road way pretreatment techniques (e.g., salting prior to storms).

d. **Use ice-cutting plow blades** to reduce the need and/or volume of de-icing materials.

e. **Implement salt use restrictions around key water bodies**.

f. **Sweep sand/salt that spills during loading operations**.

References

Pollution Prevention/Good Housekeeping for Municipal Operations, Road Salt Application and Storage. (August 15, 2002). Retrieved May 13, 2005 from the World Wide Web: URL: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/poll 12.cfm

Storm Water Management Fact Sheet, Minimizing Effects from Highway Deicing. (September 1999). Retrieved May 13, 2005 from the World Wide Web: URL: http://www.epa.gov/owm/mtb/ice.pdf

4.4 Fertilizer Management

Description

Fertilizers are a source of nutrients, particularly nitrogen and phosphorus, used to promote the growth and health of vegetation. They are used extensively in urban areas on parks, cemeteries, plant nurseries, roadsides and medians, golf courses, institutions, businesses and industrial establishments, and individual home lawns and gardens. The misapplication of fertilizers can result in discharge of these nutrients to water courses. Excess nitrogen can increase nitrate levels in groundwater, making water harmful for infants to drink. Excess phosphorus in lakes can deplete the amount of oxygen, stimulate algal growth, and even cause fish kills. These conditions require drastic measures to correct. The proper management of fertilizer, including the control of fertilizer application rate, prevention of over-spray to impervious surfaces, and method and timing are important to prevent these negative impacts.

Fertilizers are commonly used by businesses and residents to promote lush green lawns and attractive vegetation. They are often used in greater quantities than needed causing excess nutrients to be washed away with stormwater into groundwater and surface waters. Excess nitrogen easily passes through soils to ground water, making water harmful for infants to drink. Excess phosphorus in lakes can cause algal blooms and even fish kills from depleted oxygen levels. The proper management of fertilizer is important to prevent these negative impacts.

Personnel involved with commercial and industrial application of fertilizer are routinely concerned with the costs of such application and may be less likely than homeowners to use excess fertilizer or fertilize at unfavorable times. Residential homeowners, however, may apply fertilizer in the wrong weather (i.e., before heavy rains) or season and are known to use far more fertilizer (and pesticides) on lawns and gardens than they need. Since built-up residential areas border streets and drainage ways that can transport pollutants quickly to waterways, misuse or over-application of fertilizer in residential areas and wash-off of the excess can cumulatively register a significant adverse impact on water quality. Test your soil to determine fertilizer needs.

Guidelines

1. **Follow landscape design standards** at new development sites. Proper landscape design using adequate topsoil and vegetation will minimize long-term maintenance practices. Landscape design standards are included in Appendix I-B.

2. **Protect soils from erosion** during vegetative establishment. Soil enriched with fertilizer nutrients can be easily eroded and carried away in runoff if adequate soil stabilization techniques are not used. Applicable erosion control measures are referenced in the Maine Erosion and Sediment Control BMP Manual (2003).

3. **Test soils** to avoid over-application of unnecessary nutrients, especially for new lawns. Cooperative Extension Service specialists advocate a repeat test at least every three years. For instance, a soil may need nitrogen (N) but need little phosphorus (P) or potassium (K), yet in absence of a test, a fertilizer high in all three nutrients may be applied. Do not use phosphorus fertilizer for projects in lake watersheds. It has been found that in Maine, phosphorus is sufficiently present in the soil to allow for plant growth, yet phosphorous is a pollutant for lake waters.

4. **Use granular fertilizers** that allow for slow release of nutrients. The granular form is less apt to wash away than sprays or slurries. However, lawn maintenance companies may use liquid applications that are resistant to runoff when applied correctly. When used in gardens, granular fertilizer should be worked into the soil, which should be moist at the time of application.

5. **Use organic fertilizers** (compost, manures, etc.) where possible. These are less soluble than formulated chemical fertilizers. However, care must be taken to prevent these from eroding into water courses.

6. **Apply fertilizer to moist soils** when there is little likelihood of an immediate heavy rain. Lightly sprinkle the fertilized area after application. Applying fertilizer immediately before a predicted rainfall in an attempt to aid in soluble delivery to plants results in the loss of much of the fertilizer in runoff.

7. **Never apply fertilizer to frozen ground**. The vegetation and soils cannot absorb the fertilizer under these conditions and will result in the runoff of fertilizers.

References

NPS Agricultural Task Force. 1991. *State of Maine Strategy for Managing Nonpoint Source Pollution from Agricultural Sources and Best Management System Guidelines.* Maine Department of Environmental Protection. Augusta, Maine.

University of Maine Cooperative Extension Service. 1989. *Best Management Practices for Maine Agricultural Producers.* University of Maine Cooperative Extension Service. Orono, Maine.

4.5 Pesticide Management

Description

The term “pesticides” is construed broadly to cover chemicals used against pests of all kinds: insecticides to kill insects; herbicides to kill weeds, brush or other unwanted vegetation; fungicides to control fungi that cause molds, rots, and plant and animal disease; and rodenticides to kill rats and other rodents. Pesticides are used throughout urban areas on grounds of institutions, business and industrial establishments; rights-of-way of roads, power lines, pipelines and railroads; construction projects; parks, recreation areas, plant nurseries, fairgrounds, zoos, cemeteries, waterbodies, woods and other “green” areas; dumps and landfills; and home lawns and gardens. Pesticide management involves eliminating excessive pesticide use, employment of proper application procedures, and the use of alternatives to chemical pest control to reduce the pesticide load in stormwater runoff.

Pesticides are poisons. They may be characterized by acute toxicity, or they may cause long-term chronic effects via the food chain. Persistent pesticides may pass unchanged through conventional waste treatment plants, and large amounts of some of these can kill the bacteria that are essential to break down other wastes in the treatment process.

Due to the great variety of uses of pesticides, the collective amount reaching watercourses in runoff from urban areas is significant. Pesticides vary widely in toxicity and persistence. However, since all are intended to kill something, caution in their use is always essential.

Pesticides are regulated by several federal and state agencies, operating under a variety of statutes. The most significant federal statute is the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which has been amended several times since its enactment in 1947. The United States Environmental Protection Agency (EPA) currently administers FIFRA.

FIFRA emphasizes pesticide registration and labeling requirements as the means to ensure that pesticides, used according to label instructions, will be safe. EPA must approve all pesticide labels, and user compliance with the label requirements is mandated: "The label is the law."

In Maine, the "Maine Pesticide Control Act of 1975" (7 MRSA Section 601) requires the registration of pesticides legally distributed in the state. The "Maine Board of Pesticides Control" (22 MRSA Section 1471) provides for the certification and licensing of sellers and applicators.

Guidelines

1. **Pesticide Selection:**
   a. **Use the least toxic chemical** that will accomplish the purpose.

Pesticides are poisons. Although they vary in toxicity and persistence, they all have the same common purpose, to kill something. Care should be used in selecting and applying a pesticide to minimize the amount of pesticides collected by stormwater runoff.

   b. **Use organic pesticides in lieu of or in combination with chemical pesticides**. A wide variety of organic pesticides, pro duced from plants, bacteria, and other nat urally occurring substances are available in quantities for both commercial and res idential use. These substances usually present much less risk for contamination of groundwater and surface water, and much fewer problems for disposal of left over product or containers. Beneficial insects are also available in bulk or amounts suitable for residential use, and can be used alone or in combination with other pesticides to eliminate or minimize the use of toxic substances.

   c. **Use pesticides that degrade rapidly** since they are less apt to become water pollutants.

   d. **Use pesticides with low solubility** since they are less apt to cause water pollution through drainage and runoff. Loss of such chemicals can be greatly reduced by preventing erosion.

2. **Application:**
   a. **Follow the manufacturer's instruc tions on the label**. Never exceed the manufacturer's dosage recommendations. The label message includes the target point for application on plant or soil; the recommended application times (early morning or late evening, when tempera tures are down and the air is still); safety advice, and referrals to Extension Service guidance. Consult the experts.

   b. Us**e granular forms** over liquids because application losses are lower.

   c. **Apply pesticides in a narrow band** rather than wide band; do not broadcast them over an entire lawn area. **Spot-spray infested areas** rather than apply ing excess amounts of pesticides as insurance against pests. **Never apply over impervious surfaces**; this precau tion especially applies to water sprays.

   d. **Spray pesticides only when wind speeds are less than 7 mph**. Spray in the early morning or at dusk when wind speeds are usually at their lowest. Air temperature should range between 40 - 80 degrees F.

   e. **Apply dust formulations during the early morning or late evening hours** when there is little or no air movement. These are highly susceptible to wind drift, not only when being applied but also after they reach their target.

   f. **Apply spray formulations during period of low air movement**. Large droplets fall faster and are less likely to contaminate non-target areas. Ground sprays followed by soil incorporation are not likely to be a source of water pollu tion unless excessive erosion occurs.

   g. **Apply granular formulation to moist soils** when there is little likelihood of an immediate heavy rain. Lightly sprinkle the applied area after application. Applying pesticides immediately before a predicted rainfall results in the loss of much of the pesticide in runoff. Loss of granular formulations can be controlled for the most part with adequate soil conservation practices.

There are many substitutes available for pesticides that will accomplish the same goal. These should be used before resorting to pesticides to minimize the potential impacts to surface water and groundwaters.

   h. **Contain fumigant forms of pesticides** after application through the use of soil compaction, water seal, and sealing of the area with a plastic cover. These must be kept in place for specific lengths of time in order to be effective. Most fumigants act rapidly and degrade quickly. Consequently, water pollution is usually not a problem.

   i. **Professional applicators must be certified**. Golf course superintendents, nursery and tree maintenance personnel, some industrial and institutional employees, and certain municipal employees will also need state certifica tion.

   j. **Keep up with available pesticide chemicals and application methods**. New and more effective pesticides are continually being introduced. Occasional, products are banned when unanticipated detrimental effects or hazards emerge. Therefore, commercial applicators must keep current with available pesticide chemicals and application methods. Owners or operators of facilities requir ing the services of applicators should ensure that their own employees with direct responsibility in this field keep informed.

3. **Disposal:**
   a. **Limit purchases to a one-year or one-season supply**. This will prevent the accumulation of materials and minimize disposal problems associated with unused materials.

   b. **Consult with Maine DEP Remediation and Waste Management for the disposal of pesticides**. Disposal of pesticides should be minimized by using small quantities for the purpose intended in accordance with product label directions until supplies are exhausted. Undamaged, unopened containers should be returned, if feasible, to the dealer or manufacturer. They should never be burned in built-up areas. Herbicide containers must never be burned. Certain other pesticides also carry a "No Burning" label.

4. **Storage:**
   a. **Store pesticides in accordance with manufacturer's recommendations**. Pesticides should not be stored longer than the maximum time recommended by the manufacturer, as leakage may develop. Storage facilities should:

- **provide adequate protection** against excessive heat, cold and moisture.
- **not be subject to flooding**.
- **prevent contaminated runoff** if leakage should occur.
- **provide for security** to prevent non-qualified individuals from dispensing the chemicals.
- **Avoid storage of pesticides in pump houses** or other buildings adjacent or in close proximity to streams, ponds, lakes, canals, or wells.
- **Do not mix pesticides or fill, empty, or repair application equipment** where spilled pesticides could drain or be washed into stream, ponds, canals, or other bodies of water.
- **Construct aprons and sumps** at com mercial loading sites to catch any over flow and spills.
- **Install check valves** on all intake hoses to prevent back-siphoning from sprayer tanks, particularly if the same pump is used for both filling and spraying.
- **Suspend the filler hose** so as to provide an air space between the hose and the surface of the spray mix in a full tank to prevent back-siphoning.
- **The operator must stay with the sprayer while filling**.

Pesticides must be labeled and stored properly to minimize leaks and misuse. Purchases should be limited to the quantity needed for a season or year to minimize disposal problems of unused materials.

b. **Surface Waters**: If water is withdrawn from a natural water body for mixing or cleanup, withdraw with a pumping sys tem separate from that of the pesticide application equipment. Do not drive equipment into a stream or lake for fill ing and cleaning. Flush equipment only in an area where dumping and rinse water can be properly treated and dis posed. If the equipment must be filled at the stream or lake, place only a suction on line in the water. Equipment should never be emptied or cleaned adjacent to (within 100 feet of) or in a water body.

c. **Groundwaters**. Do not place toxic chemicals on the soil where there is a danger of contaminating subsurface water through percolation or through rock fissures. Contaminated groundwater could be spread to many homes through a water distribution system which has a well drawing contaminated water as its supply. Use backflow pre vention devices on all hose connections used in the vicinity of chemical mixing and filling operations for additional pro tection. Pits used for dumping flush water should have impermeable linings to avoid groundwater and soil contami nation. The pits should be designed specifically for this purpose, and should comply with applicable standards for handling and disposal of pesticides.

d. **Piped Water Supplies**. There is a risk of siphoning that can be created by other users drawing water concurrently with filling or flushing operations. Equip all hose connections with backflow preven tion devices.

Technical advice on pesticide use is available throughout the state from local agents of the Cooperative Extension Service operating through the University of Maine. Contact the Maine Organic Farmers and Gardeners Association (MOFGA, P.O. Box 170, Unity, ME 04988) for information on minimizing pesticide and herbicide application, and cost-effective alternatives to pesticide and herbicide use.

References

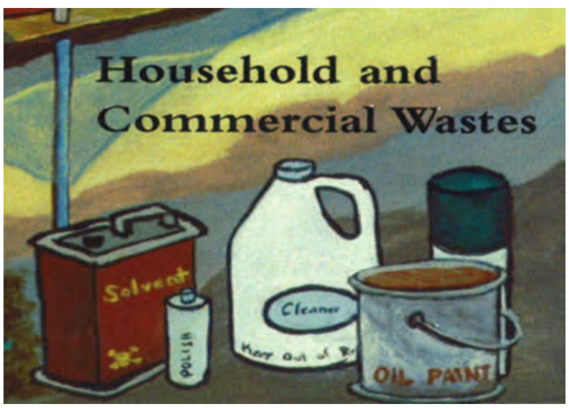
NPS Agricultural Task Force. 1991. *State of Maine Strategy for Managing Nonpoint Source Pollution from Agricultural Sources and Best Management System Guidelines*. Maine Department of Environmental Protection. Augusta, Maine.

University of Maine Cooperative *Extension Service. 1989. Best Management Practices for Maine Agricultural Producers*. University of Maine Cooperative Extension Service. Orono, Maine.

4.6 Materials Management

Description

Chemicals such as solvents, paints, cleaners and petroleum products are used extensively today by both residents and businesses for multiple purposes (i.e., home and building maintenance, auto maintenance). Many products, even common household products (i.e., moth balls, drain & oven cleaners, and motor oil) contain toxic ingredients. When released to the environment, toxics and hazardous substances may accumulate in sediment, posing risks to bottom feeding organisms and their predators. They also contaminate ground and surface drinking water supplies. Some contaminants can



Many commonly used products contain toxic ingredients (i.e., paint thinners, moth balls, drain and oven cleaners, motor oil, lubricants), requiring careful management and disposal. If released to the environ ment, toxics and hazardous substances can contaminate ground and surface waters, harming fish and other organisms, including humans.

bioaccumulate in tissues of fish and other organisms, including humans.

The proper management of these materials is essential to prevent their release to the environment and contact with stormwater. Materials management includes selection, use, storage and disposal of products.

This is an example of good storage practices for hazardous materials. Hazardous materials should be stored in their original containers off of the floor or ground. All containers should be labeled and covered. A storage cabinet is an excellent option for storing materials in a safe and convenient manner.

Guidelines

1. **Product Selection**: **Use natural and less toxic alternatives whenever possible**.

2. **Product Storage**:
   a. **Clearly label all containers with contents**.

   b. **Store chemicals in rugged, sealable, spill-resistant containers.**

   c. **Leave sufficient aisle space** to inspect materials and ease transport.

   d. **Store away from high traffic areas**. This reduces the possibility of spills associated with accidents.

   e. **Store on pallets** to avoid contact with moisture on floors, which can promote corrosion containers. This eases inspec tion of containers for leaks.

   f. **Keep materials covered** to reduce contact with stormwater and wind. This includes everyday storage, as well as handling operations.

3. **Product Use:**
   a. **Follow chemical directions** on the packaging.

   b. **Don't over-use chemicals**.

4. **Product Disposal**:
   a. **Never pour any substance, particularly hazardous or toxic products, down a storm drain inlet.** They flow directly to our lakes and streams.

   b. **Never pour hazardous or toxic products down a drain or toilet**.

   c. **Never dump hazardous or toxic products on the ground.**

   d. **Do not discard hazardous or toxic products with regular household trash**.

   e. **Recycle used motor oil** by taking it to a service station or local recycling center.

   f. **Do not mix with incompatible products**. This can cause reactions and release toxic fumes. Mixing of products could also pre vent a product from being recycled, increasing disposal costs.

   g. **Residents take unused hazardous chemicals to annual Household Hazardous Waste Collection Days.**

Unused hazardous materials or waste must be disposed of at a licensed facility. Many communities offer annual household hazardous waste days to residents, allowing residents to drop off any hazardous materials they need to dispose of. Hazardous materials should never be dumped down toilets or drains, storm drains, onto the ground, or thrown away with regular household trash. Disposal in this manner has the potential to contaminate surface waters and groundwaters.

5. **Vehicle Maintenance**:
   a. **Wash vehicles on the lawn or a car wash facility** instead of a paved surface. Washing a vehicle on a paved surface can flush detergents and other contaminants into the storm drain system and directly into streams, lakes and wetlands. Washing on a lawn or other pervious surface allows the wash water to filter through soils and vegetation, which help remove contaminants.

   b. **Keep automobiles well-tuned** to prevent toxic fluids from dripping and toxic fumes from emitting.

   c. **Dispose of used auto fluids and batteries at designated drop-off and recycling locations**.

   d. **Avoid spilling gas and oil on the ground or in the water**.

   e. **Immediately clean any spills on the ground.**

   f. **Don't top off fuel tanks**.

6. **Spill Response**:
   a. **Use as little water as possible to clean spills, leaks and drips**.

   b. **Keep absorbent materials such as kitty litter or speedy dry nearby** to contain spills and prevent them from entering drains.

   c. **Industrial facilities should consider developing a spill response plan** if not otherwise required. The plan should out line personnel responsible for implement ing the plan; the types, quantities and locations of wastes, as well as their associated hazards; measures to prevent spills; and what to do in the event of a spill (i.e., who to call, how to contain it).

References

Pollution Prevention/Good Housekeeping for Municipal Operations, Materials Management. Retrieved March 29, 2005 from the World Wide Web: URL: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/poll 9.cfm

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Chapter 5 Stormwater Design Considerations

Issues Requiring Design Consideration:

- Minimize Runoff Before Treatment
- Incorporate Reasonable Runoff Calculation Assumptions
- Provide & Size Pretreatment to Hold Annual Sediment Loadings - Accounting for Sanding
- Avoid Bypasses that allow Stormwater to Pass Untreated
- Use BMPs that Fit the Site
- Keep Snow Cover & Plowing in mind when siting BMPs
- Design for Maintenance making Access Readily Available and Frequency Realistic

Chapter 2 discussed the problems associated with traditional treatment designs and introduced the BMPs that DEP is recommending for use to meet water quality and quantity objectives. The design and installation of these BMPs, when sized correctly, will ensure that DEP's objectives are met. However, there are other stormwater design aspects that should be considered and incorporated into the planning and design process.

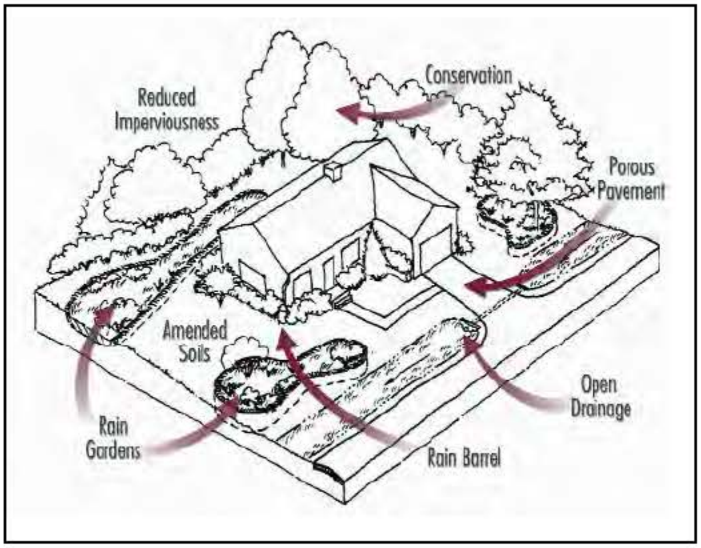
The following guidelines are recommended to address some of the issues found in traditional designs and site development, building on the existing successful techniques and improving many aspects of current stormwater handling and management.

5.1. Incorporate Low Impact Development (LID)

Many impervious areas are directly connected to drainage systems, increasing the volume and rate of runoff leaving a site. As discussed in Chapter 3, LID practices can be used to minimize the volumes and rates of runoff leaving a site, by handling it at the source, allowing for smaller 'end of pipe' treatment structures. LID practices should be encouraged as an alternative to or in combination with traditional techniques. Traditional treatment components are still 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. These stormwater control practices focus on mitigation, not prevention. Traditional designs 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.

Section Contents:

The LID methods and techniques introduced in Chapter 3 and further provided in Volume III, 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.



Drawing Courtesy of Puget Sound Action Team

This drawing reflects how LID can be incorporated into renovations or new development projects. This example shows how multiple LID techniques can be used to minimize runoff from a site. Ideally, LID should be incorporated at the design stage to most closely mimic predevelopment conditions, but many of the features could also be incorporated into a redevelopment project.

5.2. Sizing and Siting of Drainage Controls

The model TR-55, a runoff calculation model, is commonly used by developers and others to estimate pre and post runoff volumes and size drainage structures. TR-55 requires knowledge of the soil type and groundcover on the site and leaves it to the user's discretion to determine whether the existing and proposed cover types are in good, fair or poor condition. More information on hydrologic modeling can be found in Volume III.

In Maine, all pre-development conditions should be assumed to have good condition groundcover, and all post-development conditions should be assumed to have poor condition groundcover. Afterall, there is no guarantee that the property owner will maintain their property in the best possible condition. Additionally, any site that was wooded within the last five years should be considered undisturbed woods for all pre-construction runoff conditions, regardless of clearing or cutting activities that may have occurred on the site during that pre-application period.

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.

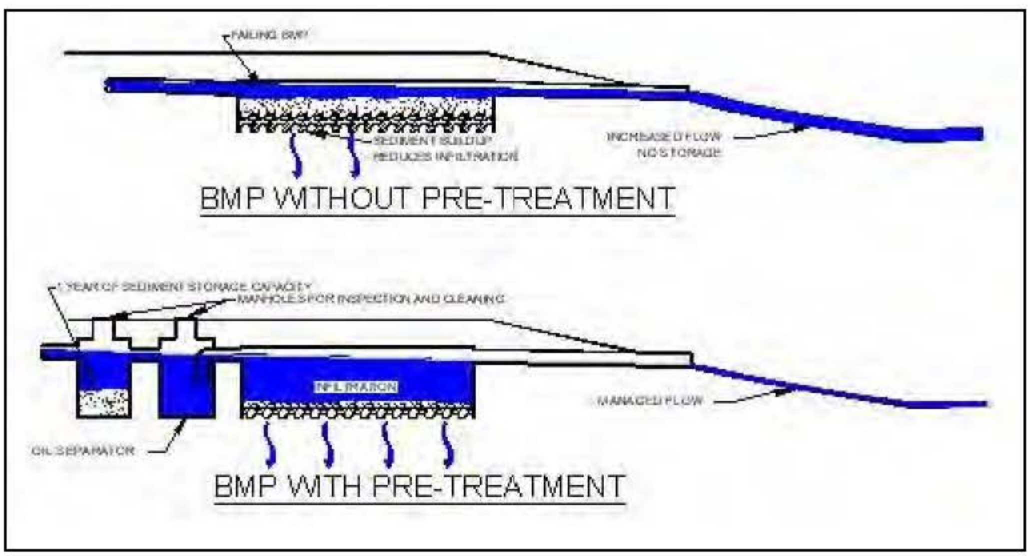
5.3. Provide Pretreatment on all BMPs

All stormwater treatment designs should include a mechanism to remove unwanted materials from the stormwater runoff prior to its entrance into the treatment unit. This is particularly important for infiltration systems. Except for rooftop runoff, stormwater contains sand and silt particles that can fill in detention structures and clog infiltration devices over time. One of the leading causes of failure in stormwater infiltration devices is clogging due to silts and sediments.

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.

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 raingardens and other LID techniques discussed in Chapter 3 and Volume III, typically provide pretreatment in the upper layers of the structure before it enters the infiltration reservoir area. Most use a



Pretreatment to remove coarse sediments is critical to the life of a stormwater treatment system, particularly infiltration and filtration systems. Without it, systems will quickly clog with the sand and silt particles carried by stormwater. This drawing shows how an infiltration system will function with and without pretreatment. Without pretreatment, as shown on the top figure, sand and silt in the stormwater deposit in the infiltration system, causing it to clog. This results in the discharge of untreated stormwater to the nearby stream. In the bottom figure, pretreatment is provided, allowing for greater infiltration of stormwater and less water being discharged to the stream..

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.[1]

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. However, infiltration should not be used at these sites.

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. An O&M plan with maintenance schedules and observable triggers identifying when maintenance is needed should be provided.

5.4. No Bypasses

Bypasses are used on some 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.

5.5. Adapt to Site-Specific Conditions

Some special site conditions may initially seem to preclude the use of infiltration techniques, including LID practices, but there are methods that may be used to adapt infiltration or LID practices to these sites. For example, sites with shallow groundwater suggest the use of wetlands treatment techniques since infiltration will not work seasonally. Similarly, organic absorption infiltration layers can be added where bedrock is shallow.

All sites can benefit from increasing the organic content of the onsite soils. In particular, the organic content of soils used in LID practices such as bioretention cells and raingardens is extremely important to the functioning of these systems. Not only do the soils promote the removal of pollutants in the water, but also provide absorption of runoff. The organic soils act as a sponge to retain water, providing more storage capacity than would normally occur. These systems can be modified to include underdrains that will carry excess water away from the site, after it has passed through the soil media. Underdrains may also be used to route stormwater flows to an area of more native soil material or sand that can be used for infiltration.

[1]Some techniques 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.

5.6. Consider Northern Climate Issues

Maine experiences very cold winters and the effects of our northern climate on BMP design should be considered. Some considerations include:

Photo courtesy of http://www.massport.com/logan/pic/c_1176b_plow2.jpg

Maine experiences very cold winters, with a lot of snow. Plowing, like shown on the left, is necessary to keep roads clear for safe passage. Stormwater treatment devices need to be designed with consideration to cold weather and plowing.

- Avoidance of curbing that could cause ice jamming by plows;
- Design of infiltration systems 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 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.

5.7. Insure Continuing Maintenance of All Stormwater Controls

Maintenance of BMPs is essential for them to perform as designed. There is widespread failure of traditional stormwater controls such as detention basins and other sediment containing controls. The good news is that they work well to remove sediments and the associated pollutants for a time, otherwise they would not fill up. The bad news is that they cease to function properly if not maintained and many are difficult to impossible to renovate and restore to original function. Some designs are too demanding for reasonable cost-effectiveness and continued attention. Issues include:

The detention area upgradient of this wetland was not properly maintained, causing large amounts of sediment to deposit in the wetland and the downstream pond. The cost to retrofit this BMP will be more costly than performing periodic maintenance originally specified.

- Difficult access for equipment;
- Difficult to clean without complete renovation;
- Lack of maintenance 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.

All BMP designs should comply with the following:

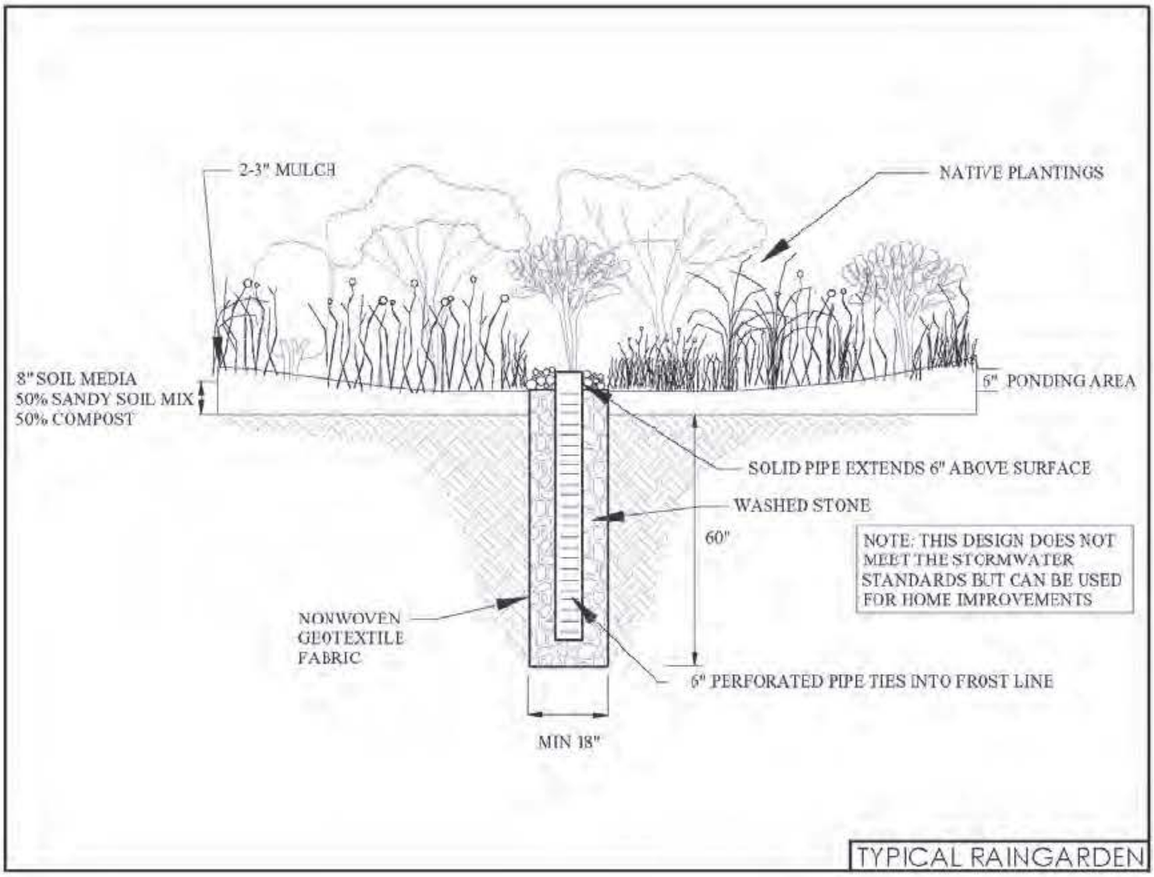
1. Formal equipment access
2. Ease and minimal cost of cleaning
3. Permanent maintenance easement
4. Method and easy access for evaluation of maintenance
5. Provisions for groundwater monitoring and assessment of the quantities of sediment removed, along with estimates in the design of expected annual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

A detailed and reasonable Operations & Maintenance plan should be developed, including manpower and budget needs.

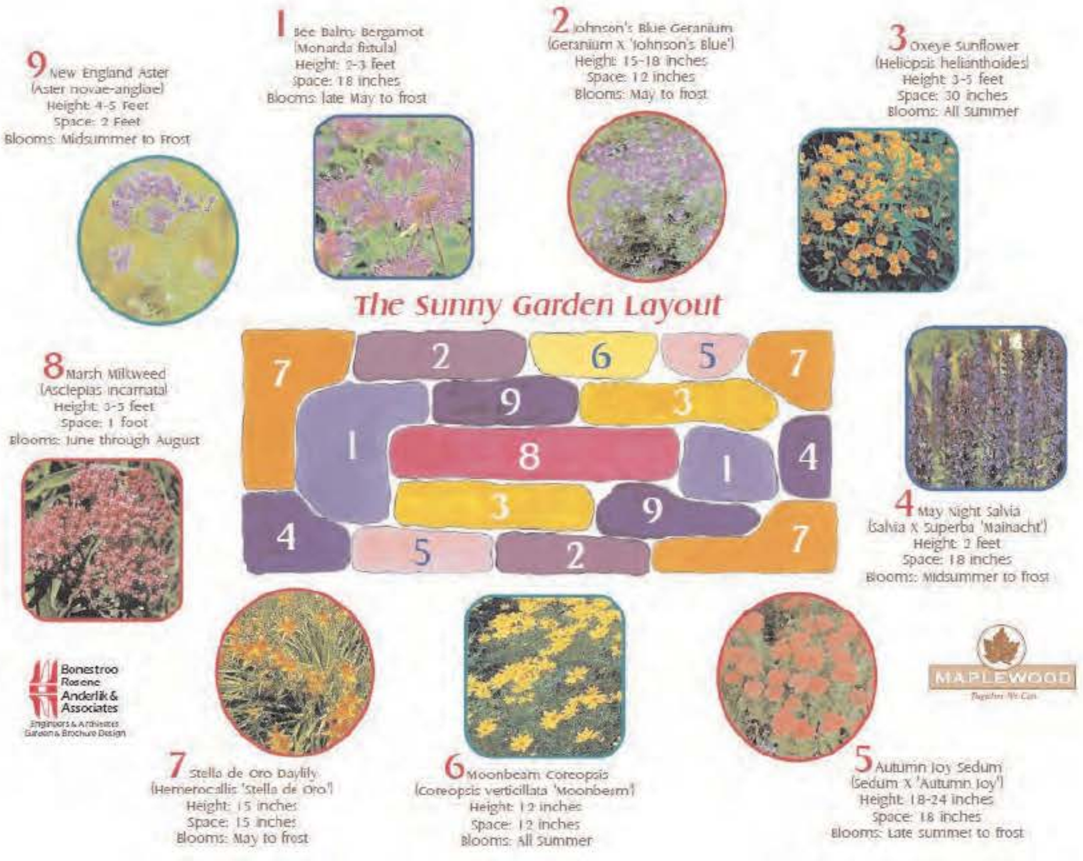
References

Comprehensive Environmental Inc. March 2003. *City of Nashua, New Hampshire Alternative Stormwater Management Methods, Part 1 – Planning & Guidance.*

Appendix A
Raingarden Layouts

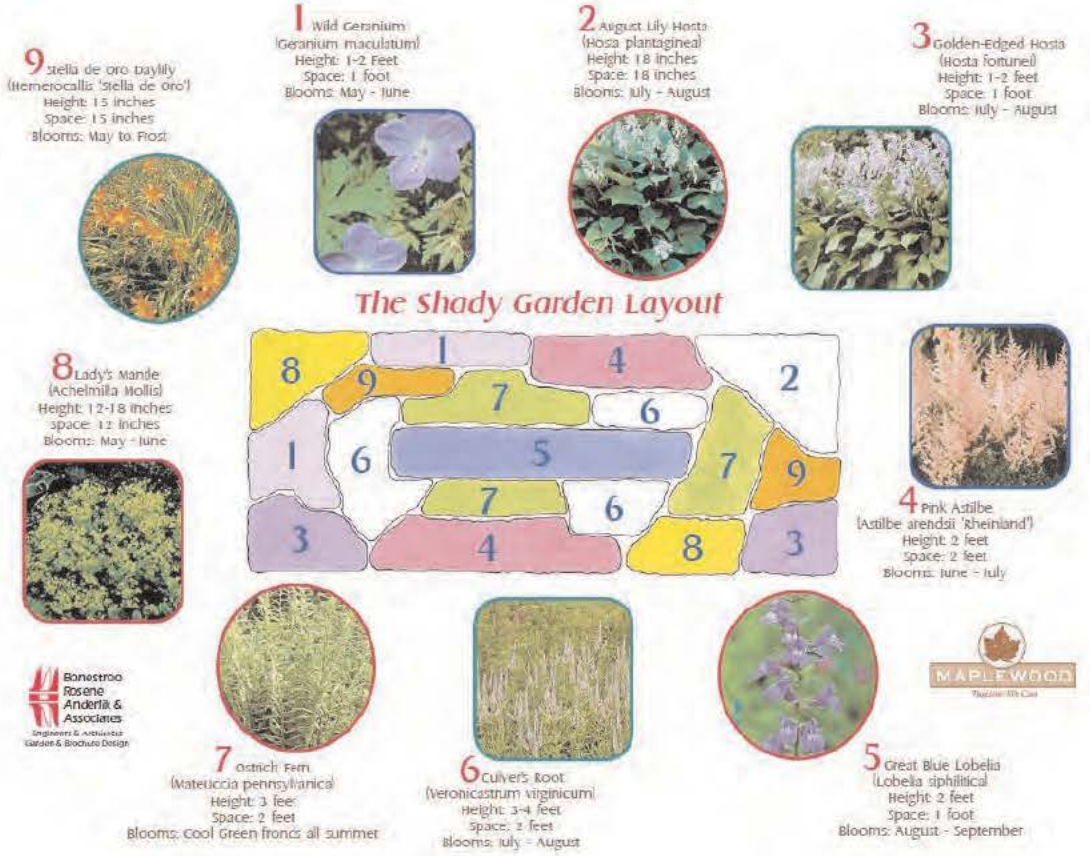


Sunny Garden



Sunny Border Garden

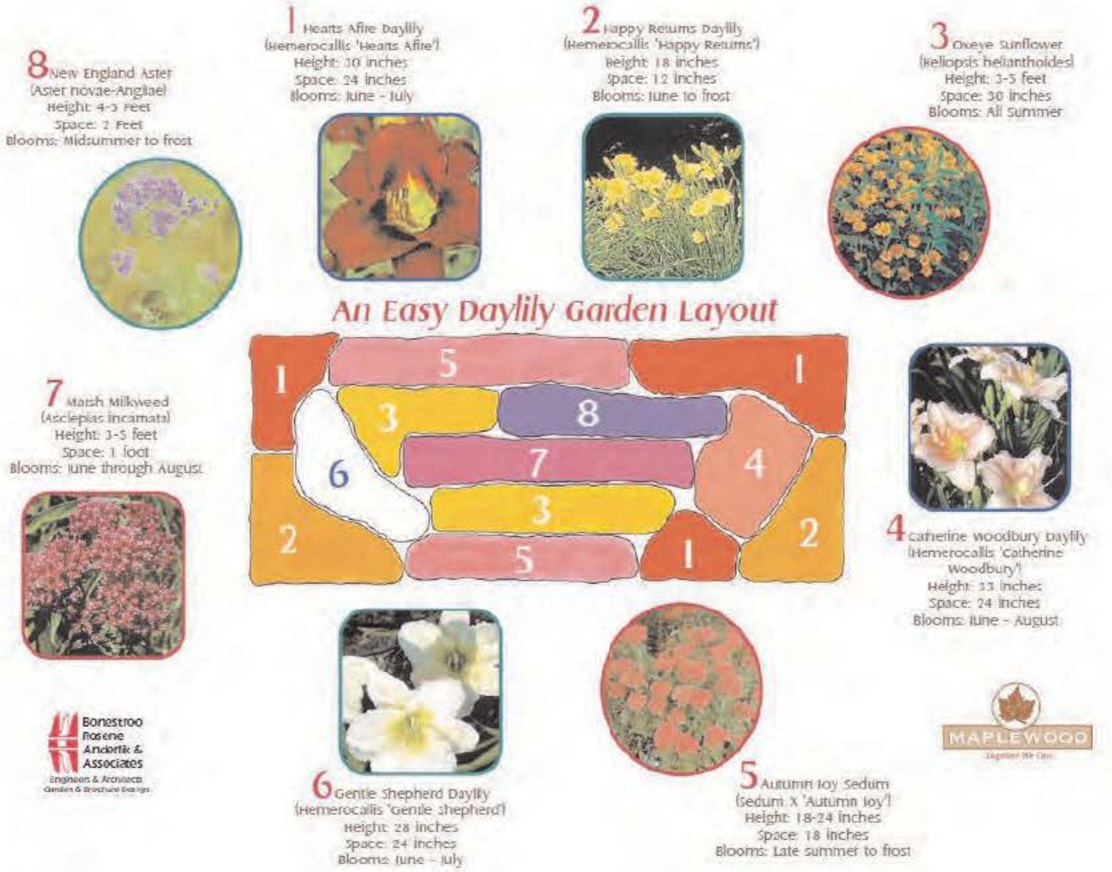
Shady Garden



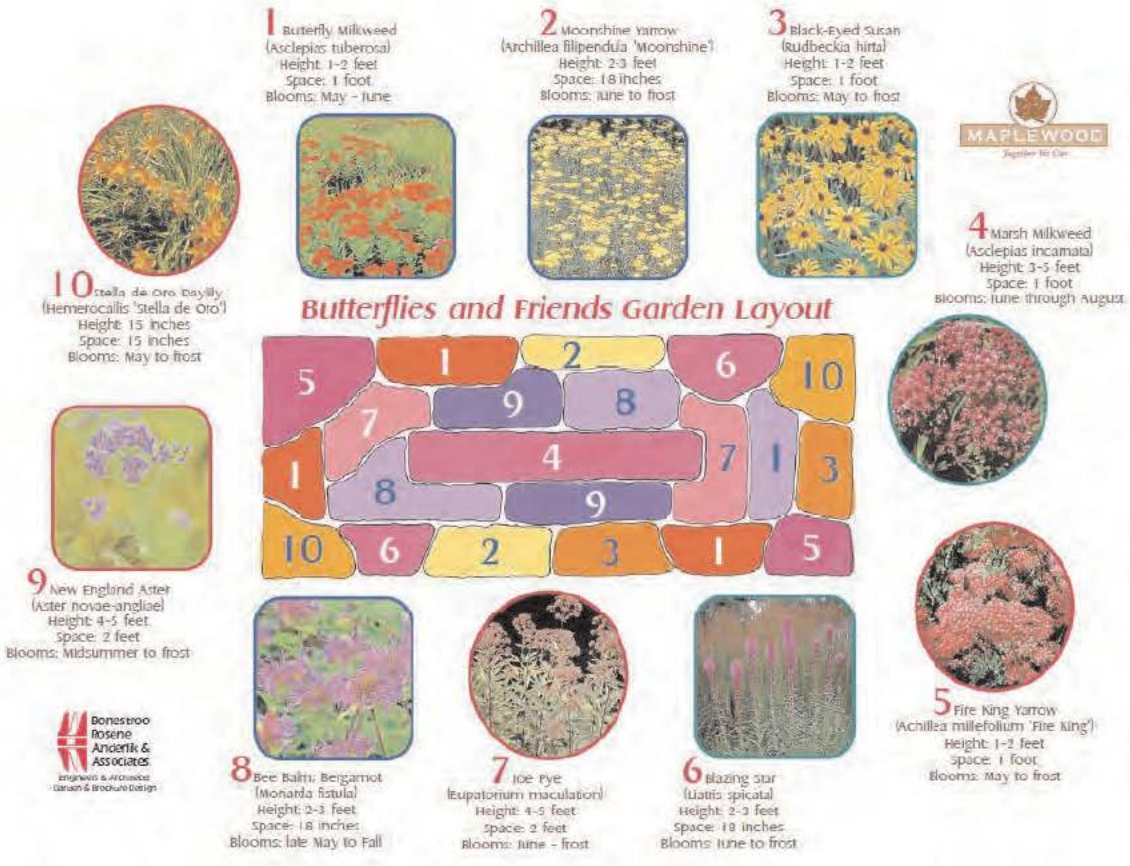
Prairie Garden

Easy Shrub Garden

Daylily Garden



Butterfly Garden



Appendix B
Landscape Design Standards for Stormwater Treatment

1. General Standards

Soil and landscaping play an important role in stormwater impacts and treatment results. From a quantity standpoint, the loss of good quality topsoil from many sites during construction results in significant increases in runoff quantities that are often not calculated in the models such as TR-55 typically used for runoff assessment. In terms of quality, high organic content of soils absorbs and adsorbs many pollutants. In fact peat and compost have been shown to provide considerable pollutant removal and are sometimes used in various treatment strategies.

Landscaping also affects stormwater quality and quantity. Grassed areas, while not totally undesirable, may have considerably more runoff due to compaction and more pollutant contribution due to the frequently-occurring overuse of fertilizers and pesticides. Alternatively, a tiered landscape containing an overstory (typically large shade trees), understory trees, shrubs and groundcovers provides the most absorption and natural uptake of rainfall. Some grass may be included but typically not an expansive monoculture. A more desirable landscape is diverse and provides wildlife habitat, shade, and beauty along with strips of grass for open areas.

Tiered landscapes, like natural landscapes, tend to require less maintenance and chemical input once established. These landscapes, including a highly organic soil profile, absorb and cleanse rainfall and runoff so that the quantity and quality are more reflective of a natural hydrology. By using these specifications, water, pesticide and fertilizer use will be minimized and vegetation will thrive with little but spring and fall cleanup.

2. Soil Preparation

1. Compacted soils restrict root penetration, impede water infiltration, and contain few macropore spaces needed for adequate aeration. In addition, compacted soils have a higher runoff coefficient and should be avoided. Preventing construction activities on parts of the site will help prevent compaction. In areas where this is not practical, methods to compensate for the compaction must be employed. Landscape areas should be deep tilled to a depth of at least 12 inches to facilitate deep water penetration and soil oxygenation. Use of soil amendments is encouraged to improve water drainage, moisture penetration, soil oxygenation, and/or water holding capacity. Soil amendments are organic matter such as compost, sewer biosolids, and forestry by-products, but do not include topsoil or any mix with soil as an element.

2. For all newly landscaped areas, including single-family residences, organic matter (three to four cubic yards of organic matter per 1,000 square feet of landscape area) should be incorporated to a depth of four to six inches. Organic content of landscaped soils shall not be less than 18% by volume in the top six inches of the finished topsoil.

3. For newly landscaped areas where topsoil is limited or nonexistent, or where soil drainage is impeded due to subsurface hardpan or bedrock, 6 to 24 inches of sandy loam topsoil should be spread in all planting and turf areas, in addition to the incorporation of organic matter into the top horizon of the imported soil. Organic content of landscaped soils shall not be less than 18% by volume in the top six inches of the finished topsoil.

4. Soil analysis of new or renovated turf areas should include a determination of soil texture, including percentage of organic matter; an approximated soil infiltration rate; and a measure of pH value.

3. Mulching

Mulch should be applied regularly to, and maintained in all, planting areas to assist soils in retaining moisture, reducing weed growth, and minimizing erosion. Mulches include organic materials such as wood chips, compost and shredded bark and inert organic materials such as decomposed lava rock, cobble, and gravel. If weed barrier mats are used, the use of inert organic mulches is recommended. Non-porous materials, such as plastic sheeting, are not recommended for use in any area of the landscape because of down-slope erosion, potential soil contamination from herbicide washing and increased runoff coefficients. Mulches should be applied to the following depths: three inches over bare soil, and two inches where plant materials will cover. Mulches for stormwater management areas should be heavier and not of a type that will float away.

4. Site Features and Layout

1. Landscaping should be designed to remain functional and attractive during all seasons of the year through a thoughtful selection of deciduous, evergreen, flowering and non-flowering plant varieties.

2. Prominent natural or man-made features of the landscape such as mature trees, surface waters, natural rock outcrops, roadways or stonewalls should be retained and incorporated into the landscape plan where possible. The addition of ornamental rocks, fencing and other features new to the landscape are encouraged.

3. Existing natural vegetation should be retained where possible. Existing trees and shrubs to be retained may be substituted for any compatible required plantings.

4. Lawn areas should be kept to a minimum. Natural re-growth, mulched planting beds and alternative groundcover plant varieties are preferred. Lawn areas should not be planted in strips of less than six feet in width, especially adjacent to roads or parking areas, since such areas require watering but have little utility and are less likely to thrive.

5. Native plant species, or plant species that have been naturalized in the area or the surrounding region should be used to meet the minimum requirements of this section. Plant varieties selected should be hardy, drought and salt resistant, and require minimal maintenance. Less hardy, exotic or higher maintenance plant varieties may be used to supplement minimum landscaping requirements where appropriate, but are not encouraged. Species listed on the current Invasive Species List for Maine shall not be used.

5. Use of Compost

Incorporation of organic matter such as compost improves the structure (tilth) of the till and any other soil types, with the exception of soils that are already highly organic. In sandy soils, compost increases the water holding capacity and nutrient retention. The physical and chemical properties of most New England soils can be significantly improved by blending in compost.

Compost-amended soil has many potential benefits when instituted with establishment of turf and landscaping, including: (1) increased water conservation, (2) increased nutrient retention, (3) better turf aesthetics, (4) reduced need for chemical use, (5) improved stormwater retention, and (6) cost-savings to the private landowner, and the Town.

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

The quantity of compost to be incorporated into a site is determined by the final organic content goal for the soil and is dependent on its existing organic content. Organic content of landscaped soils shall not be less than six percent.

6. Low Impact Development Landscaping

Landscaping that incorporates Low Impact Development (LID) strategies for stormwater management should serve to meet the requirements of the Town's stormwater management plan by absorbing and treating stormwater runoff to the greatest extent possible onsite. Low Impact Development landscaping includes the use of biofilters, raingardens, shallow swales, drywells and other features that use soil and landscaping to mimic natural hydrologic features and functions. The high organic content of the soils encourages healthy growth and absorbs and retains rainwater on site as soil moisture, minimizing irrigation needs and runoff quantities.

Landscape areas shall include all areas on the site that are not covered by buildings, structures, paving or impervious surface. The selection and location of turf, trees, ground cover (including shrubs, grasses, perennials, flowerbeds and slope retention), pedestrian paving and other landscaping elements shall be used to absorb rainfall, prevent erosion and meet the functional and visual purposes such as defining spaces, accommodating and directing circulation patterns, managing hardscape impacts, attracting attention to building entrances and other focal points, and visually integrating buildings with the landscape area. Where possible, the landscaping design should combine form and function, incorporating drainage features invisibly into the landscape such as through shallow detention areas, parking lot islands that provide for infiltration of parking lot runoff and sheet flow.

7. Neighboring Properties

Landscape Design Plans shall mitigate the impact to neighboring properties. The rear elevations of buildings, loading docks, and refuse collection areas must also be addressed in the Landscape Design Plan. It is required that rear elevations adjacent to non-commercial zoned parcels will be screened to the full height of the structure within seven (7) years of occupancy of the retail space.

8. Parking Lots

Parking lots with more than fifty (50) parking spaces shall have curbed planting areas. Planting areas shall be placed at each end of a parking row. No parking row shall contain 30 contiguous parking spaces without a curbed planting area.

Curbs around parking lot planting areas shall have a shallow descending cut that is a minimum of five feet wide to allow drainage to flow from the parking lot into the curbed planting areas for infiltration. Such planting areas shall be underlain by a suitable layer of crushed stone or other water holding reservoir, with an overlay of filter fabric to minimize clogging by fines. Topsoil depths and minimum organic content shall be as above for other landscaped areas for the maximum absorption of rainfall.

9. Vegetation

Any landscape element that dies, or is otherwise removed, shall be promptly replaced with the same, if not similar to, height or texture element as originally intended.

A split rail or picket fence, not less than two feet in height and not more than four feet in height, shall be provided between or to the rear of the trees to serve as a back drop and support for the shrubs and other planting, to serve as a unifying architectural element, and to protect against damage cause by pedestrian "cut-through" traffic. Shrubs and other smaller plantings should be placed between the fence and the street or on both sides where the fence is placed toward the center of the landscaped strip.

Landscape strips should be mulched or planted with hardy groundcover plant varieties rather than planted as lawn areas. Where landscape strips are used as part of the drainage system, plantings shall be tolerant of periodic wet conditions and shall be shallowly sloped to allow infiltration and storage.

Wheel stops should be provided in all parking areas abutting landscaped strips to avoid accidental damage.

Collector Roads: A deciduous shade tree and accompanying understory shrubs and groundcovers shall be planted in groupings along the front property line of all sites adjoining the collector road at a rate of not less than 1 tree per 25 linear feet of property frontage. Where larger shade trees may interfere with overhead utilities, minor shade or ornamental tree varieties should be used.

10. Maintenance

Low maintenance, drought, insect and disease resistant plant varieties are encouraged so that buffer areas and other required landscaping can be maintained with minimal care and the need for watering, pesticide or fertilized use is minimized. For these reasons, native species and species that have long thrived within the region are preferred since such plant species are well adapted to the local environment.

To avoid maintenance problems, soil testing should be conducted prior to planting to ensure that the appropriate plant varieties are selected for various portions of a site.

To avoid maintenance problems and excessive watering, organic matter such as compost or peat should be added to the soil before planting as appropriate to increase the water holding capacity of the soil and to provide nutrients.

Where used, irrigation systems should be installed with moisture meters or other devices designed to avoid unnecessary or excessive watering. Alternatively, irrigation systems should be manually activated.

11. Informal, Re-growth and Peripheral Landscape Areas

Disturbed areas intended for natural re-growth should be, at a minimum, graded, loamed and seeded with wildflowers, perennial rye grass or similar varieties. The planting of native trees, shrubs and other plant varieties is encouraged. The planting of blueberry, rhododendron, winterberry, bayberry, shrub dogwoods, cranberry bush, spicebush, native viburnums and other hardy shrubs along the edge of cleared woodlands provides for an attractive transition between natural woodland and more formally landscaped portions of a site. Where woodland areas are intended to serve as buffers, such plantings can fill in voids by rapidly reestablishing undergrowth. Perennial flowerbeds are also encouraged.

Plant Specifications and Definitions

1. Trees and shrubs - installation size requirements
   a) Minimum size for shade or canopy trees shall be 3 inches in diameter measured at a point six inches above grade with a height of not less than 12 feet.
   b) Minimum size for small or minor shade trees shall be 2.5 inches in diameter measured at a point six inches above grade with a height of not less than nine feet.
   c) Minimum size for ornamental or flowering fruit trees shall be 2 inches in diameter measured at a point six inches above grade with a height of not less than seven feet.
   d) Minimum size for evergreen trees shall be six feet in height.
   e) Minimum size for shrubs shall be 1.5 feet in height.

2. Planting Specifications
   a) Areas intended as planting beds for shrubs or hedges shall be cultivated to a depth of not less than 18 inches. All other planting beds shall be cultivated to a depth of not less than 12 inches.
   b) Pits for planting trees or shrubs shall be generally circular in outline with vertical sides. Pits for trees or shrubs shall be deep enough to allow one-eighth of the ball of the roots to be the existing grade. Pits for trees shall be wide enough to allow for at least 9 inches between the ball of the tree and the sides of the pit on all sides.
   c) Cultivated areas shall be covered with not less than a two to three inch deep layer of mulch after planting.
   d) All trees and shrubs shall be appropriately pruned after planting with all broken or damaged branches removed.
   e) All plants shall be nursery grown.

3. Retention of Existing Vegetation

   The boundary of areas to be cleared should be well defined in the field with tree markings, construction fencing or silt fencing as appropriate to avoid unnecessary cutting or removal. Care should be taken to protect root systems from damage from excavation or compaction. Individual trees, rock formations and other landscape features to be retained should also be clearly marked and bounded in the field.

12. Recommended Plant Varieties

See Attachment A

13. Definitions

1. Berm: a linear earthen mound designed to block views, noise or other potentially objectionable circumstances.
2. Deciduous: a plant with foliage that is shed annually.
3. Evergreen: a plant with foliage that is retained and remains green throughout the year.
4. Mulch:nonliving organic or synthetic matter spread over cultivated ground to retain moisture, limit weed growth and control erosion.
5. Ornamental tree: a deciduous tree, generally smaller than a shade tree, that is planted primarily for its aesthetic or ornamental value.
6. Shade tree: a large deciduous tree with a high crown of foliage or overhead canopy.
7. Shrub: A self-supporting woody plant, smaller than a tree, which consists of several small stems or branches from a base at or about the ground.

Attachment A

Suitable Raingarden Plant Species

Latin Name		Common Name
Acorus	*calamus*	Sweet flag
Adiantum	*pedatum*	Maidenhair fern
Agastache	*foeniculum*	Giant hyssop
Amelanchier	*canadensis*	Shadblow serviceberry
Amelanchier	*laevis*	Allegheny serviceberry
Andropogon	*gerardii*	Big bluestem
Anemone	*canadensis*	Canada anemone
Angelica	*atropurpurea*	Angelica
Apocynum	*androsaemifolium*	Dogbane
Aquilegia	*canadensis*	Columbine
Arisaema	*triphyllum*	Jack-in-the-pulpit
Aronia	*arbutifolia*	Red chokeberry
Aronia	*melanocarpa*	Black chokeberry
Asclepias	*incarnata*	Swamp/Marsh milkweed
Asclepias	*syriaca*	Common milkweed
Asclepias	*tuberosa*	Butterfly weed
Aster	*novae-angliae*	New England Aster
Athyrium	*filix-femina*	Lady fern
Betula	*nigra*	River birch
Calamagrostis	*canadensis*	Blue joint grass
Caltha	*palustris*	Marsh marigold
Campanula	*rotundifolia*	Harebell
Carex	*comosa*	Bottlebrush sedge
Carex	*crinita*	Caterpiller sedge
Carex	*interior*	Prairie star sedge
Carex	*lurida*	Lurid sedge
Carex	*pendula*	Drooping sedge
Carex	*scoparia*	Broom sedge
Carex	*stipata*	Common fox sedge
Carex	*vulpinoidea*	Brown fox sedge
Cephalanthus	*occidentalis*	Buttonbush
Chelone	*glabra*	Turtlehead
Clematis	*virginana*	Virgin's bower
Clethra	*alnifolia*	Sweet pepperbush
Cornus	*amomum*	Silky dogwood
Cornus	*racemosa*	Gray dogwood
Cornus	*sericea*	Red osier dogwood
Corylus	*american*	American hazelnut
Desmodium	*canadense*	Showy tick-trefoil
Dicentra	*eximia*	Fringed bleeding heart
Diervilla	*lonicera*	Low bush honeysuckle
Echinacea	*purpurea 'Nanna'*	Purple coneflower
Eleocharis	*palustris*	Great spike rush
Elymus	*virginicus*	Virginia wild rye
Equisetum	*fluvialle*	Horsetail
Eupatorium	*maculatum*	Joe-pye weed
Eupatorium	*perfoliatum*	Boneset
Eupatorium	*purpureum*	Savanna joe-pye weed
Filipendula	*rubra*	Queen of the prairie
Fothergilla	*gardenii*	Fothergilla
Fragaria	*virginiana*	Wild strawberry
Galium	*boreale*	Northern bedstraw
Gentiana	*andrewsii*	Bottle gentian
Geum	*triflorum*	Prairie smoke
Glyceria	*striata*	Fowl manna grass
Hamamelis	*virginiana*	Witch hazel
Helenium	*autumnale*	Sneezeweed
Helianthus	*laetiflorus*	Showy sunflower
Helianthus	*mollis*	Downy sunflower
Helianthus	*occidentalis*	Ox-eye sunflower
Hypericum	*pyramidatum*	Great St. John's wort

Suitable Raingarden Plant Species

Hypericum	*virginicum*	Marsh St. John's wort
Hystrix	*patula*	Bottlebrush grass
Itea	*virginica*	Virginia sweetspire
Ilex	*glabra*	Compact inkberry holly
Ilex	*verticilatta*	Winterberry
Iris	*versicolor*	Blue flag iris
Juncus	*effusus*	Common/soft rush
Juncus	*torreyi*	Torrey's rush
Lespedeza	*capitata*	Roundhead bush clover
Liatris	*scariosa*	Northern blazing star
Liatris	*ligulistylis*	Meadow blazing star
Liatris	*spicata*	Marsh blazing star
Lindera	*benzoin*	Common Spicebush
Lobelia	*cardinalis*	Cardinal flower
Lobelia	*siphilitica*	Blue lobelia
Matteuccia	*struthiopteris*	Ostrich Fern
Mertensia	*virginica*	Virginia Bluebells
Mimulus	*ringens*	Monkey flower
Monarda	*didyma*	Beebalm
Monarda	*fistulosa*	Wild bergamot
Onoclea	*sensibilis*	Sensitive fern
Osmunda	*cinnamomea*	Cinnamon fern
Osmunda	*regalis*	Royal fern
Panicum	*virgatum*	Switchgrass
Penstemon	*digitalis*	Smooth penstemon
Phlox	*divaricata*	Wild blue phlox
Phlox	*glaberrima*	Marsh phlox/smooth phlox
Phlox	*maculata*	Wild sweet William
Phlox	*pilosa*	Prairie phlox
Polygonatum	*falcatum*	Dwarf Solomon's seal
Pteridium	*aquilinum*	Bracken fern
Pycnanthemum	*virginianum*	Mountain mint
Quercus	*rubra*	Red oak
Ratibida	*pinnata*	Yellow coneflower
Rhododendron	*catawbiense*	Mountain rosebud rhododendron
Rhododendron	*maximum*	Rosebay rhododendron
Rudbeckia	*hirta*	Black-eyed Susan
Rudbeckia	*subtomentosa*	Brown-eyed Susan
Ruellia	*humilis*	Wild petunia
Salix	*caprea*	Pussy willow
Salix	*purpurea 'Nanna'*	Blue arctic willow
Sambucus	*canadensis*	Common elderberry
Schizachyrium	*scoparium*	Little bluestem
Scirpus	*atrovirens*	Dark green bulrush
Scirpus	*cyperinus*	Woolgrass
Scirpus	*fluviatilis*	River bulrush
Scirpus	*validus*	Softstem bulrush
Scutterlaria	*lateriflora*	Mad-dog skullcap
Solidago	*riddellii*	Riddell's goldenrod
Solidago	*rigida*	Stiff goldenrod
Solidago	*sempervirens*	Goldenrod
Spartina	*pectinata*	Prairie cord grass
Spiraea	*alba*	Meadow sweet
Spiraea	*tomentosa*	Steeplebush
Thalictrum	*dasycarpum*	Tall meadow rue
Tiarella	*cordifolia*	Foamflower
Vaccinium	*sp.*	Blueberry
Vernonia	*fasciculata*	Iron weed
Veronicastrum	*virginicum*	Culver's root
Viburnum	*dentatum*	Arrowwood viburnum
Zizia	*aurea*	Golden Alexander

Chapter 1
Introduction

Excess Phosphorus Levels in a Lake Can Cause Dense Blooms of Blue-Green Algae which Cause:

- Murky green water
- Odors
- Depleted oxygen levels in the deep, cold water which can lead to fish kills

Phosphorus is a nutrient that controls the level of algae production in lakes. Algae are microscopic plants that grow suspended in the open water of the lake or in concentrated clumps around the shallow margins of the lakeshore. The amount of algae in the lake water affects the clarity of the water, as well as the amount of well oxygenated, cold water available to cold water fish species (trout and salmon) in the summer months. Low phosphorus concentrations yield clear lakes with plenty of deep, well oxygenated cold water. High phosphorus concentrations yield cloudy lakes and oxygen may be severely depleted or eliminated from the deep, cold water in the summer months. Very high concentrations cause dense blooms of blue-green algae, which turn the water a murky green and accumulate as an odorous scum along the shoreline (for more information about lakes and phosphorus see Appendix A).

Phosphorus, a common nutrient typically associated with soil particles and organic matter, mostly reaches the lake in stormwater runoff from the lake's watershed, the land area draining to the lake. Since the portion of stormwater phosphorus that support algae growth tends to be associated with small, lightweight soil particles, it is easily carried by stormwater and can be delivered to the lake from anywhere in the watershed.

High phosphorus levels in lakes cause dense algae blooms, which can accumulate along the shoreline as shown above.

The amount of phosphorus reaching the lake depends on what the stormwater runs over on its way to the lake. For example, forested areas do not readily release phosphorus to stormwater due to duff and canopy coverage whereas developed areas, such as residential, commercial or industrial areas, contain high levels of phosphorus, which are readily released to stormwater runoff, yielding higher lake concentrations. Generally speaking, the more developed a lake's watershed is, the higher its phosphorus concentration will be (for more information about phosphorus sources and transport see Appendix A).

This volume addresses long-term phosphorus loadings to lakes by setting standards to limit phosphorus contributions from new developments, and outlines guidelines to meet these standards. It does not address the short term, often catastrophic, increase in stormwater phosphorus that can result from unmitigated soil erosion during the construction process (see Maine Erosion and Sediment Control BMPs (DEP, 2003) for information about addressing erosion from construction sites).

The standards in this volume focus on limiting, not preventing, phosphorus contributions from new developments to lakes and they are not likely to be applied to all new phosphorus sources in a lake's watershed. As such, the implementation of stormwater management alone may not be sufficient to prevent a noticeable decline in lake water quality. To effectively maintain lake water quality, the elimination of significant existing sources of phosphorus would be necessary.

Chapter 2 of this volume presents the basic phosphorus standard for new development.

Forested areas such as this one do not readily release phosphorus to stormwater due to the duff and canopy coverage. Developed areas release the greatest amounts of phosphorus and need controls in place to limit phosphorus contributions.

Chapters 3 through 6 present a procedure for new developments to meet the standard that can be used by developers and reviewing agencies (i.e. planning board). The Appendices provide detailed supporting information.

Chapter 2
The Watershed Phosphorus Budget

Lakes can only accept so much phosphorus before a significant decline in water quality occurs. The Maine Department of Environmental Protection has developed phosphorus allocations for several Maine lakes to minimize phosphorus loadings and their impacts to lake water quality.

Lakes are individuals, each one differing from the others with varying size, shape and depth. Specific lake characteristics will affect the way a lake will respond to additions of phosphorus.

The watersheds draining to lakes also vary as they can be large or small relative to lake size and can contribute relatively large or small volumes of stormwater and groundwater to the lake. The watershed can be entirely upland or it may contain a number of upstream lakes and wetlands. It may contain steep slopes and hilly terrain, or be relatively flat. Soils may range from loose sands or gravels to tight clays or shallow tills. Watersheds can range from completely forested to highly agricultural or heavily developed, and may be located in areas ranging from little to rapid growth. These factors, along with the characteristics of the lake itself, determine the potential for increased phosphorus, and hence algae, in the lake over time. This chapter describes how to estimate the amount of additional stormwater phosphorus load to the lake, called phosphorus export that will be generated as a result of the project. It applies to commercial development projects and to subdivisions involving new road construction or expansion, or having more than five lots.

A lake's watershed boundary is dictated by local topography, generally following ridgelines or high points as shown by the shading above. Precipitation that falls within the watershed and is not evapotranspired reaches the lake as groundwater or stormwater runoff. The watershed and lake characteristics dictate the potential for increased phosphorus and algae in the lake over time.

Chapter Contents:

2.1 Watershed Per Acre Phosphorus Allocation

The Department of Environmental Protection (DEP) has considered all of the factors described above in developing phosphorus budgets for the watershed of each lake. Each budget is based on how much additional phosphorus loading the lake could accept without risking a perceivable change in the lake's water quality. It then distributes this additional phosphorus load amongst anticipated new development sources in the lake's watershed on a per acre basis. The per acre phosphorus allocation (referred to as "P") defines how much phosphorus each acre of land in a lake's watershed is allowed to discharge in stormwater runoff when developed.

If a lake's watershed is located within more than one town, the value of P may vary slightly for each town, depending on its anticipated rate of growth. The process used to define watershed phosphorus budgets is presented in Appendix B.

For large subdivisions and commercial developments (Chapter 3), P defines the average amount by which a development may increase the annual stormwater phosphorus exported to the lake from each acre of the parcel being developed.

For small projects, such as single family residences and additions to existing development (Chapter 6), the budget simply defines the type and size of phosphorus runoff controls, such as wooded buffers, which should be applied.

Phosphorus allocation values range from about 0.02 lb/acre/year for very sensitive lakes in high growth areas to 0.15 lb/acre/year for less sensitive lakes in very low growth areas.

P = Per Acre Phosphorus Allocation (lb/acre/year) = the watershed specific amount of stormwater phosphorus each acre of land within a parcel that is being developed is allowed to export annually. This is calculated by the DEP for selected Maine lakes as presented in Appendix C.

If a P for a lake/town combination is not listed or if you have information that suggests the P for a lake should be higher or lower than that presented in Appendix C, contact DEP's Division of Watershed Management.

2.2 Project Phosphorus Budget (PPB)

A project's phosphorus budget (PPB) is the maximum amount of algal available phosphorus, which in a typical year, may be exported from the new development. Algal available phosphorus refers to that portion of phosphorus the stormwater runoff transports which can support algae growth in the lake. Typically about half of the total amount of phosphorus becomes available for algal growth.

PPB = Project's Phosphorus Budget = maximum amount of algal available phosphorus, which in a typical year, may be exported from the new development's parcel.

To calculate the PPB, multiply the acreage of developable land in the project parcel by the per acre phosphorus budget for the lake.

The developable land area includes all land within the parcel's boundaries except for NWI (National Wetlands Inventory) mapped wetlands over an acre in size and areas of sustained slope greater than 25% that are over one acre in size.

All areas need to be in acres to the second decimal place.

Use Worksheet 1 in Appendix D for calculating project phosphorus budgets.

Example 1: PPB Calculation for Subdivision Development

Problem:
'Homesweet Home Subdivision' is proposing a 12-lot subdivision on 40 acres. There are four acres of NWI wetlands and 1 acre of steep slopes. Calculate the PPB.

Solution:
Use Worksheet 1 to calculate the PPB.

Worksheet 1 PPB Calculations			
Project Name:	Homesweet Home Subdivision		
Standard Calculations			
Watershed per acre phosphorus allocation (Appendix C):	P	0.057	lbs/acre/year
Total acreage of development parcel	TA	40.00	acres
Existing impervious area (Pre 1980)	EIA_B	0.00	acres
Existing impervious area (post 1980)	EIA_A	0.00	acres
NWI wetland acreage:		4.00	acres
Steep slope acreage:	SA	1.00	acres
Project acreage: $A = TA-(WA+SA+EIA_B+EIA_A)$	A	35.00	acres
Project Phosphorus Budget: PPB = P x A	PPB	**1.995**	**lbs P/yr**

Based on these calculations, the PPB is 1.995 lbs P/year.

Special Considerations

Alternative method for small commercial-type development located within designated growth areas.

It can be difficult for densely developed projects on small parcels to meet their phosphorus budgets. Because of the density of high phosphorus producing surfaces like parking lots and lawns, the stormwater draining these projects carries relatively large amounts of phosphorus. The small parcel size, however, means that the phosphorus budget for the parcel will also be small. As a result, highly intensive phosphorus control measures, which are often fairly costly, may be required for the project to meet its phosphorus budget.

In these cases it may cost less to develop outside the designated growth area where land is more readily available for larger parcel sizes (and hence larger project phosphorus budgets) and for less intensive, and less expensive, phosphorus control measures like natural wooded buffers. If a municipality is concerned that the phosphorus budget will counter local planning efforts by being a disincentive for locating development within designated growth areas, they may request that the department allow commercial developers within their designated growth areas to use an alternative means of defining the project phosphorus budget. This alternative is described in Appendix E.

Project phosphorus budgets for large projects located within relatively small watersheds.

If a particularly large project is proposed in a relatively small watershed, there is a chance that the project's phosphorus budget may, by itself, use up most of, or even exceed, the watershed's total phosphorus budget, leaving little or no room for additional development within the watershed. In order to avoid this problem, an alternative method for calculating the project phosphorus budget for such projects is provided in Worksheet 1 under Small Watershed Adjustment. For each lake, DEP has identified the parcel size that would trigger use of this alternative method, called the small watershed threshold. If a project's parcel size exceeds the small watershed threshold (SWT) acreage given for each lake in the list of per acre phosphorus budgets in Appendix C, the PPB should be calculated using the Small Watershed Adjustment calculations in Worksheet 1.

Chapter 3
Meeting the Project's Phosphorus Budget

A site's phosphorus export must be calculated and compared to the Project Phosphorus Budget (PPB) to determine the extent of phosphorus reductions needed and the best method for achieving these reductions.

3.1 Estimating Stormwater Phosphorus Export from the Project

To determine if a project meets or exceeds its PPB, the project's phosphorus export (PPE) needs to be estimated. This section outlines the procedure for estimating the pre-treatment PPE (Pre-PPE), that is, the phosphorus export from the project before passing through a stormwater management practice designed to remove phosphorus (i.e. buffers, wet ponds). Estimating post treatment phosphorus export will be discussed in the next section.

PPE = Project Phosphorus Export = amount of phosphorus that will reach the lake from a new development.

Pre-treatment PPE = Raw Phosphorus that the new development will create.

Post-treatment PPE = Phosphorus that will be discharged after treatment by all stormwater management treatment practices.

The amount of phosphorus exported from a project site will depend on the land use and soil type, with greatest exports from impervious surfaces as the one shown here.

Chapter Contents:

For all project development and subdivisions projects where the land use and impact has been determined and lot development will be restricted, the pre-treatment export is estimated by:

1. dividing the project into various land use types (i.e. parking, roads, roofs, lawns by soil type),
2. determining the area within each land use in acres and to the second decimal place,
3. multiplying that area by the appropriate phosphorus export factor from Table 3.1 or Table 3.2 as is appropriate, and
4. summing the resulting phosphorus exports to get the Pre-PPE.

Use the first four columns in Worksheet 2 in Appendix D to calculate the Pre-PPE.

Table 3.1 gives pre-treatment phosphorus export for new commercial/industrial development and for roads in residential subdivision projects. Table 3.2 should be used for lots in residential subdivisions unless the dimensions and locations of buildings, driveways and lawns have been pre-determined, specifically restricted, and all construction and landscaping on the lot will be done by the developer, in which case the High Export Option from Table 3.1 may be used.

Table 3.1
Algal Available Phosphorus Export (pre-treatment) for Commercial Development and Subdivisions

		Low Export Option	**High Export Option**
Land Use	Hydrologic Soil Group	P Fertilizers restricted, roads and drives paved and constructed with stable swales (lb/acre/yr)	No restrictions on fertilizer use, road surface or ditch design and construction (lb/acre/yr)
Landscaped Areas, Lawns & Ditches	A	0.1	0.2
	B	0.2	0.4
	C	0.3	0.6
	D	0.4	0.8
Roads/Driveways	N/A	1.25	1.75
Parking	N/A	1.25	1.25
Roofs/Other	N/A	0.5	0.5

The Low Export Option factors may be selected for commercial/industrial development and roads if all of the following are incorporated in the project:

- A deed restriction prohibiting the use of fertilizers containing phosphorus except when establishing new turf or vegetation on bare soil will be established for all lots. It is recommended that the use of fertilizer containing phosphorus always be limited.
- All roads, driveways and parking areas are paved.

- All ditches and drainage ways are designed, constructed and maintained as stable vegetated swales in accordance with the specifications in Volume III, Chapter 8.1, or as riprapped swales where required by steep slopes. The algal available phosphorus export for ditches and swales is based on soil type and is the same as the export of a lawn

If all of these elements are not clearly and permanently incorporated in the project design, use the High Export Option factors of Table 3.1.

Example 2: Pre-treatment PPE Calculation for Commercial Development

Problem:

'Good Intention Business Mall' is proposing a business mall on 6 acres. The development will consist of 3.5 acres of paved parking, a 0.5 acre paved access road, 1.5 acres of buildings and 0.5 acre of lawn. A deed restriction is proposed, prohibiting the use of fertilizers containing phosphorus. Soils on the site are classified as Hydrologic Soil Group C. Calculate the Pre-treatment PPE for the proposed project.

Solution:

Use Table 3.1 and Worksheet 2 to calculate the pre-treatment Algal Average Phosphorus Export.

Worksheet 2 Pre-PPE Calculations			
Project Name: Good Intention Business Mall	Development Type:Commercial		
Land Surface Type of Lot #(s) with description	**Acres or # of lots**	**Export Coefficient from Table 3.1**	**Pre-treatment Algal Av. P Export (lbs P/year)**
Parking (pavement)	3.50	1.25	4.375
Access Road (low export)	0.50	1.25	0.625
Buildings	1.50	0.5	0.75
Lawn (HSG C)	0.50	0.3	0.15
		Pre-PPE (lbs P/year)	5.9

Based on these calculations, the Pre-treatment PPE is 5.9 lbs P/year.

Table 3.2 gives pre-treatment phosphorus export for single family residential lots. In most cases, the specific area of the development on a lot (houses, garages, driveways, lawns) within the subdivision is usually not known. Table 3.2 must be used to determine the export from each lot unless the developer:

- Has pre-determined the area of each land use on each lot
- Will be constructing the buildings and driveways and landscaping the lots, and
- Will be restricting any further expansion of these land uses
- A deed restriction will be required for each lot that incorporates an area restriction.

Table 3.2
Algal Available Phosphorus Export from Single Family Residential Lots (pre-treatment)

Hydrologic Soil Group	With Area Restrictions		Without Area Restrictions	
	Cleared Area ≤ 12,000 sq ft Driveway/Park ≤ 1,750 sq ft (lb/lot/year)		No Restriction on cleared area or driveway/parking area (lb/lot/year)	
	w/ 75% drive/park area to buffer	w/o 75% drive/park area to buffer	w/ 75% drive/park area to buffer	w/o 75% drive/park area to buffer
A	0.09	0.14	0.12	0.18
B	0.12	0.17	0.17	0.24
C	0.15	0.2	0.22	0.29
D	1.08	0.23	0.27	0.34

Note: Driveways and parking are considered to be draining directly to a buffer if the flow path to the buffer is 50 feet or less and if the runoff reaches the buffer in well distributed overland flow.

Note: The phosphorus export values in this table assume a driveway of 150 feet in length, or less. If driveways will likely exceed 150 feet, the excess driveway length should be considered a road and its export calculated using Worksheet 2 and Table 3.1.

Example 3: Pre-PPE Calculation for Subdivision Development

Problem:
The 'Homesweet Home Subdivision' in Example 1 involves the development of 12 lots and 0.5 acres of road. Four lots will be constructed on HSG B soils with no restrictions on cleared area or driveway/parking area. Eight of the lots will be constructed on HSG C soils and will have restrictions to minimize site clearing to <12,000 square feet each and to minimize driveway/parking areas to <1,750 square feet. Six of the restricted lots will not direct 75% of the driveway and parking area runoff to a buffer. Two of the restricted lots will direct the stormwater runoff from 75% or more of the driveways and parking areas to a buffer. Driveways from two of the lots will exceed 150 feet in length, with an anticipated 0.056 acres of driveway over the 150 length. The proposed road will be paved. Calculate the Pre-treatment PPE for the proposed subdivision.

Solution:
Use Tables 3.1 and 3.2 and Worksheet 2 to calculate the pre-treatment Algal Average Phosphorus Export.

Worksheet 2 Pre-PPE Calculations			
Project Name: Homesweet Home Subdivision	Development Type:Residential		
Land Surface Type of Lot #(s) with description	**Acres or # of lots**	**Export Coefficient from Table 3.1**	**Pre-treatment Algal Av. P Export (lbs P/year)**
Lots 1-4 (HSG B) no restriction, w/o 75% to buffer	4	0.24	0.96
Lots 5-10 (HSG C) <12,000 sqft clearing, w/o 75% to buffer	6	0.20	1.2
Lots 11 & 12 (HSG C) <12,000 sqft clearing, w/ 75% to buffer	2	0.15	0.30
Lots 2 & 3 driveway access > 150 feet	0.056	1.25	0.07
Subdivision Road (low export)	0.5	1.25	0.625
		Pre-PPE (lbs P/year)	3.155

Since two of the driveways exceeded 150 feet in length, the excess driveway length was considered a road and its export calculated as such.

Based on these calculations, the Pre-treatment PPE is 3.155 lbs P/year.

3.2 Redevelopment or Expansion of Existing Uses

Phosphorus export need not be estimated for any land uses that were in existence prior to 1997 (prior to 1980 for projects that require a Site Location of Development Act (SLODA) Permit from the DEP). For any proposed project that will be built within a parcel having existing development (built before 1997 or 1980 for SLODA projects) that will be enlarged, upgraded or expanded, the phosphorus export should only be estimated for the net increase. This would apply to the redevelopment or expansion of any existing buildings, parking, roads and lawns. Any existing development or land disturbance that was created after 1997 (1980 for SLODA Projects) must be included as a new phosphorus export. This includes logging roads, new access roads, and all other projects created from an undisturbed condition that did not require a phosphorus design and permit at the time of construction.

For example, if a proposed subdivision is served by an existing 2000 foot gravel road, which was built before 1997, and will be upgraded and expanded from a width of 14 feet to a width, with shoulders, of 24 feet, the phosphorus export should only be estimated for the net increase in road area, or 10 feet x 2000 feet = 20,000 square feet.

3.3 Reduction of Phosphorus Export

Most projects will generate more phosphorus than the project's phosphorus budget (PPB) will allow. In order to meet the budget, the excess phosphorus export must be reduced. Comparison of the pre-treatment PPE with the PPB will determine how much export will need to be reduced. This section describes options for reducing phosphorus export and how to estimate phosphorus export after treatment.

There are two basic options for reducing long term phosphorus export.

Option 1. Redesign to Reduce Phosphorus Export: The first option is to redesign the project so that initial phosphorus export is minimized. This can be accomplished by:

- Limiting the size or intensity of the project (i.e. reducing the number of lots, the length of roads, the size of a parking area),
- Locating the developed portion of the project on the best soils and shallowest slopes, and
- Incorporating such measures as clearing restrictions and limitations on the use of phosphorus fertilizers.

These reductions in phosphorus export will be reflected in the calculation of pre-treatment PPE described in the previous section.

Option 2. Implement Best Management Practices (BMPs): The second option for reducing a project's stormwater phosphorus export is to incorporate stormwater best management practices (BMPs) to remove phosphorus from the stormwater before it leaves the site. Some examples of BMPs are vegetated buffer areas, wet ponds, soil filters and infiltration beds. Volume III presents detailed design standards for a number of commonly used BMPs.

All BMPs are not created equal. Some BMPs do a better job of removing phosphorus from stormwater than others. Also, within a given type of BMP, differing designs or locations may result in different levels of effectiveness in removing phosphorus. For example, a broad, wooded buffer on permeable soils with a shallow slope will retain much more phosphorus than a narrow, field buffer on tight soils and steeper slopes. For stormwater treatment ponds, such as wetponds, the size of the pond relative to its contributing watershed, its depth and its shape determine its effectiveness.

In this Volume, a BMP's effectiveness in treating stormwater runoff is described in terms of a "treatment factor". The Treatment Factor (TF) indicates the fraction of stormwater phosphorus that will pass through the BMP and not be retained. A simple way of estimating treatment factors for a variety of BMPs based on an adjustment of the standard sizing specifications for BMPs described in Volume III of this manual is presented in Chapter 4 of this volume.

RE = Removal efficiency = The fraction of stormwater phosphorus that will be removed by the BMP. The higher the removal efficiency, the more effective it will be at retaining phosphorus from reaching the resource.

TF= Treatment factor = (1.0 - RE) = The fraction of the stormwater phosphorus that will pass through a BMP and not be retained. The lower the treatment factor, the more effective the BMP.

When phosphorus from a project draining to a BMP is multiplied by that BMP's Treatment factor (1.0 - RE), the resulting product is the amount of phosphorus that, after treatment, will still be exported to the lake.

For example, if a wooded buffer was projected to retain 60% and discharges 40% of the inflow phosphorus, it would have a removal efficiency of 0.6 and a treatment factor of 0.4.

When planning the project, the project designer should look for opportunities to locate the most effective BMPs (those with the highest removal efficiency) to collect runoff from the portions of the project which produce the most phosphorus export (i.e. roads, parking areas, driveways, house lots). If the project site is large enough, the preferred BMP is a natural wooded buffer area located immediately down hill of the stormwater source area. Buffers are preferred because they are natural and they require little, if any, maintenance (just don't cut the trees or disturb the ground cover). The critical element in siting buffers is to insure that the stormwater runoff enters the buffer in overland, non-channelized flow, that will not concentrate into a channelized flow within the buffer. By comparison, other BMPs require site specific design and careful construction as well as regular inspection and maintenance.

3.4 Estimating Project Phosphorus Export after Treatment (Post-PPE)

In order to determine if the BMPs incorporated into the project are adequate to meet the PPB (Project Phosphorus Budget), the pre-treatment PPE must be revised to reflect the treatment capabilities of those BMPs. This is accomplished by multiplying the phosphorus export from each source area (i.e. a parking lot, a house lot, a segment of road) by the treatment factor (1.0 - RE) of the BMP to which it drains. See Section 4.1 BMP Rules of Thumb, if the individual source areas (or subcatchments) drain cumulatively to more than one BMP. The export values for all source areas, both treated and untreated, are then added together to get the total phosphorus export for the project using Worksheet 2.

For large projects or projects where the natural topography divides the site drainage into a number of sub-drainage areas, this process may not be as straight forward. For instance, often the entire length of a road will not drain to the same BMP. The local topography will result in one segment of road being treated by one BMP, other segments by other BMPs, and still other segments receiving no treatment at all. In the case of a crowned road, the uphill side of the road might drain to a road ditch that flows to a wet pond, while sheet runoff from the downhill side of the road may drain to a wooded buffer, which for part of the road length is 75 feet wide, meadow and on shallow slopes and for the remaining length is only 50 feet wide, wooded on steep slopes. Since all three BMPs, the wet pond and the two buffers, have different treatment factors, it is necessary to break the road surface area into three discreet subcatchments based on the BMP(s) to which each road segment drains to calculate treated phosphorus export from the road. This is true not only for roads but for all other types of development as well.

Summarize the project's phosphorus export and treatment as follows:

1. Indicate, on a topographic site plan of the project, all the BMPs that will be incorporated into the project.
2. Delineate all subcatchments for which each BMP is providing treatment.
3. Identify all portions of the developed area (i.e. buildings, road segments, parking lots or portions there of, lawns, house lots) which are being treated by a given BMP or combination of BMPs on Worksheet 2.
4. List each subcatchment and export area, along with the appropriate pre-treatment phosphorus export factor from Table 3.1 or Table 3.2 and the appropriate treatment factor(s) for the BMP(s) to which the area drains on the worksheet. If there is no BMP treating runoff from a catchment enter 1.0 in the treatment factor column.
5. BMP removal efficiencies and treatment factors can be calculated from Chapter 4 of this volume and Volume III. Enter these values on the worksheet.
6. Multiply each export area by its associated export factor and treatment factor to obtain the released phosphorus export value from each area and BMP. For areas receiving no treatment, multiply by 1.0.
7. See Section 4.1., BMP Rules of Thumb, if the source area drains to more than one BMP.
8. Sum the export from all treated and untreated areas to obtain the total post treatment phosphorus export (Post-PPE) from the project.

Example 4: Post-PPE Calculation for Subdivision Development

Problem:
The 'Homesweet Home Subdivision' project described in Example 1 and 3 is proposing to treat a portion of the stormwater runoff from the subdivision through the use of buffers. Lots 1-4 will not receive any treatment. Lots 5 through 12, the excess driveway lengths from Lots 2 and 3, and the access road is superelevated and will be directed to a downgradient buffer sized in accordance with Chapter 5 of Volume III of this manual. Calculate the Post-treatment PPE for the proposed subdivision.

Solution:
The Pre-treatment PPE was calculated in Example 3. A forested buffer treating stormwater runoff that meets the standard sizing as provided in Chapter 5 of Volume III will achieve a Removal Efficiency of 0.6. Thus, the corresponding Treatment Factor is 0.4, which should be entered into Worksheet 2 as shown below. Note that 1.0 has been entered into the treatment factor column for lots 1 through 4 for which no BMPS are providing stormwater treatment.

Worksheet 2
Pre-PPE and Post-PPE Calculations

Project Name: Homesweet Home Subdivision			Development Type:Residential			Sheet #___
Land Surface Type of Lot #(s) with description	**Acres or # of lots**	**Export Coefficient from Table 3.1 Table 3.2**	**Pre-treatment Algal Av. P Export (lbs P/year)**	**Treatment Factor for BMP(s) from Chapter 6**	**Post-treatment Algal Av. P Export (lbs P/year)**	**Description of BMPs**
Lots 1-4 (HSG B) no restriction, w/o 75% to buffer	4.00	0.24	0.96	1.0	0.96	No treatment provided
Lots 5-10 (HSG C) <12,000 sqft clearing, w/o 75% to buffer	6.00	0.20	1.2	0.4	0.48	75 ft forest buffer
Lots 11 & 12 (HSG C) <12,000 sqft clearing, w/ 75% to buffer	2.00	0.15	0.30	0.4	0.012	75 ft forest buffer
Lots 2 & 3 driveway access > 150 feet	0.056	1.25	0.07	0.4	0.028	
Access Road (low export)	0.50	1.25	0.625	0.4	0.25	55 ft roadside forest buffer
		Pre-PPE (lbs P/year)	3.155	Post-PPE (lbs P/year)	1.838	

Based on these calculations, the Post-treatment PPE is 1.838 lbs P/year.

3.5 Evaluating Project Overall Phosphorus Export

For an acceptable site development, the Post-PPE needs to be smaller than the PPB for the parcel. The calculations can be summarized in Worksheet 4. If the resulting project phosphorus export (Post-PPE) is less than or equal to the project phosphorus budget (PPB) from Worksheet 1 than the project meets its budget. If not, further reductions in stormwater phosphorus are required. Credits for mitigation of existing sources may be another option for reducing the net project phosphorus export (Post-PPE) or paying a compensation fee may be an option (See Chapter 5, Credits for Mitigation and Compensation Fee for guidance).

Using Worksheet 4, summarize the Net Project Phosphorus Export as follows:

1. Bring in the Project Phosphorus Budget (PPB) from Worksheet 1
2. Bring in any Mitigation Credits from Worksheet 3
3. Bring in the total Pre-Treatment Phosphorus Export (Pre-PPE) as calculated on Worksheet 2
4. Bring in the total Post-Treatment Phosphorus Export (Post-PPE) as calculated on Worksheet 2
5. If the Post PPE is less than or equal to the site's PPB, the project meets its phosphorus budget.
6. If the Post-PPE is larger than the site's PPB but the Post-PPE is less than or equal to 0.4 times the Pre-PPE, then paying a compensation fee may be an option in certain lake watersheds. That list is available in Appendix F.
7. If the Post-PPE is larger than the site's PPB and the Post-PPE is more than 0.4 times the Pre-PPE, then more phosphorus treatment needs to be provided or less development must occur.

Example 5: Project Phosphorus Export Summary for Subdivision Development

Problem:

Summarize the Project Phosphorus Export for the 'Homesweet Home Subdivision' project described in Example 1, 3 and 4. Determine whether the project as proposed meets its phosphorus budget.

Solution:

Use Worksheet 4 to summarize the Project Phosphorus Export as shown below.

Worksheet 4 Project Phosphorus Export Summary			
Summarizing the project's algal available phosphorus export (PPE)			
Project name: Homesweet Home Subdivision			
Project Phosphorus Budget	PPB	1.995	lbs P/year
Mitigation Credit - Source Elimination Credit	SEC	0.00	lbs P/year
Source Treatment Credit	STC	0.00	lbs P/year
Total Phosphorus Mitigation Credit (SWC+STC)	TMC	0.00	lbs P/year
Total Pre-treatment Phosphorus Export Worksheet 2	Pre-PPE	3.155	lbs P/year
Total Post-treatment Phosphorus Export Worksheet 2	Post-PPE	1.838	lbs P/year
Project Phosphorus Export (Post-PPE - TMC)	PPE	1.838	lbs P/year

Since the calculated PPE of 1.838 lbs P/year is less than the PPB of 1.995 lbs P/year, the project meets its phosphorus budget and no further treatment or reduction actions are necessary.

Chapter 4
Treatment Factors for Phosphorus BMPs

Best Management Practices (BMPs) must be designed to meet the required phosphorus reductions based on the Project Phosphorus Budget (PPB). The lowest maintenance BMP that meets the PPB should be selected.

This chapter presents the treatment factors that the Department recommends using for the design of a variety of phosphorus control BMPs.

4.1 Rules of Thumb for BMP Design and Selection

Before presenting the recommended treatment factors for actual BMPs, there are several rules of thumb about selecting a BMP that should be considered.

1. **Given a choice, select the lowest maintenance BMP that will provide the required phosphorus removal.** For example, natural wooded buffers require much less long term inspection and maintenance than most other BMPs, so, if space and topography allow, buffers are the preferred BMP.

2. **The buffer and source area (i.e. lawn, parking lot, etc.) should be laid out for runoff to pass in non-channelized sheet flow from the source area and be evenly distributed across the face of the buffer.** If this design is not possible, runoff may first be concentrated and then redistributed into the buffer using a level spreader or ditch turnout, but care must be taken not to hydrologically overload the buffer and to maintain the level spreader (see design standards for level lip spreaders in Volume III, Chapter 8).

Natural wooded buffers are preferred over other BMPs due to their low maintenance.

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4.2 Common BMPs and their Standard Sizing

Volume III of this manual, BMP Technical Design Manual, presents the standard designs for the most commonly used BMPs including buffers, wet detention basins and filtration and infiltration systems. These standard BMP designs are sized to provide retention of approximately 60% of the annual stormwater phosphorus export, and thus would have a treatment factor of 0.40. The standard sizing of these BMPs is as follows:

- Wetponds. Standard sizing (BMP_{ST}) for wet ponds requires a storage volume below the permanent pool elevation of at least 1.5 inch of runoff times the subcatchment's impervious area plus 0.6 inch of runoff times the subcatchment's non-impervious developed area. The pond must have a mean depth of at least three feet, and a length to width ratio of 2:1 or greater. See Chapter 4 of Volume III.

- Underdrained vegetated soil filter or other approved filter. Standard sizing (BMP_{ST}) for filters requires storage of a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's non-impervious developed area for discharge solely through an underdrained vegetated soil filter having a single outlet with a diameter no greater than eight inches, or though a proprietary filter system approved by the department. See Chapter 7 of Volume III.

- Infiltration Systems. Standard sizing (BMP_{ST}) for infiltration systems requires storage of a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's non-impervious developed area for infiltration into the ground. Pre-treatment of stormwater must occur prior to discharge to the infiltration area. See Chapter 6 of Volume III.

- Vegetated Buffers. Standard sizing (BMP_{ST}) of flow path lengths for buffers depends on the type of buffer, the soil type and slope of the buffer, and the nature and extent of land use in the contributing watershed for phosphorus export reduction. Standard sizing for a given buffer type in a given landscape and development setting can be determined using the tables found in the Buffer Chapter, Chapter 5, of Volume III. There are four types of buffers:
  - Buffers with stone bermed level lip spreader;
  - Buffers adjacent to the down hill side of a road;
  - Ditch turn-out buffers; and
  - Buffers adjacent to residential, largely pervious or small impervious areas.

4.3 Determining BMP Phosphorus Treatment Factors

In designing the stormwater management system, the treatment factor of the selected BMPs for the project can be adjusted based on their sizing. A BMP's treatment factor may be reduced or enhanced by modifying either the volume of stormwater runoff it will store and treat or the length of flow path through a buffer. The two formulas presented below provide (1) a way of adjusting the standard sizing of BMPs described in Volume III and in Section 4.2 of this volume to provide a desired treatment factor, or (2) a way of determining the treatment factor of a given size BMP.

Wetponds, underdrained soil filters, infiltration systems and vegetated buffers may be sized to provide more or less treatment than if sized as provided in Volume III by adjusting, up or down, the volume of runoff stored and treated, or, in the case of buffers, the flow path length. There is, however, a point at which further increase in sizing of a BMP is not likely to significantly improve the BMP's ability to retain phosphorus. This limit is expressed as a minimum treatment factor for each type of BMP. Treatment factors may not be adjusted below this minimum. Minimum treatment factors are discussed later in this chapter and are presented in Table 4.1.

(1) If you know the treatment factor that is needed and can adjust your BMP design to meet it, use the following equation to determine either the volume of runoff that must be stored and treated or the necessary buffer flow path length to provide a required treatment factor:

$$BMP_{TF} = 0.4*(BMP_{ST}/TF)$$

Where:

TF = Desired treatment factor (1-Removal Efficiency of the BMP)
BMP_{ST} = Standard sizing for the BMP, as described in Section 4.2
BMP_{TF} = Required sizing to achieve the desired treatment factor

BMP sizing is based on either volume of runoff stored and treated or buffer flow path length.

Example 6: Alternative BMP Sizing

Problem:
5.0 pounds/year of phosphorus is created from the runoff of a four acre parking lot. The owner wishes to design a wetpond to achieve a desired maximum phosphorus export from the parking lot of 1.8 pounds/year to meet the project's phosphorus budget for that area. What size pond will be needed to achieve this export?

Solution:
The desired treatment factor is calculated as:

TF = Desired Export/Existing Export = 1.8/5.0 = 0.36 or

Using the Volume III sizing criteria, 60% removal efficiency can be achieved with a wet pond, or a 0.4 TF. This requires a permanent pool volume of 1.5 inch of runoff over the impervious area. Since this project requires a 36% TF, the designed pond's permanent volume for this project will need to be relatively sized to the 1.5 inch of runoff over the impervious area. Thus, the permanent pool of the pond can be sized as follows:

$BMP_{TF} = 0.4*(BMP_{ST}/TF)$
$= 0.4*(1.5/0.36)$
$= 1.57$ inch of runoff for the impervious area

The permanent pool of the pond must be sized for 1.57 inches of runoff over the impervious area. If the pond is discharging to a stream before reaching the lake, then the channel protection volume needs to be provided per Volume III.

(2) If, on the other hand, you know the size of a given BMP, and need to determine its treatment factor, use the following formula:

$$TF = 0.4\ BMP_{ST} / BMP_{TF}$$

Where:

TF = Treatment Factor (1-Removal Efficiency of the BMP) of the BMP

BMP_{ST} = Standard sizing for the BMP as described in Section 4.2

BMP_{TF} = Actual sizing of the given BMP

BMP sizing is based on either volume of runoff stored and treated or buffer flow path length.

4.4 Minimum Treatment Factors

There is a limit to the amount of phosphorus removal a BMP can accomplish, no matter how large one makes it. The physical, chemical and biological processes that a BMP relies on to remove pollutants have limitations and making a BMP larger generally does not change the limits on the effectiveness of these processes; it only means that all, rather than just part, of the runoff from larger, infrequent storms will get treated by the BMP. However, a limit has been placed on the amount which various BMPs may be enlarged to increase their removal efficiency and reduce their treatment factor. Table 4.1 presents the minimum treatment factors that are allowed for selected BMPs. BMPs may be enlarged from their standard sizing criteria as outlined in Volume III to reduce their treatment factors to a point, but treatment factors may not be reduced below the minimums in Table 4.1.

Table 4.1
Minimum Treatment Factors for Selected BMPs

	Treatment Factor (1-RE)	
Wetponds		
• Single Pond	0.3	
• Two ponds in series (designed per Volume III, Chapter 4)	0.25	
• Three ponds in series (designed per Volume III, Chapter 4)	0.2	
Underdrained Soil Filters and Other Approved Filters		
• On sand, loamy sand or sandy loam with 2 ft between bottom of system and restrictive layer	0.15	
• All other filters	0.25	
Infiltration		
• All infiltration BMPs	0.1	
Vegetated Buffers (maximum flow path length = 150'*)	**Meadow**	
Buffer Hydrologic Soil Group (and Texture)	**Forest**	**Meadow**
• A or B	.15	0.2
• C (sandy loam or loamy sand)	0.2	0.3
• C (silt loam, clay loam or silty clay loam)	0.3	0.4
• D (non wetland)	0.4	NA

*The maximum allowed flow path length in a buffer is 150 feet unless the runoff is redistributed by a midcourse stone bermed level lip spreader.

Example 7: Alternative Treatment Factor and Minimum Treatment Factor

Problem:
The available downgradient meadow buffer for a one acre parking lot has 150 feet of sheet flow on a 6% slope and on HSG C soil (sandy loam). What would be the allowable treatment factor for this buffer?

Solution:
According to Table 5.1 from Volume III, the required forested buffer length on sandy loam C soils to adequately treat stormwater runoff is 100 feet. Thus, the Treatment Factor for the available buffer on this project is:

$$TF = 0.4\ BMP_{ST}/BMP_{TF}$$
$$= 0.4\ (100/150)$$
$$= 0.27$$

However, according to Table 4.1, the minimum treatment factor that may be used for a forested buffer on C sandy loam soil is 0.3. Therefore, the treatment factor is limited to 0.3.

Example 8: Maximum Treatment

Problem:
Using the minimum treatment factors in Table 4.1, calculate the maximum amount of runoff that can be treated using an underdrained filter that has less than 2 feet of separation between the bottom of the system and the restrictive layer and that is treating runoff from an impervious area.

Solution:
For this situation, the minimum treatment factor from Table 4.1 is 0.25. Standard BMP sizing calls for treatment of 1.0 inch of runoff over the impervious surface. The maximum runoff that can be treated in such a filter is calculated as follows:

$$BMP_{TF} = 0.4*(BMP_{ST}/TF)$$
$$= 0.4*(1.0/0.25)$$
$$= 1.6 \text{ inch of runoff}$$

The filter bed can only be expanded by area and not depth.

4.5 Multiple BMPs Placed in Series

If multiple BMPs are being used in series, make sure that the last BMP in the series has the ability to remove the types of pollutants which are likely to reach it. For example, treatment credit should not be taken for a filter located downstream of an efficient forested buffer. The filter will not add significant additional treatment because the buffer will most likely have already removed all the fractions of stormwater phosphorus that the filter could.

If multiple BMPs are being used appropriately in series, the net treatment factor for the series of BMPs is the product of the lowest (most efficient) treatment factor of the individual BMPs in the series and the square root of the treatment factor(s) of the less effective BMP(s). For example, if a small wetpond with a treatment factor of 0.6 drained to an engineered infiltration area with a treatment factor of 0.4, the net treatment factor for the two BMPs would be 0.4 x 0.6 = 0.31.

Chapter 5
Credits for Mitigation and Compensation Fees

Phosphorus reduction can also be achieved through mitigation measures that focus on eliminating or reducing phosphorus loads from existing sources.

The objective of this project planning process is to limit increases in phosphorus loading to the lake resulting from development. The methods discussed thus far have focused on limiting the scope of the development or reducing its phosphorus export by incorporating BMPs. Phosphorus load to the lake can also be limited by reducing export from long standing, existing sources of phosphorus, a trade off usually referred to as mitigation.

5.1 Types of Mitigation

Mitigation can take a number of forms. It can involve the elimination of an historical source or a reduction of the source, usually by treatment with BMPs.

Phosphorus loads can also be limited by reducing export from existing sources of phosphorus on a site, a trade off usually referred to as mitigation. Mitigation credits can be achieved through two means:

(1) elimination of existing phosphorus sources (e.g., elimination of an old gravel road so it can revert back to a forested condition); or

(2) reduction of existing phosphorus sources through treatment (e.g., diverting stormwater flows from an existing road to a treatment device for phosphorus removal).

(3) to be considered an existing source, it must have been in existence prior to 1980.

Elimination

A wood lot being developed as a subdivision can provide a good example of elimination. An old, gravel road passes through the wood lot. It will not, however, be used by the developer, who plans to eliminate the old road and construct a new road in a different location to access the new house lots. The old road has been exporting phosphorus to the lake for the last 50 years. Elimination of the road and

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return to a forested condition will result in a reduction of phosphorus loading to the lake. This reduction in historical phosphorus export can be used to balance, or mitigate, some of the project's new phosphorus export. In this chapter we will discuss various ways of mitigating new phosphorus export by reducing or eliminating historical phosphorus sources, and how credit for this mitigation can be applied to a project's phosphorus budget.

Reduction by Treatment

Suppose the developer actually wants to use the old road in his subdivision scheme. In order to reduce phosphorus export from other parts of his development he is constructing a wet pond BMP down gradient of the development. The old road, which formerly drained directly to the lake, now drains first to the wet pond, which has a treatment factor of 0.40. This means that only 40% of the old road's phosphorus export is now reaching the lake, with the remainder retained in the wet pond. Phosphorus export from the road has now been reduced by 60%. This reduction in phosphorus, called a credit, can now be subtracted from the phosphorus export associated with newly developed portions of the project.

Another variation on this example illustrates an even more common situation. Suppose the old gravel road is not wide enough to meet current town standards for subdivision roads and it must be widened from 12 feet to 24 feet. This expansion of road width means that half of the 24 foot road must be considered new in terms of phosphorus export. Its export, as modified by the wet pond's treatment factor, would be included in the list of phosphorus exports in Worksheet 2. Stormwater from the half of the road which can be considered old, however, is now being treated and the resulting reduction in phosphorus export is a credit that can be subtracted from the project's total phosphorus export.

Problems with Estimating Credit for Mitigation

But how does one estimate the amount of phosphorus export that is being reduced or eliminated? Phosphorus export from old, pre-existing sources can be estimated in the same way as new sources, using the export factors in Table 3.1. However, in doing so two important issues must be considered.

1) **Comparability of existing and proposed phosphorus export sources:** Let's return to the road example. Suppose the old gravel road has seen only very light use as a woods road over the last 50 years. It has started to revert with vegetation encroaching on the sides and in the middle between the tire tracks. It is unlikely that it currently exports nearly as much phosphorus per square foot as will the new subdivision road, which will receive comparably heavy use. So treatment or elimination of this export will not provide equivalent mitigation for the new road which replaces it. To avoid this problem, this evaluation process automatically cuts the estimated phosphorus export from pre-existing sources in half unless it is clearly demonstrated that the old source is equivalent in both structure and use to the new sources being mitigated. A multiplier of 0.5 is included in Worksheet 3 for this purpose.

2) **Historic drainage patterns of the phosphorus export:** If the runoff from the historic road immediately drained into a road ditch and continued, untreated, to the lake there is no problem with taking credit for elimination or treatment of the old road. But often the runoff from old roads sheets into the woods or fields adjacent to the road where much of its phosphorus export is retained in a natural buffer, and never reaches the lake. In this case credit should not be taken for treatment of the road's stormwater runoff because it was already receiving treatment, unless the new BMP has a much better treatment factor than the

historic BMP. In that case, credit may be taken for treatment, but only for the difference between the old and new phosphorus export. If the road is being eliminated, credit should only be taken for an amount of export which has been reduced by the treatment factor of the historic buffer.

5.2 Estimating Credits for Mitigation

Worksheet 3 may be used to calculate mitigation credits. The upper portion of the worksheet is used to calculate credit when a pre-existing source is being eliminated. The lower portion of Worksheet 3 is used when a pre-existing, historically untreated source is being treated by new BMPs. Credits are determined as follows:

1. List the size of the source area (in acres and to the second decimal place) and phosphorus export factor from Table 3.1 for each pre-existing mitigation source in the appropriate spaces on Worksheet 3.
2. If the source is being eliminated, enter the estimated treatment factor for any natural buffers or other BMPs that historically provided treatment of the source in Worksheet 3 or enter 1.0 if the source drains directly to the lake. If the source is being treated, enter the treatment factor for the new BMP which will be treating each mitigation source in the worksheet. Also enter the estimated treatment factor for any natural buffers or other BMPs that historically provided treatment of the source in Worksheet 3 or enter 1.0 if the source drained directly to the lake.
3. For source elimination and treatment multiply the source area by the phosphorus export factor and by 0.5 (unless it has been clearly demonstrated that the old source is equivalent in both structure and use to the new sources being mitigated) to calculate the creditable pre-treatment phosphorus export from each source area. Then multiply the pre-treatment phosphorus export (from Step 3) by any treatment factors for historical BMPs to obtain the historical phosphorus export.
4. For each source that is being eliminated, the mitigation credit value is equivalent to the historical phosphorus export value (from Step 3). For sources being treated by new BMP(s), subtract the new BMP treatment factor from 1.0 and multiply this times the source's historical phosphorus export (from Step 3) to get the mitigation credit value for each source.
5. Sum the phosphorus export credit values for all mitigation sources to obtain the total credit value in Worksheet 3.

5.3 On-site vs. Off-site Mitigation

Another important mitigation consideration is whether the mitigation source and, in the case of treatment, the BMP, are located on the parcel (on-site) or elsewhere in the lake's watershed (off-site). If the treatment source and the treatment BMP are located on-site, the developer can insure through property owner agreements, deed covenants and restrictions, conservation easements, endowments and/or long term agreements with maintenance contractors that eliminated sources will be allowed to revert and remain in a forested condition and that BMPs will be properly maintained. Essentially these mitigation measures are treated no differently than the buffers and other BMPs incorporated in the project to address new sources of phosphorus export.

If the mitigation measures are being implemented elsewhere in the watershed, it is a much greater challenge, for both the developer and any regulating body which is requiring the mitigation, to insure that the measures are maintained over the long term. In the case of elimination of off-site mitigation sources, these areas can be reasonably protected by deed restrictions and conservation easements. However, insuring long term maintenance of off-site BMPs is much more problematic. Because of these difficulties, *it is recommended that treatment of mitigation sources with off site BMPs not be allowed unless (a) the property on which the off-site mitigation is taking place and the project parcel are in common ownership, and that owner is a permanent entity, such as a town or a school district, that is not likely to transfer ownership of either parcel or (b) a local regulatory or management agency (i.e. municipality, watershed district) has adopted a program for long term tracking and monitoring of mitigation measures in the watershed.*

Mitigation Dos and Don'ts	
Don't take credit for mitigation of relatively recent phosphorus sources. Credit should not be allowed on sources, which were not in existence prior to 1980.	**Do** halve the phosphorus export from mitigation sources unless it is clearly demonstrated that the old source is equivalent in both structure and use to the new sources being mitigated.
Don't take credit for treatment of mitigation sources, which have been historically treated by adjacent buffers or treatment ponds.	**Do** adjust the credit for any source elimination to reflect historical treatment by buffers or ponds.
	Do insure, through property owner agreements, deed covenants and restrictions, conservation easements, endowments and/or long term agreements with maintenance contractors, that eliminated sources will be allowed to revert and remain in a forested condition and that BMPs will be properly maintained.

5.4 Compensation Fees

The Maine Stormwater Management Law (38 MRSA § 420-D) and its accompanying regulations (DEP Chapter 500) address some of the problems associated with off-site mitigation discussed above by allowing an alternative known as the Compensation Fee Program. The law recognizes the difficulties a state agency would have in tracking and insuring the maintenance of off-site BMPs used for mitigation on a project. The regulations therefore allow only the elimination or reduction (by land use change) of off-site sources of phosphorus, called off-sets. The regulations do not allow treatment of off-site sources as a form of mitigation.

As an alternative to project based off-site treatment mitigation, the Law sets up the Compensation Fee Program. This program allows the department to let the developer offset a portion of the phosphorus reduction required for the project to meet its phosphorus budget by paying a compensation fee to the Department. The Department, or an authorized local entity, accumulates compensation fee funds in accounts for each individual lake watershed, and uses these funds to provide long term solutions to priority chronic phosphorus sources within the watershed. The department is not required to allow use of this program in all cases, and there are a number of lake watersheds where it is not appropriate. These include small, relatively undeveloped lake watersheds that happen to be in a region of high growth. In these cases there are few if any opportunities to address existing problems in the watershed. It may also include watersheds where a large amount of restoration work has already been performed and any problems remaining to be addressed are more expensive than the compensation rate can cover. Lastly, it includes areas where there are no local watershed management agencies (i.e. soil and water conservation districts, watershed districts, etc.) interested in developing and implementing mitigation projects. Developers should not assume that the compensation fee is an option until they have checked to be sure it is available in the lake watershed in which the proposed development is located. Appendix F is a list of lake watersheds that the Department is confident eligible mitigation projects can be found and implemented. The compensation fee option is available for all lakes on the Appendix F list, which will be updated on a regular basis. If the proposed development is in a lake watershed that is not on this list, the developer may check with the DEP Division of Watershed Management staff to see if the lake in question might be added to the list.

The current compensation rate (November 2007) is $10,000 per pound of algal available phosphorus. This means that if a project's phosphorus budget was 0.5 lb P/yr and, after application of reasonable BMPs, the project export could only be reduced to 1.0 lb P/yr, the remaining 0.5 lb reduction required to meet the project's budget could be offset by a compensation fee payment of $5,000 (0.5 lb x $10,000 /lb). In the near future, the compensation rate may be adjusted upwards to reflect the rising cost of appropriate BMPs, perhaps to $25,000 per pound.

For most projects, the Department requires a 60% reduction in phosphorus export before a compensation fee can be applied. To express this in terms of the worksheets used to calculate project phosphorus export, the sum of post-treatment export expressed on Worksheet 2 must be less than or equal to 0.4 times the sum of pre-treatment export expressed on Worksheet 2 in order for a project to offset any additional phosphorus reductions through payment of a compensation fee.

Projects in lake watersheds regulated by the state under the Stormwater Management Law may have the opportunity to use compensation fees to help meet their project's phosphorus budget as required by that law. These projects may, however, also come under local regulation, which may or may not recognize compensation fee payment as an alternative to on-site reduction of phosphorus export.

Chapter 6 Performance Standards for Smaller Projects

Alternative performance standards may be used for certain smaller, residential projects. These generally include specific development restrictions on the use of Low Impact Development (LID) practices.

6.1 Single Family Residences and Small Subdivisions with No New Road

There are some kinds of relatively low impact, residential development where the level of analysis applied in the previous sections may be inappropriate or unreasonable. This section prescribes comparatively simple, alternative performance standards which may be applied to: (1) new single family residences or duplexes on existing lots which are not part of a subdivision that has already incorporated appropriate phosphorus controls; and (2) subdivisions of five or fewer lots that do not involve the construction of a new road or expansion of an existing road. New residential developments which fall into either of these categories may meet their phosphorus control obligations by incorporating the phosphorus control measures listed either under Basic Single Family Residential Lot Standards or Alternative Single Family Residential Lot Standards below; and by maintaining these measures over the long term.

Smaller residential development projects can use alternative performance standards to meet their phosphorus control obligations. These generally involve restrictions on disturbance, buffers and impervious area or the incorporation of Low Impact Development (LID) techniques.

Basic Single Family Residential (SFR) Lot Standards

The following basic Single Family Residence Lot Standard is the preferred way of addressing new development of individual residential lots or small residential subdivisions that do not include a new road. A project must meet all provisions of the standard. The standards for appropriate buffer design and maintenance are presented in section 6.2.

Chapter Contents:

Basic SFR Lot Standard
Requirements for New Single Family Lot Development:
• Disturbance on an individual lot must be less than 15,000 square feet (including building, driveway, walkways, lawn area, construction access, grading).
• A minimum natural vegetated buffer must be maintained downgradient of all developed area on the lot. This buffer shall be 35 feet deep if naturally forested or 50 feet deep if maintained as a natural meadow.*
• No more than 7,500 square feet of impervious cover is located on the property.
• A minimum of 25 percent of the lot area must be maintained as undisturbed natural area.*

*Note: If the lot or a portion of the lot is located within a watershed to a Lake Most at Risk from New Development, Urban Impaired Stream, or other impaired or sensitive waterbodies as designated by the municipality for the purposes of this standard, a minimum buffer of 50 feet if naturally forested or 75 feet if maintained as a meadow must be maintained downgradient of all developed area on the lot, and a minimum of 40 percent of the lot area must be maintained as undisturbed natural area. If the existing land has been disturbed by prior activities, a natural vegetated buffer and/or undisturbed natural area may be proposed through restoration and revegetation.

Alternative Single Family Residential Lot Standards

A property owner or developer may choose not to meet the Basic Single Family Residential Lot Standard due to site constraints or design preference. In situations where the Basic Standard is not met on a project, the project must meet the following Alternative Single Family Residential Lot Standards.

Alternative SFR Lot Standards
Requirements for New Single Family Residential Lot Development
• Use Low Impact Development (LID) practices from those listed in Section 6.2 and described in the Maine LID Guidance Manual (September 2007) prepared for the DEP by the Horsley Whitten Group, Inc. These measures should be sized to treat 0.5 inches of runoff from all impervious surfaces on the site, and 0.2 inches of runoff from all disturbed pervious areas of the site (lawn).*
• The LID practices installed on the site must be maintained in perpetuity. If necessary, LID practices may be replaced with new LID practices as long as the overall site treatment standard above is met.

* Note: If the lot or a portion of the lot is located within watersheds to Lakes Most at Risk from New Development or other impaired or sensitive waterbodies as designated by the municipality for the purposes of this standard, the project must treat one inch of runoff from impervious surfaces and 0.4 inch from disturbed pervious surfaces.

Meeting this standard may require the use of more than one LID practice on the site, due to existing site topography and the layout of the property. For example, half of the roof may drain to the front of a building while the other half drains to the back of the building, and the lawn and driveway/parking area drain off to one side of the property. Drainage in each of these directions must be captured and treated using an LID practice. The selection, size and location of the LID practices used on a given site will depend on the size of the area draining to each practice and the impervious area versus lawn area. While this may not always be feasible, applicants are encouraged to maintain natural buffers to the extent possible as a primary LID technique, which can then be augmented by other practices on the site. Guidance on how to size each LID practice is found in section 6.2 below.

6.2 LID Practices

LID practices can be used to capture and treat runoff from residential rooftops, non-rooftop impervious areas such as paved driveways, patios and walkways, and maintained lawn areas. While there are a number of practices considered to be LID practices, this section lists just those that are appropriate for single family residential lots. These include:

- Buffers;
- Underdrain soil filters (rain gardens and swales);
- Infiltration practices (dry wells and infiltration trench); and
- Pervious pavements.

The design and maintenance standard for Buffer are presented below, and should be applied to projects meeting the Basic SFR Lot Standard. Design and maintenance standards for the other measures are described in detail in the Maine LID Guidance Manual (September 2007) prepared for the DEP by the Horsley Whitten Group, Inc., and these should be applied to projects meeting the Alternative SFR Lot Standards.

Vegetative Buffers

Vegetative buffers are areas of dense forest or meadow vegetation located adjacent and downgradient of developed areas that provide storage and treatment for stormwater that enters them in diffuse overland flow. They should be designed, implemented and maintained in accordance with the following:

a. *Discharge of stormwater to the buffer* - It is essential that the stormwater entering the buffer not be channelized prior to discharge into the buffer. Grading of developed areas upgradient of the buffer must be done in a way that maintains diffuse overland flow and avoids concentration of the runoff..

b. *Topography* - The topography of a buffer area must maintain well-distributed stormwater runoff and can not allow stormwater runoff to concentrate as it flows across the buffer. Flow paths of runoff through a buffer must not converge, but must be essentially parallel or diverging.

c. *Vegetative cover* - The vegetative cover of a buffer must be either forest or meadow. In most instances the sizing of a buffer varies depending on vegetative cover type.

   i. Forest buffer - A forest buffer must have a well distributed stand of trees with essentially complete canopy cover, and must be maintained as such. A forested buffer must also have an undisturbed layer of duff covering the mineral soil. Activities that may result in disturbance of the duff layer are prohibited in a buffer.

ii. Meadow buffer - A meadow buffer must have a dense cover of grasses, or a combination of grasses and shrubs or trees. A buffer must be maintained as a meadow with a generally tall stand of grass, not as a lawn. It must not be mown more than twice per calendar year. If a buffer is not located on natural soils, but is constructed on fill or reshaped slopes, a buffer surface must either be isolated from stormwater discharge until a dense sod is established, or must be protected by a three inch layer of erosion control mix or other woodwaste material approved by the department before stormwater is directed to it, with vegetation established using an appropriate seed mix.

iii. Mixed meadow and forest buffer - If a buffer is part meadow and part forest, the required sizing of the buffer must be determined as a weighted average, based on the percent of the buffer in meadow and the percent in forest.

d. *Deed restrictions and covenants* - Areas designated as vegetated buffers must be clearly identified on site plans and protected from disturbance by deed restrictions and covenants.

Appendix A
Phosphorus and Lake Water Quality

The Relationship Between Phosphorus and Lake Water Quality

Lakes are biological systems that are clearly affected by changes in water quality. They are most noticeably affected by an increase in nutrients, particularly phosphorus. Increases in phosphorus usually result in more noticeable changes to water quality than increases in other nutrients. Algae, which are microscopic plants common in lakes, need phosphorus in order to grow. Consequently, when phosphorus is abundant in lake water, algal populations soar in number, causing a decline in water transparency. In some cases, algal blooms may occur causing the growth of billions of algae to color the lake water green and release strong odors as they decay.

Beyond the aesthetic impacts, algal blooms have serious impacts on a lake's biological community. Through a complex chain of events, algal blooms lead to depletion of the lake water's oxygen supply, usually resulting in the eventual loss of trout and salmon (cold water) fisheries. In addition, large algal populations cause odor, taste, and treatment problems in lakes used for public water supplies.

The biological term for the process described above is eutrophication - the gradual increase in nutrient inputs to a lake over time. Lake eutrophication can be dramatically accelerated by human activities, causing the noticeable changes described above in a relatively short period of time. Many lakes in Maine have already experienced dramatic declines in water quality as a result of human disturbances.

How Phosphorus Gets into Lakes

Understanding how phosphorus gets into lake water requires an understanding of where lake water comes from. Precipitation and stormwater runoff are significant sources of water in rivers and lakes. Rain and melting snow flow downhill over the land surface into streams and lakes or seep into the ground becoming groundwater, which also ultimately discharges to streams and lakes.

The land area that contributes water to a particular lake is known as its watershed. Watershed boundaries can be identified by connecting points of highest elevation around a lake and its tributaries. All rain and snow falling within this area eventually flow by gravity in surface runoff, streams, and groundwater to the lake, which is the lowest point in the watershed.

The quality of water in a lake depends on the condition of the land in its watershed. Phosphorus is abundant in the environment, but in an undisturbed environment it is tightly bound up by soil and organic matter for eventual use by plants. Natural systems conserve and recycle nutrients, water, and other materials needed to sustain plant growth. Water is stored in depressions on the uneven forest floor and seeps into the ground to become groundwater, thereby preventing it from running over the land surface and exporting valuable nutrients form the system.

Land development changes the natural landscape in ways that alter the normally tight cycling of phosphorus. The removal of vegetation, smoothing of the land surface, compaction of soils, and creation of impervious surface combine to reduce the amount of precipitation stored and retained on-site, dramatically increasing the amount of water running off the land as surface runoff.

These changes to the land surface and the associated increase in surface runoff dramatically increase phosphorus export. Land disturbance upsets the environment's ability to retain phosphorus. Stormwater flowing over the land surface picks up phosphorus and transports it in soluble form or attached to eroded soil particles. The phosphorus in stormwater comes from natural and human sources, including eroded soil, road dust, plants, lawn fertilizer and detergents. The smooth surfaces, closely cropped lawns, and compacted soils common in developed areas do not retain phosphorus, and only speed its removal by generating surface runoff. The end result is more phosphorus is stormwater, and thus more phosphorus in lakes.

A study in Maine has documented the elevated levels of phosphorus exported from developed land (Dennis, 1985). In adjacent watersheds, one developed and one undisturbed, phosphorus export from the developed watershed was up to 10 times greater than the export from the forested watershed. Because the built watershed was developed years ago, these figures represent the permanent increase in phosphorus export caused by alteration of the landscape. This permanent increase in the phosphorus supply of the lake creates an equally permanent and irreversible decline in water quality.

Though in most lakes the majority of phosphorus comes from the watershed, there is another source of phosphorus that can be very significant in some lakes. Over the centuries phosphorus rich organic sediments have accumulated on the bottom of our lakes. In most cases, the phosphorus in these sediments is trapped there by a blanket of iron hydroxide and or aluminum hydroxide, which makes the sediments a sink for, rather than a source of, phosphorus. However, in lakes with sufficient algal production to cause a severe loss of oxygen concentrations above the sediments, the iron hydroxide blanket dissolves and large amounts of phosphorus may be recycled into the lake water. The "surges" of phosphorus feed algal growth which further depletes dissolved oxygen, thus creating a vicious cycle of very rapid, internally driven eutrophication. This process, which can be initially triggered by relatively small increases in phosphorus input from the watershed, may drive a lake from apparently good, clear water quality to having intense algal blooms in a matter of years. It is particularly important to limit any increases in phosphorus input from the watershed to lakes with a high potential for sediment phosphorus recycling.

How Stormwater Phosphorus Can be Controlled

All land disturbance and development in a lake's watershed increases phosphorus export to a lake. Although some increase must be accepted as the inevitable and unavoidable effect of development, a variety of measures can substantially reduce phosphorus export to lakes and help to preserve good water quality.

The simplest way to reduce phosphorus export is to limit clearing of vegetation and minimize the area developed, especially road length. Beyond this, a variety of control measures are available. They generally focus on detaining and storing stormwater where it can be treated and released or infiltrated into the soil.

Buffer areas are naturally vegetated areas preserved downslope of developed areas. These buffers intercept and store surface runoff, allowing it to infiltrate rather than flow off-site as surface flow.

Infiltration systems are more sophisticated. Runoff is collected from rooftops, driveways and/or impervious parts of a lot and then directed to surface or underground storage, similar to a subsurface wastewater disposal area, from which it infiltrates into the soil. Soils must be fairly deep, coarse, and permeable for infiltration systems to work.

Underdrained soil filters are similar to infiltration systems in that runoff is collected and directed to a storage depression, but the depression is vegetated with flood and drought tolerant species and is lined with a specific soil filter media which is underlain with a pipe system to discharge the filtered runoff.

Wet ponds are generally used to treat runoff from a large area. They receive and retain stormwater from large drainage areas, allowing sediment to settle out and dissolve phosphorus to be removed by biological activity.

Development can proceed in lake watersheds without generating more phosphorus than the lake can tolerate by limiting the extent of development and incorporating one or more of these phosphorus controls. Once a lake has accepted more phosphorus than it can tolerate, there will be a noticeable decline in water quality.

Appendix B
DEP's Method for Defining Watershed Per Acre Phosphorus Allocations

The Department defines per acre phosphorus allocations (P) for lake watersheds and these are presented in Appendix C. The list in Appendix C is not complete, so if a per acre allocation for a town's portion of a lake watershed is needed and it is not listed in Appendix C, request the Division of Watershed Management to provide a per acre allocation for the desired watershed. The Department will continually update Appendix C, both by adding new lakes to the list and by revising allocations for lakes already on the list as new information becomes available. This Appendix describes the process the Department uses to define watershed per acre phosphorus allocations.

Step 1. Defining the Acceptable Increase in Lake Phosphorus Concentration (C)

The first step is to determine how much the lake's phosphorus concentration could be increased without risking a perceivable increase in its ability to support algal production or a decline in its ability to support a healthy, natural fish community. This value, the acceptable increase in lake phosphorus concentration (C), is a function of two variables: the lake's Water Quality Category and the Level of Protection appropriate for the lake. The Department has assigned Water Quality Categories to each lake for which sufficient water quality data is available based on the information in the following table. If insufficient data is available the lake is assigned a default water quality category of Moderate Sensitive.

Lake Water Quality Categories

Category	Lake Conditions
Outstanding	Exceptional clarity; very low phosphorus and chlorophyll concentrations; low risk of internal recycling from sediments
Good	Average to better than average clarity, phosphorus and chlorophyll; low risk of internal recycling from bottom sediments
Moderate Sensitive	Average clarity, phosphorus and chlorophyll; high potential for internal recycling from the bottom sediments
Poor (Restorable)	Poor clarity; high phosphorus and chlorophyll concentrations; supports blue green algal blooms; good prospects for restoration
Poor (Natural)	Poor clarity; high phosphorus and chlorophyll concentrations; supports blue green algal blooms; poor prospects for restoration because lake is naturally very productive

Step 2. Determine the Allowable Increase in Annual Phosphorus Load

The next step is to determine how much the annual phosphorus load to the lake could be increased without risking an increase in lake phosphorus concentration greater than the acceptable increase (C) defined in Step 1. This is accomplished by multiplying "C" by a lake specific coefficient (F) that estimates the amount of increase in annual phosphorus load to the lake that will result in a 1.0 ppb lake phosphorus concentration. Where a lake has upstream lakes draining to it, "F" represents the direct watershed's (that portion of the total watershed that does not first pass through an upstream lake) share of this load. Where a lake's direct watershed is located in more than one town, "F" reflects the given town's portion of the load. "F" is derived using a steady state solution of Vollenwieder's 1976 phosphorus loading model and is expressed in lbs/ppb/year.

Allowable increase in annual phosphorus load = F x C or FC

Step 3. Determine the Per Acres Phosphorus Budget (P)

The next and final step is to determine the per acre phosphorus budget (P, in lbsP/acre/year) by allocating the allowable increase in annual phosphorus load (FC) over the portion of the direct watershed most likely to be developed. This is accomplished by projecting how much of the direct watershed area is likely to be developed (D, in acres) and dividing FC by this acreage.

P = FC / D

"D" is estimated by:

- Determining the area available for development within the town's share of the direct watershed by subtracting undevelopable acreage (i.e. wetlands, steep slopes, state parks) and already developed land from direct watersheds area.

- Projecting how much of the area available for development will be developed over time based on:
  - o The general growth rate in the town or region
  - o The quality, density and distribution of the road network within the town's share of the direct watershed
  - o Other lake specific, locally identified information

Appendix C

Per Acre Phosphorus Allocations for Selected Maine Lakes

Updated 11/8/10

This **Appendix C** presents per acre phosphorus allcations (**P**) for all to the lake watersed/town combinations that have been dertermined by the Department to this point. It also presents the information and assumptions used to derive the value for **P**, as well as the small watershed threshold value (**SWT**). This Appendix will be modified on a regular basis as additional lake watershed/town combinations are added and/or allocations are amended as new information becomes available. It was last updated on 11/8/10. If you do not find the lake watershed/town combination that you are looking for in the table, contact Jeff Dennis at the DEP Division of Watershed Management (207-287-7847 or jeff.dennis@maine.gov) to request an allocation for the watershed of concern.

Lake Name	Town in which development is located	Direct Watershed Area in Town (acres) **DDA**	Area not available for development (acres) **ANAD**	Area available for development (acres) **AAD**	**GF**	Expected developed area (acres) **D**	(lbP/y) **F**	Water Quality Category **WQC**	**LOP**	**C**	**FC**	Per acre phosphorus allocation (lb/acre/yr) **P**	Small Watershed Threshold (acres) **SWT**
Abbott Pond	Peru	17	10	7	0.2	1	0.15	mod-sensitive	m	1.00	0.15	0.107	0
Abbotts Pond	Sumner	190	40	150	0.15	23	1.67	mod-sensitive	h	0.75	1.25	0.056	6
Adams Pond	Boothbay	869	87	782	0.3	235	8.31	mod-sensitive	h	0.75	6.23	0.027	59
Adams Pond	Bridgton	172	17	155	0.35	54	2.77	mod-sensitive	h	0.75	2.08	0.038	14
Adams Pond	Standish	32	3	29	0.2	6	0.24	mod-sensitive	m	1.00	0.24	0.041	1
Alamoosook Lake	Bucksport	2011	250	1761	0.25	440	21.89	mod-sensitive	h	0.75	16.42	0.037	110
Alamoosook Lake	Orland	9901	990	8911	0.25	2228	107.8	mod-sensitive	h	0.75	80.84	0.036	557
Alamoosook Lake	Penobscot	1149	100	1049	0.2	210	12.5	mod-sensitive	h	0.75	9.38	0.045	52
Alder Stream Impoundment	Corinna	8181	1600	6581	0.2	1316	41.03	mod-sensitive	m	1.00	41.03	0.031	329
Alder Stream Impoundment	Dexter	143	25	118	0.2	24	0.7	mod-sensitive	m	1.00	0.70	0.030	6
Alewife Pond	Lyman	308	20	288	0.25	72	2.16	mod-sensitive	m	1.00	2.16	0.030	18
Alford Lake	Hope	2374	150	2224	0.25	556	38.71	good	h	1.00	38.71	0.070	139
Allen Pond	Greene	1687	170	1517	0.25	379	15.74	mod-sensitive	h	0.75	11.81	0.031	95
Anasagunticook Lake	Canton	941	100	841	0.25	210	9.96	mod-sensitive	m	0.75	7.47	0.036	53
Anasagunticook Lake	Hartford	7321	500	6821	0.2	1364	77.54	mod-sensitive	h	0.75	58.16	0.043	341
Anasagunticook Lake	Peru	298	150	148	0.2	30	3.17	mod-sensitive	h	0.75	2.38	0.080	7
Anderson Pond	Augusta	96	5	91	0.3	27	1.16	mod-sensitive	h	0.75	0.87	0.032	7
Androscoggin Lake	Leeds	5700	1000	4700	0.3	1410	121	poor-restorable	m	0.50	60.51	0.043	353
Androscoggin Lake	Monmouth	1623	250	1373	0.3	412	34.44	poor-restorable	m	0.50	17.22	0.042	103
Annabessacook Lake	Monmouth	6123	750	5373	0.25	1343	91.24	poor restorable	m	0.50	45.62	0.034	336
Annabessacook Lake	Winthrop	4477	600	3877	0.3	1163	66.61	poor restorable	m	0.50	33.31	0.029	291
Apple Valley Lake	Winthrop	982	98	884	0.25	221	6.39	mod-sensitive	m	1.00	6.39	0.029	55
Badger Pond	Willimantic	383	10	373	0.15	56	3.08	mod-sensitive	m	1.00	3.08	0.055	14
Balch Pond	Acton	597	60	537	0.3	161	6.81	mod-sensitive	m	1.00	6.81	0.042	40
Barker Pond	Denmark	911	50	861	0.2	172	12.85	mod-sensitive	h	0.75	9.64	0.056	43
Barker Pond	Hiram	1569	230	1339	0.25	335	22.18	mod-sensitive	h	0.75	16.64	0.050	84
Barker Pond	Sebago	1062	100	962	0.25	241	15.01	mod-sensitive	h	0.75	11.26	0.047	60
Bartlett Pond	Livermore	331	30	301	0.25	75	2.77	mod-sensitive	h	0.75	2.08	0.028	19
Bartlett Pond	Waterboro	2234	284	1950	0.25	488	13.2	m-sens	m	1.00	13.20	0.027	122
Baskahegan Lake	Brookton Twp	6182	1600	4582	0.15	687	61.76	mod-sensitive	m	1.00	61.76	0.090	172
Baskahegan Lake	Carroll Plt	9439	1400	8039	0.15	1206	94.3	mod-sensitive	m	1.00	94.30	0.078	301
Baskahegan Lake	Codyville Plt	66	5	61	0.15	9	0.66	mod-sensitive	m	1.00	0.66	0.072	2

Appendix C

Per Acre Phosphorus Allocations for Selected Maine Lakes

Updated 11/8/10

Lake Name	Town in which development is located	Direct Watershed Area in Town (acres) **DDA**	Area not available for development (acres) **ANAD**	Area available for development (acres) **AAD**	**GF**	Expected developed area (acres) **D**	(lbP/y) **F**	Water Quality Category **WQC**	**LOP**	**C**	**FC**	Per acre phosphorus allocation (lb/acre/yr) **P**	Small Watershed Threshold (acres) **SWT**
Baskahegan Lake	Danforth	333	5	328	0.15	49	3.32	mod-sensitive	m	1.00	3.32	0.067	12
Baskahegan Lake	Forest Twp	66	5	61	0.15	9	0.66	mod-sensitive	m	1.00	0.66	0.072	2
Baskahegan Lake	Kossuth Twp	23931	7100	16831	0.15	2525	239.1	mod-sensitive	m	1.00	239.08	0.095	631
Baskahegan Lake	Prentiss Plt	3921	500	3421	0.15	513	39.18	mod-sensitive	m	1.00	39.18	0.076	128
Baskahegan Lake	T8 R3 NBPP	12762	1300	11462	0.15	1719	127.5	mod-sensitive	m	1.00	127.51	0.074	430
Baskahegan Lake	Topsfield	9772	1800	7972	0.15	1196	97.63	mod-sensitive	m	1.00	97.63	0.082	299
Bauds Pond	New Vineyard	2209	350	1859	0.25	465	21.63	mod-sensitive	m	1.00	21.63	0.047	116
Bauneg Beg	Sanford	5446	750	4696	0.35	1644	34.42	m-sens	m	1.00	34.42	0.021	411
Bear Pond	Hartford	788	150	638	0.25	160	8.26	mod-sensitive	m	1.00	8.26	0.052	40
Bear Pond	Turner	222	25	197	0.25	49	2.31	mod-sensitive	m	1.00	2.31	0.047	12
Bear Pond	Waterford	5275	744	4531	0.3	1359	62.22	mod-sensitive	h	0.75	46.67	0.034	340
Beaver Lake	Calais	511	25	486	0.2	97	6.06	mod-sensitive	m	1.00	6.06	0.062	24
Beaver Pond	Bridgton	1653	300	1353	0.4	541	13.05	mod-sensitive	m	1.00	13.05	0.024	135
Beaver Pond	Denmark	1284	65	1219	0.2	244	10.05	mod-sensitive	m	1.00	10.05	0.041	61
Beddington Lake	Beddington	3365	600	2765	0.15	415	25.4	mod-sensitive	h	0.75	19.05	0.046	104
Belfast Reservoir #1	Belfast	669	150	519	0.25	130	4.6	mod-sensitive	m	1.00	4.60	0.035	32
Belfast Reservoir #1	Northport	1326	70	1256	0.25	314	9.08	mod-sensitive	m	1.00	9.08	0.029	79
Belfast Reservoir #2	Belfast	6921	1000	5921	0.25	1480	43.54	mod-sensitive	m	1.00	43.54	0.029	370
Belfast Reservoir #2	Northport	1084	55	1029	0.25	257	6.83	mod-sensitive	m	1.00	6.83	0.027	64
Ben Annis Pond	Hampden	575	170	405	0.25	101	3.52	mod-sensitive	m	1.00	3.52	0.035	25
Ben Annis Pond	Hermon	202	70	132	0.25	33	1.23	mod-sensitive	m	1.00	1.23	0.037	8
Berry Pond	Readfield	1307	100	1207	0.25	302	8.73	mod-sensitive	m	1.00	8.73	0.029	75
Berry Pond	Winthrop	2080	150	1930	0.25	483	13.91	mod-sensitive	m	1.00	13.91	0.029	121
Big Benson Pond	Willimantic	296	5	291	0.2	58	5.02	good	h	1.00	5.02	0.086	15
Big Cathance Lake	Cooper	7138	350	6788	0.2	1358	132.4	good	h	1.00	132.41	0.098	339
Big Cathance Lake	Plantation # 14	1514	100	1414	0.2	283	28.09	good	h	1.00	28.09	0.099	71
Big Concord Pond	Peru	56	25	31	0.2	6	0.46	mod-sensitive	h	0.75	0.35	0.056	2
Big Concord Pond	Woodstock	1317	150	1167	0.2	233	10.78	mod-sensitive	h	0.75	8.09	0.035	58
Big Greenwood Pond	Willimantic	321	10	311	0.2	62	7.38	mod-sensitive	h	0.75	5.54	0.089	16
Big Pond	Phippsburg	101	15	86	0.25	22	1.05	mod-sensitive	m	1.00	1.05	0.049	5
Birch Harbor Pond	Winter Harbor	259	25	234	0.25	59	2.53	mod-sensitive	m	1.00	2.53	0.043	15
Biscay Pond	Bremen	906	91	815	0.25	204	17.97	mod-sensitive	h	0.75	13.48	0.066	51
Biscay Pond	Bristol	649	65	584	0.25	146	12.87	mod-sensitive	h	0.75	9.65	0.066	37
Biscay Pond	Damariscotta	941	94	847	0.3	254	18.65	mod-sensitive	h	0.75	13.99	0.055	64
Black Pond	Fryeburg	74	4	70	0.2	14	0.83	mod-sensitive	m	1.00	0.83	0.059	4
Black Pond	Sweden	1198	125	1073	0.2	215	8.37	mod-sensitive	m	1.00	8.37	0.039	54
Black Pond	Turner	12	0	12	0.3	4	0.13	mod-sensitive	m	1.00	0.13	0.036	1

Appendix C

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Black Pond	Vienna	889	150	739	0.15	111	6.43	mod-sensitive	m	1.00	6.43	0.058	28
Bog Lake	Northfield	1887	300	1587	0.25	397	37.74	mod-sensitive	h	0.75	28.31	0.071	99
Bog Pond	Fryeburg	378	10	368	0.2	74	3.9	mod-sensitive	m	1.00	3.90	0.053	18
Bog Pond	Harrison	229	100	129	0.25	32	1.63	mod-sensitive	h	0.75	1.22	0.038	8
Bog Pond	Mount Vernon	301	40	261	0.25	65	1.74	mod-sensitive	m	1.00	1.74	0.027	16
Bog Pond	Readfield	1230	120	1110	0.2	222	7.12	mod-sensitive	m	1.00	7.12	0.032	56
Bog Pond	Waterford	284	28	256	0.2	51	3.13	mod-sensitive	m	1.00	3.13	0.061	13
Bogus Meadow Pond	Gouldsboro	153	3	150	0.15	23	1.25	mod-sensitive	m	1.00	1.25	0.056	6
Bonney Eagle Lake	Buxton	274	75	199	0.35	70	2.07	mod-sensitive	m	1.00	2.07	0.030	17
Bonney Eagle Lake	Standish	1981	400	1581	0.3	474	14.86	mod-sensitive	m	1.00	14.86	0.031	119
Bonny Pond	Leeds	138	40	98	0.2	20	1.01	mod-sensitive	m	1.00	1.01	0.052	5
Bonny Pond	Monmouth	249	30	219	0.25	55	1.83	mod-sensitive	m	1.00	1.83	0.033	14
Boody Pond	Vienna	182	50	132	0.15	20	1.25	mod-sensitive	h	0.75	0.94	0.047	5
Boston Pond	Denmark	113	30	83	0.2	17	1.3	mod-sensitive	m	1.00	1.30	0.078	4
Boyd Pond	Limington	336	35	301	0.25	75	2.82	mod-sensitive	m	1.00	2.82	0.037	19
Branch Lake	Dedham	1991	100	1891	0.3	567	31.79	good	h	1.00	31.79	0.056	142
Branch Lake	Ellsworth	11559	1000	10559	0.25	2640	184.5	good	h	1.00	184.51	0.070	660
Branch Lake	Orland	1423	120	1303	0.3	391	22.71	good	h	1.00	22.71	0.058	98
Brandy Pond (Bay of Naples)	Naples	2174	300	1874	0.4	750	37.9	mod-sensitive	h	0.75	28.43	0.038	187
Branns Mill Pond	Dover-Foxcroft	3805	900	2905	0.2	581	23.52	mod-sensitive	m	1.00	23.52	0.040	145
Branns Mill Pond	Garland	3899	800	3099	0.2	620	24.1	mod-sensitive	m	1.00	24.10	0.039	155
Brassua Lake	Tomhegan Twp.	4899	200	4699	0.22	1034	53.29	mod-sensitive	h	0.75	39.97	0.039	258
Brettuns Pond	Hartford	340	10	330	0.2	66	3.1	mod-sensitive	m	1.00	3.10	0.047	17
Brettuns Pond	Livermore	2048	100	1948	0.25	487	18.58	mod-sensitive	h	0.75	13.94	0.029	122
Brewer Pond	Bucksport	1111	60	1051	0.2	210	16.38	mod-sensitive	h	0.75	12.29	0.058	53
Brewer Pond	Holden	901	80	821	0.25	205	13.29	mod-sensitive	h	0.75	9.97	0.049	51
Brishlotte Lake	Frenchville	269	40	229	0.2	46	1.47	mod-sensitive	m	1.00	1.47	0.032	11
Brooks Pond	Corinna	363	60	303	0.2	61	2.38	mod-sensitive	m	1.00	2.38	0.039	15
Browns Pond	Denmark	34	3	31	0.2	6	0.3	mod-sensitive	m	1.00	0.30	0.048	2
Browns Pond	Sebago	659	60	599	0.25	150	5.71	mod-sensitive	m	1.00	5.71	0.038	37
Bryant Pond	Hiram	696	100	596	0.2	119	4.98	mod-sensitive	m	1.00	4.98	0.042	30
Bryant Pond	Woodstock	1868	300	1568	0.25	392	25.68	mod-sensitive	h	0.75	19.26	0.049	98
Bubble Pond	Mount Desert	96	96	0	0	0	1.01	outstanding	h	0.50	0.51	Park	0
Bunganock Pond	Hartford	1591	150	1441	0.2	288	10.62	mod-sensitive	m	1.00	10.62	0.037	72
Bunganut Pond	Lyman	1168	150	1018	0.3	305	17.08	mod-sensitive	h	0.75	12.81	0.042	76
Bunker Pond	Roxbury	326	10	316	0.15	47	2.58	mod-sensitive	m	1.00	2.58	0.054	12
Burnt Meadow Pond	Brownfield	2031	700	1331	0.2	266	17.66	mod-sensitive	h	0.75	13.25	0.050	67

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Burnt Pond	Clifton	526	50	476	0.2	95	7.56	good	h	1.00	7.56	0.079	24
Burnt Pond	Dedham	657	20	637	0.25	159	9.45	good	m	1.50	14.18	0.089	40
Cabbage Yard Pond	Waterford	259	13	246	0.2	49	1.54	mod-sensitive	m	1.00	1.54	0.031	12
Caesar Pond	Bowdoin	148	35	113	0.25	28	1.63	mod-sensitive	m	1.00	1.63	0.058	7
Cain Pond	Searsport	454	25	429	0.2	86	3.66	mod-sensitive	m	1.00	3.66	0.043	21
Cambolasse Pond	Lincoln	837	120	717	0.25	179	13.2	mod-sensitive	m	1.00	13.20	0.074	45
Campbell Pond	West Bath	103	8	95	0.25	24	0.99	mod-sensitive	m	1.00	0.99	0.042	6
Caribou Pond (Caribou, Egg, & Long)	Lincoln	2050	150	1900	0.2	380	32.63	mod-sensitive	m	1.00	32.63	0.086	95
Carlton Pond	Detroit	3049	1000	2049	0.2	410	17.48	mod-stable	m	1.25	21.85	0.053	102
Carlton Pond	Readfield	1383	400	983	0.25	246	16.93	mod-sensitive	h	0.75	12.70	0.052	61
Carlton Pond	Troy	7445	750	6695	0.2	1339	42.68	mod-sensitive	m	1.00	42.68	0.032	335
Carlton Pond	Winthrop	108	0	108	0.25	27	1.32	mod-sensitive	h	0.75	0.99	0.037	7
Cat Lake	Fryeburg	442	5	437	0.2	87	6.85	mod-sensitive	m	1.00	6.85	0.078	22
Cathance Lake	Plantation # 14	1514	100	1414	0.2	283	28.09	mod-sensitive	h	1.00	28.09	0.099	71
Cedar Swamp Pond	Clifton	847	80	767	0.15	115	5.6	mod-sensitive	m	1.00	5.60	0.049	29
Center Pond	Lincoln	1262	120	1142	0.2	228	11.26	mod-sensitive	m	1.00	11.26	0.049	57
Center Pond	Phippsburg	966	90	876	0.25	219	7.27	mod-sensitive	m	1.00	7.27	0.033	55
Chaffin Pond	Windham	79	10	69	0.35	24	0.94	mod-sensitive	m	1.00	0.94	0.039	6
Chain of Ponds - Long	Chain of Ponds	9513	240	9273	0.15	1391	114.4	mod-sensitive	h	0.75	85.82	0.062	348
Chain of Ponds - Natanis	Chain of Ponds	2357	60	2297	0.15	345	28.24	mod-sensitive	h	0.75	21.18	0.061	86
Chalk Pond	Beddington	338	0	338	0.15	51	2.35	mod-sensitive	m	1.00	2.35	0.046	13
Chamberlain Pond	Belgrade	96	40	56	0.4	22	0.72	mod-sensitive	h	0.75	0.54	0.024	6
Chemo Pond	Clifton	6810	1500	5310	0.25	1328	67.8	mod-sensitive	h	0.75	50.85	0.038	332
Chemo Pond	Eddington	3439	350	3089	0.25	772	34.24	mod-sensitive	m	1.00	34.24	0.044	193
Chesuncook, Caribou Lake	T3R13	6822	200	6622	0.15	993	111.9	mod-sensitive	h	0.75	83.89	0.084	248
Chickawaukie Lake	Rockland	333	66	267	0.35	93	5.02	mod-sensitive	h	0.75	3.77	0.040	23
Chickawaukie Pond	Rockport	1321	132	1189	0.3	357	20.2	mod-sensitive	h	0.75	15.15	0.042	89
China Lake East Basin	China	11957	3587.1	8369.9	0.25	2092	142.7	poor restorable		0.50	71.36	0.034	523
China Lake West Basin	China	2804	672.96	2131.04	0.25	533	61.03	poor restorable		0.50	30.52	0.057	133
China Lake, West Basin	Vassalboro	1430	125	1305	0.25	326	31.15	poor restorable	h	0.40	12.46	0.038	82
Clary Lake	Whitefield	2340	250	2090	0.25	523	25.07	mod-sensitive	m	1.00	25.07	0.048	131
Clays Pond	Fryeburg	323	25	298	0.25	75	4.43	mod-sensitive	h	0.75	3.32	0.045	19
Clemons Pond	Hiram	766	150	616	0.2	123	8.75	mod-sensitive	h	0.75	6.56	0.053	31
Cloutman Pond	Rangeley	150	10	140	0.2	28	1.56	mod-sensitive	m	1.00	1.56	0.056	7
Cobbossee Lake	Manchester	3405	320	3085	0.3	926	64.51	poor restorable	h	0.50	32.26	0.035	231
Cobbossee Lake	Monmouth	7304	900	6404	0.25	1601	138.5	poor restorable	h	0.50	69.23	0.043	400

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Cobbossee Lake	Wales	5735	600	5135	0.25	1284	108.7	poor restorable	m	0.50	54.36	0.042	321
Cobbossee Lake	Winthrop	2248	250	1998	0.3	599	42.62	poor restorable	h	0.50	21.31	0.036	150
Cochnewagon	Monmouth	1769	200	1569	0.25	392	23.65	mod-sensitive	h	0.75	17.74	0.045	98
Coffee Pond	Casco	452	135	317	0.35	111	7.91	mod-sensitive	h	0.75	5.93	0.053	28
Cold Rain Pond	Naples	469	50	419	0.3	126	3.92	mod-sensitive	h	0.75	2.94	0.023	31
Cold Rain Pond	Sebago	34	0	34	0.2	7	0.28	mod-sensitive	h	0.75	0.21	0.031	2
Cold Stream Pond - Lower Basin	Enfield	2045	200	1845	0.25	461	61.82	outstanding	h	0.50	30.91	0.067	115
Cold Stream Pond - Upper Basin	Enfield	684	160	524	0.25	131	9.08	outstanding	h	0.50	4.54	0.035	33
Cold Stream Pond - Upper Basin	Lincoln	2068	160	1908	0.2	382	27.45	mod-sensitive	h	0.75	20.59	0.054	95
Coleman Pond	Lincolnville	1225	125	1100	0.25	275	14.83	mod-sensitive	m	1.00	14.83	0.054	69
Cooks Pond	Jefferson	1581	158	1423	0.2	285	12.7	mod-sensitive	m	1.00	12.70	0.045	71
Cooks Pond	Nobleboro	219	22	197	0.3	59	1.76	mod-sensitive	m	1.00	1.76	0.030	15
Corundel Lake	Corinna	6839	1200	5639	0.25	1410	83.54	mod-sensitive	m	1.00	83.54	0.059	352
Corundel Lake	Dexter	3553	500	3053	0.25	763	43.41	mod-sensitive	m	1.00	43.41	0.057	191
Cotton Pond	Hope	42	1	41	0.25	10	0.44	mod-sensitive	m	1.00	0.44	0.043	3
Craig Pond	Orland	595	70	525	0.25	131	13.4	outstanding	h	0.50	6.70	0.051	33
Cranberry Pond	Clifton	457	150	307	0.15	46	3.74	mod-sensitive	m	1.00	3.74	0.081	12
Crawford Pond	Hope	1193	150	1043	0.25	261	15.58	mod-sensitive	h	0.75	11.69	0.045	65
Crawford Pond	Rockport	336	20	316	0.2	63	4.38	mod-sensitive	h	0.75	3.29	0.052	16
Crawford Pond	Union	3659	350	3309	0.25	827	47.84	mod-sensitive	h	0.75	35.88	0.043	207
Crescent Lake	Casco	904	103	801	0.35	280	12.3	mod-sensitive	h	0.75	9.23	0.033	70
Crescent Lake	Raymond	2898	290	2608	0.35	913	39.38	mod-sensitive	h	0.75	29.54	0.032	228
Crescent Pond	Poland	96	5	91	0.2	18	1.32	mod-sensitive	h	0.75	0.99	0.054	5
Crooked Brook Flowage	Danforth	16333	3000	13333	0.2	2667	154.5	mod-sensitive	m	1.00	154.52	0.058	667
Crooked Pond	Lincoln	1107	110	997	0.25	249	11.53	mod-sensitive	m	1.00	11.53	0.046	62
Crowell Pond	Vienna	4825	500	4325	0.2	865	29.87	mod-sensitive	m	1.00	29.87	0.035	216
Crystal Lake	Gray	941	94	847	0.3	254	13.86	mod-sensitive	m	1.00	13.86	0.055	64
Crystal Lake	Harrison	4558	779	3779	0.4	1512	101.1	mod-sensitive	h	0.75	75.80	0.050	378
Crystal Lake	Waterford	862	43	819	0.25	205	19.11	mod-sensitive	h	0.75	14.33	0.070	51
Crystal Pond	Turner	284	20	264	0.25	66	3.04	mod-sensitive	h	0.75	2.28	0.035	17
Crystal Pond	Washington	444	35	409	0.2	82	5.62	mod-sensitive	h	0.75	4.22	0.052	20
Curtis Bog	Sabattus	1045	450	595	0.25	149	9.72	mod-sensitive	m	1.00	9.72	0.065	37
Cushman Pond	Sumner	86	20	66	0.15	10	0.85	mod-sensitive	h	0.75	0.64	0.064	2
Dam Pond	Augusta	766	115	651	0.3	195	9.81	mod-sensitive	m	1.00	9.81	0.050	49

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Davis Pond	Eddington	3041	300	2741	0.25	685	27.65	mod-sensitive	m	1.00	27.65	0.040	171
Davis Pond	Holden	946	90	856	0.25	214	8.59	mod-sensitive	m	1.00	8.59	0.040	54
Davis Pond	Vienna	150	50	100	0.2	20	1.25	mod-sensitive	m	1.00	1.25	0.063	5
Dead Lake	Fryeburg	452	125	327	0.2	65	4.76	mod-sensitive	m	1.00	4.76	0.073	16
Debec Pond	Clifton	244	150	94	0.2	19	2.13	mod-sensitive	h	0.75	1.60	0.085	5
Deer Pond	Hollis	64	20	44	0.35	15	1.6	mod-sensitive	h	0.75	1.20	0.078	4
Desert Pond	Mount Vernon	484	30	454	0.2	91	3.79	mod-sensitive	h	0.75	2.84	0.031	23
Dexter Pond	Winthrop	390	90	300	0.25	75	3.32	mod-sensitive	m	1.00	3.32	0.044	19
Dipper Pond	Carroll Plt	66	10	56	0.15	8	0.44	mod-sensitive	m	1.00	0.44	0.052	2
Dodge Pond	Rangeley	1482	100	1382	0.25	346	14.9	mod-sensitive	h	0.75	11.18	0.032	86
Doles Pond	Limington	724	100	624	0.2	125	4.43	mod-sensitive	m	1.00	4.43	0.035	31
Doliff Pond	Searsmont	143	10	133	0.2	27	0.92	mod-sensitive	m	1.00	0.92	0.035	7
Dresden Bog	Wiscasset	294	0	294	0.2	59	3.1	mod-sensitive	m	1.00	3.10	0.053	15
Duck Pond	Standish	93	5	88	0.25	22	0.9	mod-sensitive	m	1.00	0.90	0.041	6
Duck Pond	Waterford	308	15	293	0.2	59	2.97	mod-sensitive	m	1.00	2.97	0.051	15
Duckpuddle Pond	Bremen	29	0	29	0.15	4	0.26	mod-sensitive	m	1.00	0.26	0.060	1
Duckpuddle Pond	Nobleboro	1373	137	1236	0.3	371	12.32	mod-sensitive	m	1.00	12.32	0.033	93
Duckpuddle Pond	Waldoboro	3575	400	3175	0.25	794	32.08	mod-sensitive	m	1.00	32.08	0.040	198
Dumpling Pond	Casco	375	56	319	0.25	80	4.32	mod-sensitive	m	1.00	4.32	0.054	20
Dunham Pond	Dover-Foxcroft	126	0	126	0.2	25	1.14	mod-sensitive	m	1.00	1.14	0.045	6
Dutton Pond	Brooks	160	10	150	0.2	30	1.14	mod-sensitive	m	1.00	1.14	0.038	8
Dyer Pond	Brownfield	360	30	330	0.2	66	2.49	mod-sensitive	m	1.00	2.49	0.038	17
Eagle Lake	Mount Desert	86	86	0	0	0	1.98	outstanding	h	0.50	0.99	Park	0
East Pond	Oakland	1270	130	1140	0.3	342	26.51	poor restorable	m	0.50	13.26	0.039	86
East Pond	Smithfield	1492	130	1362	0.25	341	29.96	poor restorable	m	0.50	14.98	0.044	85
Eastern Lake	Whiting	192	20	172	0.15	26	1.85	mod-sensitive	m	1.00	1.85	0.072	6
Echo Lake	Mount Desert	716	290	426	0.3	128	10.89	good	h	1.00	10.89	0.085	32
Echo Lake	Mount Vernon	3229	300	2929	0.35	1025	66.56	good	h	1.00	66.56	0.065	256
Echo Lake	Readfield	311	30	281	0.3	84	6.41	good	h	1.00	6.41	0.076	21
Echo Lake (Little)	Mount Desert	311	30	281	0.3	84	4.49	mod-sensitive	m	0.75	3.37	0.040	21
Egg Pond	Lee	630	100	530	0.2	106	4.18	mod-sensitive	m	1.00	4.18	0.039	27
Egg Pond (Egg, Long, & Caribou)	Lincoln	420	30	390	0.2	78	4.71	mod-sensitive	m	1.00	4.71	0.060	20
Egypt Pond	Vienna	284	35	249	0.2	50	2.71	mod-sensitive	h	0.75	2.03	0.041	12
Ellis Pond	Brooks	434	25	409	0.2	82	4.49	mod-sensitive	m	1.00	4.49	0.055	20
Ellis Pond	Roxbury	3496	230	3266	0.2	653	26.68	mod-sensitive	m	1.00	26.68	0.041	163
Escutasis (Little) Lake	Burlington	449	50	399	0.2	80	5.55	mod-sensitive	m	1.00	5.55	0.070	20

Appendix C

Per Acre Phosphorus Allocations for Selected Maine Lakes

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Lake Name	Town in which development is located	Direct Watershed Area in Town (acres) **DDA**	Area not available for development (acres) **ANAD**	Area available for development (acres) **AAD**	**GF**	Expected developed area (acres) **D**	(lbP/y) **F**	Water Quality Category **WQC**	**LOP**	**C**	**FC**	Per acre phosphorus allocation (lb/acre/yr) **P**	Small Watershed Threshold (acres) **SWT**
Estes Lake	Alfred	11149	1115	10034	0.3	3010	72.73	mod-sensitive	m	1.00	72.73	0.024	753
Estes Lake	Sanford	5127	775	4352	0.35	1523	41.58	mod-sensitive	m	1.00	41.58	0.027	381
Estes Lake, Upper Basin	Sanford	3165	700	2465	0.35	863	20.5	mod-sensitive	m	1.00	20.50	0.024	216
Etna Pond	Carmel	417	80	337	0.2	67	2.86	mod-sensitive	m	1.00	2.86	0.042	17
Etna Pond	Etna	882	90	792	0.25	198	6.06	mod-sensitive		1.00	6.06	0.031	50
Farrington Pond	Lovell	340	30	310	0.25	78	3.88	mod-sensitive	m	1.00	3.88	0.050	19
Farwell Bog	Raymond	1045	209	836	0.25	209	6.35	mod-stable	m	1.25	7.94	0.038	52
Faulkner Lake	Weston	516	40	476	0.15	71	4.6	mod-sensitive	m	1.00	4.60	0.064	18
Fields Pond	Holden	696	80	616	0.25	154	8.55	mod-sensitive	m	1.00	8.55	0.056	39
First Pond	Blue Hill	2241	200	2041	0.2	408	23.17	mod-sensitive	h	0.75	17.38	0.043	102
Fish Pond	Hope	617	30	587	0.25	147	7.96	mod-sensitive	m	1.00	7.96	0.054	37
Fitts Pond	Clifton	395	60	335	0.2	67	4.25	good	h	1.00	4.25	0.063	17
Fitts Pond	Eddington	316	25	291	0.2	58	3.41	good	h	1.00	3.41	0.059	15
Flagstaff Lake	Carrabassett Val	6533	2000	4533	0.2	907	58.85	mod-sensitive	h	0.75	44.14	0.049	227
Flagstaff Lake	Carrying Place T	6997	450	6547	0.15	982	63.04	mod-sensitive	h	0.75	47.28	0.048	246
Flagstaff Lake	Eustis	23795	1500	22295	0.15	3344	214.3	mod-sensitive	h	0.75	160.76	0.048	836
Flagstaff Lake	Highland Plt	1865	40	1825	0.15	274	16.8	mod-sensitive	h	0.75	12.60	0.046	68
Flagstaff Lake	Jim Pond Twp	9332	15	9317	0.15	1398	84.05	mod-sensitive	h	0.75	63.04	0.045	349
Flagstaff Lake	Kibby Twp	4198	15	4183	0.15	627	37.83	mod-sensitive	h	0.75	28.37	0.045	157
Flagstaff Lake	Redington Twp	17731	0	17731	0.15	2660	159.7	mod-sensitive	h	0.75	119.78	0.045	665
Flanders Pond	Sullivan	3560	900	2660	0.25	665	40.5	mod-sensitive	m	1.00	40.50	0.061	166
Floods Pond	Clifton	551	125	426	0.2	85	11.22	good	h	1.00	11.22	0.132	21
Floods Pond	Dedham	180	0	180	0.25	45	3.66	good	h	1.00	3.66	0.081	11
Flowed Land Pond	Calais	679	0	679	0.2	136	10	mod-sensitive	m	1.00	10.00	0.074	34
Flying Pond	Mount Vernon	518	50	468	0.3	140	8.35	mod-sensitive	h	0.75	6.26	0.045	35
Flying Pond	Vienna	3133	500	2633	0.25	658	50.51	mod-sensitive	h	0.75	37.88	0.058	165
Folsom Pond	Lincoln	2438	200	2238	0.25	560	26.63	mod-sensitive	m	1.00	26.63	0.048	140
Forbes Pond	Gouldsboro	3721	350	3371	0.2	674	26.81	mod-sensitive	m	1.00	26.81	0.040	169
Ford Mill Pond (Midas# 6841)	Waterboro	1025	154	871	0.3	261	6.57	mod-sensitive	m	1.00	6.57	0.025	65
Forest Lake	Cumberland	165	50	115	0.35	40	1.6	mod-sensitive	m	1.00	1.60	0.040	10
Forest Lake	Gray	639	100	539	0.3	162	6.19	mod-sensitive	m	1.00	6.19	0.038	40
Forest Lake	Windham	1040	100	940	0.3	282	10.05	mod-sensitive	m	1.00	10.05	0.036	71
Forest Pond	Canton	197	10	187	0.25	47	2.55	mod-sensitive	m	1.00	2.55	0.055	12
Foss Pond	Kingsbury Planta	726	110	616	0.2	123	10.45	good	h	1.00	10.45	0.085	31
Fourth Davis Pond	Willimantic	165	7	158	0.15	24	1.71	mod-sensitive	m	1.00	1.71	0.072	6
Fourth Pond	Blue Hill	793	70	723	0.2	145	5.9	mod-sensitive	m	1.00	5.90	0.041	36
Fox Pond	Windsor	103	15	88	0.2	18	0.94	mod-sensitive	m	1.00	0.94	0.053	4

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Fresh Pond	Cushing	192	20	172	0.25	43	1.91	mod-sensitive	m	1.00	1.91	0.044	11
Fresh Pond	North Haven	951	150	801	0.15	120	9.04	mod-sensitive	h	0.75	6.78	0.056	30
Frog Pond	Turner	88	15	73	0.2	15	0.55	mod-sensitive	m	1.00	0.55	0.038	4
Fulton Lake	Northfield	331	40	291	0.25	73	4.96	mod-sensitive	m	1.00	4.96	0.068	18
Gammon Pond	New Portland	126	30	96	0.2	19	0.97	mod-sensitive	m	1.00	0.97	0.051	5
Garcock Pond	Willimantic	51	1	50	0.15	8	0.46	mod-sensitive	m	1.00	0.46	0.061	2
Gardiner Lake	Whiting	1961	200	1761	0.25	440	43.39	good	h	1.00	43.39	0.099	110
Gardiner Pond	Wiscasset	400	40	360	0.25	90	4.01	mod-sensitive	m	1.00	4.01	0.045	23
Gardner Lake	Marion Twp.	830	100	730	0.25	183	18.34	mod-stable	h	1.00	18.34	0.100	46
Garland Pond	Dover-Foxcroft	365	20	345	0.2	69	3.3	mod-sensitive	m	1.00	3.30	0.048	17
Garland Pond	Garland	2681	300	2381	0.2	476	16.58	mod-sensitive	m	1.00	16.58	0.035	119
George Pond	Hermon	7724	3000	4724	0.25	1181	37.22	mod-sensitive	m	1.00	37.22	0.032	295
George Pond	Holden	1423	75	1348	0.2	270	8.33	mod-sensitive	m	1.00	8.33	0.031	67
Georges Pond	Deer Isle	14	3	11	0.3	3.3	0.15	mod-sensitive	m	1.00	0.15	0.045	1
Gilman Pond	Carrabassett Val	1203	600	603	0.15	90	6.68	mod-sensitive	h	0.75	5.01	0.055	23
Gilman Pond	Highland Plt	21470	700	20770	0.15	3116	119	mod-sensitive	m	1.00	119.02	0.038	779
Gilman Pond	Lexington Twp	19061	1500	17561	0.15	2634	105.7	mod-sensitive	m	1.00	105.68	0.040	659
Gilman Pond	New Portland	2908	450	2458	0.2	492	16.14	mod-sensitive	m	1.00	16.14	0.033	123
Gilman Pond	Pleasant Ridge	1855	200	1655	0.1	166	10.29	mod-sensitive	m	1.00	10.29	0.062	41
Givens (Longfellow) Pond	Whitefield	93	20	73	0.25	18	1.03	mod-sensitive	m	1.00	1.03	0.056	5
Givens (Longfellow) Pond	Windsor	49	15	34	0.25	9	0.55	mod-sensitive	m	1.00	0.55	0.065	2
Gold Stream Pond	Surry	1386	100	1286	0.2	257	10.18	mod-sensitive	m	1.00	10.18	0.040	64
Goose Pond	Dedham	1094	100	994	0.25	249	12.89	good	m	1.50	19.34	0.078	62
Gould Pond	Dexter	249	50	199	0.2	40	1.63	poor-restorable	m	0.50	0.82	0.020	10
Graham Lake	Clifton	869	80	789	0.2	158	12.43	good	m	1.50	18.65	0.118	39
Graham Lake	Ellsworth	3728	400	3328	0.3	998	53.33	good	m	1.50	80.00	0.080	250
Graham Lake	Mariaville	8547	1000	7547	0.25	1887	122.2	mod-stable	m	1.25	152.75	0.081	472
Graham Lake	Waltham	10195	500	9695	0.25	2424	146.8	mod-stable	m	1.25	183.46	0.076	606
Granger Pond	Denmark	647	100	547	0.3	164	8.55	mod-sensitive	m	1.00	8.55	0.052	41
Grassy Pond	Hope	331	45	286	0.25	72	2.95	mod-sensitive	h	0.75	2.21	0.031	18
Grassy Pond	Rockport	961	100	861	0.25	215	8.51	mod-sensitive	m	1.00	8.51	0.040	54
Great East Lake	Acton	2391	300	2091	0.3	627	40.1	outstanding	h	0.50	20.05	0.032	157
Great Moose Lake	Dexter	7368	1000	6368	0.2	1274	50.8	mod-sensitive	m	0.75	38.10	0.030	318
Great Moose Lake	Dover-Foxcroft	509	30	479	0.2	96	3.5	mod-sensitive	m	1.00	3.50	0.037	24
Great Moose Lake	Garland	4193	900	3293	0.2	659	28.9	mod-sensitive	h	0.75	21.68	0.033	165
Great Pond	Rome	7198	800	6398	0.3	1919	150.5	mod-sensitive	h	0.75	112.87	0.059	480
Great Pond	Smithfield	1267	275	992	0.25	248	26.5	mod-sensitive	h	0.75	19.88	0.080	62

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Great Pond	Belgrade	10941	2167	8774	0.25	2194	228.7	mod-sensitive	h	0.75	171.54	0.078	548
Greeley Pond	Augusta	1074	130	944	0.3	283	7.16	mod-sensitive	m	1.00	7.16	0.025	71
Green Lake	Dedham	6244	350	5894	0.3	1768	117.9	good	h	1.00	117.85	0.067	442
Green Lake	Ellsworth	6434	700	5734	0.25	1434	121.5	good	h	1.00	121.47	0.085	358
Green Pond	Lee	106	0	106	0.2	21	1.08	mod-sensitive	m	1.00	1.08	0.051	5
Green Pond	T3R1 NBPP	536	20	516	0.2	103	5.38	mod-sensitive	m	1.00	5.38	0.052	26
Grindstone Pond	Willimantic	145	5	140	0.15	21	1.74	mod-sensitive	h	0.75	1.31	0.062	5
Gull Pond	Dallas Plt.	1793	180	1613	0.2	323	9.79	mod-sensitive	h	0.75	7.34	0.023	81
Gull Pond	Rangeley	879	112	767	0.3	230	8.82	mod-sensitive	h	0.75	4.62	0.020	58
Hadley Lake	Northfield	3904	150	3754	0.2	751	39.91	mod-stable	m	1.25	49.89	0.066	188
Hales Pond	Fayette	2233	300	1933	0.2	387	15.65	mod-sensitive	m	1.00	15.65	0.040	97
Haley Pond	Dallas Plt.	2438	350	2088	0.25	522	22.09	mod-sensitive	m	1.00	22.09	0.042	131
Haley Pond	Rangeley	410	50	360	0.25	90	3.72	mod-sensitive	m	1.00	3.72	0.041	23
Half Moon Pond	Dexter	79	5	74	0.2	15	0.48	mod-sensitive	m	1.00	0.48	0.032	4
Halfmoon Pond	Brooks	200	10	190	0.2	38	2.42	mod-sensitive	m	0.75	1.82	0.048	10
Halfmoon Pond	Searsport	380	40	340	0.25	85	5.79	mod-sensitive	h	0.75	4.34	0.051	21
Halfmoon Pond	Standish	54	10	44	0.25	11	0.55	mod-sensitive	m	1.00	0.55	0.050	3
Halls Pond	Paris	148	20	128	0.25	32	1.94	mod-sensitive	h	0.75	1.46	0.045	8
Hamilton Pond	Belgrade	96	50	46	0.4	18	1.36	mod-sensitive	h	0.75	1.02	0.055	5
Hancock Pond	Bridgton	358	40	318	0.3	95	6.19	mod-sensitive	h	0.75	4.64	0.049	24
Hancock Pond	Bucksport	805	100	705	0.25	176	7.34	mod-sensitive	h	0.75	5.51	0.031	44
Hancock Pond	Denmark	1292	120	1172	0.3	352	22.31	mod-sensitive	h	0.75	16.73	0.048	88
Hancock Pond	New Portland	14	0	14	0.2	3	0.15	mod-sensitive	h	0.75	0.11	0.040	1
Hancock Pond	Sebago	1025	100	925	0.3	278	17.7	mod-sensitive	h	0.75	13.28	0.048	69
Hansen Pond	Acton	219	20	199	0.2	40	1.65	mod-sensitive	m	1.00	1.65	0.041	10
Hanson Pond	Dedham	200	15	185	0.2	37	1.47	mod-sensitive	m	1.00	1.47	0.040	9
Harriman Pond	Dedham	143	30	113	0.25	28	3.06	outstanding	h	0.50	1.53	0.054	7
Hastings Pond	Bristol	138	14	124	0.25	31	1.21	mod-sensitive	m	1.00	1.21	0.039	8
Hatcase Pond	Dedham	1331	80	1251	0.25	313	16.49	good	h	1.00	16.49	0.053	78
Hatcase Pond	Eddington	616	40	576	0.2	115	3.9	good	h	1.00	3.90	0.034	29
Havener Pond	Waldoboro	383	50	333	0.25	83	3.55	mod-sensitive	m	1.00	3.55	0.043	21
Heart Pond	Orland	546	60	486	0.3	146	6.9	mod-sensitive	h	0.75	5.18	0.035	36
Hermon Pond	Hampden	59	6	53	0.3	16	0.35	poor-natural	m	2.00	0.70	0.044	4
Hermon Pond	Hermon	4329	600	3729	0.3	1119	24.91	poor-natural	m	2.00	49.82	0.045	280
Highland Lake	Bridgton	3600	360	3240	0.4	1296	56.64	mod-sensitive	h	0.75	42.48	0.033	324
Highland Lake	Sweden	1457	90	1367	0.3	410	22.95	mod-sensitive	h	0.75	17.21	0.042	103
Highland Lake	Waterford	42	0	42	0.25	11	0.63	mod-sensitive	h	0.75	0.47	0.045	3

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Highland Lake	Westbrook	385	90	295	0.35	103	4.71	mod-sensitive	h	0.75	3.53	0.034	26
Highland Lake	Windham	2194	300	1894	0.4	758	26.87	mod-sensitive	h	0.75	20.15	0.027	189
Hilton Pond 1	Kingsbury Planta	439	25	414	0.2	83	3.46	mod-sensitive	m	1.00	3.46	0.042	21
Hilton Pond 2	Kingsbury Planta	135	10	125	0.2	25	1.23	mod-sensitive	m	1.00	1.23	0.049	6
Hobbs Pond	Camden	51	5	46	0.25	12	0.61	mod-stable	m	1.25	0.76	0.066	3
Hobbs Pond	Hope	1655	180	1475	0.25	369	19.95	poor restorable	m	0.50	9.98	0.027	92
Hodgdon Pond	Mount Desert	553	0	553	0	0	4.89	good	h	1.00	4.89	Park	0
Hodgdon Pond	Tremont	227	25	202	0.25	51	2	mod-sensitive	m	1.00	2.00	0.040	13
Hog Meadow Pond	Casco	135	25	110	0.25	28	1.41	mod-sensitive	m	1.00	1.41	0.051	7
Hogan Pond	Mechanic Falls	941	90	851	0.3	255	9.56	mod-sensitive	m	1.00	9.56	0.037	64
Hogan Pond	Oxford	1361	130	1231	0.25	308	13.82	mod-sensitive	m	1.00	13.82	0.045	77
Hogan Pond	Poland	155	15	140	0.3	42	1.56	mod-sensitive	m	1.00	1.56	0.037	11
Holbrook Pond	Dedham	499	40	459	0.25	115	5	mod-sensitive	m	1.00	5.00	0.044	29
Holbrook Pond	Eddington	805	90	715	0.25	179	8.04	mod-sensitive	m	1.00	8.04	0.045	45
Holbrook Pond	Holden	2309	200	2109	0.25	527	23.72	mod-sensitive	m	1.00	23.72	0.045	132
Holland Pond (Sokokis L.)	Limerick	2327	500	1827	0.25	457	16.94	mod-sensitive	m	1.00	16.94	0.037	114
Holmes Pond	Whiting	2060	200	1860	0.15	279	14.42	mod-sensitive	m	1.00	14.42	0.052	70
Holt Pond	Bridgton	1877	400	1477	0.35	517	14.77	mod-sensitive	m	1.00	14.77	0.029	129
Holt Pond	Deer Isle	172	26	146	0.2	29	1.47	mod-sensitive	m	1.00	1.47	0.050	7
Holt Pond	Naples	224	15	209	0.35	73	1.76	mod-sensitive	m	1.00	1.76	0.024	18
Hopkins Pond	Clifton	1025	100	925	0.2	185	17.75	good	h	1.00	17.75	0.096	46
Hopkins Pond	Mariaville	518	45	473	0.25	118	8.97	good	h	1.00	8.97	0.076	30
Horn Pond	Acton	373	60	313	0.3	94	7.05	mod-sensitive	h	0.75	5.29	0.056	23
Horne Pond	Limington	1821	400	1421	0.25	355	17.97	mod-sensitive	h	0.75	13.48	0.038	89
Horseshoe Lake	Northfield	93	3	90	0.2	18	1.34	mod-sensitive	m	1.00	1.34	0.074	5
Horseshoe Pond	Beddington	674	100	574	0.15	86	6.21	mod-sensitive	m	1.00	6.21	0.072	22
Horseshoe Pond	Denmark	32	5	27	0.2	5	0.92	mod-sensitive	m	1.00	0.92	0.170	1
Horseshoe Pond	Fryeburg	24	5	19	0.2	4	0.5	mod-sensitive	m	1.00	0.50	0.132	1
Horseshoe Pond	Willimantic	420	10	410	0.15	62	4.6	mod-sensitive	m	1.00	4.60	0.075	15
Horseshoe Pond 1	Fryeburg	138	4	134	0.2	27	1.41	mod-sensitive	m	1.00	1.41	0.053	7
Hosmer Pond	Camden	1168	300	868	0.3	260	9.37	mod-sensitive	m	1.00	9.37	0.036	65
Hosmer Pond	Rockport	303	100	203	0.2	41	2.42	mod-sensitive	m	1.00	2.42	0.060	10
Hothole Pond	Bucksport	439	20	419	0.2	84	2.69	mod-sensitive	m	1.00	2.69	0.032	21
Hothole Pond	Orland	5512	800	4712	0.2	942	33.69	mod-sensitive	h	0.75	25.27	0.027	236
Houghton Pond	West Bath	84	5	79	0.25	20	0.79	mod-sensitive	m	1.00	0.79	0.040	5
House Pond	Lee	93	5	88	0.15	13	0.57	mod-sensitive	h	0.75	0.43	0.032	3
Howard Lake	Calais	647	35	612	0.25	153	8.18	mod-sensitive	h	0.75	6.14	0.040	38

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Howard Pond	Hanover	546	40	506	0.2	101	6.04	good	h	1.00	6.04	0.060	25
Hunt Pond	Fryeburg	123	5	118	0.2	24	1.32	mod-sensitive	m	1.00	1.32	0.056	6
Hurd Pond	Dedham	929	110	819	0.25	205	7.62	mod-sensitive	h	0.75	5.72	0.028	51
Hurds Pond	Belfast	541	100	441	0.25	110	3.28	mod-sensitive	m	1.00	3.28	0.030	28
Hutchinson Pond	Farmingdale	788	70	718	0.25	180	7.18	mod-sensitive	m	1.00	7.18	0.040	45
Indian Lake	Whiting	593	60	533	0.25	133	8	mod-sensitive	h	0.75	6.00	0.045	33
Indian Pond	Sapling Twp.	16207	2000	14207	0.15	2131	334.4	good	h	1.00	334.43	0.157	533
Ingalls Pond	Bridgton	1030	100	930	0.35	326	12.14	good	h	1.00	12.14	0.037	81
Ingalls Pond	Hiram	128	25	103	0.2	21	0.81	mod-sensitive	h	0.75	0.61	0.029	5
Ingham Pond	Mount Vernon	4279	450	3829	0.2	766	24.67	mod-sensitive	m	1.00	24.67	0.032	191
Iron Pond	Washington	158	0	158	0.2	32	1.58	mod-sensitive	h	0.75	1.19	0.038	8
Isinglass Pond	Limington	126	15	111	0.25	28	1.23	mod-sensitive	h	0.75	0.92	0.033	7
Island Pond	Harrison	467	50	417	0.25	104	4.34	mod-sensitive	h	0.75	3.26	0.031	26
Island Pond	Leeds	81	10	71	0.2	14	0.81	mod-sensitive	m	1.00	0.81	0.057	4
Island Pond	Waterford	679	130	549	0.25	137	6.3	mod-sensitive	h	0.75	4.73	0.034	34
Jacob Buck Pond	Bucksport	1275	128	1147	0.25	287	13.03	mod-sensitive	h	0.75	9.77	0.034	72
Jaybird Pond	Hiram	202	100	102	0.25	26	1.52	mod-sensitive	h	0.75	1.14	0.045	6
Jerry Pond	Millinocket	140	125	15	0.25	4	1.58	mod-sensitive	m	1.00	1.58	0.421	1
Jesse Bog	Ellsworth	101	30	71	0.3	21	0.72	mod-sensitive	m	1.00	0.72	0.034	5
Jesse Bog	Orland	254	10	244	0.2	49	1.8	mod-sensitive	m	1.00	1.80	0.037	12
Jewett Pond	Waterford	395	30	365	0.25	91	3.41	mod-sensitive	m	1.00	3.41	0.037	23
Jimmie Pond	Farmingdale	533	45	488	0.25	122	4.8	good	h	1.00	4.80	0.039	31
Jimmie Pond	Hallowell	390	150	240	0.25	60	3.5	good	h	1.00	3.50	0.058	15
Jimmy Pond	Bowdoin	595	80	515	0.25	129	3.46	mod-sensitive	m	1.00	3.46	0.027	32
Jimmy Pond	Litchfield	3197	800	2397	0.2	479	18.54	mod-sensitive	m	1.00	18.54	0.039	120
Jimmy Pond	Sabattus	798	40	758	0.15	114	4.63	mod-sensitive	m	1.00	4.63	0.041	28
Joe Pond	Belgrade	19	3	16	0.4	6	0.28	mod-sensitive	h	0.75	0.21	0.033	2
Johnson Pond	Appleton	69	5	64	0.25	16	0.74	mod-sensitive	m	1.00	0.74	0.046	4
Joice Pond	Pittston	128	30	98	0.2	20	1.47	mod-sensitive	m	1.00	1.47	0.075	5
Joice Pond	Whitefield	200	25	175	0.25	44	2.29	mod-sensitive	m	1.00	2.29	0.052	11
Jones Pond	Gouldsboro	2006	220	1786	0.25	447	29.94	mod-sensitive	h	0.75	22.46	0.050	112
Jordan Pond	Mount Desert	948	0	948	0	0	21.14	outstanding	h	0.50	10.57	Park	0
Josh Pond	Whiting	1564	100	1464	0.2	293	13.64	mod-sensitive	m	1.00	13.64	0.047	73
Kalers Pond	Waldoboro	365	165	200	0.25	50	4.36	mod-sensitive	h	0.75	3.27	0.065	13
Keenes Lake	Calais	780	20	760	0.25	190	8.93	mod-sensitive	h	0.75	6.70	0.035	48
Keewaydin Lake	Stoneham	2463	1600	863	0.3	259	26.12	good	h	0.75	19.59	0.076	65
Kennebunk Pond	Lyman	476	100	376	0.35	132	9.61	mod-sensitive	h	0.75	7.21	0.055	33

Appendix C

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Keoka Lake	Waterford	3644	772	2872	0.3	862	42.88	mod-sensitive	h	0.75	32.16	0.037	215
Keys Pond	Sweden	1235	130	1105	0.35	387	15.23	good	h	1.00	15.23	0.039	97
Kezar Lake	Lovell	3780	250	3530	0.25	883	54.13	mod-sensitive	h	0.75	40.60	0.046	221
Kezar Pond	Bridgton	2651	250	2401	0.3	720	35.08	mod-sensitive	m	1.00	35.08	0.049	180
Kezar Pond	Denmark	2651	1000	1651	0.25	413	35.08	mod-sensitive	m	1.00	35.08	0.085	103
Kezar Pond	Fryeburg	3390	450	2940	0.25	735	44.84	mod-sensitive	m	1.00	44.84	0.061	184
Kezar Pond	Sweden	2174	200	1974	0.25	494	28.75	mod-sensitive	m	1.00	28.75	0.058	123
Kezar Pond	Winthrop	205	70	135	0.3	41	1.85	mod-sensitive	m	1.00	1.85	0.046	10
Kidder Pond	Vienna	249	50	199	0.2	40	1.87	mod-sensitive	m	1.00	1.87	0.047	10
Killick Pond	Hollis	2646	500	2146	0.25	537	16.11	mod-sensitive	m	1.00	16.11	0.030	134
Killick Pond	Limington	103	10	93	0.2	19	0.63	mod-sensitive	m	1.00	0.63	0.034	5
Killick Pond	Waterboro	1957	300	1657	0.25	414	11.92	mod-stable	h	1.00	11.92	0.029	104
Kimball Pond	Vienna	106	20	86	0.25	22	1.43	good	h	1.00	1.43	0.067	5
Knickerboocker Pond	Boothbay	726	73	653	0.3	196	8.31	mod-sensitive	h	0.75	6.23	0.032	49
Knight Pond	Lincolnville	49	3	46	0.2	9	0.48	mod-sensitive	m	1.00	0.48	0.052	2
Knight Pond	Northport	795	150	645	0.25	161	7.6	mod-sensitive	m	1.00	7.60	0.047	40
Labrador Pond	Sumner	2159	250	1909	0.2	382	15.76	mod-sensitive	m	1.00	15.76	0.041	95
Lake Auburn	Auburn	4704	350	4354	0.35	1524	109.9	good	h	1.00	109.87	0.072	381
Lake Auburn	Turner	160	8	152	0.3	46	3.74	good	h	1.00	3.74	0.082	11
Lake George	Canaan	1455	400	1055	0.2	211	13.84	mod-sensitive	h	0.75	10.38	0.049	53
Lard Pond	Turner	106	42	64	0.3	19	0.85	mod-sensitive	m	1.00	0.85	0.044	5
Lawry Pond	Searsmont	2263	200	2063	0.2	413	16.71	mod-sensitive	m	1.00	16.71	0.040	103
Lermond Pond	Hope	464	50	414	0.35	145	9.17	good	h	1.00	9.17	0.063	36
Lermond Pond	Union	148	30	118	0.35	41	2.93	good	h	1.00	2.93	0.071	10
Levenseller Pond	Lincolnville	32	5	27	0.25	7	0.3	mod-sensitive	m	1.00	0.30	0.044	2
Levenseller Pond	Searsmont	219	40	179	0.25	45	2.09	mod-stable	m	1.25	2.61	0.058	11
Lilly Pond	Camden	24	2	22	0.3	7	0.3	mod-sensitive	m	1.00	0.30	0.045	2
Lilly Pond	Rockport	150	25	125	0.3	38	1.74	poor-restorable	m	0.50	0.87	0.023	9
Lily Pond	Deer Isle	237	45	192	0.25	48	2.6	mod-sensitive	h	0.75	1.95	0.041	12
Lily Pond	Denmark	345	35	310	0.25	78	2.22	mod-sensitive	m	1.00	2.22	0.029	19
Lily Pond	Dexter	66	2	64	0.2	13	0.7	mod-sensitive	m	1.00	0.70	0.055	3
Lily Pond	Edgecomb	625	62	563	0.25	141	5.75	mod-sensitive	m	1.00	5.75	0.041	35
Lily Pond	Gouldsboro	234	20	214	0.2	43	2.31	mod-sensitive	m	1.00	2.31	0.054	11
Lily Pond	Hollis	239	45	194	0.25	49	1.67	mod-sensitive	m	1.00	1.67	0.034	12
Lily Pond	Hope	197	15	182	0.25	46	2.27	mod-sensitive	m	1.00	2.27	0.050	11
Lily Pond	New Gloucester	615	120	495	0.3	149	4.43	mod-sensitive	m	1.00	4.43	0.030	37
Lily Pond	New Vineyard	506	50	456	0.25	114	7.76	mod-sensitive	m	1.00	7.76	0.068	29

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Lily Pond	Turner	252	40	212	0.2	42	2.16	mod-sensitive	m	1.00	2.16	0.051	11
Lily Pond	West Bath	575	50	525	0.25	131	2.73	mod-sensitive	m	1.25	3.41	0.026	33
Little Bear Pond	Hartford	3385	600	2785	0.2	557	22.51	mod-sensitive	m	1.00	22.51	0.040	139
Little Burnt Pond	Clifton	286	40	246	0.2	49	2.27	mod-sensitive	m	1.00	2.27	0.046	12
Little Clemons Pond	Hiram	227	45	182	0.25	46	1.96	mod-sensitive	m	1.00	1.96	0.043	11
Little Cobbossee Lake	Readfield	533	50	483	0.2	97	4.07	poor restorable	m	0.50	2.04	0.021	24
Little Cobbossee Lake	Winthrop	531	120	411	0.25	103	4.05	poor restorable	m	0.50	2.03	0.020	26
Little Duck Pond	Dedham	39	8	31	0.2	6	0.39	mod-sensitive	m	1.00	0.39	0.063	2
Little Duck Pond	Ellsworth	469	75	394	0.2	79	4.71	mod-sensitive	m	1.00	4.71	0.060	20
Little Duck Pond	Windham	261	25	236	0.3	71	2.49	mod-sensitive	m	1.00	2.49	0.035	18
Little Dyer Pond	Whitefield	1245	250	995	0.2	199	9.7	mod-sensitive	m	1.00	9.70	0.049	50
Little Horseshoe Pond	Beddington	66	3	63	0.2	13	0.99	mod-sensitive	m	1.00	0.99	0.079	3
Little Labrador Pond	Sumner	931	110	821	0.2	164	5.95	mod-sensitive	m	1.00	5.95	0.036	41
Little Lake	Whiting	793	50	743	0.15	111	7.36	mod-sensitive	m	1.00	7.36	0.066	28
Little Machias Lake	Portage Lake	3167	1300	1867	0.15	280	18.61	mod-sensitive	h	0.75	13.96	0.050	70
Little Medomak Pond	Union	135	10	125	0.2	25	1.43	mod-sensitive	h	0.75	1.07	0.043	6
Little Medomak Pond	Waldoboro	610	70	540	0.25	135	6.37	mod-sensitive	h	0.75	4.78	0.035	34
Little Moose Pond	Sweden	289	10	279	0.2	56	3.52	good	h	1.00	3.52	0.063	14
Little Moose Pond	Waterford	924	74	850	0.25	213	11.28	good	h	1.00	11.28	0.053	53
Little Ossipee Lake	Waterboro	2984	400	2584	0.3	775	35.5	good	h	1.00	35.50	0.046	194
Little Pond	Bristol	56	6	50	0.25	13	0.79	mod-sensitive	m	1.00	0.79	0.061	3
Little Pond	Damariscotta	340	34	306	0.3	92	4.8	mod-sensitive	h	0.75	3.60	0.039	23
Little Pond	Fryeburg	14	0	14	0.2	3	0.15	mod-sensitive	m	1.00	0.15	0.054	1
Little Pond	Orland	84	0	84	0.2	17	0.7	mod-sensitive	m	1.00	0.70	0.042	4
Little Pond	Otisfield	340	25	315	0.25	79	2.6	mod-sensitive	m	1.00	2.60	0.033	20
Little Pond	Searsmont	158	70	88	0.2	18	2.13	mod-sensitive	m	1.00	2.13	0.121	4
Little Pond	Smithfield	29	9	20	0.2	4	0.28	mod-sensitive	m	1.00	0.28	0.070	1
Little Pond	Sweden	71	5	66	0.2	13	0.74	mod-sensitive	m	1.00	0.74	0.056	3
Little Purgatory	Monmouth	49	0	49	0.25	12	0.46	mod-sensitive	m	1.00	0.46	0.038	3
Little Rocky Pond	Ellsworth	731	150	581	0.2	116	6.37	mod-sensitive	m	1.00	6.37	0.055	29
Little Round Pond	Lincoln	385	15	370	0.25	93	4.12	mod-sensitive	h	0.75	3.09	0.033	23
Little Round Pond	Mount Desert	172	20	152	0.25	38	1.63	mod-sensitive	m	1.00	1.63	0.043	10
Little Sabattus Pond	Greene	914	90	824	0.2	165	5.46	mod-sensitive	m	1.00	5.46	0.033	41
Little Sabattus Pond	Leeds	773	150	623	0.2	125	4.6	mod-sensitive	m	1.00	4.60	0.037	31
Little Sebago L., Hunger Bay	Windham	748	180	568	0.35	199	13.91	mod-sensitive	h	0.75	10.43	0.052	50
Little Sebago L., Main Basin	Windham	590	75	515	0.35	180	9.19	mod-sensitive	h	0.75	6.89	0.038	45
Little Sebago Lake, Main Basin	Gray	2858	300	2558	0.3	767	44.51	mod-sensitive	h	0.75	33.38	0.044	192

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Little Sebago Lake, Main Basin	Raymond	412	12	400	0.25	100	6.43	mod-sensitive	m	1.00	6.43	0.064	25
Little Sebago Lake, Upper Bay	Gray	1818	182	1636	0.3	491	14.9	mod-sensitive	m	1.00	14.90	0.030	123
Little Sebago Lake, Upper Bay	Raymond	2065	125	1940	0.25	485	16.95	mod-sensitive	m	1.00	16.95	0.035	121
Little Togus Pond	Augusta	126	10	116	0.3	35	1.54	mod-sensitive	m	1.00	1.54	0.044	9
Little Watchic Pond	Standish	1037	150	887	0.25	222	8.44	mod-sensitive	m	1.00	8.44	0.038	55
Little Wilson Pond	Auburn	116	15	101	0.3	30	1.01	mod-sens	h	0.75	0.76	0.025	8
Little Wilson Pond	Minot	9	1	8	0.2	2	0.08	mod-sensitive	h	0.75	0.06	0.038	0
Little Wilson Pond	Turner	827	120	707	0.25	177	7.27	mod-sensitive	h	0.75	5.45	0.031	44
Long Cove Pond	Phillips	118	0	118	0.2	24	1.01	mod-sensitive	h	0.75	0.76	0.032	6
Long Lake	Bridgton	17672	1576	16096	0.4	6438	247.4	mod-sensitive	h	0.75	185.55	0.029	1610
Long Lake	Denmark	1981	150	1831	0.25	458	27.76	mod-sensitive	h	0.75	20.82	0.045	114
Long Lake	Frenchville	338	50	288	0.2	58	4.96	mod-sensitive	h	0.75	3.72	0.065	14
Long Lake	Harrison	8715	508	8207	0.4	3283	122	mod-sens	h	0.75	91.52	0.028	821
Long Lake	Naples	4546	455	4091	0.4	1636	63.63	mod-sens	h	0.75	47.72	0.029	409
Long Lake	Northfield	689	35	654	0.2	131	10.95	mod-sensitive	m	1.00	10.95	0.084	33
Long Lake	St. Agatha	11003	600	10403	0.2	2081	161.3	mod-sensitive	h	0.75	120.98	0.058	520
Long Lake	Waterford	1265	126	1139	0.3	342	17.7	mod-sensitive	h	0.75	13.28	0.039	85
Long Pond	Bucksport	5623	700	4923	0.25	1231	45.04	mod-sensitive	m	1.00	45.04	0.037	308
Long Pond	Dedham	2841	500	2341	0.25	585	22.77	mod-sensitive	m	1.00	22.77	0.039	146
Long Pond	Denmark	207	35	172	0.25	43	2.42	mod-stable	h	0.75	1.82	0.042	11
Long Pond	Holden	3412	325	3087	0.25	772	27.34	mod-sensitive	h	0.75	20.51	0.027	193
Long Pond	Livermore	1089	110	979	0.25	245	13.45	mod-sensitive	h	0.75	10.09	0.041	61
Long Pond	Mount Desert	773	260	513	0.25	128	5.44	mod-sensitive	h	0.75	4.08	0.032	32
Long Pond	Mount Desert	2179	1000	1179	0.3	354	42.13	outstanding	h	0.50	21.07	0.060	88
Long Pond	Orland	266	20	246	0.2	49	2.13	mod-sensitive	m	1.00	2.13	0.043	12
Long Pond	Sandy River Plar	3066	1000	2066	0.25	517	34.72	good	h	1.00	34.72	0.067	129
Long Pond	T7R9 NWP	3286	170	3116	0.2	623	37.88	mod-sensitive	h	0.75	28.41	0.046	156
Long Pond	Windsor	1546	500	1046	0.25	262	17.37	mod-sensitive	m	1.00	17.37	0.066	65
Long Pond (Long, Caribou and Egg)	Lincoln	3417	210	3207	0.2	641	42.9	mod-sensitive	m	1.00	42.90	0.067	160
Long Pond (Long, Caribou, & Egg)	Winn	254	10	244	0.2	49	3.19	mod-sensitive	m	1.00	3.19	0.065	12
Long Pond (Long, Caribou, Egg)	Lee	121	0	121	0.2	24	1.52	mod-sensitive	m	1.00	1.52	0.063	6
Long Pond, North Basin	Belgrade	1314	253	1061	0.4	421	30.89	poor restorable	h	0.50	15.45	0.037	105
Long Pond, North Basin	Rome	3689	500	3189	0.35	1116	86.61	poor restorable	h	0.50	43.31	0.039	279
Long Pond, North Basin	Vienna	973	200	773	0.25	193	22.88	poor restorable	h	0.50	11.44	0.059	48
Long Pond, South Basin	Belgrade	1714	252	1462	0.39	568	38.12	poor restorable	h	0.50	19.06	0.034	142

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Long Pond, South Basin	Mount Vernon	5317	400	4917	0.3	1475	118.3	poor restorable	h	0.50	59.13	0.040	369
Long Pond, South Basin	Rome	1097	80	1017	0.25	254	24.43	poor restorable	h	0.50	12.22	0.048	64
Long Pond, Upper Basin	Jackman	18245	2500	15745	0.1	1575	167.5	mod-sensitive	m	1.00	167.53	0.106	394
Loon Lake	Rangeley	170	0	170	0.2	34	2.53	mod-sensitive	h	0.75	1.90	0.056	9
Loon Pond	Acton	420	50	370	0.3	111	4.38	mod-sensitive	m	1.00	4.38	0.039	28
Loon Pond	Sabattus	190	10	180	0.25	45	2.4	mod-sensitive	m	1.00	2.40	0.053	11
Lovejoy Pond	Readfield	1158	100	1058	0.3	317	23.08	mod-sensitive	h	0.75	17.31	0.055	79
Lovewell Pond	Fryeburg	3101	250	2851	0.25	713	52.56	mod-sensitive	m	1.00	52.56	0.074	178
Lower Hadlock Pond	Mount Desert	214	214	0	0	0	2.57	good	h	1.00	2.57	Park	0
Lower Kimball Lake	Fryeburg	748	75	673	0.25	168	8.79	mod-sensitive	h	0.75	6.59	0.039	42
Lower Mud Pond	Windham	46	23	23	0.25	6	0.35	mod-sensitive	m	1.00	0.35	0.061	1
Lower Narrows Pond	Winthrop	862	40	822	0.25	206	14.88	good	h	1.00	14.88	0.072	51
Lower Patten Pond	Ellsworth	3036	400	2636	0.3	791	44.73	good	h	1.00	44.73	0.057	198
Lower Patten Pond	Orland	79	0	79	0.25	20	1.16	mod-sensitive	h	0.75	0.87	0.044	5
Lower Patten Pond	Surry	1838	180	1658	0.25	415	27.07	good	h	1.00	27.07	0.065	104
Lower Pond	Bristol	74	7	67	0.25	17	0.74	mod-sensitive	m	1.00	0.74	0.044	4
Lower Range Pond	Poland	2214	530	1684	0.25	421	31.26	mod-sensitive	h	0.75	23.45	0.056	105
Lower Richardson Lake	Township C	7039	300	6739	0.2	1348	218.1	good	h	1.00	218.11	0.162	337
Lower Springy Pond	Clifton	1158	250	908	0.2	182	13.49	mod-sensitive	h	0.75	10.12	0.056	45
Lower West Bay Pond	Gouldsboro	1532	100	1432	0.15	215	18.47	mod-sensitive	m	1.00	18.47	0.086	54
Lower Wilson Pond	Greenville	3634	300	3334	0.25	834	70.42	good	h	1.00	70.42	0.084	208
Lufkin Pond	Phillips	575	0	575	0.2	115	5.84	mod-sensitive	h	0.75	4.38	0.038	29
Maces Pond	Rockport	516	55	461	0.25	115	4.36	mod-sensitive	m	1.00	4.36	0.038	29
Madagascal Pond	Burlington	2322	300	2022	0.2	404	17.86	mod-sensitive	h	0.75	13.40	0.033	101
Madagascal Pond	Lee	1134	350	784	0.2	157	8.7	mod-sensitive	h	0.75	6.53	0.042	39
Madagascal Pond	Lincoln	3862	360	3502	0.2	700	29.7	mod-sensitive	h	0.75	22.28	0.032	175
Mann Bog	Dedham	172	20	152	0.2	30	2.18	mod-sensitive	m	1.00	2.18	0.072	8
Mansfield Pond	Hope	1363	100	1263	0.25	316	9.67	mod-sensitive	m	1.00	9.67	0.031	79
Maranacook Lake North Basin	Winthrop	177	5	172	0.2	34	1.65	mod-sensitive	h	0.75	1.24	0.036	9
Maranacook Lake South Basin	Winthrop	2814	340	2474	0.25	619	44.69	mod-sensitive	h	0.75	33.52	0.054	155
Maranacook Lake, North Basin	Mount Vernon	1272	50	1222	0.25	306	11.88	mod-sensitive	h	0.75	8.91	0.029	76
Maranacook Lake, North Basin	Readfield	6604	750	5854	0.25	1464	61.65	mod-sensitive	h	0.75	46.24	0.032	366
Maranacook Lake, South Basin	Readfield	2908	250	2658	0.25	665	46.15	mod sensitive	h	0.75	34.61	0.052	166
Mariner Pond	Sebago	2379	500	1879	0.25	470	16.69	mod-sensitive	m	1.00	16.69	0.036	117
Marshall Pond	Hebron	1578	175	1403	0.25	351	10.84	mod-sensitive	m	1.00	10.84	0.031	88
Marshall Pond	Paris	1561	200	1361	0.25	340	10.73	mod-sensitive	m	1.00	10.73	0.032	85
Martin Pond	The Forks	714	71	643	0.2	129	4.96	m-sens	h	0.75	3.72	0.051	32

Appendix C

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Mattakeunk Lake (Silver Lake)	Lee	3125	300	2825	0.2	565	32.32	good	m	1.50	48.48	0.086	141
Mattakeunk Lake (Silver Lake)	Lincoln	261	5	256	0.2	51	2.69	good	m	1.50	4.04	0.079	13
Mattanawcook Pond	Lincoln	10299	1600	8699	0.25	2175	91.97	mod-sensitive	m	1.00	91.97	0.042	544
Mattawamkeag Lake Lower Basin	Island Falls	2095	200	1895	0.2	379	16.42	mod-sensitive	m	1.00	16.42	0.043	95
Mattawamkeag Lake Upper Basin	Island Falls	17637	2000	15637	0.2	3127	104.1	mod-sensitive	m	1.00	104.14	0.033	782
McClure Pond	Searsport	593	85	508	0.25	127	5.71	mod-sensitive	m	1.00	5.71	0.045	32
McCurdy Pond	Bremen	479	48	431	0.25	108	9.61	mod-sensitive	h	0.75	7.21	0.067	27
McGann Bog Pond	Bucksport	412	100	312	0.2	62	2.49	mod-sensitive	m	1.00	2.49	0.040	16
McGrath Pond	Belgrade	316	34	282	0.19	54	3.55	mod-sensitive	h	0.75	2.66	0.049	13
McGrath Pond	Oakland	2102	230	1872	0.25	468	23.59	mod-sensitive	h	0.75	17.69	0.038	117
Mcwain Pond (Long Pond)	Waterford	2406	240	2166	0.25	542	31.53	mod-sensitive	h	0.75	23.65	0.044	135
Meadow Pond	Islesboro	145	15	130	0.3	39	1.61	mod-sensitive	m	1.00	1.61	0.041	10
Medomak Pond	Appleton	8122	1000	7122	0.2	1424	54.79	mod-sensitive	m	1.00	54.79	0.038	356
Medomak Pond	Union	4835	450	4385	0.25	1096	32.63	mod-sensitive	m	1.00	32.63	0.030	274
Medomak Pond	Waldoboro	1734	200	1534	0.25	384	11.7	mod-sensitive	m	1.00	11.70	0.031	96
Medomak Pond	Washington	9916	1000	8916	0.2	1783	66.89	mod-sensitive	m	1.00	66.89	0.038	446
Meduxnekeag Lake	Oakfield	6958	500	6458	0.15	969	70.05	mod-sensitive	h	0.75	52.54	0.054	242
Meetinghouse Pond	Phippsburg	69	15	54	0.25	14	0.66	mod-sensitive	m	1.00	0.66	0.049	3
Megunticook Lake Basin 1	Lincolnville	1176	240	936	0.25	234	17.61	mod-sensitive	h	0.75	13.21	0.056	59
Megunticook Lake Basin 2	Lincolnville	2513	250	2263	0.25	566	28.86	mod-sensitive	h	0.75	21.65	0.038	141
Megunticook Lake North Basin	Hope	874	100	774	0.25	194	10.03	mod-sensitive	h	0.75	7.52	0.039	48
Megunticook Lake South Basin	Camden	2807	560	2247	0.3	674	42.07	mod-sensitive	h	0.75	31.55	0.047	169
Megunticook Lake South Basin	Hope	1363	150	1213	0.25	303	20.44	mod-sensitive	h	0.75	15.33	0.051	76
Merril Pond	Lee	1465	500	965	0.25	241	14.57	mod-sensitive	m	1.00	14.57	0.060	60
Messalonskee Lake	Belgrade	11312	1286	10026	0.23	2274	205.7	mod-sensitive	h	0.75	154.31	0.068	568
Messalonskee Lake	Mount Vernon	3830	300	3530	0.25	883	69.65	mod-sensitive	h	0.75	52.24	0.059	221
Messalonskee Lake	Readfield	2915	150	2765	0.25	691	53.05	mod-sensitive	h	0.75	39.79	0.058	173
Mid Basin, Damariscotta Lake	Jefferson	405	40	365	0.2	73	7.49	mod-sensitive	h	0.75	5.62	0.077	18
Mid Basin, Damariscotta Lake	Nobleboro	4047	405	3642	0.3	1093	75.27	mod-sensitive	h	0.75	56.45	0.051	273
Middle Pond	Waterford	39	20	19	0.25	5	0.39	mod-sensitive	h	0.75	0.29	0.062	1
Middle Range Pond	Poland	3170	300	2870	0.25	718	43.52	mod-sensitive	h	0.75	32.64	0.045	179
Middle Springy Pond	Clifton	69	35	34	0.2	7	0.79	mod-sensitive	m	1.00	0.79	0.116	2
Mill Pond	Deer Isle	429	64	365	0.25	91	4.63	mod-sensitive	m	1.00	4.63	0.051	23
Mill Pond	Lee	1596	175	1421	0.25	355	11.86	mod-sensitive	m	1.00	11.86	0.033	89
Mill Pond	New Vineyard	751	75	676	0.25	169	9.67	mod-sensitive	m	1.00	9.67	0.057	42

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Mill Pond	Washington	1008	40	968	0.2	194	7.18	mod-sensitive	m	1.00	7.18	0.037	48
Mill Privilege Lake	Carroll Plt	2614	300	2314	0.15	347	17.08	mod-sensitive	m	1.00	17.08	0.049	87
Mill Privilege Lake	Lakeville	513	40	473	0.15	71	3.35	mod-sensitive	m	1.00	3.35	0.047	18
Mill Privilege Lake	Pukakon Twp / T	343	20	323	0.15	48	2.24	mod-sensitive	m	1.00	2.24	0.046	12
Millinocket Lake	T1R8 WELS	4190	200	3990	0.25	998	53.31	good	h	1.00	53.31	0.053	249
Millinocket Lake	T1R9 WELS	3165	500	2665	0.25	666	40.28	good	h	1.00	40.28	0.060	167
Milton Pond	Lebanon	931	110	821	0.25	205	9.06	mod-sensitive	m	1.00	9.06	0.044	51
Minnehonk Lake	Mount Vernon	1116	200	916	0.35	321	20.13	good	h	1.00	20.13	0.063	80
Mirror Lake	Camden	182	30	152	0.25	38	2.29	good	h	1.00	2.29	0.060	10
Mirror Lake	Hope	200	10	190	0.25	48	2.51	mod-sensitive	h	0.75	1.88	0.040	12
Mirror Lake	Rockport	753	175	578	0.2	116	9.48	mod-sensitive	h	0.75	7.11	0.062	29
Mitchell Pond	Dedham	242	20	222	0.25	56	1.76	mod-sensitive	m	1.00	1.76	0.032	14
Molasses Pond	Eastbrook	2891	280	2611	0.25	653	57.19	good	h	1.00	57.19	0.088	163
Moody Pond	Lincolnville	457	85	372	0.25	93	5.07	mod-sensitive	h	0.75	3.80	0.041	23
Moody Pond	Windsor	281	75	206	0.2	41	2.71	mod-sensitive	m	1.00	2.71	0.066	10
Moose Pond	Acton	79	8	71	0.25	18	1.05	mod-sensitive	h	0.75	0.79	0.044	4
Moose Pond	Mount Vernon	711	40	671	0.25	168	5.24	mod-sensitive	m	1.00	5.24	0.031	42
Moose Pond	Otisfield	1153	100	1053	0.25	263	10.18	mod-sensitive	m	1.00	10.18	0.039	66
Moose Pond	Sumner	2018	100	1918	0.15	288	12.01	mod-sensitive	m	1.00	12.01	0.042	72
Moose Pond, Basin 1	Bridgton	773	150	623	0.35	218	8.73	mod-sensitive	h	0.75	6.55	0.030	55
Moose Pond, Basin 1	Sweden	3135	250	2885	0.25	721	35.34	mod-sensitive	h	0.75	26.51	0.037	180
Moose Pond, Basin 2	Bridgton	2777	400	2377	0.35	832	45.29	mod-sensitive	h	0.75	33.97	0.041	208
Moose Pond, Basin 2	Denmark	1588	500	1088	0.3	326	25.9	mod-sensitive	h	0.75	19.43	0.060	82
Moose Pond, Basin 3	Denmark	4381	650	3731	0.3	1119	67.78	mod-sensitive	h	0.75	50.84	0.045	280
Moosehead Lake	Greenville	7393	739	6654	0.25	1664	163.5	good	h	1.00	163.50	0.098	416
Moosehead Lake	Rockwood Strip	4079	400	3679	0.3	1104	90.2	good	h	1.00	90.20	0.082	276
Moosehead Lake	Sand Bar Tract a	3061	250	2811	0.3	843	67.64	good	h	1.00	67.64	0.080	211
Moosehead Lake	Sapling Twp.	1275	150	1125	0.2	225	28.17	good	h	1.00	28.17	0.125	56
Moosehead Lake	Taunton and Ray	2295	100	2195	0.25	549	50.73	good	h	1.00	50.73	0.092	137
Mooselookmeguntic	Rangeley	7509	1500	6009	0.25	1502	141.6	m-sens	h	0.75	106.20	0.071	376
Mooselookmeguntic Lake	Adamstown Twp	8539	1025	7514	0.2	1503	161.1	mod-sensitive	h	0.75	120.80	0.080	376
Mooselookmeguntic Lake	Rangeley Planta	8915	700	8215	0.2	1643	169.1	mod-sensitive	h	0.75	126.80	0.077	411
Morancy Pond	Gouldsboro	118	0	118	0.15	18	1.01	mod-sensitive	h	0.75	0.76	0.043	4
Morrill Pond	Canaan	464	150	314	0.2	63	3.85	mod-sensitive	h	0.75	2.89	0.046	16
Mosher Pond	New Vineyard	46	0	46	0.2	9	0.35	mod-sensitive	m	1.00	0.35	0.038	2
Moulton Pond	Bucksport	168	10	158	0.2	32	2.09	good	h	1.00	2.09	0.066	8
Moulton Pond	Dedham	138	30	108	0.25	27	1.69	good	h	1.00	1.69	0.063	7

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Mountain Pond	Beddington	140	22	118	0.2	24	1.38	mod-sensitive	m	1.00	1.38	0.058	6
Mountainy Pond	Dedham	2480	450	2030	0.25	508	40.5	mod-sensitive	h	0.75	30.38	0.060	127
Mountainy Pond	Eddington	111	15	96	0.2	19	1.83	mod-sensitive	h	0.75	1.37	0.071	5
Mousam Lake, North Basin	Acton	625	150	475	0.35	166	9.63	mod-sensitive	h	0.75	7.22	0.043	42
Mousam Lake, North Basin	Shapleigh	4665	550	4115	0.35	1440	71.94	mod-sensitive	h	0.75	53.96	0.037	360
Mousam Lake, South Basin	Acton	4539	700	3839	0.3	1152	50.97	mod-sensitive	h	0.75	38.23	0.033	288
Mousam Lake, South Basin	Shapleigh	1205	250	955	0.3	287	13.56	mod-sensitive	h	0.75	10.17	0.035	72
Mower Pond	Corinna	370	40	330	0.2	66	2.57	mod-stable	m	1.25	3.21	0.049	17
Mower Pond	Dexter	202	20	182	0.2	36	1.41	mod-stable	m	1.25	1.76	0.048	9
Moxie Pond	East Moxie Twp	17361	400	16961	0.15	2544	158.5	mod-sensitive	h	0.75	118.90	0.047	636
Moxie Pond	The Forks	5488	700	4788	0.2	958	50.11	mod-sensitive	h	0.75	37.58	0.039	239
Mt Blue Pond	Weld	96	0	96	0.1	10	0.85	mod-sensitive	h	0.75	0.64	0.066	2
Muckleberry Pond	Gouldsboro	14	0	14	0.15	2	0.11	mod-sensitive	m	1.00	0.11	0.052	1
Mud Greenwood Pond	Willimantic	224	45	179	0.15	27	2.27	mod-sensitive	h	0.75	1.70	0.063	7
Mud Lake	Calais	190	0	190	0.2	38	1.34	mod-sensitive	m	1.00	1.34	0.035	10
Mud Lake	T17R4	5715	286	5429	0.15	814	88.02	m-sens	m	1.00	88.02	0.108	204
Mud Pond	Augusta	111	12	99	0.25	25	0.88	mod-sensitive	m	1.00	0.88	0.036	6
Mud Pond	Buckfield	42	0	42	0.25	11	0.37	mod-sensitive	m	1.00	0.37	0.035	3
Mud Pond	Bucksport	1013	100	913	0.2	183	9.12	mod-sensitive	m	1.00	9.12	0.050	46
Mud Pond	Dedham	143	15	128	0.2	26	1.23	mod-sensitive	h	0.75	0.92	0.036	6
Mud Pond	Hebron	378	100	278	0.2	56	2.02	mod-sensitive	m	1.00	2.02	0.036	14
Mud Pond	Minot	229	40	189	0.2	38	1.23	mod-sensitive	m	1.00	1.23	0.033	9
Mud Pond	Monmouth	338	85	253	0.2	51	2.35	mod-sensitive	m	1.00	2.35	0.046	13
Mud Pond	Newport	1660	400	1260	0.2	252	9.01	mod-sensitive	m	1.00	9.01	0.036	63
Mud Pond	Peru	1378	300	1078	0.2	216	8.29	mod-sensitive	m	1.00	8.29	0.038	54
Mud Pond	Phillips	29	0	29	0.2	6	0.22	mod-sensitive	h	0.75	0.17	0.028	1
Mud Pond	Turner	1519	300	1219	0.2	244	8.11	mod-sensitive	m	1.00	8.11	0.033	61
Mud Pond	Turner	44	3	41	0.2	8	0.39	mod-sensitive	m	1.00	0.39	0.048	2
Mud Pond	Turner	29	2	27	0.25	7	0.39	mod-sensitive	h	0.75	0.29	0.043	2
Mud Pond	Waterford	1655	83	1572	0.2	314	13.23	mod-sensitive	m	1.00	13.23	0.042	79
Mud Pond	Windsor	439	200	239	0.2	48	3.41	mod-sensitive	m	1.00	3.41	0.071	12
Mud Pond (3752)	Poland	958	200	758	0.25	190	5.07	mod-sensitive	m	1.00	5.07	0.027	47
Mud Pond (3756)	Poland	318	35	283	0.25	71	2.22	mod-sensitive	m	1.00	2.22	0.031	18
Mud Pond (Cole Pond)	Paris	138	10	128	0.2	26	0.83	mod-sensitive	m	1.00	0.83	0.032	6
Mud Pond (in Turner)	Buckfield	284	40	244	0.25	61	1.52	mod-sensitive	m	1.00	1.52	0.025	15
Muddy Pond	Washington	91	9	82	0.2	16	1.14	mod-sensitive	m	1.00	1.14	0.071	4
N. Basin, Damariscotta Lake	Jefferson	6404	640	5764	0.2	1153	75.85	mod-sensitive	h	0.75	56.89	0.049	288

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N. Basin, Damariscotta Lake	Nobleboro	165	16	149	0.3	45	1.96	mod-sensitive	h	0.75	1.47	0.033	11
N. Basin, Damariscotta Lake	Somerville	4628	463	3702	0.2	740	54.81	mod-sensitive	h	0.75	41.11	0.055	185
N. Basin, Damariscotta Lake	Washington	9463	946	8517	0.2	1703	112.1	mod-sensitive	h	0.75	84.04	0.049	426
Narraguagus Lake	Eastbrook	1880	170	1710	0.2	342	17.83	mod-sensitive	h	0.75	13.37	0.039	86
Narraguagus Lake	T16 MD	1235	160	1075	0.2	215	11.7	mod-sensitive	h	0.75	8.78	0.041	54
Nash Pond	Strong	123	10	113	0.2	23	0.88	mod-sensitive	m	1.00	0.88	0.039	6
Nashs Lake	Calais	3694	200	3494	0.25	874	51.37	good	h	1.00	51.37	0.059	218
Nehumkeag Pond	Pittston	1559	50	1509	0.2	302	14.15	mod-sensitive	m	1.00	14.15	0.047	75
Nelson Pond	Livermore	64	30	34	0.25	9	0.66	mod-sensitive	m	1.00	0.66	0.078	2
Nequasset Pond	Wiscasset	845	120	725	0.25	181	7.54	mod-sensitive	h	0.75	5.66	0.031	45
Nequasset Pond	Woolwich	7432	600	6832	0.25	1708	66.34	mod-sensitive	h	0.75	49.76	0.029	427
Newbert Pond	Appleton	333	75	258	0.2	52	3.17	mod-sensitive	m	1.00	3.17	0.061	13
Nicatous Lake	T3ND	3629	363	3266	0.2	653	63.76	mod-sensitive	h	0.75	47.82	0.073	163
Nichols Pond	Swanville	118	0	118	0.25	30	1.16	mod-sensitive	h	0.75	0.87	0.029	7
Nisbit Pond	Lebanon	111	20	91	0.25	23	0.77	mod-sensitive	m	1.00	0.77	0.034	6
No Name Pond	Lewiston	724	100	624	0.3	187	6.96	mod-sensitive	h	0.75	5.22	0.028	47
Nokomis Pond	Newport	632	100	532	0.25	133	7.1	mod-sensitive	m	1.00	7.10	0.053	33
North Pond	Buckfield	84	0	84	0.25	21	0.97	mod-sensitive	h	0.75	0.73	0.035	5
North Pond	Jay	593	40	553	0.2	111	5.51	mod-sensitive	m	1.00	5.51	0.050	28
North Pond	Rome	242	20	222	0.25	56	3.28	mod-sensitive	m	1.00	3.28	0.059	14
North Pond	Smithfield	6100	530	5570	0.25	1393	82.7	mod-sensitive	m	1.00	82.70	0.059	348
North Pond	Sumner	951	30	921	0.2	184	10.98	good	h	1.00	10.98	0.060	46
North Pond	Waldoboro	130	10	120	0.2	24	1.8	mod-sensitive	m	1.00	1.80	0.075	6
North Pond	Woodstock	1126	220	906	0.2	181	11.64	mod-sensitive	h	0.75	8.73	0.048	45
North Pond, Little	Rome	1067	250	817	0.25	204	8.55	mod-sensitive	m	1.00	8.55	0.042	51
Northeast Pond	Acton	3484	600	2884	0.25	721	27.91	mod-sensitive	m	1.00	27.91	0.039	180
Northeast Pond	Hartford	588	75	513	0.15	77	3.9	mod-sensitive	m	1.00	3.90	0.051	19
Northeast Pond	Lebanon	1598	200	1398	0.25	350	12.81	mod-sensitive	m	1.00	12.81	0.037	87
Norton Pond	Lincolnville	5228	700	4528	0.25	1132	41.87	mod-sensitive	h	0.75	31.40	0.028	283
Notched Pond	Gray	148	8	140	0.3	42	1.8	mod-sensitive	m	1.00	1.80	0.043	11
Notched Pond	Raymond	200	19	181	0.3	54	2.44	mod-sensitive	m	1.00	2.44	0.045	14
Noyes Pond	Blue Hill	518	70	448	0.2	90	3.9	mod-sensitive	h	0.75	2.93	0.033	22
Nubble Pond	Casco	187	95	92	0.25	23	1.6	poor restorable	m	0.50	0.80	0.035	6
Nubble Pond	Raymond	175	30	145	0.25	44	1.49	poor-restorable	m	0.50	0.75	0.020	11
Number One Pond	Sanford	4484	650	3834	0.3	1150	40.28	mod-sensitive	m	1.00	40.28	0.035	288
Number Three Pond	Lee	1949	200	1749	0.2	350	16.27	mod-sensitive	m	1.00	16.27	0.047	87
Number Three Pond	T3R1 NBPP	2804	600	2204	0.2	441	23.41	mod-sensitive	m	1.00	23.41	0.053	110

Appendix C

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Nutting Pond	Rangeley	86	30	56	0.2	11	0.92	mod-sensitive	m	1.00	0.92	0.082	3
Olivers Pond	Deer Isle	479	72	407	0.2	81	3.57	mod-sensitive	m	1.00	3.57	0.044	20
Onawa Lake	Willimantic	143	5	138	0.2	28	1.56	good	h	1.00	1.56	0.057	7
Oran Pond	Mariaville	69	5	64	0.25	16	1.32	mod-sensitive	m	1.00	1.32	0.083	4
Orange Lake	Whiting	1670	160	1510	0.2	302	23.59	mod-sensitive	h	0.75	17.69	0.059	76
Otter Lake	Northfield	79	0	79	0.15	12	0.7	mod-sensitive	m	1.00	0.70	0.059	3
Otter Pond	Bridgton	790	79	711	0.4	284	7.21	mod-sensitive	m	1.00	7.21	0.025	71
Otter Ponds #2	Standish	34	2	32	0.3	10	0.55	mod-sensitive	h	0.75	0.41	0.043	2
Otter Ponds #3	Standish	14	1	13	0.3	4	0.3	mod-sensitive	m	1.00	0.30	0.077	1
Owl Pond	Casco	286	60	226	0.25	57	1.8	mod-sensitive	m	1.00	1.80	0.032	14
Paine Pond	Paris	212	20	192	0.2	38	1.76	mod-sensitive	m	1.00	1.76	0.046	10
Panther Pond	Casco	2139	200	1939	0.35	679	33.58	mod-sensitive	h	0.75	25.19	0.037	170
Panther Pond	Raymond	5530	400	5130	0.35	1796	86.78	mod sensitive	h	0.75	65.09	0.036	449
Panther Pond	Windham	71	3	68	0.3	20	1.1	mod-sensitive	h	0.75	0.83	0.040	5
Papoose Pond	Waterford	155	50	105	0.3	32	2.2	mod-sensitive	h	0.75	1.65	0.052	8
Paradise Pond	Damariscotta	701	120	581	0.3	174	8.13	mod-sensitive	m	1.00	8.13	0.047	44
Parker Pond	Casco	677	160	517	0.3	155	5.82	mod-sensitive	m	1.00	5.82	0.038	39
Parker Pond	Dayton	12	1	11	0.25	3	0.19	mod-sensitive	m	1.00	0.19	0.069	1
Parker Pond	Jay	4781	400	4381	0.2	876	31.46	mod-sensitive	m	1.00	31.46	0.036	219
Parker Pond	Lyman	51	15	36	0.3	11	0.85	mod-sensitive	m	1.00	0.85	0.079	3
Parker Pond	Mount Vernon	627	30	597	0.25	149	10.36	mod-sensitive	h	0.75	7.77	0.052	37
Parker Pond	Vienna	1156	60	1096	0.25	274	19.13	mod-sensitive	h	0.75	14.35	0.052	69
Parks Pond	Clifton	966	135	831	0.25	208	10.91	good	h	1.00	10.91	0.053	52
Passagassawakeag Lake	Brooks	2191	220	1971	0.25	493	20.24	mod-sensitive	m	1.00	20.24	0.041	123
Pattee Pond	Vassalboro	1079	250	829	0.25	207	9.45	mod-sensitive	m	1.00	9.45	0.046	52
Patten Pond	Hampden	627	150	477	0.2	95	3.57	mod-sensitive	m	1.00	3.57	0.037	24
Peabody Pond	Bridgton	516	52	464	0.3	139	9.74	mod-sensitive	h	0.75	7.31	0.052	35
Peabody Pond	Naples	830	80	750	0.35	263	15.63	mod-sensitive	h	0.75	11.72	0.045	66
Peabody Pond	Sebago	1151	115	1036	0.35	363	21.69	mod-sensitive	h	0.75	16.27	0.045	91
Peaked Mountain Pond	Northfield	96	0	96	0.2	19	1.76	mod-sensitive	h	0.75	1.32	0.069	5
Pease Pond	Jay	531	40	491	0.25	123	4.96	mod-sensitive	m	1.00	4.96	0.040	31
Pease Pond	Wilton	854	80	774	0.25	194	7.96	mod-sensitive	m	1.00	7.96	0.041	48
Peat Pond	Fryeburg	222	5	217	0.2	43	1.74	mod-sensitive	m	1.00	1.74	0.040	11
Pemadumcook Chain	T1R8 WELS	1519	150	1369	0.2	274	197.9	mod-sensitive	h	0.75	148.44	0.542	68
Pemadumcook Chain	T1R9 WELS	8789	500	8289	0.2	1658	1143	mod-sensitive	h	0.75	857.12	0.517	414
Pemaquid Pond	Bremen	1999	200	1799	0.25	450	30.45	mod-sensitive	h	0.75	22.84	0.051	112
Pemaquid Pond	Damariscotta	1717	172	1545	0.3	464	26.15	mod-sensitive	h	0.75	19.61	0.042	116

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Pemaquid Pond	Nobleboro	1868	206	1662	0.3	499	28.44	mod-sensitive	h	0.75	21.33	0.043	125
Pemaquid Pond	Waldoboro	420	120	300	0.25	75	6.39	mod-sensitive	h	0.75	4.79	0.064	19
Pemiquid Pond	Bremen	1999	200	1799	0.25	450	30.45	mod-sensitive	h	0.75	22.84	0.051	112
Pennamaquan Lake	Calais	143	0	143	0.2	29	1.52	mod-sensitive	h	0.75	1.14	0.040	7
Pennell Pond	New Portland	279	5	274	0.2	55	2.09	mod-sensitive	m	1.00	2.09	0.038	14
Pennesseewassee Lake	Norway	9673	1200	8473	0.25	2118	97.7	mod-sensitive	m	1.00	97.70	0.046	530
Penney Pond	Belgrade	42	20	22	0.4	9	0.83	mod-sensitive	h	0.75	0.62	0.071	2
Pequawket Lake	Brownfield	410	40	370	0.25	93	4.01	mod-sensitive	m	1.00	4.01	0.043	23
Peqwaket Lake	Hiram	422	40	382	0.25	96	4.14	mod-sensitive	m	1.00	4.14	0.043	24
Perley Pond	Denmark	281	25	256	0.25	64	3.61	mod-sensitive	h	0.75	2.71	0.042	16
Perley Pond	Sebago	81	2	79	0.25	20	0.99	mod-sensitive	m	1.00	0.99	0.050	5
Pettingill Pond	Windham	360	60	300	0.35	105	3.35	mod-sensitive	h	0.75	2.51	0.024	26
Phillips Lake	Dedham	4262	1200	3062	0.3	919	67.56	good	h	1.00	67.56	0.074	230
Pickerel Pond	Denmark	271	20	251	0.25	63	3.5	mod-stable	m	1.00	3.50	0.056	16
Pickerel Pond	Limerick	358	100	258	0.25	65	3.19	mod-sensitive	m	1.25	3.99	0.062	16
Pierce Pond	Penobscot	1697	100	1597	0.15	240	13.61	mod-sensitive	m	1.00	13.61	0.057	60
Pine Lake	Calais	145	0	145	0.2	29	1.6	mod-sensitive	m	1.00	1.60	0.055	7
Pitcher Pond	Lincolnville	644	60	584	0.26	149	6.48	mod-sensitive	m	1.00	6.48	0.044	37
Pitcher Pond	Northport	3800	380	3420	0.25	855	38.23	mod-sensitve	m	1.00	38.23	0.045	214
Pleasant Lake	Carroll Plt	1868	60	1808	0.15	271	22.9	mod-sensitive	h	0.75	17.18	0.063	68
Pleasant Lake	Kossuth Twp	6016	350	5666	0.15	850	73.8	mod-sensitive	h	0.75	55.35	0.065	212
Pleasant Lake	Otisfield	2841	300	2541	0.35	889	55.89	outstanding	h	0.50	27.95	0.031	222
Pleasant Lake	T6 R1 NBPP	3864	400	3464	0.15	520	47.4	mod-sensitive	h	0.75	35.55	0.068	130
Pleasant Pond	Brownfield	227	30	197	0.2	39	1.98	mod-sensitive	m	1.00	1.98	0.050	10
Pleasant Pond	Casco	768	300	468	0.35	164	15.12	outstanding	m	0.50	7.56	0.046	41
Pleasant Pond	Denmark	2045	300	1745	0.2	349	17.88	mod-sensitive	m	1.00	17.88	0.051	87
Pleasant Pond	Fryeburg	2656	900	1756	0.2	351	23.32	mod-sensitive	m	1.00	23.32	0.066	88
Pleasant Pond	Island Falls	1109	60	1049	0.25	262	31.2	outstanding	h	0.50	15.60	0.059	66
Pleasant Pond	Sumner	956	30	926	0.2	185	19.31	mod-sensitive	m	1.00	19.31	0.104	46
Pleasant Pond	Turner	570	100	470	0.3	141	8.48	mod-sensitive	h	0.75	6.36	0.045	35
Pleasant Pond, Upper Basin	Litchfield	7104	710	6394	0.2	1279	46.79	poor-restorable	m	0.50	23.40	0.018	320
Pleasant Pond, Upper Basin #2	Bowdoin	2540	800	1740	0.2	348	16.73	poor restorable	m	0.50	8.37	0.024	87
Pleasant River Lake	Beddington	3489	350	3139	0.2	628	38.21	good	h	1.00	38.21	0.061	157
Plymouth Pond	Plymouth	4156	1000	3156	0.25	789	21.63	mod-stable	m	1.25	27.04	0.034	197
Plymouth Pond	Troy	5342	650	4692	0.2	938	27.82	mod-sensitive	m	1.00	27.82	0.030	235
Pocamoonshine Lake	Princeton	12762	2800	9962	0.2	1992	148	mod-sensitive	m	1.00	147.95	0.074	498
Portage Lake	Portage Lake	9945	2500	7445	0.25	1861	167.1	mod-sensitive	h	0.75	125.33	0.067	465

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Porter Lake	New Vineyard	1882	150	1732	0.25	433	23.65	good	h	1.00	23.65	0.055	108
Porter Lake	Strong	1114	150	964	0.25	241	14.02	good	h	1.00	14.02	0.058	60
Poverty Pond	Willimantic	338	10	328	0.15	49	3.41	mod-sensitive	m	1.00	3.41	0.069	12
Prong Pond	Beaver Cove Tw	1756	400	1356	0.25	339	15.34	mod-sensitive	h	0.75	11.51	0.034	85
Puffers Pond	Dexter	1013	125	888	0.25	222	8.93	mod-sensitive	h	0.75	6.70	0.030	56
Pug Pond	Hermon	56	28	28	0.25	7	0.37	mod-sensitive	m	1.00	0.37	0.053	2
Pushaw Lake	Glenburn	5152	700	4452	0.25	1113	44.62	mod-sensitive	m	1.00	44.62	0.040	278
Quantabacook Lake	Searsmont	6807	700	6107	0.25	1527	61.62	mod-sensitive	m	1.00	61.62	0.040	382
Quimby Pond	Rangeley	256	100	156	0.3	47	4.14	poor restorable	h	0.50	2.07	0.044	12
Rangeley Lake	Dallas Plt.	1551	150	1401	0.2	280	28.51	good	h	1.00	28.51	0.102	70
Rangeley Lake	Rangeley	7702	770	6932	0.3	2080	141.5	good	h	1.00	141.51	0.068	520
Rangeley Lake	Rangeley Plt	12330	1000	11330	0.25	2833	226.5	good	h	1.00	226.50	0.080	708
Rangeley Lake	Sandy River Plar	6629	1100	5529	0.25	1382	121.2	good	h	1.00	121.23	0.088	346
Raymond Pond	Raymond	2772	120	2652	0.3	796	28.7	mod-sensitive	h	0.75	21.53	0.027	199
Reddington Pond	Carrabassett Val	622	210	412	0.25	103	5.79	mod-sensitive	h	0.75	4.34	0.042	26
Redington Pond	Redington Twp	4519	0	4519	0.15	678	35.1	mod-sensitive	h	0.75	26.33	0.039	169
Rich Mill Pond	Standish	1981	500	1481	0.25	370	12.3	mod-sensitive	m	1.00	12.30	0.033	93
Roaring Lake	Whiting	1598	100	1498	0.15	225	12.23	mod-sensitive	m	1.00	12.23	0.054	56
Roberts Pond	Lyman	1522	200	1322	0.25	331	10.27	mod-sensitive	m	1.00	10.27	0.031	83
Robinson Pond	Jay	7	0.25	6.75	0.2	1	0.06	mod-sensitive	m	1.00	0.06	0.044	0
Rocky Pond	Dedham	400	80	320	0.2	64	6.15	mod-sensitive	m	1.00	6.15	0.096	16
Rocky Pond	Orland	1109	120	989	0.25	247	11.2	mod-sensitive	m	1.00	11.20	0.045	62
Rocky Pond	Rockport	153	10	143	0.25	36	1.45	mod-sensitive	m	1.00	1.45	0.041	9
Rocky Pond (Little)	Dedham	108	10	98	0.25	25	0.94	mod-sensitive	m	1.00	0.94	0.038	6
Ross Pond	Bristol	108	11	97	0.25	24	1.25	mod-sensitive	h	0.75	0.94	0.039	6
Ross Pond	Rangeley	674	40	634	0.15	95	3.57	mod-sensitive	m	1.00	3.57	0.038	24
Round Pond	Fryeburg	59	3	56	0.2	11	0.55	mod-sensitive	h	0.75	0.41	0.037	3
Round Pond	Lee	7	0	7	0.25	2	0.13	mod-sensitive	h	0.75	0.10	0.056	0
Round Pond	Livermore	815	60	755	0.25	189	9.34	mod-sensitive	h	0.75	7.01	0.037	47
Round Pond	Lyman	32	2	30	0.25	8	0.33	mod-sensitive	h	0.75	0.25	0.033	2
Round Pond	Mount Desert	249	75	174	0.25	44	2.95	good	h	1.00	2.95	0.068	11
Round Pond	Rangeley	6844	1000	5844	0.15	877	49.17	mod-sensitive	h	0.75	36.88	0.042	219
Round Pond	Troy	489	20	469	0.2	94	3.59	mod-sensitive	m	1.00	3.59	0.038	23
Round Pond	Turner	24	5	19	0.35	7	0.35	mod-sensitive	m	1.00	0.35	0.053	2
Round Pond	Union	5517	400	5117	0.25	1279	55.23	mod-sensitive	m	1.00	55.23	0.043	320
Round Pond	Waldoboro	175	20	155	0.2	31	1.76	mod-sensitive	m	1.00	1.76	0.057	8
Ruffingham Meadow Pond Pond	Searsmont	1798	400	1398	0.2	280	10.82	mod-stable	m	1.25	13.53	0.048	70

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Runaround Pond	Durham	4371	400	3971	0.25	993	24.71	mod-sensitive	m	1.00	24.71	0.025	248
S. Basin, Damariscotta Lake	Jefferson	1776	178	1598	0.2	320	30.56	mod-sensitive	h	0.75	22.92	0.072	80
S. Basin, Damariscotta Lake	Newcastle	1267	127	1140	0.25	285	21.87	mod-sensitive	h	0.75	16.40	0.057	71
S. Basin, Damariscotta Lake	Nobleboro	1512	151	1361	0.3	408	26.12	mod-sensitive	h	0.75	19.59	0.048	102
Sabattus Pond	Greene	7674	1200	6474	0.25	1619	71.68	poor restorable	m	0.50	35.84	0.022	405
Sabattus Pond	Leeds	2330	300	2030	0.25	508	21.78	poor restorable	m	0.50	10.89	0.021	127
Sabattus Pond	Monmouth	1877	150	1727	0.2	345	17.55	poor-restorable	m	0.50	8.78	0.025	86
Sabattus Pond	Sabattus	565	200	365	0.25	91	5.29	poor-restorable	m	0.50	2.65	0.029	23
Sabattus Pond	Wales	3741	500	3241	0.25	810	34.92	poor-restorable	m	0.50	17.46	0.022	203
Sabbathday Lake	New Gloucester	2609	300	2309	0.25	577	30.78	mod-sensitive	h	0.75	23.09	0.040	144
Sabbathday Lake	Poland	200	20	180	0.25	45	2.38	mod-sensitive	h	0.75	1.79	0.040	11
Sabbathday Lake	Raymond	600	54	546	0.25	137	7.07	mod-sensitive	h	0.75	5.30	0.039	34
Saddleback Lake	Dallas Plt.	4015	600	3415	0.25	854	25.04	mod-sensitive	h	0.75	18.78	0.022	213
Saddleback Lake	Sandy River Plar	2147	350	1797	0.25	449	13.38	mod-sensitive	h	0.75	10.04	0.022	112
Salmon Lake	Belgrade	1667	177	1490	0.25	373	30.07	poor-restorable	h	0.50	15.04	0.040	93
Sanborn Pond	Brooks	316	30	286	0.25	72	3.39	mod-sensitive	m	0.75	2.54	0.036	18
Sand Pond	Denmark	1376	140	1236	0.3	371	17.04	mod-stable	h	0.75	12.78	0.034	93
Sand Pond	Limington	27	6	21	0.25	5	0.52	mod-sensitive	h	0.75	0.39	0.074	1
Sand Pond	Litchfield	966	110	856	0.25	214	11.51	mod-sensitive	h	0.75	8.63	0.040	54
Sand Pond	Monmouth	207	70	137	0.25	34	2.46	mod-sensitive	h	0.75	1.85	0.054	9
Sand Pond	Norway	538	50	488	0.25	122	8.51	mod-sensitive	h	0.75	6.38	0.052	31
Sandy Bottom Pond	Turner	59	8	51	0.3	15	0.74	mod-sensitive	m	1.00	0.74	0.048	4
Saponac Pond	Lee	180	10	170	0.2	34	1.3	mod-sensitive	m	1.00	1.30	0.038	9
Saturday Pond	Otisfield	835	70	765	0.25	191	9.17	mod-sensitive	h	0.75	6.88	0.036	48
Saulter Pond	Dedham	232	30	202	0.25	51	1.63	mod-sensitive	m	1.00	1.63	0.032	13
Savade Pond	Windsor	820	250	570	0.25	143	7.8	mod-sensitive	h	0.75	5.85	0.041	36
Sawyer Pond	Greenville	617	50	567	0.2	113	5.68	mod-sensitive	h	0.75	4.26	0.038	28
Schoodic Lake	Brownville	5305	1000	4305	0.25	1076	175.6	outstanding	h	0.50	87.79	0.082	269
Schoodic Lake	Lakeview Plt.	6538	500	6038	0.2	1208	216.5	outstanding	h	0.50	108.24	0.090	302
Seal Cove Pond	Tremont	1766	1000	766	0.25	192	20.83	mod-sensitive	h	0.75	15.62	0.082	48
Sebago Lake	Casco	8707	870	7837	0.35	2743	259.8	outstanding	h	0.50	129.92	0.047	686
Sebago Lake	Harrison	7010	700	6310	0.3	1893	209.2	outstanding	h	0.50	104.62	0.055	473
Sebago Lake	Naples	10968	1000	9968	0.4	3987	327.3	outstanding	h	0.50	163.67	0.041	997
Sebago Lake	Norway	9725	500	9225	0.25	2306	290.2	outstanding	h	0.50	145.10	0.063	577
Sebago Lake	Otisfield	11986	1000	10986	0.3	3296	357.7	outstanding	h	0.50	178.85	0.054	824
Sebago Lake	Raymond	4410	1323	3087	0.35	1080	131.6	outstanding	h	0.50	65.81	0.061	270
Sebago Lake	Sebago	12214	2400	9814	0.3	2944	364.5	outstanding	h	0.50	182.23	0.062	736

Appendix C

Per Acre Phosphorus Allocations for Selected Maine Lakes

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Lake Name	Town in which development is located	Direct Watershed Area in Town (acres) **DDA**	Area not available for development (acres) **ANAD**	Area available for development (acres) **AAD**	**GF**	Expected developed area (acres) **D**	(lbP/y) **F**	Water Quality Category **WQC**	**LOP**	**C**	**FC**	Per acre phosphorus allocation (lb/acre/yr) **P**	Small Watershed Threshold (acres) **SWT**
Sebago Lake	Standish	10743	3200	7543	0.35	2640	320.6	outstanding	h	0.50	160.29	0.061	660
Sebago Lake	Waterford	13232	800	12432	0.3	3730	394.8	outstanding	h	0.50	197.41	0.053	932
Sebago Lake	Windham	1356	271	1084	0.35	380	40.5	outst	h	0.50	20.25	0.053	95
Sebasticook Lake	Corinna	5381	800	4581	0.2	916	60.48	poor-restorable	m	0.50	30.24	0.033	229
Sebasticook Lake	Newport	14027	1400	12627	0.25	3157	157.7	poor rest	m	0.50	78.83	0.025	789
Sebec Lake	Bowerbank	11356	1200	10156	0.2	2031	157.4	good	h	1.00	157.41	0.077	508
Sebec Lake	Dover-Foxcroft	9105	700	8405	0.25	2101	126.2	good	h	1.00	126.21	0.060	525
Sebec Lake	Willimantic	23432	2000	21432	0.2	4286	324.8	good	h	1.00	324.77	0.076	1072
Second Davis Pond	Willimantic	266	15	251	0.2	50	2.09	mod-sensitive	m	1.00	2.09	0.042	13
Second Lake	Marion Twp.	12226	1000	11226	0.15	1684	124.1	mod-sensitive	h	0.75	93.05	0.055	421
Second Lake	Whiting	311	20	291	0.15	44	3.17	mod-sensitive	h	0.75	2.38	0.054	11
Second Pond	Blue Hill	775	70	705	0.25	176	9.32	mod-sensitive	h	0.75	6.99	0.040	44
Second Pond	Dedham	489	45	444	0.25	111	5.4	mod-sensitive	h	0.75	4.05	0.036	28
Sennebec Pond	Appleton	11336	1500	9836	0.25	2459	101.3	mod-sensitive	h	0.75	76.01	0.031	615
Sennebec Pond	Hope	1793	30	1763	0.2	353	16.03	mod-sensitive	h	0.75	12.02	0.034	88
Sennebec Pond	Lincolnville	303	30	273	0.2	55	2.71	mod-sensitive	h	0.75	2.03	0.037	14
Sennebec Pond	Searsmont	14161	1500	12661	0.2	2532	126.6	mod-sensitive	h	0.75	94.96	0.038	633
Sennebec Pond	Union	1702	170	1532	0.25	383	15.21	mod-sensitive	h	0.75	11.41	0.030	96
Seven Tree Pond	Hope	168	5	163	0.2	33	2.13	mod-sensitive	h	0.75	1.60	0.049	8
Seven Tree Pond	Union	2748	300	2448	0.3	734	35.52	mod-sensitive	h	0.75	26.64	0.036	184
Shagg Pond	Sumner	74	15	59	0.15	9	0.68	mod-sensitive	h	0.75	0.51	0.058	2
Shagg Pond	Woodstock	743	50	693	0.2	139	6.83	mod-sensitive	h	0.75	5.12	0.037	35
Shaker Bog	Poland	378	40	338	0.25	85	4.6	mod-sensitive	m	1.00	4.60	0.054	21
Shaker Pond	Lyman	756	50	706	0.2	141	5.29	mod-sensitive	m	1.00	5.29	0.037	35
Shaker Pond	Waterboro	9421	1200	8221	0.3	2466	66.12	mod-sensitive	m	1.00	66.12	0.027	617
Shaking Bog	Denmark	106	11	95	0.25	24	0.79	mod-sensitive	m	1.00	0.79	0.033	6
Shattuck Lake	Calais	42	2	40	0.25	10	0.66	mod-sensitive	h	0.75	0.50	0.050	3
Shaw Lake	Carroll Plt	2471	200	2271	0.15	341	18.87	mod-sensitive	m	1.00	18.87	0.055	85
Shaw Lake	Pukakon Twp / T	197	30	167	0.15	25	1.49	mod-sensitive	m	1.00	1.49	0.059	6
Shaw Lake	T6 R1 NBPP	360	50	310	0.15	47	2.75	mod-sensitive	m	1.00	2.75	0.059	12
Shed Pond	Readfield	316	30	286	0.25	72	2.2	mod-sensitive	m	1.00	2.20	0.031	18
Sheepscot Lake	Washington	929	30	899	0.2	180	10.34	good	h	1.00	10.34	0.058	45
Sherman Lake	Edgecomb	2364	236	2128	0.25	532	16.31	mod-sensitive	m	1.00	16.31	0.031	133
Sherman Lake	Newcastle	1942	194	1748	0.25	437	13.4	mod-sensitive	m	1.00	13.40	0.031	109
Shermans Mill Pond	Appleton	884	100	784	0.2	157	5.71	mod-sensitive	m	1.00	5.71	0.036	39
Shermans Mill Pond	Hope	716	20	696	0.2	139	4.6	mod-sensitive	m	1.00	4.60	0.033	35
Sibley Pond	Canaan	4341	700	3641	0.2	728	27.34	mod-sensitive	m	1.00	27.34	0.038	182

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Sibley Pond	Pittsfield	9046	905	8141	0.2	1628	56.95	m-sens	m	1.00	56.95	0.035	407
Sidensparker Pond	Waldoboro	936	100	836	0.25	209	9.39	mod-sensitive	m	1.00	9.39	0.045	52
Silver Lake	Bucksport	2562	260	2302	0.25	576	31.24	mod-sensitive	h	0.75	23.43	0.041	144
Silver Lake	Phippsburg	64	5	59	0.25	15	0.63	mod-sensitive	h	0.75	0.47	0.032	4
Skitacook Lake	Oakfield	3943	320	3623	0.2	725	33.86	mod-sensitive	m	1.00	33.86	0.047	181
Snag Pond	Lincoln	1102	170	932	0.2	186	15.96	mod-sensitive	m	1.00	15.96	0.086	47
Snake Pond	Standish	39	3	36	0.25	9	0.39	mod-sensitive	m	1.00	0.39	0.043	2
Snow's Pond	Dover-Foxcroft	1423	80	1343	0.2	269	9.41	mod-sensitive	m	1.00	9.41	0.035	67
Snowshoe Pond	Clifton	81	8	73	0.2	15	0.68	mod-sensitive	m	1.00	0.68	0.047	4
Somes Pond	Mount Desert	1042	200	842	0.3	253	17.59	mod-sensitive	h	0.75	13.19	0.052	63
Songo Pond	Bethel	1448	300	1148	0.25	287	14.35	mod-sensitive	h	0.75	10.76	0.038	72
South Pond	Buckfield	1628	160	1468	0.25	367	10.58	mod-sensitive	m	1.00	10.58	0.029	92
South Pond	Cushing	783	10	773	0.2	155	7.69	mod-sensitive	m	1.00	7.69	0.050	39
South Pond	Warren	4860	420	4440	0.25	1110	47.65	mod-sensitive	m	1.00	47.65	0.043	278
South Pond	Woodstock	138	15	123	0.2	25	2.11	mod-sensitive	h	0.75	1.58	0.064	6
Southeast Pond	Hiram	37	2	35	0.25	9	0.33	mod-sensitive	m	1.00	0.33	0.038	2
Southeast Pond	Sebago	1312	100	1212	0.25	303	12.12	mod-sensitive	m	1.00	12.12	0.040	76
Southwest Pond	Beddington	635	150	485	0.15	73	9.28	mod-sensitive	m	1.00	9.28	0.128	18
Spaulding Lake	Oakfield	2446	200	2246	0.2	449	17.75	mod-sensitive	h	0.75	13.31	0.030	112
Speck Pond 1	Waterford	4	0	4	0.2	1	0.06	mod-sensitive	m	1.00	0.06	0.075	0
Speck Pond 2	Waterford	22	6	16	0.2	3	0.24	mod-sensitive	m	1.00	0.24	0.075	1
Spectacle Pond	Augusta	323	30	293	0.3	88	4.34	good	h	1.00	4.34	0.049	22
Spectacle Pond	Eastbrook	738	20	718	0.2	144	8.86	mod-sensitive	m	1.00	8.86	0.062	36
Spectacle Pond	T16 MD	509	20	489	0.2	98	6.08	mod-sensitive	m	1.00	6.08	0.062	24
Spectacle Pond	Vassalboro	686	40	646	0.25	162	9.21	good	h	1.00	9.21	0.057	40
Spirit Lake	Phippsburg	301	20	281	0.25	70	3.68	mod-sensitive	m	1.00	3.68	0.052	18
Sprague Lake	Phippsburg	395	50	345	0.2	69	2.91	mod-sensitive	h	0.75	2.18	0.032	17
Spring Pond	Washington	46	0	46	0.2	9	0.5	mod-sensitive	h	0.75	0.38	0.041	2
Spruce Mountain Lake	Beddington	1712	170	1542	0.15	231	25.04	mod-sensitive	h	0.75	18.78	0.081	58
Squankin Pond	Willimantic	17	0	17	0.15	3	0.15	mod-sensitive	m	1.00	0.15	0.059	1
Square Pond	Acton	2646	200	2446	0.3	734	39.38	mod-sensitive	h	0.75	29.54	0.040	183
St. Froid Lake	Portage Lake	1984	1000	984	0.2	197	22.68	mod-sensitive	h	0.75	17.01	0.086	49
Stanley Pond	Hiram	182	35	147	0.25	37	2.44	good	h	1.00	2.44	0.066	9
Stearns Pond	Sweden	3565	300	3265	0.25	816	34.94	mod-sensitive	h	0.75	26.21	0.032	204
Stearns Pond	Waterford	551	50	501	0.2	100	5.4	mod-sensitive	h	0.75	4.05	0.040	25
Stetson Pond	Phillips	64	0	64	0.2	13	0.99	mod-sensitive	h	0.75	0.74	0.058	3
Stoddard Pond	Bowdoin	29	2	27	0.25	7	0.46	mod-sensitive	m	1.00	0.46	0.068	2

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Stone Pond	Brownfield	171	50	121	0.2	24	1.51	mod-sensitive	m	1.00	1.51	0.062	6
Stuart Pond	Belgrade	42	25	17	0.4	7	0.5	mod-sensitive	h	0.75	0.38	0.055	2
Sunken and Rocky Lakes	Whiting	2154	150	2004	0.2	401	27.03	mod-sensitive	m	1.00	27.03	0.067	100
Sutherland Pond	Sabattus	227	12	215	0.25	54	2.18	mod-sensitive	m	1.00	2.18	0.041	13
Swains Pond	Rumford	84	2	82	0.15	12	0.81	mod-sensitive	m	1.00	0.81	0.066	3
Swan Lake	Searsport	2132	200	1932	0.25	483	36.49	mod-sensitive	h	0.75	27.37	0.057	121
Swan Lake	Swanville	2994	300	2694	0.25	674	51.22	m-sens	h	0.75	38.42	0.057	168
Swan Pond	Acton	667	70	597	0.2	119	4.05	mod-sensitive	m	1.00	4.05	0.034	30
Swan Pond	Hartford	1754	150	1604	0.15	241	11.06	mod-sensitive	m	1.00	11.06	0.046	60
Swan Pond	Lyman	459	45	414	0.25	104	7.32	mod-sensitive	h	0.75	5.49	0.053	26
Tarkill Pond	Windham	234	60	174	0.35	61	2.18	mod-sensitive	m	1.00	2.18	0.036	15
Tarwater Pond	Lyman	1030	650	380	0.25	95	6.21	mod-sensitive	m	1.00	6.21	0.065	24
Taylor Hill Pond	Strong	748	100	648	0.2	130	5.38	mod-sensitive	m	1.00	5.38	0.042	32
Taylor Pond	Auburn	3874	500	3374	0.3	1012	35.25	mod-sensitive	m	1.00	35.25	0.035	253
Taylor Pond	Minot	4813	500	4313	0.25	1078	43.79	mod-sensitive	m	1.00	43.79	0.041	270
The Basin	Minot	607	70	537	0.25	134	5.75	mod-sensitive	m	1.00	5.75	0.043	34
The Basin	Turner	34	10	24	0.2	5	0.13	mod-sensitive	m	1.00	0.13	0.027	1
Third Davis Pond	Willimantic	1593	60	1533	0.15	230	9.67	mod-sensitive	m	1.00	9.67	0.042	57
Third Pond	Blue Hill	679	60	619	0.25	155	10.78	mod-sensitive	m	1.00	10.78	0.070	39
Thomas Pond	Casco	2159	300	1859	0.4	744	21.05	mod-sensitive	h	0.75	15.79	0.021	186
Thomas Pond	Raymond	716	72	644	0.35	225	6.97	mod-sensitive	h	0.75	5.23	0.023	56
Thompson Lake	Casco	2574	330	2244	0.3	673	41.98	outstanding	h	0.50	20.99	0.031	168
Thompson Lake	Otisfield	8806	750	8056	0.3	2417	143.6	outstanding	h	0.50	71.79	0.030	604
Thompson Lake	Oxford	5307	500	4807	0.25	1202	86.52	outstanding	h	0.50	43.26	0.036	300
Thompson Lake	Poland	2868	300	2568	0.25	642	46.76	outstanding	h	0.50	23.38	0.036	161
Thompson Lake	Raymond	135	0	135	0.25	34	2.2	outstanding	h	0.50	1.10	0.033	8
Threecornered Pond	Augusta	1472	110	1362	0.3	409	11.53	mod-sensitive	m	1.00	11.53	0.028	102
Threecornered Pond	Vassalboro	1662	350	1312	0.25	328	13	poor restorable	m	0.50	6.50	0.020	82
Threecornered Pond	Windsor	138	20	118	0.2	24	1.08	poor-restorable	m	0.50	0.54	0.023	6
Threemile Pond	Augusta	118	35	83	0.25	21	1.38	poor restorable	m	0.50	0.69	0.033	5
Threemile Pond	China	1796	449	1347	0.25	337	20.96	poor restorable		0.50	10.48	0.031	84
Threemile Pond	Vassalboro	1299	350	949	0.25	237	15.19	poor-restorable	m	0.50	7.60	0.032	59
Threemile Pond	Windsor	2750	600	2150	0.25	538	32.1	poor-restorable	m	0.50	16.05	0.030	134
Thurston Pond	Bucksport	892	70	822	0.2	164	8.86	mod-sensitive	m	1.00	8.86	0.054	41
Tilden Pond	Lincolnville	59	3	56	0.2	11	0.55	mod-sensitive	m	1.00	0.55	0.049	3
Tilden Pond	Northport	321	20	301	0.25	75	2.97	mod-sensitive	m	1.00	2.97	0.039	19
Tilden Pond	Searsmont	217	25	192	0.2	38	2.02	mod-stable	m	1.25	2.53	0.066	10

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Tinkham Pond	Whitefield	66	5	61	0.2	12	0.63	mod-sensitive	m	1.00	0.63	0.052	3
Tobias Pond	Nobleboro	165	16	149	0.3	45	1.43	mod-sensitive	m	1.00	1.43	0.032	11
Tobias Pond	Waldoboro	22	5	17	0.25	4	0.19	mod-sensitive	m	1.00	0.19	0.045	1
Toddy Pond	Blue Hill	4677	300	4377	0.3	1313	71.13	good	h	1.00	71.13	0.054	328
Toddy Pond	Brooks	469	30	439	0.2	88	5.15	mod-sensitive	m	1.00	5.15	0.059	22
Toddy Pond	Orland	2399	240	2159	0.25	540	36.49	good	h	1.00	36.49	0.068	135
Toddy Pond	Penobscot	2663	250	2413	0.25	603	40.5	good	h	1.00	40.50	0.067	151
Toddy Pond	Surry	1265	150	1115	0.25	279	19.24	good	h	1.00	19.24	0.069	70
Togus Pond	Augusta	2184	125	2059	0.3	618	37.35	poor restorable	m	0.50	18.68	0.030	154
Togus Pond (Lower)	Augusta	2839	350	2489	0.25	622	28.53	poor restorable	m	0.50	14.27	0.023	156
Togus Pond (Lower)	Whitefield	699	300	399	0.25	100	7.01	mod-sensitive	m	1.00	7.01	0.070	25
Togus Pond (Lower)	Windsor	1712	700	1012	0.25	253	17.22	mod-sensitive	m	1.00	17.22	0.068	63
Tolman Pond	Augusta	306	15	291	0.25	73	3.37	mod-sensitive	m	1.00	3.37	0.046	18
Tolman Pond	Rockport	2463	350	2113	0.25	528	17.02	mod-sensitive	m	1.00	17.02	0.032	132
Toothaker Pond	Phillips	51	10	41	0.25	10	0.72	poor restorable	m	0.50	0.36	0.035	3
Torrey Pond	Deer Isle	770	115	655	0.2	131	5.53	mod-sensitive	m	1.00	5.53	0.042	33
Torsey Lake	Readfield	1094	150	944	0.25	236	12.12	mod-sensitive	h	0.75	9.09	0.039	59
Torsey Pond	Mount Vernon	2162	140	2022	0.25	506	23.99	mod-sensitive	h	0.75	17.99	0.036	126
Tracy Pond	Hermon	2238	1130	1108	0.25	277	12.92	mod-sensitive	m	1.00	12.92	0.047	69
Trafton Pond	Hiram	941	150	791	0.2	158	8.55	mod-sensitive	h	0.75	6.41	0.041	40
Travel Pond	Jefferson	2826	500	2326	0.2	465	17.26	mod-sensitive	m	1.00	17.26	0.037	116
Travel Pond	Washington	289	15	274	0.15	41	1.76	mod-sensitive	m	1.00	1.76	0.043	10
Trickey Pond	Naples	528	100	428	0.4	171	14.13	outstanding	h	0.50	7.07	0.041	43
Tripp Pond	Poland	3993	350	3643	0.25	911	44.34	mod-sensitive	m	1.00	44.34	0.049	228
Turtle Pond	Penobscot	222	20	202	0.2	40	1.58	mod-sensitive	m	1.00	1.58	0.039	10
Tyler Pond	Augusta	12	0	12	0.25	3	0.19	mod-sensitive	h	0.75	0.14	0.048	1
U. Sandy River Pond	Sandy River Plar	1287	100	1187	0.2	237	8.11	mod-sensitive	h	0.75	6.08	0.026	59
Unity Pond	Troy	8366	1300	7066	0.2	1413	85.37	poor-restorable	m	0.50	42.69	0.030	353
Unity Pond	Unity	2270	500	1770	0.25	443	23.17	poor restorable	m	0.50	11.59	0.026	111
Unnamed Pond	Raymond	29	3	26	0.25	7	0.26	mod-sensitive	m	1.00	0.26	0.040	2
Unnamed Pond	Whiting	158	10	148	0.15	22	1.41	mod-sensitive	m	1.00	1.41	0.064	6
Unnamed Pond	Wilton	434	0	434	0.15	65	2.88	mod-sensitive	m	1.00	2.88	0.044	16
Unnamed Pond #0057	Corinna	736	70	666	0.2	133	4.23	mod-sensitive	m	1.00	4.23	0.032	33
Unnamed Pond #2263	Corinna	402	40	362	0.2	72	2.93	mod-sensitive	m	1.00	2.93	0.040	18
Unnamed Pond #2263	Newport	459	20	439	0.15	66	3.32	mod-sensitive	m	1.00	3.32	0.050	16
Unnamed Pond (0081)	Calais	19	0	19	0.2	4	0.19	mod-sensitive	m	1.00	0.19	0.050	1
Unnamed Pond (5313)	Winthrop	706	50	656	0.25	164	4.16	mod-sensitive	m	1.00	4.16	0.025	41

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Unnamed Pond (7501)	Beddington	158	30	128	0.15	19	2.18	mod-sensitive	m	1.00	2.18	0.114	5
Unnamed Pond (8127)	Mount Vernon	64	0	64	0.25	16	0.59	mod-sensitive	m	1.00	0.59	0.037	4
Unnamed Pond (8129)	Mount Vernon	259	10	249	0.2	50	2.11	mod-sensitive	m	1.00	2.11	0.042	12
Unnamed Pond (8137)	Monmouth	474	45	429	0.2	86	3.46	mod-sensitive	m	1.00	3.46	0.040	21
Unnamed Pond (8223)	Augusta	37	4	33	0.2	7	0.35	mod-sensitive	m	1.00	0.35	0.053	2
Unnamed Pond (8533)	Dedham	160	5	155	0.2	31	1.05	mod-sensitive	m	1.00	1.05	0.034	8
Unnamed Pond (8535)	Dedham	358	10	348	0.2	70	2	mod-sensitive	m	1.00	2.00	0.029	17
Unnamed Pond (8797)	Jay	170	10	160	0.15	24	1.12	mod-sensitive	m	1.00	1.12	0.047	6
Unnamed Pond (8801)	Jay	538	40	498	0.15	75	3.26	mod-sensitive	m	1.00	3.26	0.044	19
Unnamed Pond (Hibberts Gore)	Washington	51	30	21	0.2	4	0.33	mod-sensitive	m	1.00	0.33	0.079	1
Unnamed Pond (in Dresden)	Pittston	471	25	446	0.2	89	3.21	mod-sensitive	m	1.00	3.21	0.036	22
Unnamed Pond (in Twelvemile Stream)	Canaan	370	37	333	0.2	67	1.98	mod-sensitive	m	1.00	1.98	0.030	17
Unnamed Pond (Spencer Brook)	Limerick	691	70	621	0.2	124	3.79	mod-sensitive	m	1.00	3.79	0.031	31
Unnamed Pond 6735	Hartford	434	40	394	0.15	59	2.86	mod-sensitive	m	1.00	2.86	0.048	15
Unnamed Pond 8895	Casco	422	100	322	0.3	97	3.72	mod-sensitive	m	1.00	3.72	0.039	24
Unnamed Pond 8897	Casco	143	15	128	0.3	38	1.38	mod-sensitive	m	1.00	1.38	0.036	10
Unnamed Pond 9520	Clifton	343	40	303	0.15	45	2.22	mod-sensitive	m	1.00	2.22	0.049	11
Unnamed Pond 9558	Clifton	108	8	100	0.15	15	0.97	mod-sensitive	m	1.00	0.97	0.065	4
Unnamed Pond, Beaver Brook	Denmark	1761	300	1461	0.25	365	13.23	mod-sensitive	m	1.00	13.23	0.036	91
Unnamed Pond, drains to Quantabacook L. wetland	Searsmont	128	12	116	0.2	23	1.12	mod-sensitive	m	1.00	1.12	0.048	6
Unnamed Pond,drains to Sidensparker	Waldoboro	496	40	456	0.2	91	3.96	mod-sensitive	m	1.00	3.96	0.043	23
Upper Cold Stream Pond (east)	Lincoln	558	90	468	0.25	117	7.78	good	h	1.00	7.78	0.066	29
Upper Cold Stream Pond (west)	Lincoln	736	160	576	0.25	144	14.2	outstanding	h	0.50	7.10	0.049	36
Upper Hadlock Pond	Mount Desert	808	808	0	0	0	7.14	mod-sensitive	h	0.75	5.36	Park	0
Upper Mud Pond	Windham	61	5	56	0.25	14	0.39	mod-sensitive	m	1.00	0.39	0.028	4
Upper Narrows Pond	Winthrop	2545	220	2325	0.25	581	29.39	mod-sensitive	h	0.75	22.04	0.038	145
Upper Patten Pond	Ellsworth	405	50	355	0.25	89	3.9	mod-sensitive	h	1.00	3.90	0.044	22
Upper Patten Pond	Orland	2260	200	2060	0.3	618	21.8	mod-sensitive	h	0.75	16.35	0.026	155
Upper Patten Pond	Surry	1233	125	1108	0.2	222	11.88	mod-sensitive	h	0.75	8.91	0.040	55
Upper Pond	Bristol	101	10	91	0.25	23	0.99	mod-sensitive	h	0.75	0.74	0.032	6
Upper Pond	Burlington	2060	230	1830	0.2	366	20.92	mod-sensitive	m	1.00	20.92	0.057	92
Upper Pond	Lincoln	1924	130	1794	0.25	449	19.55	mod-sensitive	m	1.00	19.55	0.044	112
Upper Range Pond	New Gloucester	543	30	513	0.25	128	6.15	mod-sensitive	h	0.75	4.61	0.036	32

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Upper Range Pond	Poland	1692	250	1442	0.25	361	19.13	mod-sensitive	h	0.75	14.35	0.040	90
Upper Range Pond	Raymond	375	25	350	0.25	88	4.25	mod-sensitive	h	0.75	3.19	0.036	22
Upper Richardson	Township C	6412	321	6091	0.2	1218	147.6	good	h	1.00	147.55	0.121	305
Upper Springy Pond	Clifton	672	120	552	0.2	110	5.4	mod-sensitive	m	1.00	5.40	0.049	28
Varnum Pond	Wilton	847	80	767	0.25	192	11.79	good	h	1.00	11.79	0.061	48
Vose Pond	Calais	1598	0	1598	0.2	320	25	mod-sensitive	m	1.00	25.00	0.078	80
Wadley Pond	Lyman	1329	400	929	0.25	232	11.39	mod-sensitive	m	1.00	11.39	0.049	58
Wales Pond	Hollis	407	20	387	0.2	77	2.73	mod-sensitive	m	1.00	2.73	0.035	19
Walker Pond	Brooksville	1680	160	1520	0.3	456	26.96	mod-sensitive	h	0.75	20.22	0.044	114
Wards Pond	Fryeburg	1186	250	936	0.25	234	8.4	mod-sensitive	m	1.00	8.40	0.036	59
Wards Pond	Limington	783	160	623	0.25	156	6.41	mod-sensitive	m	1.00	6.41	0.041	39
Washburn Pond	Sumner	66	12	54	0.15	8	0.59	mod-sensitive	h	0.75	0.44	0.055	2
Washington Pond	Washington	1789	200	1589	0.2	318	14.75	mod-sensitive	h	0.75	11.06	0.035	79
Wassookeag Lake	Dexter	5577	600	4977	0.25	1244	77.35	good	h	1.00	77.35	0.062	311
Watchic Pond	Standish	2228	300	1928	0.35	675	33.89	mod-sensitive	h	0.75	25.42	0.038	169
Watson Pond	Rome	454	40	414	0.2	83	4.25	mod-sensitive	h	0.75	3.19	0.038	21
Wat-tuh Lake	Phippsburg	499	40	459	0.25	115	3.77	mod-sensitive	m	1.00	3.77	0.033	29
Weary Pond	Whitefield	311	20	291	0.2	58	3.26	mod-sensitive	m	1.00	3.26	0.056	15
Webb Lake	Phillips	830	200	630	0.25	158	8.07	mod-sensitive	h	0.75	6.05	0.038	39
Webb Lake	Weld	30771	15000	15771	0.25	3943	299.7	mod-sensitive	h	0.75	224.74	0.057	986
Webber Pond	Bremen	1494	200	1294	0.25	324	17.33	mod-sensitive	m	1.00	17.33	0.054	81
Webber Pond	Bristol	180	18	162	0.25	41	2.09	mod-sensitive	m	1.00	2.09	0.051	10
Webber Pond	Sweden	205	35	170	0.25	43	1.89	mod-sensitive	m	1.00	1.89	0.044	11
Webber Pond	Vassalboro	5169	300	4869	0.25	1217	77.17	poor rest	m	0.50	38.59	0.032	304
Weir Pond	Lee	1979	400	1579	0.2	316	10.87	mod-sensitive	h	0.75	8.15	0.026	79
Wellman Pond	Augusta	74	15	59	0.2	12	0.5	mod-sensitive	h	0.75	0.38	0.032	3
Wellman Pond	Belgrade	32	15	17	0.4	7	0.44	mod-sensitive	h	0.75	0.33	0.049	2
Wellman Pond	Windsor	237	100	137	0.2	27	1.6	mod-sensitive	m	1.00	1.60	0.058	7
Wesserunstt Lake	Madison	10037	1004	9033	0.2	1807	92.05	mod-stable	h	1.00	92.05	0.051	452
West Bay Pond	Gouldsboro	1653	100	1553	0.15	233	14.15	mod-sensitive	h	0.75	10.61	0.046	58
West Garland Pond	Dexter	3666	300	3366	0.2	673	20.33	mod-sensitive	h	0.75	15.25	0.023	168
West Garland Pond	Garland	1294	300	994	0.2	199	7.18	mod-sensitive	h	1.00	7.18	0.036	50
West Harbor Pond	Boothbay	175	18	157	0.3	47	2.18	mod-sensitive	m	1.00	2.18	0.046	12
West Pond	T3ND	2110	105	2005	0.2	401	42.71	good	h	1.00	42.71	0.106	100
West Pond	T40MD	1326	66	1260	0.2	252	26.85	good	h	1.00	26.85	0.106	63
Western Lake	Whiting	180	10	170	0.15	26	1.76	mod-sensitive	m	1.00	1.76	0.069	6
Weymouth Pond	Corinna	363	30	333	0.2	67	3.28	mod-sensitive	m	1.00	3.28	0.049	17

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Whetstone Pond	Kingsbury Planta	291	10	281	0.2	56	5.84	mod-sensitive	h	0.75	4.38	0.078	14
Whitney Pond	Oxford	706	80	626	0.3	188	8.26	mod-sensitive	m	1.00	8.26	0.044	47
Whitney Pond	Waterford	39	0	39	0.2	8	0.28	mod-sensitive	m	1.00	0.28	0.036	2
Whittier Pond	Rome	2115	200	1915	0.2	383	12.74	mod-sensitive	h	0.75	9.56	0.025	96
Whittier Pond	Vienna	252	15	237	0.2	47	2.29	mod-sensitive	m	1.00	2.29	0.048	12
Wight Pond	Penobscot	5831	300	5531	0.2	1106	45.33	mod-sensitive	m	1.00	45.33	0.041	277
Wiley Pond	Boothbay	71	7	64	0.3	19	0.85	mod-sensitive	h	0.75	0.64	0.034	5
Williams Pond	Bucksport	768	100	668	0.2	134	7.25	mod-sensitive	h	0.75	5.44	0.041	33
Wilson Lake	Acton	2241	300	1941	0.3	582	26.17	mod-sensitive	h	0.75	19.63	0.034	146
Wilson Pond	Jay	32	4	28	0.2	6	0.28	mod-sensitive	h	0.75	0.21	0.038	1
Wilson Pond	Monmouth	1828	150	1678	0.3	503	20.77	mod-sensitive	m	1.00	20.77	0.041	126
Wilson Pond	Wilton	8048	970	7078	0.25	1770	72.1	mod-sensitive	h	0.75	54.08	0.031	442
Wilson Pond	Winthrop	808	50	758	0.25	190	9.19	mod-sensitive	h	0.75	6.89	0.036	47
Woodbury Pond	Litchfield	1423	150	1273	0.3	382	22.88	mod-sensitive	h	0.75	17.16	0.045	95
Woodbury Pond	Monmouth	187	10	177	0.25	44	3.04	mod-sensitive	h	1.00	3.04	0.069	11
Woods Millpond	Sebago	266	15	251	0.2	50	1.54	mod-sensitive	m	1.00	1.54	0.031	13
Woods Pond	Bridgton	3266	327	2939	0.35	1029	37.04	mod-sensitive	m	1.00	37.04	0.036	257
Wormwood Pond	Ellsworth	605	50	555	0.2	111	3.83	mod-sensitive	m	1.00	3.83	0.035	28
Worthley Pond	Peru	3518	800	2718	0.25	680	39.97	mod-sensitive	h	0.75	29.98	0.044	170
Worthley Pond	Poland	936	94	842	0.25	211	7.43	mod-sensitive	h	0.75	5.57	0.026	53
Wytopitlock Lake	Glenwood Plt	2555	230	2325	0.2	465	28.81	mod-sensitive	m	1.00	28.81	0.062	116

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This **Appendix C** presents per acre phosphorus allcations (**P**) for all to the lake watersed/town combinations that have been dertermined by the Department to this point. It also presents the information and assumptions used to derive the value for **P**, as well as the small watershed threshold value (**SWT**). This Appendix will be modified on a regular basis as additional lake watershed/town combinations are added and/or allocations are amended as new information becomes available. It was last updated on 11/8/10. If you do not find the lake watershed/town combination that you are looking for in the table, contact Jeff Dennis at the DEP Division of Watershed Management (207-287-7847 or jeff.dennis@maine.gov) to request an allocation for the watershed of concern.

Lake Name	Town in which development is located	Direct Watershed Area in Town (acres) **DDA**	Area not available for development (acres) **ANAD**	Area available for development (acres) **AAD**	**GF**	Expected developed area (acres) **D**	(lbP/y) **F**	Water Quality Category **WQC**	**LOP**	**C**	**FC**	Per acre phosphorus allocation (lb/acre/yr) **P**	Small Watershed Threshold (acres) **SWT**
Wilson Lake	Acton	2241	300	1941	0.3	582	26.17	mod-sensitive	h	0.75	19.63	0.034	146
Balch Pond	Acton	597	60	537	0.3	161	6.81	mod-sensitive	m	1.00	6.81	0.042	40
Great East Lake	Acton	2391	300	2091	0.3	627	40.1	outstanding	h	0.50	20.05	0.032	157
Hansen Pond	Acton	219	20	199	0.2	40	1.65	mod-sensitive	m	1.00	1.65	0.041	10
Horn Pond	Acton	373	60	313	0.3	94	7.05	mod-sensitive	h	0.75	5.29	0.056	23
Loon Pond	Acton	420	50	370	0.3	111	4.38	mod-sensitive	m	1.00	4.38	0.039	28
Moose Pond	Acton	79	8	71	0.25	18	1.05	mod-sensitive	h	0.75	0.79	0.044	4
Mousam Lake, North Basin	Acton	625	150	475	0.35	166	9.63	mod-sensitive	h	0.75	7.22	0.043	42
Mousam Lake, South Basin	Acton	4539	700	3839	0.3	1152	50.97	mod-sensitive	h	0.75	38.23	0.033	288
Northeast Pond	Acton	3484	600	2884	0.25	721	27.91	mod-sensitive	m	1.00	27.91	0.039	180
Square Pond	Acton	2646	200	2446	0.3	734	39.38	mod-sensitive	h	0.75	29.54	0.040	183
Swan Pond	Acton	667	70	597	0.2	119	4.05	mod-sensitive	m	1.00	4.05	0.034	30
Mooselookmeguntic Lake	Adamstown Twp	8539	1025	7514	0.2	1503	161.1	mod-sensitive	h	0.75	120.80	0.080	376
Estes Lake	Alfred	11149	1115	10034	0.3	3010	72.73	mod-sensitive	m	1.00	72.73	0.024	753
Johnson Pond	Appleton	69	5	64	0.25	16	0.74	mod-sensitive	m	1.00	0.74	0.046	4
Medomak Pond	Appleton	8122	1000	7122	0.2	1424	54.79	mod-sensitive	m	1.00	54.79	0.038	356
Newbert Pond	Appleton	333	75	258	0.2	52	3.17	mod-sensitive	m	1.00	3.17	0.061	13
Sennebec Pond	Appleton	11336	1500	9836	0.25	2459	101.3	mod-sensitive	h	0.75	76.01	0.031	615
Shermans Mill Pond	Appleton	884	100	784	0.2	157	5.71	mod-sensitive	m	1.00	5.71	0.036	39
Little Wilson Pond	Auburn	116	15	101	0.3	30	1.01	mod-sens	h	0.75	0.76	0.025	8
Taylor Pond	Auburn	3874	500	3374	0.3	1012	35.25	mod-sensitive	m	1.00	35.25	0.035	253
Lake Auburn	Auburn	4704	350	4354	0.35	1524	109.9	good	h	1.00	109.87	0.072	381
Anderson Pond	Augusta	96	5	91	0.3	27	1.16	mod-sensitive	h	0.75	0.87	0.032	7
Dam Pond	Augusta	766	115	651	0.3	195	9.81	mod-sensitive	m	1.00	9.81	0.050	49
Greeley Pond	Augusta	1074	130	944	0.3	283	7.16	mod-sensitive	m	1.00	7.16	0.025	71
Little Togus Pond	Augusta	126	10	116	0.3	35	1.54	mod-sensitive	m	1.00	1.54	0.044	9
Mud Pond	Augusta	111	12	99	0.25	25	0.88	mod-sensitive	m	1.00	0.88	0.036	6
Spectacle Pond	Augusta	323	30	293	0.3	88	4.34	good	h	1.00	4.34	0.049	22
Threecornered Pond	Augusta	1472	110	1362	0.3	409	11.53	mod-sensitive	m	1.00	11.53	0.028	102
Threemile Pond	Augusta	118	35	83	0.25	21	1.38	poor restorable	m	0.50	0.69	0.033	5
Togus Pond	Augusta	2184	125	2059	0.3	618	37.35	poor restorable	m	0.50	18.68	0.030	154
Togus Pond (Lower)	Augusta	2839	350	2489	0.25	622	28.53	poor restorable	m	0.50	14.27	0.023	156

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Tolman Pond	Augusta	306	15	291	0.25	73	3.37	mod-sensitive	m	1.00	3.37	0.046	18
Tyler Pond	Augusta	12	0	12	0.25	3	0.19	mod-sensitive	h	0.75	0.14	0.048	1
Unnamed Pond (8223)	Augusta	37	4	33	0.2	7	0.35	mod-sensitive	m	1.00	0.35	0.053	2
Wellman Pond	Augusta	74	15	59	0.2	12	0.5	mod-sensitive	h	0.75	0.38	0.032	3
Prong Pond	Beaver Cove Tw	1756	400	1356	0.25	339	15.34	mod-sensitive	h	0.75	11.51	0.034	85
Beddington Lake	Beddington	3365	600	2765	0.15	415	25.4	mod-sensitive	h	0.75	19.05	0.046	104
Chalk Pond	Beddington	338	0	338	0.15	51	2.35	mod-sensitive	m	1.00	2.35	0.046	13
Horseshoe Pond	Beddington	674	100	574	0.15	86	6.21	mod-sensitive	m	1.00	6.21	0.072	22
Little Horseshoe Pond	Beddington	66	3	63	0.2	13	0.99	mod-sensitive	m	1.00	0.99	0.079	3
Mountain Pond	Beddington	140	22	118	0.2	24	1.38	mod-sensitive	m	1.00	1.38	0.058	6
Pleasant River Lake	Beddington	3489	350	3139	0.2	628	38.21	good	h	1.00	38.21	0.061	157
Southwest Pond	Beddington	635	150	485	0.15	73	9.28	mod-sensitive	m	1.00	9.28	0.128	18
Spruce Mountain Lake	Beddington	1712	170	1542	0.15	231	25.04	mod-sensitive	h	0.75	18.78	0.081	58
Unnamed Pond (7501)	Beddington	158	30	128	0.15	19	2.18	mod-sensitive	m	1.00	2.18	0.114	5
Belfast Reservoir #1	Belfast	669	150	519	0.25	130	4.6	mod-sensitive	m	1.00	4.60	0.035	32
Belfast Reservoir #2	Belfast	6921	1000	5921	0.25	1480	43.54	mod-sensitive	m	1.00	43.54	0.029	370
Hurds Pond	Belfast	541	100	441	0.25	110	3.28	mod-sensitive	m	1.00	3.28	0.030	28
Great Pond	Belgrade	10941	2167	8774	0.25	2194	228.7	mod-sensitive	h	0.75	171.54	0.078	548
Long Pond, North Basin	Belgrade	1314	253	1061	0.4	421	30.89	poor restorable	h	0.50	15.45	0.037	105
Long Pond, South Basin	Belgrade	1714	252	1462	0.39	568	38.12	poor restorable	h	0.50	19.06	0.034	142
McGrath Pond	Belgrade	316	34	282	0.19	54	3.55	mod-sensitive	h	0.75	2.66	0.049	13
Salmon Lake	Belgrade	1667	177	1490	0.25	373	30.07	poor-restorable	h	0.50	15.04	0.040	93
Messalonskee Lake	Belgrade	11312	1286	10026	0.23	2274	205.7	mod-sensitive	h	0.75	154.31	0.068	568
Chamberlain Pond	Belgrade	96	40	56	0.4	22	0.72	mod-sensitive	h	0.75	0.54	0.024	6
Hamilton Pond	Belgrade	96	50	46	0.4	18	1.36	mod-sensitive	h	0.75	1.02	0.055	5
Joe Pond	Belgrade	19	3	16	0.4	6	0.28	mod-sensitive	h	0.75	0.21	0.033	2
Penney Pond	Belgrade	42	20	22	0.4	9	0.83	mod-sensitive	h	0.75	0.62	0.071	2
Stuart Pond	Belgrade	42	25	17	0.4	7	0.5	mod-sensitive	h	0.75	0.38	0.055	2
Wellman Pond	Belgrade	32	15	17	0.4	7	0.44	mod-sensitive	h	0.75	0.33	0.049	2
Songo Pond	Bethel	1448	300	1148	0.25	287	14.35	mod-sensitive	h	0.75	10.76	0.038	72
First Pond	Blue Hill	2241	200	2041	0.2	408	23.17	mod-sensitive	h	0.75	17.38	0.043	102
Fourth Pond	Blue Hill	793	70	723	0.2	145	5.9	mod-sensitive	m	1.00	5.90	0.041	36
Noyes Pond	Blue Hill	518	70	448	0.2	90	3.9	mod-sensitive	h	0.75	2.93	0.033	22
Second Pond	Blue Hill	775	70	705	0.25	176	9.32	mod-sensitive	h	0.75	6.99	0.040	44
Third Pond	Blue Hill	679	60	619	0.25	155	10.78	mod-sensitive	m	1.00	10.78	0.070	39
Toddy Pond	Blue Hill	4677	300	4377	0.3	1313	71.13	good	h	1.00	71.13	0.054	328
Adams Pond	Boothbay	869	87	782	0.3	235	8.31	mod-sensitive	h	0.75	6.23	0.027	59

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Per Acre Phosphorus Allocations for Selected Maine Lakes

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Lake Name	Town in which development is located	Direct Watershed Area in Town (acres) **DDA**	Area not available for development (acres) **ANAD**	Area available for development (acres) **AAD**	**GF**	Expected developed area (acres) **D**	(lbP/y) **F**	Water Quality Category **WQC**	**LOP**	**C**	**FC**	Per acre phosphorus allocation (lb/acre/yr) **P**	Small Watershed Threshold (acres) **SWT**
Knickerboocker Pond	Boothbay	726	73	653	0.3	196	8.31	mod-sensitive	h	0.75	6.23	0.032	49
West Harbor Pond	Boothbay	175	18	157	0.3	47	2.18	mod-sensitive	m	1.00	2.18	0.046	12
Wiley Pond	Boothbay	71	7	64	0.3	19	0.85	mod-sensitive	h	0.75	0.64	0.034	5
Pleasant Pond, Upper Basin #2	Bowdoin	2540	800	1740	0.2	348	16.73	poor restorable	m	0.50	8.37	0.024	87
Caesar Pond	Bowdoin	148	35	113	0.25	28	1.63	mod-sensitive	m	1.00	1.63	0.058	7
Jimmy Pond	Bowdoin	595	80	515	0.25	129	3.46	mod-sensitive	m	1.00	3.46	0.027	32
Stoddard Pond	Bowdoin	29	2	27	0.25	7	0.46	mod-sensitive	m	1.00	0.46	0.068	2
Sebec Lake	Bowerbank	11356	1200	10156	0.2	2031	157.4	good	h	1.00	157.41	0.077	508
Pemiquid Pond	Bremen	1999	200	1799	0.25	450	30.45	mod-sensitive	h	0.75	22.84	0.051	112
Biscay Pond	Bremen	906	91	815	0.25	204	17.97	mod-sensitive	h	0.75	13.48	0.066	51
Duckpuddle Pond	Bremen	29	0	29	0.15	4	0.26	mod-sensitive	m	1.00	0.26	0.060	1
McCurdy Pond	Bremen	479	48	431	0.25	108	9.61	mod-sensitive	h	0.75	7.21	0.067	27
Pemaquid Pond	Bremen	1999	200	1799	0.25	450	30.45	mod-sensitive	h	0.75	22.84	0.051	112
Webber Pond	Bremen	1494	200	1294	0.25	324	17.33	mod-sensitive	m	1.00	17.33	0.054	81
Peabody Pond	Bridgton	516	52	464	0.3	139	9.74	mod-sensitive	h	0.75	7.31	0.052	35
Long Lake	Bridgton	17672	1576	16096	0.4	6438	247.4	mod-sensitive	h	0.75	185.55	0.029	1610
Otter Pond	Bridgton	790	79	711	0.4	284	7.21	mod-sensitive	m	1.00	7.21	0.025	71
Highland Lake	Bridgton	3600	360	3240	0.4	1296	56.64	mod-sensitive	h	0.75	42.48	0.033	324
Woods Pond	Bridgton	3266	327	2939	0.35	1029	37.04	mod-sensitive	m	1.00	37.04	0.036	257
Adams Pond	Bridgton	172	17	155	0.35	54	2.77	mod-sensitive	h	0.75	2.08	0.038	14
Beaver Pond	Bridgton	1653	300	1353	0.4	541	13.05	mod-sensitive	m	1.00	13.05	0.024	135
Hancock Pond	Bridgton	358	40	318	0.3	95	6.19	mod-sensitive	h	0.75	4.64	0.049	24
Holt Pond	Bridgton	1877	400	1477	0.35	517	14.77	mod-sensitive	m	1.00	14.77	0.029	129
Ingalls Pond	Bridgton	1030	100	930	0.35	326	12.14	good	h	1.00	12.14	0.037	81
Kezar Pond	Bridgton	2651	250	2401	0.3	720	35.08	mod-sensitive	m	1.00	35.08	0.049	180
Moose Pond, Basin 1	Bridgton	773	150	623	0.35	218	8.73	mod-sensitive	h	0.75	6.55	0.030	55
Moose Pond, Basin 2	Bridgton	2777	400	2377	0.35	832	45.29	mod-sensitive	h	0.75	33.97	0.041	208
Biscay Pond	Bristol	649	65	584	0.25	146	12.87	mod-sensitive	h	0.75	9.65	0.066	37
Hastings Pond	Bristol	138	14	124	0.25	31	1.21	mod-sensitive	m	1.00	1.21	0.039	8
Little Pond	Bristol	56	6	50	0.25	13	0.79	mod-sensitive	m	1.00	0.79	0.061	3
Lower Pond	Bristol	74	7	67	0.25	17	0.74	mod-sensitive	m	1.00	0.74	0.044	4
Ross Pond	Bristol	108	11	97	0.25	24	1.25	mod-sensitive	h	0.75	0.94	0.039	6
Upper Pond	Bristol	101	10	91	0.25	23	0.99	mod-sensitive	h	0.75	0.74	0.032	6
Webber Pond	Bristol	180	18	162	0.25	41	2.09	mod-sensitive	m	1.00	2.09	0.051	10
Dutton Pond	Brooks	160	10	150	0.2	30	1.14	mod-sensitive	m	1.00	1.14	0.038	8
Ellis Pond	Brooks	434	25	409	0.2	82	4.49	mod-sensitive	m	1.00	4.49	0.055	20
Halfmoon Pond	Brooks	200	10	190	0.2	38	2.42	mod-sensitive	m	0.75	1.82	0.048	10

Appendix C

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Passagassawakeag Lake	Brooks	2191	220	1971	0.25	493	20.24	mod-sensitive	m	1.00	20.24	0.041	123
Sanborn Pond	Brooks	316	30	286	0.25	72	3.39	mod-sensitive	m	0.75	2.54	0.036	18
Toddy Pond	Brooks	469	30	439	0.2	88	5.15	mod-sensitive	m	1.00	5.15	0.059	22
Walker Pond	Brooksville	1680	160	1520	0.3	456	26.96	mod-sensitive	h	0.75	20.22	0.044	114
Baskahegan Lake	Brookton Twp	6182	1600	4582	0.15	687	61.76	mod-sensitive	m	1.00	61.76	0.090	172
Burnt Meadow Pond	Brownfield	2031	700	1331	0.2	266	17.66	mod-sensitive	h	0.75	13.25	0.050	67
Dyer Pond	Brownfield	360	30	330	0.2	66	2.49	mod-sensitive	m	1.00	2.49	0.038	17
Pequawket Lake	Brownfield	410	40	370	0.25	93	4.01	mod-sensitive	m	1.00	4.01	0.043	23
Pleasant Pond	Brownfield	227	30	197	0.2	39	1.98	mod-sensitive	m	1.00	1.98	0.050	10
Stone Pond	Brownfield	171	50	121	0.2	24	1.51	mod-sensitive	m	1.00	1.51	0.062	6
Schoodic Lake	Brownville	5305	1000	4305	0.25	1076	175.6	outstanding	h	0.50	87.79	0.082	269
Mud Pond (in Turner)	Buckfield	284	40	244	0.25	61	1.52	mod-sensitive	m	1.00	1.52	0.025	15
Mud Pond	Buckfield	42	0	42	0.25	11	0.37	mod-sensitive	m	1.00	0.37	0.035	3
North Pond	Buckfield	84	0	84	0.25	21	0.97	mod-sensitive	h	0.75	0.73	0.035	5
South Pond	Buckfield	1628	160	1468	0.25	367	10.58	mod-sensitive	m	1.00	10.58	0.029	92
Jacob Buck Pond	Bucksport	1275	128	1147	0.25	287	13.03	mod-sensitive	h	0.75	9.77	0.034	72
Alamoosook Lake	Bucksport	2011	250	1761	0.25	440	21.89	mod-sensitive	h	0.75	16.42	0.037	110
Brewer Pond	Bucksport	1111	60	1051	0.2	210	16.38	mod-sensitive	h	0.75	12.29	0.058	53
Hancock Pond	Bucksport	805	100	705	0.25	176	7.34	mod-sensitive	h	0.75	5.51	0.031	44
Hothole Pond	Bucksport	439	20	419	0.2	84	2.69	mod-sensitive	m	1.00	2.69	0.032	21
Long Pond	Bucksport	5623	700	4923	0.25	1231	45.04	mod-sensitive	m	1.00	45.04	0.037	308
McGann Bog Pond	Bucksport	412	100	312	0.2	62	2.49	mod-sensitive	m	1.00	2.49	0.040	16
Moulton Pond	Bucksport	168	10	158	0.2	32	2.09	good	h	1.00	2.09	0.066	8
Mud Pond	Bucksport	1013	100	913	0.2	183	9.12	mod-sensitive	m	1.00	9.12	0.050	46
Silver Lake	Bucksport	2562	260	2302	0.25	576	31.24	mod-sensitive	h	0.75	23.43	0.041	144
Thurston Pond	Bucksport	892	70	822	0.2	164	8.86	mod-sensitive	m	1.00	8.86	0.054	41
Williams Pond	Bucksport	768	100	668	0.2	134	7.25	mod-sensitive	h	0.75	5.44	0.041	33
Escutasis (Little) Lake	Burlington	449	50	399	0.2	80	5.55	mod-sensitive	m	1.00	5.55	0.070	20
Madagascal Pond	Burlington	2322	300	2022	0.2	404	17.86	mod-sensitive	h	0.75	13.40	0.033	101
Upper Pond	Burlington	2060	230	1830	0.2	366	20.92	mod-sensitive	m	1.00	20.92	0.057	92
Bonney Eagle Lake	Buxton	274	75	199	0.35	70	2.07	mod-sensitive	m	1.00	2.07	0.030	17
Beaver Lake	Calais	511	25	486	0.2	97	6.06	mod-sensitive	m	1.00	6.06	0.062	24
Flowed Land Pond	Calais	679	0	679	0.2	136	10	mod-sensitive	m	1.00	10.00	0.074	34
Howard Lake	Calais	647	35	612	0.25	153	8.18	mod-sensitive	h	0.75	6.14	0.040	38
Keenes Lake	Calais	780	20	760	0.25	190	8.93	mod-sensitive	h	0.75	6.70	0.035	48
Mud Lake	Calais	190	0	190	0.2	38	1.34	mod-sensitive	m	1.00	1.34	0.035	10
Nashs Lake	Calais	3694	200	3494	0.25	874	51.37	good	h	1.00	51.37	0.059	218

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Pennamaquan Lake	Calais	143	0	143	0.2	29	1.52	mod-sensitive	h	0.75	1.14	0.040	7
Pine Lake	Calais	145	0	145	0.2	29	1.6	mod-sensitive	m	1.00	1.60	0.055	7
Shattuck Lake	Calais	42	2	40	0.25	10	0.66	mod-sensitive	h	0.75	0.50	0.050	3
Unnamed Pond (0081)	Calais	19	0	19	0.2	4	0.19	mod-sensitive	m	1.00	0.19	0.050	1
Vose Pond	Calais	1598	0	1598	0.2	320	25	mod-sensitive	m	1.00	25.00	0.078	80
Megunticook Lake South Basin	Camden	2807	560	2247	0.3	674	42.07	mod-sensitive	h	0.75	31.55	0.047	169
Hosmer Pond	Camden	1168	300	868	0.3	260	9.37	mod-sensitive	m	1.00	9.37	0.036	65
Lilly Pond	Camden	24	2	22	0.3	7	0.3	mod-sensitive	m	1.00	0.30	0.045	2
Hobbs Pond	Camden	51	5	46	0.25	12	0.61	mod-stable	m	1.25	0.76	0.066	3
Mirror Lake	Camden	182	30	152	0.25	38	2.29	good	h	1.00	2.29	0.060	10
Lake George	Canaan	1455	400	1055	0.2	211	13.84	mod-sensitive	h	0.75	10.38	0.049	53
Morrill Pond	Canaan	464	150	314	0.2	63	3.85	mod-sensitive	h	0.75	2.89	0.046	16
Sibley Pond	Canaan	4341	700	3641	0.2	728	27.34	mod-sensitive	m	1.00	27.34	0.038	182
Unnamed Pond (in Twelvemile Stream)	Canaan	370	37	333	0.2	67	1.98	mod-sensitive	m	1.00	1.98	0.030	17
Anasagunticook Lake	Canton	941	100	841	0.25	210	9.96	mod-sensitive	m	0.75	7.47	0.036	53
Forest Pond	Canton	197	10	187	0.25	47	2.55	mod-sensitive	m	1.00	2.55	0.055	12
Etna Pond	Carmel	417	80	337	0.2	67	2.86	mod-sensitive	m	1.00	2.86	0.042	17
Flagstaff Lake	Carrabassett Val	6533	2000	4533	0.2	907	58.85	mod-sensitive	h	0.75	44.14	0.049	227
Gilman Pond	Carrabassett Val	1203	600	603	0.15	90	6.68	mod-sensitive	h	0.75	5.01	0.055	23
Reddington Pond	Carrabassett Val	622	210	412	0.25	103	5.79	mod-sensitive	h	0.75	4.34	0.042	26
Baskahegan Lake	Carroll Plt	9439	1400	8039	0.15	1206	94.3	mod-sensitive	m	1.00	94.30	0.078	301
Dipper Pond	Carroll Plt	66	10	56	0.15	8	0.44	mod-sensitive	m	1.00	0.44	0.052	2
Mill Privilege Lake	Carroll Plt	2614	300	2314	0.15	347	17.08	mod-sensitive	m	1.00	17.08	0.049	87
Pleasant Lake	Carroll Plt	1868	60	1808	0.15	271	22.9	mod-sensitive	h	0.75	17.18	0.063	68
Shaw Lake	Carroll Plt	2471	200	2271	0.15	341	18.87	mod-sensitive	m	1.00	18.87	0.055	85
Flagstaff Lake	Carrying Place T	6997	450	6547	0.15	982	63.04	mod-sensitive	h	0.75	47.28	0.048	246
Crescent Lake	Casco	904	103	801	0.35	280	12.3	mod-sensitive	h	0.75	9.23	0.033	70
Sebago Lake	Casco	8707	870	7837	0.35	2743	259.8	outstanding	h	0.50	129.92	0.047	686
Coffee Pond	Casco	452	135	317	0.35	111	7.91	mod-sensitive	h	0.75	5.93	0.053	28
Dumpling Pond	Casco	375	56	319	0.25	80	4.32	mod-sensitive	m	1.00	4.32	0.054	20
Hog Meadow Pond	Casco	135	25	110	0.25	28	1.41	mod-sensitive	m	1.00	1.41	0.051	7
Nubble Pond	Casco	187	95	92	0.25	23	1.6	poor restorable	m	0.50	0.80	0.035	6
Owl Pond	Casco	286	60	226	0.25	57	1.8	mod-sensitive	m	1.00	1.80	0.032	14
Panther Pond	Casco	2139	200	1939	0.35	679	33.58	mod-sensitive	h	0.75	25.19	0.037	170
Parker Pond	Casco	677	160	517	0.3	155	5.82	mod-sensitive	m	1.00	5.82	0.038	39
Pleasant Pond	Casco	768	300	468	0.35	164	15.12	outstanding	m	0.50	7.56	0.046	41

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Thomas Pond	Casco	2159	300	1859	0.4	744	21.05	mod-sensitive	h	0.75	15.79	0.021	186
Thompson Lake	Casco	2574	330	2244	0.3	673	41.98	outstanding	h	0.50	20.99	0.031	168
Unnamed Pond 8895	Casco	422	100	322	0.3	97	3.72	mod-sensitive	m	1.00	3.72	0.039	24
Unnamed Pond 8897	Casco	143	15	128	0.3	38	1.38	mod-sensitive	m	1.00	1.38	0.036	10
Chain of Ponds - Long	Chain of Ponds	9513	240	9273	0.15	1391	114.4	mod-sensitive	h	0.75	85.82	0.062	348
Chain of Ponds - Natanis	Chain of Ponds	2357	60	2297	0.15	345	28.24	mod-sensitive	h	0.75	21.18	0.061	86
China Lake West Basin	China	2804	672.96	2131.04	0.25	533	61.03	poor restorable		0.50	30.52	0.057	133
China Lake East Basin	China	11957	3587.1	8369.9	0.25	2092	142.7	poor restorable		0.50	71.36	0.034	523
Threemile Pond	China	1796	449	1347	0.25	337	20.96	poor restorable		0.50	10.48	0.031	84
Burnt Pond	Clifton	526	50	476	0.2	95	7.56	good	h	1.00	7.56	0.079	24
Little Burnt Pond	Clifton	286	40	246	0.2	49	2.27	mod-sensitive	m	1.00	2.27	0.046	12
Cedar Swamp Pond	Clifton	847	80	767	0.15	115	5.6	mod-sensitive	m	1.00	5.60	0.049	29
Chemo Pond	Clifton	6810	1500	5310	0.25	1328	67.8	mod-sensitive	h	0.75	50.85	0.038	332
Cranberry Pond	Clifton	457	150	307	0.15	46	3.74	mod-sensitive	m	1.00	3.74	0.081	12
Debec Pond	Clifton	244	150	94	0.2	19	2.13	mod-sensitive	h	0.75	1.60	0.085	5
Fitts Pond	Clifton	395	60	335	0.2	67	4.25	good	h	1.00	4.25	0.063	17
Floods Pond	Clifton	551	125	426	0.2	85	11.22	good	h	1.00	11.22	0.132	21
Graham Lake	Clifton	869	80	789	0.2	158	12.43	good	m	1.50	18.65	0.118	39
Hopkins Pond	Clifton	1025	100	925	0.2	185	17.75	good	h	1.00	17.75	0.096	46
Lower Springy Pond	Clifton	1158	250	908	0.2	182	13.49	mod-sensitive	h	0.75	10.12	0.056	45
Middle Springy Pond	Clifton	69	35	34	0.2	7	0.79	mod-sensitive	m	1.00	0.79	0.116	2
Parks Pond	Clifton	966	135	831	0.25	208	10.91	good	h	1.00	10.91	0.053	52
Snowshoe Pond	Clifton	81	8	73	0.2	15	0.68	mod-sensitive	m	1.00	0.68	0.047	4
Upper Springy Pond	Clifton	672	120	552	0.2	110	5.4	mod-sensitive	m	1.00	5.40	0.049	28
Unnamed Pond 9558	Clifton	108	8	100	0.15	15	0.97	mod-sensitive	m	1.00	0.97	0.065	4
Unnamed Pond 9520	Clifton	343	40	303	0.15	45	2.22	mod-sensitive	m	1.00	2.22	0.049	11
Baskahegan Lake	Codyville Plt	66	5	61	0.15	9	0.66	mod-sensitive	m	1.00	0.66	0.072	2
Big Cathance Lake	Cooper	7138	350	6788	0.2	1358	132.4	good	h	1.00	132.41	0.098	339
Alder Stream Impoundment	Corinna	8181	1600	6581	0.2	1316	41.03	mod-sensitive	m	1.00	41.03	0.031	329
Brooks Pond	Corinna	363	60	303	0.2	61	2.38	mod-sensitive	m	1.00	2.38	0.039	15
Corundel Lake	Corinna	6839	1200	5639	0.25	1410	83.54	mod-sensitive	m	1.00	83.54	0.059	352
Mower Pond	Corinna	370	40	330	0.2	66	2.57	mod-stable	m	1.25	3.21	0.049	17
Sebasticook Lake	Corinna	5381	800	4581	0.2	916	60.48	poor-restorable	m	0.50	30.24	0.033	229
Unnamed Pond #0057	Corinna	736	70	666	0.2	133	4.23	mod-sensitive	m	1.00	4.23	0.032	33
Unnamed Pond #2263	Corinna	402	40	362	0.2	72	2.93	mod-sensitive	m	1.00	2.93	0.040	18
Weymouth Pond	Corinna	363	30	333	0.2	67	3.28	mod-sensitive	m	1.00	3.28	0.049	17
Forest Lake	Cumberland	165	50	115	0.35	40	1.6	mod-sensitive	m	1.00	1.60	0.040	10

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Fresh Pond	Cushing	192	20	172	0.25	43	1.91	mod-sensitive	m	1.00	1.91	0.044	11
South Pond	Cushing	783	10	773	0.2	155	7.69	mod-sensitive	m	1.00	7.69	0.050	39
Gull Pond	Dallas Plt.	1793	180	1613	0.2	323	9.79	mod-sensitive	h	0.75	7.34	0.023	81
Rangeley Lake	Dallas Plt.	1551	150	1401	0.2	280	28.51	good	h	1.00	28.51	0.102	70
Saddleback Lake	Dallas Plt.	4015	600	3415	0.25	854	25.04	mod-sensitive	h	0.75	18.78	0.022	213
Haley Pond	Dallas Plt.	2438	350	2088	0.25	522	22.09	mod-sensitive	m	1.00	22.09	0.042	131
Biscay Pond	Damariscotta	941	94	847	0.3	254	18.65	mod-sensitive	h	0.75	13.99	0.055	64
Little Pond	Damariscotta	340	34	306	0.3	92	4.8	mod-sensitive	h	0.75	3.60	0.039	23
Paradise Pond	Damariscotta	701	120	581	0.3	174	8.13	mod-sensitive	m	1.00	8.13	0.047	44
Pemaquid Pond	Damariscotta	1717	172	1545	0.3	464	26.15	mod-sensitive	h	0.75	19.61	0.042	116
Crooked Brook Flowage	Danforth	16333	3000	13333	0.2	2667	154.5	mod-sensitive	m	1.00	154.52	0.058	667
Baskahegan Lake	Danforth	333	5	328	0.15	49	3.32	mod-sensitive	m	1.00	3.32	0.067	12
Parker Pond	Dayton	12	1	11	0.25	3	0.19	mod-sensitive	m	1.00	0.19	0.069	1
Green Lake	Dedham	6244	350	5894	0.3	1768	117.9	good	h	1.00	117.85	0.067	442
Branch Lake	Dedham	1991	100	1891	0.3	567	31.79	good	h	1.00	31.79	0.056	142
Burnt Pond	Dedham	657	20	637	0.25	159	9.45	good	m	1.50	14.18	0.089	40
Floods Pond	Dedham	180	0	180	0.25	45	3.66	good	h	1.00	3.66	0.081	11
Goose Pond	Dedham	1094	100	994	0.25	249	12.89	good	m	1.50	19.34	0.078	62
Hanson Pond	Dedham	200	15	185	0.2	37	1.47	mod-sensitive	m	1.00	1.47	0.040	9
Harriman Pond	Dedham	143	30	113	0.25	28	3.06	outstanding	h	0.50	1.53	0.054	7
Hatcase Pond	Dedham	1331	80	1251	0.25	313	16.49	good	h	1.00	16.49	0.053	78
Holbrook Pond	Dedham	499	40	459	0.25	115	5	mod-sensitive	m	1.00	5.00	0.044	29
Hurd Pond	Dedham	929	110	819	0.25	205	7.62	mod-sensitive	h	0.75	5.72	0.028	51
Little Duck Pond	Dedham	39	8	31	0.2	6	0.39	mod-sensitive	m	1.00	0.39	0.063	2
Long Pond	Dedham	2841	500	2341	0.25	585	22.77	mod-sensitive	m	1.00	22.77	0.039	146
Mann Bog	Dedham	172	20	152	0.2	30	2.18	mod-sensitive	m	1.00	2.18	0.072	8
Mitchell Pond	Dedham	242	20	222	0.25	56	1.76	mod-sensitive	m	1.00	1.76	0.032	14
Moulton Pond	Dedham	138	30	108	0.25	27	1.69	good	h	1.00	1.69	0.063	7
Mountainy Pond	Dedham	2480	450	2030	0.25	508	40.5	mod-sensitive	h	0.75	30.38	0.060	127
Mud Pond	Dedham	143	15	128	0.2	26	1.23	mod-sensitive	h	0.75	0.92	0.036	6
Phillips Lake	Dedham	4262	1200	3062	0.3	919	67.56	good	h	1.00	67.56	0.074	230
Rocky Pond	Dedham	400	80	320	0.2	64	6.15	mod-sensitive	m	1.00	6.15	0.096	16
Rocky Pond (Little)	Dedham	108	10	98	0.25	25	0.94	mod-sensitive	m	1.00	0.94	0.038	6
Saulter Pond	Dedham	232	30	202	0.25	51	1.63	mod-sensitive	m	1.00	1.63	0.032	13
Second Pond	Dedham	489	45	444	0.25	111	5.4	mod-sensitive	h	0.75	4.05	0.036	28
Unnamed Pond (8533)	Dedham	160	5	155	0.2	31	1.05	mod-sensitive	m	1.00	1.05	0.034	8
Unnamed Pond (8535)	Dedham	358	10	348	0.2	70	2	mod-sensitive	m	1.00	2.00	0.029	17

Appendix C

Per Acre Phosphorus Allocations for Selected Maine Lakes

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Holt Pond	Deer Isle	172	26	146	0.2	29	1.47	mod-sensitive	m	1.00	1.47	0.050	7
Lily Pond	Deer Isle	237	45	192	0.25	48	2.6	mod-sensitive	h	0.75	1.95	0.041	12
Mill Pond	Deer Isle	429	64	365	0.25	91	4.63	mod-sensitive	m	1.00	4.63	0.051	23
Olivers Pond	Deer Isle	479	72	407	0.2	81	3.57	mod-sensitive	m	1.00	3.57	0.044	20
Torrey Pond	Deer Isle	770	115	655	0.2	131	5.53	mod-sensitive	m	1.00	5.53	0.042	33
Georges Pond	Deer Isle	14	3	11	0.3	3.3	0.15	mod-sensitive	m	1.00	0.15	0.045	1
Barker Pond	Denmark	911	50	861	0.2	172	12.85	mod-sensitive	h	0.75	9.64	0.056	43
Beaver Pond	Denmark	1284	65	1219	0.2	244	10.05	mod-sensitive	m	1.00	10.05	0.041	61
Boston Pond	Denmark	113	30	83	0.2	17	1.3	mod-sensitive	m	1.00	1.30	0.078	4
Browns Pond	Denmark	34	3	31	0.2	6	0.3	mod-sensitive	m	1.00	0.30	0.048	2
Granger Pond	Denmark	647	100	547	0.3	164	8.55	mod-sensitive	m	1.00	8.55	0.052	41
Hancock Pond	Denmark	1292	120	1172	0.3	352	22.31	mod-sensitive	h	0.75	16.73	0.048	88
Horseshoe Pond	Denmark	32	5	27	0.2	5	0.92	mod-sensitive	m	1.00	0.92	0.170	1
Kezar Pond	Denmark	2651	1000	1651	0.25	413	35.08	mod-sensitive	m	1.00	35.08	0.085	103
Lily Pond	Denmark	345	35	310	0.25	78	2.22	mod-sensitive	m	1.00	2.22	0.029	19
Long Lake	Denmark	1981	150	1831	0.25	458	27.76	mod-sensitive	h	0.75	20.82	0.045	114
Long Pond	Denmark	207	35	172	0.25	43	2.42	mod-stable	h	0.75	1.82	0.042	11
Moose Pond, Basin 2	Denmark	1588	500	1088	0.3	326	25.9	mod-sensitive	h	0.75	19.43	0.060	82
Moose Pond, Basin 3	Denmark	4381	650	3731	0.3	1119	67.78	mod-sensitive	h	0.75	50.84	0.045	280
Perley Pond	Denmark	281	25	256	0.25	64	3.61	mod-sensitive	h	0.75	2.71	0.042	16
Pickerel Pond	Denmark	271	20	251	0.25	63	3.5	mod-stable	m	1.00	3.50	0.056	16
Pleasant Pond	Denmark	2045	300	1745	0.2	349	17.88	mod-sensitive	m	1.00	17.88	0.051	87
Sand Pond	Denmark	1376	140	1236	0.3	371	17.04	mod-stable	h	0.75	12.78	0.034	93
Shaking Bog	Denmark	106	11	95	0.25	24	0.79	mod-sensitive	m	1.00	0.79	0.033	6
Unnamed Pond, Beaver Brook	Denmark	1761	300	1461	0.25	365	13.23	mod-sensitive	m	1.00	13.23	0.036	91
Carlton Pond	Detroit	3049	1000	2049	0.2	410	17.48	mod-stable	m	1.25	21.85	0.053	102
Alder Stream Impoundment	Dexter	143	25	118	0.2	24	0.7	mod-sensitive	m	1.00	0.70	0.030	6
Corundel Lake	Dexter	3553	500	3053	0.25	763	43.41	mod-sensitive	m	1.00	43.41	0.057	191
Gould Pond	Dexter	249	50	199	0.2	40	1.63	poor-restorable	m	0.50	0.82	0.020	10
Great Moose Lake	Dexter	7368	1000	6368	0.2	1274	50.8	mod-sensitive	m	0.75	38.10	0.030	318
Half Moon Pond	Dexter	79	5	74	0.2	15	0.48	mod-sensitive	m	1.00	0.48	0.032	4
Lily Pond	Dexter	66	2	64	0.2	13	0.7	mod-sensitive	m	1.00	0.70	0.055	3
Mower Pond	Dexter	202	20	182	0.2	36	1.41	mod-stable	m	1.25	1.76	0.048	9
Puffers Pond	Dexter	1013	125	888	0.25	222	8.93	mod-sensitive	h	0.75	6.70	0.030	56
Wassookeag Lake	Dexter	5577	600	4977	0.25	1244	77.35	good	h	1.00	77.35	0.062	311
West Garland Pond	Dexter	3666	300	3366	0.2	673	20.33	mod-sensitive	h	0.75	15.25	0.023	168
Branns Mill Pond	Dover-Foxcroft	3805	900	2905	0.2	581	23.52	mod-sensitive	m	1.00	23.52	0.040	145

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Dunham Pond	Dover-Foxcroft	126	0	126	0.2	25	1.14	mod-sensitive	m	1.00	1.14	0.045	6
Garland Pond	Dover-Foxcroft	365	20	345	0.2	69	3.3	mod-sensitive	m	1.00	3.30	0.048	17
Great Moose Lake	Dover-Foxcroft	509	30	479	0.2	96	3.5	mod-sensitive	m	1.00	3.50	0.037	24
Sebec Lake	Dover-Foxcroft	9105	700	8405	0.25	2101	126.2	good	h	1.00	126.21	0.060	525
Snow's Pond	Dover-Foxcroft	1423	80	1343	0.2	269	9.41	mod-sensitive	m	1.00	9.41	0.035	67
Runaround Pond	Durham	4371	400	3971	0.25	993	24.71	mod-sensitive	m	1.00	24.71	0.025	248
Moxie Pond	East Moxie Twp	17361	400	16961	0.15	2544	158.5	mod-sensitive	h	0.75	118.90	0.047	636
Molasses Pond	Eastbrook	2891	280	2611	0.25	653	57.19	good	h	1.00	57.19	0.088	163
Narraguagus Lake	Eastbrook	1880	170	1710	0.2	342	17.83	mod-sensitive	h	0.75	13.37	0.039	86
Spectacle Pond	Eastbrook	738	20	718	0.2	144	8.86	mod-sensitive	m	1.00	8.86	0.062	36
Chemo Pond	Eddington	3439	350	3089	0.25	772	34.24	mod-sensitive	m	1.00	34.24	0.044	193
Davis Pond	Eddington	3041	300	2741	0.25	685	27.65	mod-sensitive	m	1.00	27.65	0.040	171
Fitts Pond	Eddington	316	25	291	0.2	58	3.41	good	h	1.00	3.41	0.059	15
Hatcase Pond	Eddington	616	40	576	0.2	115	3.9	good	h	1.00	3.90	0.034	29
Holbrook Pond	Eddington	805	90	715	0.25	179	8.04	mod-sensitive	m	1.00	8.04	0.045	45
Mountainy Pond	Eddington	111	15	96	0.2	19	1.83	mod-sensitive	h	0.75	1.37	0.071	5
Lily Pond	Edgecomb	625	62	563	0.25	141	5.75	mod-sensitive	m	1.00	5.75	0.041	35
Sherman Lake	Edgecomb	2364	236	2128	0.25	532	16.31	mod-sensitive	m	1.00	16.31	0.031	133
Branch Lake	Ellsworth	11559	1000	10559	0.25	2640	184.5	good	h	1.00	184.51	0.070	660
Graham Lake	Ellsworth	3728	400	3328	0.3	998	53.33	good	m	1.50	80.00	0.080	250
Green Lake	Ellsworth	6434	700	5734	0.25	1434	121.5	good	h	1.00	121.47	0.085	358
Jesse Bog	Ellsworth	101	30	71	0.3	21	0.72	mod-sensitive	m	1.00	0.72	0.034	5
Little Duck Pond	Ellsworth	469	75	394	0.2	79	4.71	mod-sensitive	m	1.00	4.71	0.060	20
Little Rocky Pond	Ellsworth	731	150	581	0.2	116	6.37	mod-sensitive	m	1.00	6.37	0.055	29
Lower Patten Pond	Ellsworth	3036	400	2636	0.3	791	44.73	good	h	1.00	44.73	0.057	198
Upper Patten Pond	Ellsworth	405	50	355	0.25	89	3.9	mod-sensitive	h	1.00	3.90	0.044	22
Wormwood Pond	Ellsworth	605	50	555	0.2	111	3.83	mod-sensitive	m	1.00	3.83	0.035	28
Cold Stream Pond - Upper Basin	Enfield	684	160	524	0.25	131	9.08	outstanding	h	0.50	4.54	0.035	33
Cold Stream Pond - Lower Basin	Enfield	2045	200	1845	0.25	461	61.82	outstanding	h	0.50	30.91	0.067	115
Etna Pond	Etna	882	90	792	0.25	198	6.06	mod-sensitive		1.00	6.06	0.031	50
Flagstaff Lake	Eustis	23795	1500	22295	0.15	3344	214.3	mod-sensitive	h	0.75	160.76	0.048	836
Hutchinson Pond	Farmingdale	788	70	718	0.25	180	7.18	mod-sensitive	m	1.00	7.18	0.040	45
Jimmie Pond	Farmingdale	533	45	488	0.25	122	4.8	good	h	1.00	4.80	0.039	31
Hales Pond	Fayette	2233	300	1933	0.2	387	15.65	mod-sensitive	m	1.00	15.65	0.040	97
Baskahegan Lake	Forest Twp	66	5	61	0.15	9	0.66	mod-sensitive	m	1.00	0.66	0.072	2
Long Lake	Frenchville	338	50	288	0.2	58	4.96	mod-sensitive	h	0.75	3.72	0.065	14
Brishlotte Lake	Frenchville	269	40	229	0.2	46	1.47	mod-sensitive	m	1.00	1.47	0.032	11

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Kezar Pond	Fryeburg	3390	450	2940	0.25	735	44.84	mod-sensitive	m	1.00	44.84	0.061	184
Black Pond	Fryeburg	74	4	70	0.2	14	0.83	mod-sensitive	m	1.00	0.83	0.059	4
Bog Pond	Fryeburg	378	10	368	0.2	74	3.9	mod-sensitive	m	1.00	3.90	0.053	18
Cat Lake	Fryeburg	442	5	437	0.2	87	6.85	mod-sensitive	m	1.00	6.85	0.078	22
Clays Pond	Fryeburg	323	25	298	0.25	75	4.43	mod-sensitive	h	0.75	3.32	0.045	19
Dead Lake	Fryeburg	452	125	327	0.2	65	4.76	mod-sensitive	m	1.00	4.76	0.073	16
Horseshoe Pond	Fryeburg	24	5	19	0.2	4	0.5	mod-sensitive	m	1.00	0.50	0.132	1
Horseshoe Pond 1	Fryeburg	138	4	134	0.2	27	1.41	mod-sensitive	m	1.00	1.41	0.053	7
Hunt Pond	Fryeburg	123	5	118	0.2	24	1.32	mod-sensitive	m	1.00	1.32	0.056	6
Little Pond	Fryeburg	14	0	14	0.2	3	0.15	mod-sensitive	m	1.00	0.15	0.054	1
Lovewell Pond	Fryeburg	3101	250	2851	0.25	713	52.56	mod-sensitive	m	1.00	52.56	0.074	178
Lower Kimball Lake	Fryeburg	748	75	673	0.25	168	8.79	mod-sensitive	h	0.75	6.59	0.039	42
Peat Pond	Fryeburg	222	5	217	0.2	43	1.74	mod-sensitive	m	1.00	1.74	0.040	11
Pleasant Pond	Fryeburg	2656	900	1756	0.2	351	23.32	mod-sensitive	m	1.00	23.32	0.066	88
Round Pond	Fryeburg	59	3	56	0.2	11	0.55	mod-sensitive	h	0.75	0.41	0.037	3
Wards Pond	Fryeburg	1186	250	936	0.25	234	8.4	mod-sensitive	m	1.00	8.40	0.036	59
Branns Mill Pond	Garland	3899	800	3099	0.2	620	24.1	mod-sensitive	m	1.00	24.10	0.039	155
Garland Pond	Garland	2681	300	2381	0.2	476	16.58	mod-sensitive	m	1.00	16.58	0.035	119
Great Moose Lake	Garland	4193	900	3293	0.2	659	28.9	mod-sensitive	h	0.75	21.68	0.033	165
West Garland Pond	Garland	1294	300	994	0.2	199	7.18	mod-sensitive	h	1.00	7.18	0.036	50
Pushaw Lake	Glenburn	5152	700	4452	0.25	1113	44.62	mod-sensitive	m	1.00	44.62	0.040	278
Wytopitlock Lake	Glenwood Plt	2555	230	2325	0.2	465	28.81	mod-sensitive	m	1.00	28.81	0.062	116
Bogus Meadow Pond	Gouldsboro	153	3	150	0.15	23	1.25	mod-sensitive	m	1.00	1.25	0.056	6
Forbes Pond	Gouldsboro	3721	350	3371	0.2	674	26.81	mod-sensitive	m	1.00	26.81	0.040	169
Jones Pond	Gouldsboro	2006	220	1786	0.25	447	29.94	mod-sensitive	h	0.75	22.46	0.050	112
Lily Pond	Gouldsboro	234	20	214	0.2	43	2.31	mod-sensitive	m	1.00	2.31	0.054	11
Lower West Bay Pond	Gouldsboro	1532	100	1432	0.15	215	18.47	mod-sensitive	m	1.00	18.47	0.086	54
Morancy Pond	Gouldsboro	118	0	118	0.15	18	1.01	mod-sensitive	h	0.75	0.76	0.043	4
Muckleberry Pond	Gouldsboro	14	0	14	0.15	2	0.11	mod-sensitive	m	1.00	0.11	0.052	1
West Bay Pond	Gouldsboro	1653	100	1553	0.15	233	14.15	mod-sensitive	h	0.75	10.61	0.046	58
Crystal Lake	Gray	941	94	847	0.3	254	13.86	mod-sensitive	m	1.00	13.86	0.055	64
Little Sebago Lake, Upper Bay	Gray	1818	182	1636	0.3	491	14.9	mod-sensitive	m	1.00	14.90	0.030	123
Little Sebago Lake, Main Basin	Gray	2858	300	2558	0.3	767	44.51	mod-sensitive	h	0.75	33.38	0.044	192
Notched Pond	Gray	148	8	140	0.3	42	1.8	mod-sensitive	m	1.00	1.80	0.043	11
Forest Lake	Gray	639	100	539	0.3	162	6.19	mod-sensitive	m	1.00	6.19	0.038	40
Sabattus Pond	Greene	7674	1200	6474	0.25	1619	71.68	poor restorable	m	0.50	35.84	0.022	405
Little Sabattus Pond	Greene	914	90	824	0.2	165	5.46	mod-sensitive	m	1.00	5.46	0.033	41

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Allen Pond	Greene	1687	170	1517	0.25	379	15.74	mod-sensitive	h	0.75	11.81	0.031	95
Moosehead Lake	Greenville	7393	739	6654	0.25	1664	163.5	good	h	1.00	163.50	0.098	416
Lower Wilson Pond	Greenville	3634	300	3334	0.25	834	70.42	good	h	1.00	70.42	0.084	208
Sawyer Pond	Greenville	617	50	567	0.2	113	5.68	mod-sensitive	h	0.75	4.26	0.038	28
Jimmie Pond	Hallowell	390	150	240	0.25	60	3.5	good	h	1.00	3.50	0.058	15
Hermon Pond	Hampden	59	6	53	0.3	16	0.35	poor-natural	m	2.00	0.70	0.044	4
Ben Annis Pond	Hampden	575	170	405	0.25	101	3.52	mod-sensitive	m	1.00	3.52	0.035	25
Patten Pond	Hampden	627	150	477	0.2	95	3.57	mod-sensitive	m	1.00	3.57	0.037	24
Howard Pond	Hanover	546	40	506	0.2	101	6.04	good	h	1.00	6.04	0.060	25
Crystal Lake	Harrison	4558	779	3779	0.4	1512	101.1	mod-sensitive	h	0.75	75.80	0.050	378
Long Lake	Harrison	8715	508	8207	0.4	3283	122	mod-sens	h	0.75	91.52	0.028	821
Bog Pond	Harrison	229	100	129	0.25	32	1.63	mod-sensitive	h	0.75	1.22	0.038	8
Island Pond	Harrison	467	50	417	0.25	104	4.34	mod-sensitive	h	0.75	3.26	0.031	26
Sebago Lake	Harrison	7010	700	6310	0.3	1893	209.2	outstanding	h	0.50	104.62	0.055	473
Anasagunticook Lake	Hartford	7321	500	6821	0.2	1364	77.54	mod-sensitive	h	0.75	58.16	0.043	341
Bear Pond	Hartford	788	150	638	0.25	160	8.26	mod-sensitive	m	1.00	8.26	0.052	40
Brettuns Pond	Hartford	340	10	330	0.2	66	3.1	mod-sensitive	m	1.00	3.10	0.047	17
Bunganock Pond	Hartford	1591	150	1441	0.2	288	10.62	mod-sensitive	m	1.00	10.62	0.037	72
Little Bear Pond	Hartford	3385	600	2785	0.2	557	22.51	mod-sensitive	m	1.00	22.51	0.040	139
Northeast Pond	Hartford	588	75	513	0.15	77	3.9	mod-sensitive	m	1.00	3.90	0.051	19
Swan Pond	Hartford	1754	150	1604	0.15	241	11.06	mod-sensitive	m	1.00	11.06	0.046	60
Unnamed Pond 6735	Hartford	434	40	394	0.15	59	2.86	mod-sensitive	m	1.00	2.86	0.048	15
Marshall Pond	Hebron	1578	175	1403	0.25	351	10.84	mod-sensitive	m	1.00	10.84	0.031	88
Mud Pond	Hebron	378	100	278	0.2	56	2.02	mod-sensitive	m	1.00	2.02	0.036	14
Ben Annis Pond	Hermon	202	70	132	0.25	33	1.23	mod-sensitive	m	1.00	1.23	0.037	8
George Pond	Hermon	7724	3000	4724	0.25	1181	37.22	mod-sensitive	m	1.00	37.22	0.032	295
Hermon Pond	Hermon	4329	600	3729	0.3	1119	24.91	poor-natural	m	2.00	49.82	0.045	280
Pug Pond	Hermon	56	28	28	0.25	7	0.37	mod-sensitive	m	1.00	0.37	0.053	2
Tracy Pond	Hermon	2238	1130	1108	0.25	277	12.92	mod-sensitive	m	1.00	12.92	0.047	69
Flagstaff Lake	Highland Plt	1865	40	1825	0.15	274	16.8	mod-sensitive	h	0.75	12.60	0.046	68
Gilman Pond	Highland Plt	21470	700	20770	0.15	3116	119	mod-sensitive	m	1.00	119.02	0.038	779
Barker Pond	Hiram	1569	230	1339	0.25	335	22.18	mod-sensitive	h	0.75	16.64	0.050	84
Bryant Pond	Hiram	696	100	596	0.2	119	4.98	mod-sensitive	m	1.00	4.98	0.042	30
Clemons Pond	Hiram	766	150	616	0.2	123	8.75	mod-sensitive	h	0.75	6.56	0.053	31
Ingalls Pond	Hiram	128	25	103	0.2	21	0.81	mod-sensitive	h	0.75	0.61	0.029	5
Jaybird Pond	Hiram	202	100	102	0.25	26	1.52	mod-sensitive	h	0.75	1.14	0.045	6
Little Clemons Pond	Hiram	227	45	182	0.25	46	1.96	mod-sensitive	m	1.00	1.96	0.043	11

Appendix C

Per Acre Phosphorus Allocations for Selected Maine Lakes

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Peqwaket Lake	Hiram	422	40	382	0.25	96	4.14	mod-sensitive	m	1.00	4.14	0.043	24
Southeast Pond	Hiram	37	2	35	0.25	9	0.33	mod-sensitive	m	1.00	0.33	0.038	2
Stanley Pond	Hiram	182	35	147	0.25	37	2.44	good	h	1.00	2.44	0.066	9
Trafton Pond	Hiram	941	150	791	0.2	158	8.55	mod-sensitive	h	0.75	6.41	0.041	40
Brewer Pond	Holden	901	80	821	0.25	205	13.29	mod-sensitive	h	0.75	9.97	0.049	51
Davis Pond	Holden	946	90	856	0.25	214	8.59	mod-sensitive	m	1.00	8.59	0.040	54
Fields Pond	Holden	696	80	616	0.25	154	8.55	mod-sensitive	m	1.00	8.55	0.056	39
George Pond	Holden	1423	75	1348	0.2	270	8.33	mod-sensitive	m	1.00	8.33	0.031	67
Holbrook Pond	Holden	2309	200	2109	0.25	527	23.72	mod-sensitive	m	1.00	23.72	0.045	132
Long Pond	Holden	3412	325	3087	0.25	772	27.34	mod-sensitive	h	0.75	20.51	0.027	193
Deer Pond	Hollis	64	20	44	0.35	15	1.6	mod-sensitive	h	0.75	1.20	0.078	4
Killick Pond	Hollis	2646	500	2146	0.25	537	16.11	mod-sensitive	m	1.00	16.11	0.030	134
Lily Pond	Hollis	239	45	194	0.25	49	1.67	mod-sensitive	m	1.00	1.67	0.034	12
Wales Pond	Hollis	407	20	387	0.2	77	2.73	mod-sensitive	m	1.00	2.73	0.035	19
Alford Lake	Hope	2374	150	2224	0.25	556	38.71	good	h	1.00	38.71	0.070	139
Cotton Pond	Hope	42	1	41	0.25	10	0.44	mod-sensitive	m	1.00	0.44	0.043	3
Crawford Pond	Hope	1193	150	1043	0.25	261	15.58	mod-sensitive	h	0.75	11.69	0.045	65
Fish Pond	Hope	617	30	587	0.25	147	7.96	mod-sensitive	m	1.00	7.96	0.054	37
Grassy Pond	Hope	331	45	286	0.25	72	2.95	mod-sensitive	h	0.75	2.21	0.031	18
Hobbs Pond	Hope	1655	180	1475	0.25	369	19.95	poor restorable	m	0.50	9.98	0.027	92
Lermond Pond	Hope	464	50	414	0.35	145	9.17	good	h	1.00	9.17	0.063	36
Lily Pond	Hope	197	15	182	0.25	46	2.27	mod-sensitive	m	1.00	2.27	0.050	11
Mansfield Pond	Hope	1363	100	1263	0.25	316	9.67	mod-sensitive	m	1.00	9.67	0.031	79
Megunticook Lake South Basin	Hope	1363	150	1213	0.25	303	20.44	mod-sensitive	h	0.75	15.33	0.051	76
Megunticook Lake North Basin	Hope	874	100	774	0.25	194	10.03	mod-sensitive	h	0.75	7.52	0.039	48
Mirror Lake	Hope	200	10	190	0.25	48	2.51	mod-sensitive	h	0.75	1.88	0.040	12
Sennebec Pond	Hope	1793	30	1763	0.2	353	16.03	mod-sensitive	h	0.75	12.02	0.034	88
Seven Tree Pond	Hope	168	5	163	0.2	33	2.13	mod-sensitive	h	0.75	1.60	0.049	8
Shermans Mill Pond	Hope	716	20	696	0.2	139	4.6	mod-sensitive	m	1.00	4.60	0.033	35
Mattawamkeag Lake Upper Basin	Island Falls	17637	2000	15637	0.2	3127	104.1	mod-sensitive	m	1.00	104.14	0.033	782
Mattawamkeag Lake Lower Basin	Island Falls	2095	200	1895	0.2	379	16.42	mod-sensitive	m	1.00	16.42	0.043	95
Pleasant Pond	Island Falls	1109	60	1049	0.25	262	31.2	outstanding	h	0.50	15.60	0.059	66
Meadow Pond	Islesboro	145	15	130	0.3	39	1.61	mod-sensitive	m	1.00	1.61	0.041	10
Long Pond, Upper Basin	Jackman	18245	2500	15745	0.1	1575	167.5	mod-sensitive	m	1.00	167.53	0.106	394
North Pond	Jay	593	40	553	0.2	111	5.51	mod-sensitive	m	1.00	5.51	0.050	28
Parker Pond	Jay	4781	400	4381	0.2	876	31.46	mod-sensitive	m	1.00	31.46	0.036	219
Pease Pond	Jay	531	40	491	0.25	123	4.96	mod-sensitive	m	1.00	4.96	0.040	31

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Robinson Pond	Jay	7	0.25	6.75	0.2	1	0.06	mod-sensitive	m	1.00	0.06	0.044	0
Unnamed Pond (8797)	Jay	170	10	160	0.15	24	1.12	mod-sensitive	m	1.00	1.12	0.047	6
Unnamed Pond (8801)	Jay	538	40	498	0.15	75	3.26	mod-sensitive	m	1.00	3.26	0.044	19
Wilson Pond	Jay	32	4	28	0.2	6	0.28	mod-sensitive	h	0.75	0.21	0.038	1
N. Basin, Damariscotta Lake	Jefferson	6404	640	5764	0.2	1153	75.85	mod-sensitive	h	0.75	56.89	0.049	288
Mid Basin, Damariscotta Lake	Jefferson	405	40	365	0.2	73	7.49	mod-sensitive	h	0.75	5.62	0.077	18
S. Basin, Damariscotta Lake	Jefferson	1776	178	1598	0.2	320	30.56	mod-sensitive	h	0.75	22.92	0.072	80
Cooks Pond	Jefferson	1581	158	1423	0.2	285	12.7	mod-sensitive	m	1.00	12.70	0.045	71
Travel Pond	Jefferson	2826	500	2326	0.2	465	17.26	mod-sensitive	m	1.00	17.26	0.037	116
Flagstaff Lake	Jim Pond Twp	9332	15	9317	0.15	1398	84.05	mod-sensitive	h	0.75	63.04	0.045	349
Flagstaff Lake	Kibby Twp	4198	15	4183	0.15	627	37.83	mod-sensitive	h	0.75	28.37	0.045	157
Whetstone Pond	Kingsbury Planta	291	10	281	0.2	56	5.84	mod-sensitive	h	0.75	4.38	0.078	14
Foss Pond	Kingsbury Planta	726	110	616	0.2	123	10.45	good	h	1.00	10.45	0.085	31
Hilton Pond 1	Kingsbury Planta	439	25	414	0.2	83	3.46	mod-sensitive	m	1.00	3.46	0.042	21
Hilton Pond 2	Kingsbury Planta	135	10	125	0.2	25	1.23	mod-sensitive	m	1.00	1.23	0.049	6
Baskahegan Lake	Kossuth Twp	23931	7100	16831	0.15	2525	239.1	mod-sensitive	m	1.00	239.08	0.095	631
Pleasant Lake	Kossuth Twp	6016	350	5666	0.15	850	73.8	mod-sensitive	h	0.75	55.35	0.065	212
Schoodic Lake	Lakeview Plt.	6538	500	6038	0.2	1208	216.5	outstanding	h	0.50	108.24	0.090	302
Mill Privilege Lake	Lakeville	513	40	473	0.15	71	3.35	mod-sensitive	m	1.00	3.35	0.047	18
Milton Pond	Lebanon	931	110	821	0.25	205	9.06	mod-sensitive	m	1.00	9.06	0.044	51
Nisbit Pond	Lebanon	111	20	91	0.25	23	0.77	mod-sensitive	m	1.00	0.77	0.034	6
Northeast Pond	Lebanon	1598	200	1398	0.25	350	12.81	mod-sensitive	m	1.00	12.81	0.037	87
Egg Pond	Lee	630	100	530	0.2	106	4.18	mod-sensitive	m	1.00	4.18	0.039	27
Green Pond	Lee	106	0	106	0.2	21	1.08	mod-sensitive	m	1.00	1.08	0.051	5
House Pond	Lee	93	5	88	0.15	13	0.57	mod-sensitive	h	0.75	0.43	0.032	3
Long Pond (Long, Caribou, Egg)	Lee	121	0	121	0.2	24	1.52	mod-sensitive	m	1.00	1.52	0.063	6
Madagascal Pond	Lee	1134	350	784	0.2	157	8.7	mod-sensitive	h	0.75	6.53	0.042	39
Mattakeunk Lake (Silver Lake)	Lee	3125	300	2825	0.2	565	32.32	good	m	1.50	48.48	0.086	141
Merril Pond	Lee	1465	500	965	0.25	241	14.57	mod-sensitive	m	1.00	14.57	0.060	60
Mill Pond	Lee	1596	175	1421	0.25	355	11.86	mod-sensitive	m	1.00	11.86	0.033	89
Number Three Pond	Lee	1949	200	1749	0.2	350	16.27	mod-sensitive	m	1.00	16.27	0.047	87
Round Pond	Lee	7	0	7	0.25	2	0.13	mod-sensitive	h	0.75	0.10	0.056	0
Saponac Pond	Lee	180	10	170	0.2	34	1.3	mod-sensitive	m	1.00	1.30	0.038	9
Weir Pond	Lee	1979	400	1579	0.2	316	10.87	mod-sensitive	h	0.75	8.15	0.026	79
Sabattus Pond	Leeds	2330	300	2030	0.25	508	21.78	poor restorable	m	0.50	10.89	0.021	127
Androscoggin Lake	Leeds	5700	1000	4700	0.3	1410	121	poor-restorable	m	0.50	60.51	0.043	353
Bonny Pond	Leeds	138	40	98	0.2	20	1.01	mod-sensitive	m	1.00	1.01	0.052	5

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Island Pond	Leeds	81	10	71	0.2	14	0.81	mod-sensitive	m	1.00	0.81	0.057	4
Little Sabattus Pond	Leeds	773	150	623	0.2	125	4.6	mod-sensitive	m	1.00	4.60	0.037	31
No Name Pond	Lewiston	724	100	624	0.3	187	6.96	mod-sensitive	h	0.75	5.22	0.028	47
Gilman Pond	Lexington Twp	19061	1500	17561	0.15	2634	105.7	mod-sensitive	m	1.00	105.68	0.040	659
Holland Pond (Sokokis L.)	Limerick	2327	500	1827	0.25	457	16.94	mod-sensitive	m	1.00	16.94	0.037	114
Pickerel Pond	Limerick	358	100	258	0.25	65	3.19	mod-sensitive	m	1.25	3.99	0.062	16
Unnamed Pond (Spencer Brook)	Limerick	691	70	621	0.2	124	3.79	mod-sensitive	m	1.00	3.79	0.031	31
Boyd Pond	Limington	336	35	301	0.25	75	2.82	mod-sensitive	m	1.00	2.82	0.037	19
Doles Pond	Limington	724	100	624	0.2	125	4.43	mod-sensitive	m	1.00	4.43	0.035	31
Horne Pond	Limington	1821	400	1421	0.25	355	17.97	mod-sensitive	h	0.75	13.48	0.038	89
Isinglass Pond	Limington	126	15	111	0.25	28	1.23	mod-sensitive	h	0.75	0.92	0.033	7
Killick Pond	Limington	103	10	93	0.2	19	0.63	mod-sensitive	m	1.00	0.63	0.034	5
Sand Pond	Limington	27	6	21	0.25	5	0.52	mod-sensitive	h	0.75	0.39	0.074	1
Wards Pond	Limington	783	160	623	0.25	156	6.41	mod-sensitive	m	1.00	6.41	0.041	39
Crooked Pond	Lincoln	1107	110	997	0.25	249	11.53	mod-sensitive	m	1.00	11.53	0.046	62
Folsom Pond	Lincoln	2438	200	2238	0.25	560	26.63	mod-sensitive	m	1.00	26.63	0.048	140
Mattanawcook Pond	Lincoln	10299	1600	8699	0.25	2175	91.97	mod-sensitive	m	1.00	91.97	0.042	544
Upper Pond	Lincoln	1924	130	1794	0.25	449	19.55	mod-sensitive	m	1.00	19.55	0.044	112
Caribou Pond (Caribou, Egg, & Long)	Lincoln	2050	150	1900	0.2	380	32.63	mod-sensitive	m	1.00	32.63	0.086	95
Egg Pond (Egg, Long, & Caribou)	Lincoln	420	30	390	0.2	78	4.71	mod-sensitive	m	1.00	4.71	0.060	20
Long Pond (Long, Caribou and Egg)	Lincoln	3417	210	3207	0.2	641	42.9	mod-sensitive	m	1.00	42.90	0.067	160
Madagascal Pond	Lincoln	3862	360	3502	0.2	700	29.7	mod-sensitive	h	0.75	22.28	0.032	175
Mattakeunk Lake (Silver Lake)	Lincoln	261	5	256	0.2	51	2.69	good	m	1.50	4.04	0.079	13
Cambolasse Pond	Lincoln	837	120	717	0.25	179	13.2	mod-sensitive	m	1.00	13.20	0.074	45
Center Pond	Lincoln	1262	120	1142	0.2	228	11.26	mod-sensitive	m	1.00	11.26	0.049	57
Cold Stream Pond - Upper Basin	Lincoln	2068	160	1908	0.2	382	27.45	mod-sensitive	h	0.75	20.59	0.054	95
Little Round Pond	Lincoln	385	15	370	0.25	93	4.12	mod-sensitive	h	0.75	3.09	0.033	23
Snag Pond	Lincoln	1102	170	932	0.2	186	15.96	mod-sensitive	m	1.00	15.96	0.086	47
Upper Cold Stream Pond (west)	Lincoln	736	160	576	0.25	144	14.2	outstanding	h	0.50	7.10	0.049	36
Upper Cold Stream Pond (east)	Lincoln	558	90	468	0.25	117	7.78	good	h	1.00	7.78	0.066	29
Norton Pond	Lincolnville	5228	700	4528	0.25	1132	41.87	mod-sensitive	h	0.75	31.40	0.028	283
Coleman Pond	Lincolnville	1225	125	1100	0.25	275	14.83	mod-sensitive	m	1.00	14.83	0.054	69
Knight Pond	Lincolnville	49	3	46	0.2	9	0.48	mod-sensitive	m	1.00	0.48	0.052	2
Levenseller Pond	Lincolnville	32	5	27	0.25	7	0.3	mod-sensitive	m	1.00	0.30	0.044	2

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Megunticook Lake Basin 1	Lincolnville	1176	240	936	0.25	234	17.61	mod-sensitive	h	0.75	13.21	0.056	59
Megunticook Lake Basin 2	Lincolnville	2513	250	2263	0.25	566	28.86	mod-sensitive	h	0.75	21.65	0.038	141
Moody Pond	Lincolnville	457	85	372	0.25	93	5.07	mod-sensitive	h	0.75	3.80	0.041	23
Pitcher Pond	Lincolnville	644	60	584	0.26	149	6.48	mod-sensitive	m	1.00	6.48	0.044	37
Sennebec Pond	Lincolnville	303	30	273	0.2	55	2.71	mod-sensitive	h	0.75	2.03	0.037	14
Tilden Pond	Lincolnville	59	3	56	0.2	11	0.55	mod-sensitive	m	1.00	0.55	0.049	3
Pleasant Pond, Upper Basin	Litchfield	7104	710	6394	0.2	1279	46.79	poor-restorable	m	0.50	23.40	0.018	320
Jimmy Pond	Litchfield	3197	800	2397	0.2	479	18.54	mod-sensitive	m	1.00	18.54	0.039	120
Woodbury Pond	Litchfield	1423	150	1273	0.3	382	22.88	mod-sensitive	h	0.75	17.16	0.045	95
Sand Pond	Litchfield	966	110	856	0.25	214	11.51	mod-sensitive	h	0.75	8.63	0.040	54
Long Pond	Livermore	1089	110	979	0.25	245	13.45	mod-sensitive	h	0.75	10.09	0.041	61
Bartlett Pond	Livermore	331	30	301	0.25	75	2.77	mod-sensitive	h	0.75	2.08	0.028	19
Brettuns Pond	Livermore	2048	100	1948	0.25	487	18.58	mod-sensitive	h	0.75	13.94	0.029	122
Nelson Pond	Livermore	64	30	34	0.25	9	0.66	mod-sensitive	m	1.00	0.66	0.078	2
Round Pond	Livermore	815	60	755	0.25	189	9.34	mod-sensitive	h	0.75	7.01	0.037	47
Farrington Pond	Lovell	340	30	310	0.25	78	3.88	mod-sensitive	m	1.00	3.88	0.050	19
Kezar Lake	Lovell	3780	250	3530	0.25	883	54.13	mod-sensitive	h	0.75	40.60	0.046	221
Alewife Pond	Lyman	308	20	288	0.25	72	2.16	mod-sensitive	m	1.00	2.16	0.030	18
Bunganut Pond	Lyman	1168	150	1018	0.3	305	17.08	mod-sensitive	h	0.75	12.81	0.042	76
Kennebunk Pond	Lyman	476	100	376	0.35	132	9.61	mod-sensitive	h	0.75	7.21	0.055	33
Parker Pond	Lyman	51	15	36	0.3	11	0.85	mod-sensitive	m	1.00	0.85	0.079	3
Roberts Pond	Lyman	1522	200	1322	0.25	331	10.27	mod-sensitive	m	1.00	10.27	0.031	83
Round Pond	Lyman	32	2	30	0.25	8	0.33	mod-sensitive	h	0.75	0.25	0.033	2
Shaker Pond	Lyman	756	50	706	0.2	141	5.29	mod-sensitive	m	1.00	5.29	0.037	35
Swan Pond	Lyman	459	45	414	0.25	104	7.32	mod-sensitive	h	0.75	5.49	0.053	26
Tarwater Pond	Lyman	1030	650	380	0.25	95	6.21	mod-sensitive	m	1.00	6.21	0.065	24
Wadley Pond	Lyman	1329	400	929	0.25	232	11.39	mod-sensitive	m	1.00	11.39	0.049	58
Wesserunstt Lake	Madison	10037	1004	9033	0.2	1807	92.05	mod-stable	h	1.00	92.05	0.051	452
Cobbossee Lake	Manchester	3405	320	3085	0.3	926	64.51	poor restorable	h	0.50	32.26	0.035	231
Graham Lake	Mariaville	8547	1000	7547	0.25	1887	122.2	mod-stable	m	1.25	152.75	0.081	472
Hopkins Pond	Mariaville	518	45	473	0.25	118	8.97	good	h	1.00	8.97	0.076	30
Oran Pond	Mariaville	69	5	64	0.25	16	1.32	mod-sensitive	m	1.00	1.32	0.083	4
Gardner Lake	Marion Twp.	830	100	730	0.25	183	18.34	mod-stable	h	1.00	18.34	0.100	46
Second Lake	Marion Twp.	12226	1000	11226	0.15	1684	124.1	mod-sensitive	h	0.75	93.05	0.055	421
Hogan Pond	Mechanic Falls	941	90	851	0.3	255	9.56	mod-sensitive	m	1.00	9.56	0.037	64
Jerry Pond	Millinocket	140	125	15	0.25	4	1.58	mod-sensitive	m	1.00	1.58	0.421	1
Little Wilson Pond	Minot	9	1	8	0.2	2	0.08	mod-sensitive	h	0.75	0.06	0.038	0

Appendix C | **Per Acre Phosphorus Allocations for Selected Maine Lakes** | Updated 11/8/10

Lake Name	Town in which development is located	Direct Watershed Area in Town (acres) **DDA**	Area not available for development (acres) **ANAD**	Area available for development (acres) **AAD**	**GF**	Expected developed area (acres) **D**	(lbP/y) **F**	Water Quality Category **WQC**	**LOP**	**C**	**FC**	Per acre phosphorus allocation (lb/acre/yr) **P**	Small Watershed Threshold (acres) **SWT**
Mud Pond	Minot	229	40	189	0.2	38	1.23	mod-sensitive	m	1.00	1.23	0.033	9
Taylor Pond	Minot	4813	500	4313	0.25	1078	43.79	mod-sensitive	m	1.00	43.79	0.041	270
The Basin	Minot	607	70	537	0.25	134	5.75	mod-sensitive	m	1.00	5.75	0.043	34
Androscoggin Lake	Monmouth	1623	250	1373	0.3	412	34.44	poor-restorable	m	0.50	17.22	0.042	103
Wilson Pond	Monmouth	1828	150	1678	0.3	503	20.77	mod-sensitive	m	1.00	20.77	0.041	126
Sabattus Pond	Monmouth	1877	150	1727	0.2	345	17.55	poor-restorable	m	0.50	8.78	0.025	86
Annabessacook Lake	Monmouth	6123	750	5373	0.25	1343	91.24	poor restorable	m	0.50	45.62	0.034	336
Bonny Pond	Monmouth	249	30	219	0.25	55	1.83	mod-sensitive	m	1.00	1.83	0.033	14
Cobbossee Lake	Monmouth	7304	900	6404	0.25	1601	138.5	poor restorable	h	0.50	69.23	0.043	400
Cochnewagon	Monmouth	1769	200	1569	0.25	392	23.65	mod-sensitive	h	0.75	17.74	0.045	98
Little Purgatory	Monmouth	49	0	49	0.25	12	0.46	mod-sensitive	m	1.00	0.46	0.038	3
Mud Pond	Monmouth	338	85	253	0.2	51	2.35	mod-sensitive	m	1.00	2.35	0.046	13
Sand Pond	Monmouth	207	70	137	0.25	34	2.46	mod-sensitive	h	0.75	1.85	0.054	9
Unnamed Pond (8137)	Monmouth	474	45	429	0.2	86	3.46	mod-sensitive	m	1.00	3.46	0.040	21
Woodbury Pond	Monmouth	187	10	177	0.25	44	3.04	mod-sensitive	h	1.00	3.04	0.069	11
Bubble Pond	Mount Desert	96	96	0	0	0	1.01	outstanding	h	0.50	0.51	Park	0
Eagle Lake	Mount Desert	86	86	0	0	0	1.98	outstanding	h	0.50	0.99	Park	0
Echo Lake	Mount Desert	716	290	426	0.3	128	10.89	good	h	1.00	10.89	0.085	32
Echo Lake (Little)	Mount Desert	311	30	281	0.3	84	4.49	mod-sensitive	m	0.75	3.37	0.040	21
Hodgdon Pond	Mount Desert	553	0	553	0	0	4.89	good	h	1.00	4.89	Park	0
Jordan Pond	Mount Desert	948	0	948	0	0	21.14	outstanding	h	0.50	10.57	Park	0
Little Round Pond	Mount Desert	172	20	152	0.25	38	1.63	mod-sensitive	m	1.00	1.63	0.043	10
Long Pond	Mount Desert	773	260	513	0.25	128	5.44	mod-sensitive	h	0.75	4.08	0.032	32
Long Pond	Mount Desert	2179	1000	1179	0.3	354	42.13	outstanding	h	0.50	21.07	0.060	88
Lower Hadlock Pond	Mount Desert	214	214	0	0	0	2.57	good	h	1.00	2.57	Park	0
Round Pond	Mount Desert	249	75	174	0.25	44	2.95	good	h	1.00	2.95	0.068	11
Somes Pond	Mount Desert	1042	200	842	0.3	253	17.59	mod-sensitive	h	0.75	13.19	0.052	63
Upper Hadlock Pond	Mount Desert	808	808	0	0	0	7.14	mod-sensitive	h	0.75	5.36	Park	0
Bog Pond	Mount Vernon	301	40	261	0.25	65	1.74	mod-sensitive	m	1.00	1.74	0.027	16
Desert Pond	Mount Vernon	484	30	454	0.2	91	3.79	mod-sensitive	h	0.75	2.84	0.031	23
Echo Lake	Mount Vernon	3229	300	2929	0.35	1025	66.56	good	h	1.00	66.56	0.065	256
Flying Pond	Mount Vernon	518	50	468	0.3	140	8.35	mod-sensitive	h	0.75	6.26	0.045	35
Ingham Pond	Mount Vernon	4279	450	3829	0.2	766	24.67	mod-sensitive	m	1.00	24.67	0.032	191
Long Pond, South Basin	Mount Vernon	5317	400	4917	0.3	1475	118.3	poor restorable	h	0.50	59.13	0.040	369
Maranacook Lake, North Basin	Mount Vernon	1272	50	1222	0.25	306	11.88	mod-sensitive	h	0.75	8.91	0.029	76
Messalonskee Lake	Mount Vernon	3830	300	3530	0.25	883	69.65	mod-sensitive	h	0.75	52.24	0.059	221
Minnehonk Lake	Mount Vernon	1116	200	916	0.35	321	20.13	good	h	1.00	20.13	0.063	80

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Moose Pond	Mount Vernon	711	40	671	0.25	168	5.24	mod-sensitive	m	1.00	5.24	0.031	42
Parker Pond	Mount Vernon	627	30	597	0.25	149	10.36	mod-sensitive	h	0.75	7.77	0.052	37
Torsey Pond	Mount Vernon	2162	140	2022	0.25	506	23.99	mod-sensitive	h	0.75	17.99	0.036	126
Unnamed Pond (8127)	Mount Vernon	64	0	64	0.25	16	0.59	mod-sensitive	m	1.00	0.59	0.037	4
Unnamed Pond (8129)	Mount Vernon	259	10	249	0.2	50	2.11	mod-sensitive	m	1.00	2.11	0.042	12
Long Lake	Naples	4546	455	4091	0.4	1636	63.63	mod-sens	h	0.75	47.72	0.029	409
Trickey Pond	Naples	528	100	428	0.4	171	14.13	outstanding	h	0.50	7.07	0.041	43
Brandy Pond (Bay of Naples)	Naples	2174	300	1874	0.4	750	37.9	mod-sensitive	h	0.75	28.43	0.038	187
Cold Rain Pond	Naples	469	50	419	0.3	126	3.92	mod-sensitive	h	0.75	2.94	0.023	31
Holt Pond	Naples	224	15	209	0.35	73	1.76	mod-sensitive	m	1.00	1.76	0.024	18
Peabody Pond	Naples	830	80	750	0.35	263	15.63	mod-sensitive	h	0.75	11.72	0.045	66
Sebago Lake	Naples	10968	1000	9968	0.4	3987	327.3	outstanding	h	0.50	163.67	0.041	997
Lily Pond	New Gloucester	615	120	495	0.3	149	4.43	mod-sensitive	m	1.00	4.43	0.030	37
Sabbathday Lake	New Gloucester	2609	300	2309	0.25	577	30.78	mod-sensitive	h	0.75	23.09	0.040	144
Upper Range Pond	New Gloucester	543	30	513	0.25	128	6.15	mod-sensitive	h	0.75	4.61	0.036	32
Gammon Pond	New Portland	126	30	96	0.2	19	0.97	mod-sensitive	m	1.00	0.97	0.051	5
Gilman Pond	New Portland	2908	450	2458	0.2	492	16.14	mod-sensitive	m	1.00	16.14	0.033	123
Hancock Pond	New Portland	14	0	14	0.2	3	0.15	mod-sensitive	h	0.75	0.11	0.040	1
Pennell Pond	New Portland	279	5	274	0.2	55	2.09	mod-sensitive	m	1.00	2.09	0.038	14
Porter Lake	New Vineyard	1882	150	1732	0.25	433	23.65	good	h	1.00	23.65	0.055	108
Bauds Pond	New Vineyard	2209	350	1859	0.25	465	21.63	mod-sensitive	m	1.00	21.63	0.047	116
Lily Pond	New Vineyard	506	50	456	0.25	114	7.76	mod-sensitive	m	1.00	7.76	0.068	29
Mill Pond	New Vineyard	751	75	676	0.25	169	9.67	mod-sensitive	m	1.00	9.67	0.057	42
Mosher Pond	New Vineyard	46	0	46	0.2	9	0.35	mod-sensitive	m	1.00	0.35	0.038	2
S. Basin, Damariscotta Lake	Newcastle	1267	127	1140	0.25	285	21.87	mod-sensitive	h	0.75	16.40	0.057	71
Sherman Lake	Newcastle	1942	194	1748	0.25	437	13.4	mod-sensitive	m	1.00	13.40	0.031	109
Sebasticook Lake	Newport	14027	1400	12627	0.25	3157	157.7	poor rest	m	0.50	78.83	0.025	789
Mud Pond	Newport	1660	400	1260	0.2	252	9.01	mod-sensitive	m	1.00	9.01	0.036	63
Nokomis Pond	Newport	632	100	532	0.25	133	7.1	mod-sensitive	m	1.00	7.10	0.053	33
Unnamed Pond #2263	Newport	459	20	439	0.15	66	3.32	mod-sensitive	m	1.00	3.32	0.050	16
Cooks Pond	Nobleboro	219	22	197	0.3	59	1.76	mod-sensitive	m	1.00	1.76	0.030	15
N. Basin, Damariscotta Lake	Nobleboro	165	16	149	0.3	45	1.96	mod-sensitive	h	0.75	1.47	0.033	11
Mid Basin, Damariscotta Lake	Nobleboro	4047	405	3642	0.3	1093	75.27	mod-sensitive	h	0.75	56.45	0.051	273
S. Basin, Damariscotta Lake	Nobleboro	1512	151	1361	0.3	408	26.12	mod-sensitive	h	0.75	19.59	0.048	102
Duckpuddle Pond	Nobleboro	1373	137	1236	0.3	371	12.32	mod-sensitive	m	1.00	12.32	0.033	93
Pemaquid Pond	Nobleboro	1868	206	1662	0.3	499	28.44	mod-sensitive	h	0.75	21.33	0.043	125
Tobias Pond	Nobleboro	165	16	149	0.3	45	1.43	mod-sensitive	m	1.00	1.43	0.032	11

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Fresh Pond	North Haven	951	150	801	0.15	120	9.04	mod-sensitive	h	0.75	6.78	0.056	30
Bog Lake	Northfield	1887	300	1587	0.25	397	37.74	mod-sensitive	h	0.75	28.31	0.071	99
Fulton Lake	Northfield	331	40	291	0.25	73	4.96	mod-sensitive	m	1.00	4.96	0.068	18
Hadley Lake	Northfield	3904	150	3754	0.2	751	39.91	mod-stable	m	1.25	49.89	0.066	188
Horseshoe Lake	Northfield	93	3	90	0.2	18	1.34	mod-sensitive	m	1.00	1.34	0.074	5
Long Lake	Northfield	689	35	654	0.2	131	10.95	mod-sensitive	m	1.00	10.95	0.084	33
Otter Lake	Northfield	79	0	79	0.15	12	0.7	mod-sensitive	m	1.00	0.70	0.059	3
Peaked Mountain Pond	Northfield	96	0	96	0.2	19	1.76	mod-sensitive	h	0.75	1.32	0.069	5
Belfast Reservoir #1	Northport	1326	70	1256	0.25	314	9.08	mod-sensitive	m	1.00	9.08	0.029	79
Belfast Reservoir #2	Northport	1084	55	1029	0.25	257	6.83	mod-sensitive	m	1.00	6.83	0.027	64
Knight Pond	Northport	795	150	645	0.25	161	7.6	mod-sensitive	m	1.00	7.60	0.047	40
Pitcher Pond	Northport	3800	380	3420	0.25	855	38.23	mod-sensitve	m	1.00	38.23	0.045	214
Tilden Pond	Northport	321	20	301	0.25	75	2.97	mod-sensitive	m	1.00	2.97	0.039	19
Pennesseewassee Lake	Norway	9673	1200	8473	0.25	2118	97.7	mod-sensitive	m	1.00	97.70	0.046	530
Sebago Lake	Norway	9725	500	9225	0.25	2306	290.2	outstanding	h	0.50	145.10	0.063	577
Sand Pond	Norway	538	50	488	0.25	122	8.51	mod-sensitive	h	0.75	6.38	0.052	31
Meduxnekeag Lake	Oakfield	6958	500	6458	0.15	969	70.05	mod-sensitive	h	0.75	52.54	0.054	242
Skitacook Lake	Oakfield	3943	320	3623	0.2	725	33.86	mod-sensitive	m	1.00	33.86	0.047	181
Spaulding Lake	Oakfield	2446	200	2246	0.2	449	17.75	mod-sensitive	h	0.75	13.31	0.030	112
McGrath Pond	Oakland	2102	230	1872	0.25	468	23.59	mod-sensitive	h	0.75	17.69	0.038	117
East Pond	Oakland	1270	130	1140	0.3	342	26.51	poor restorable	m	0.50	13.26	0.039	86
Alamoosook Lake	Orland	9901	990	8911	0.25	2228	107.8	mod-sensitive	h	0.75	80.84	0.036	557
Toddy Pond	Orland	2399	240	2159	0.25	540	36.49	good	h	1.00	36.49	0.068	135
Branch Lake	Orland	1423	120	1303	0.3	391	22.71	good	h	1.00	22.71	0.058	98
Craig Pond	Orland	595	70	525	0.25	131	13.4	outstanding	h	0.50	6.70	0.051	33
Heart Pond	Orland	546	60	486	0.3	146	6.9	mod-sensitive	h	0.75	5.18	0.035	36
Hothole Pond	Orland	5512	800	4712	0.2	942	33.69	mod-sensitive	h	0.75	25.27	0.027	236
Jesse Bog	Orland	254	10	244	0.2	49	1.8	mod-sensitive	m	1.00	1.80	0.037	12
Little Pond	Orland	84	0	84	0.2	17	0.7	mod-sensitive	m	1.00	0.70	0.042	4
Long Pond	Orland	266	20	246	0.2	49	2.13	mod-sensitive	m	1.00	2.13	0.043	12
Lower Patten Pond	Orland	79	0	79	0.25	20	1.16	mod-sensitive	h	0.75	0.87	0.044	5
Rocky Pond	Orland	1109	120	989	0.25	247	11.2	mod-sensitive	m	1.00	11.20	0.045	62
Upper Patten Pond	Orland	2260	200	2060	0.3	618	21.8	mod-sensitive	h	0.75	16.35	0.026	155
Little Pond	Otisfield	340	25	315	0.25	79	2.6	mod-sensitive	m	1.00	2.60	0.033	20
Moose Pond	Otisfield	1153	100	1053	0.25	263	10.18	mod-sensitive	m	1.00	10.18	0.039	66
Pleasant Lake	Otisfield	2841	300	2541	0.35	889	55.89	outstanding	h	0.50	27.95	0.031	222
Saturday Pond	Otisfield	835	70	765	0.25	191	9.17	mod-sensitive	h	0.75	6.88	0.036	48

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Sebago Lake	Otisfield	11986	1000	10986	0.3	3296	357.7	outstanding	h	0.50	178.85	0.054	824
Thompson Lake	Otisfield	8806	750	8056	0.3	2417	143.6	outstanding	h	0.50	71.79	0.030	604
Hogan Pond	Oxford	1361	130	1231	0.25	308	13.82	mod-sensitive	m	1.00	13.82	0.045	77
Whitney Pond	Oxford	706	80	626	0.3	188	8.26	mod-sensitive	m	1.00	8.26	0.044	47
Thompson Lake	Oxford	5307	500	4807	0.25	1202	86.52	outstanding	h	0.50	43.26	0.036	300
Halls Pond	Paris	148	20	128	0.25	32	1.94	mod-sensitive	h	0.75	1.46	0.045	8
Marshall Pond	Paris	1561	200	1361	0.25	340	10.73	mod-sensitive	m	1.00	10.73	0.032	85
Mud Pond (Cole Pond)	Paris	138	10	128	0.2	26	0.83	mod-sensitive	m	1.00	0.83	0.032	6
Paine Pond	Paris	212	20	192	0.2	38	1.76	mod-sensitive	m	1.00	1.76	0.046	10
Alamoosook Lake	Penobscot	1149	100	1049	0.2	210	12.5	mod-sensitive	h	0.75	9.38	0.045	52
Pierce Pond	Penobscot	1697	100	1597	0.15	240	13.61	mod-sensitive	m	1.00	13.61	0.057	60
Toddy Pond	Penobscot	2663	250	2413	0.25	603	40.5	good	h	1.00	40.50	0.067	151
Turtle Pond	Penobscot	222	20	202	0.2	40	1.58	mod-sensitive	m	1.00	1.58	0.039	10
Wight Pond	Penobscot	5831	300	5531	0.2	1106	45.33	mod-sensitive	m	1.00	45.33	0.041	277
Abbott Pond	Peru	17	10	7	0.2	1	0.15	mod-sensitive	m	1.00	0.15	0.107	0
Anasagunticook Lake	Peru	298	150	148	0.2	30	3.17	mod-sensitive	h	0.75	2.38	0.080	7
Big Concord Pond	Peru	56	25	31	0.2	6	0.46	mod-sensitive	h	0.75	0.35	0.056	2
Mud Pond	Peru	1378	300	1078	0.2	216	8.29	mod-sensitive	m	1.00	8.29	0.038	54
Worthley Pond	Peru	3518	800	2718	0.25	680	39.97	mod-sensitive	h	0.75	29.98	0.044	170
Long Cove Pond	Phillips	118	0	118	0.2	24	1.01	mod-sensitive	h	0.75	0.76	0.032	6
Lufkin Pond	Phillips	575	0	575	0.2	115	5.84	mod-sensitive	h	0.75	4.38	0.038	29
Mud Pond	Phillips	29	0	29	0.2	6	0.22	mod-sensitive	h	0.75	0.17	0.028	1
Stetson Pond	Phillips	64	0	64	0.2	13	0.99	mod-sensitive	h	0.75	0.74	0.058	3
Toothaker Pond	Phillips	51	10	41	0.25	10	0.72	poor restorable	m	0.50	0.36	0.035	3
Webb Lake	Phillips	830	200	630	0.25	158	8.07	mod-sensitive	h	0.75	6.05	0.038	39
Big Pond	Phippsburg	101	15	86	0.25	22	1.05	mod-sensitive	m	1.00	1.05	0.049	5
Center Pond	Phippsburg	966	90	876	0.25	219	7.27	mod-sensitive	m	1.00	7.27	0.033	55
Meetinghouse Pond	Phippsburg	69	15	54	0.25	14	0.66	mod-sensitive	m	1.00	0.66	0.049	3
Silver Lake	Phippsburg	64	5	59	0.25	15	0.63	mod-sensitive	h	0.75	0.47	0.032	4
Spirit Lake	Phippsburg	301	20	281	0.25	70	3.68	mod-sensitive	m	1.00	3.68	0.052	18
Sprague Lake	Phippsburg	395	50	345	0.2	69	2.91	mod-sensitive	h	0.75	2.18	0.032	17
Wat-tuh Lake	Phippsburg	499	40	459	0.25	115	3.77	mod-sensitive	m	1.00	3.77	0.033	29
Sibley Pond	Pittsfield	9046	905	8141	0.2	1628	56.95	m-sens	m	1.00	56.95	0.035	407
Joice Pond	Pittston	128	30	98	0.2	20	1.47	mod-sensitive	m	1.00	1.47	0.075	5
Nehumkeag Pond	Pittston	1559	50	1509	0.2	302	14.15	mod-sensitive	m	1.00	14.15	0.047	75
Unnamed Pond (in Dresden)	Pittston	471	25	446	0.2	89	3.21	mod-sensitive	m	1.00	3.21	0.036	22
Big Cathance Lake	Plantation # 14	1514	100	1414	0.2	283	28.09	good	h	1.00	28.09	0.099	71

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Cathance Lake	Plantation # 14	1514	100	1414	0.2	283	28.09	mod-sensitive	h	1.00	28.09	0.099	71
Gilman Pond	Pleasant Ridge	1855	200	1655	0.1	166	10.29	mod-sensitive	m	1.00	10.29	0.062	41
Plymouth Pond	Plymouth	4156	1000	3156	0.25	789	21.63	mod-stable	m	1.25	27.04	0.034	197
Worthley Pond	Poland	936	94	842	0.25	211	7.43	mod-sensitive	h	0.75	5.57	0.026	53
Hogan Pond	Poland	155	15	140	0.3	42	1.56	mod-sensitive	m	1.00	1.56	0.037	11
Crescent Pond	Poland	96	5	91	0.2	18	1.32	mod-sensitive	h	0.75	0.99	0.054	5
Lower Range Pond	Poland	2214	530	1684	0.25	421	31.26	mod-sensitive	h	0.75	23.45	0.056	105
Middle Range Pond	Poland	3170	300	2870	0.25	718	43.52	mod-sensitive	h	0.75	32.64	0.045	179
Mud Pond (3752)	Poland	958	200	758	0.25	190	5.07	mod-sensitive	m	1.00	5.07	0.027	47
Mud Pond (3756)	Poland	318	35	283	0.25	71	2.22	mod-sensitive	m	1.00	2.22	0.031	18
Sabbathday Lake	Poland	200	20	180	0.25	45	2.38	mod-sensitive	h	0.75	1.79	0.040	11
Shaker Bog	Poland	378	40	338	0.25	85	4.6	mod-sensitive	m	1.00	4.60	0.054	21
Thompson Lake	Poland	2868	300	2568	0.25	642	46.76	outstanding	h	0.50	23.38	0.036	161
Tripp Pond	Poland	3993	350	3643	0.25	911	44.34	mod-sensitive	m	1.00	44.34	0.049	228
Upper Range Pond	Poland	1692	250	1442	0.25	361	19.13	mod-sensitive	h	0.75	14.35	0.040	90
Portage Lake	Portage Lake	9945	2500	7445	0.25	1861	167.1	mod-sensitive	h	0.75	125.33	0.067	465
Little Machias Lake	Portage Lake	3167	1300	1867	0.15	280	18.61	mod-sensitive	h	0.75	13.96	0.050	70
St. Froid Lake	Portage Lake	1984	1000	984	0.2	197	22.68	mod-sensitive	h	0.75	17.01	0.086	49
Baskahegan Lake	Prentiss Plt	3921	500	3421	0.15	513	39.18	mod-sensitive	m	1.00	39.18	0.076	128
Pocamoonshine Lake	Princeton	12762	2800	9962	0.2	1992	148	mod-sensitive	m	1.00	147.95	0.074	498
Mill Privilege Lake	Pukakon Twp / T	343	20	323	0.15	48	2.24	mod-sensitive	m	1.00	2.24	0.046	12
Shaw Lake	Pukakon Twp / T	197	30	167	0.15	25	1.49	mod-sensitive	m	1.00	1.49	0.059	6
Mooselookmeguntic	Rangeley	7509	1500	6009	0.25	1502	141.6	m-sens	h	0.75	106.20	0.071	376
Rangeley Lake	Rangeley	7702	770	6932	0.3	2080	141.5	good	h	1.00	141.51	0.068	520
Haley Pond	Rangeley	410	50	360	0.25	90	3.72	mod-sensitive	m	1.00	3.72	0.041	23
Gull Pond	Rangeley	879	112	767	0.3	230	8.82	mod-sensitive	h	0.75	4.62	0.020	58
Cloutman Pond	Rangeley	150	10	140	0.2	28	1.56	mod-sensitive	m	1.00	1.56	0.056	7
Dodge Pond	Rangeley	1482	100	1382	0.25	346	14.9	mod-sensitive	h	0.75	11.18	0.032	86
Loon Lake	Rangeley	170	0	170	0.2	34	2.53	mod-sensitive	h	0.75	1.90	0.056	9
Nutting Pond	Rangeley	86	30	56	0.2	11	0.92	mod-sensitive	m	1.00	0.92	0.082	3
Quimby Pond	Rangeley	256	100	156	0.3	47	4.14	poor restorable	h	0.50	2.07	0.044	12
Ross Pond	Rangeley	674	40	634	0.15	95	3.57	mod-sensitive	m	1.00	3.57	0.038	24
Round Pond	Rangeley	6844	1000	5844	0.15	877	49.17	mod-sensitive	h	0.75	36.88	0.042	219
Mooselookmeguntic Lake	Rangeley Planta	8915	700	8215	0.2	1643	169.1	mod-sensitive	h	0.75	126.80	0.077	411
Rangeley Lake	Rangeley Plt	12330	1000	11330	0.25	2833	226.5	good	h	1.00	226.50	0.080	708
Panther Pond	Raymond	5530	400	5130	0.35	1796	86.78	mod sensitive	h	0.75	65.09	0.036	449
Farwell Bog	Raymond	1045	209	836	0.25	209	6.35	mod-stable	m	1.25	7.94	0.038	52

Appendix C

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Little Sebago Lake, Upper Bay	Raymond	2065	125	1940	0.25	485	16.95	mod-sensitive	m	1.00	16.95	0.035	121
Little Sebago Lake, Main Basin	Raymond	412	12	400	0.25	100	6.43	mod-sensitive	m	1.00	6.43	0.064	25
Notched Pond	Raymond	200	19	181	0.3	54	2.44	mod-sensitive	m	1.00	2.44	0.045	14
Nubble Pond	Raymond	175	30	145	0.25	44	1.49	poor-restorable	m	0.50	0.75	0.020	11
Raymond Pond	Raymond	2772	120	2652	0.3	796	28.7	mod-sensitive	h	0.75	21.53	0.027	199
Sabbathday Lake	Raymond	600	54	546	0.25	137	7.07	mod-sensitive	h	0.75	5.30	0.039	34
Sebago Lake	Raymond	4410	1323	3087	0.35	1080	131.6	outstanding	h	0.50	65.81	0.061	270
Thompson Lake	Raymond	135	0	135	0.25	34	2.2	outstanding	h	0.50	1.10	0.033	8
Unnamed Pond	Raymond	29	3	26	0.25	7	0.26	mod-sensitive	m	1.00	0.26	0.040	2
Upper Range Pond	Raymond	375	25	350	0.25	88	4.25	mod-sensitive	h	0.75	3.19	0.036	22
Crescent Lake	Raymond	2898	290	2608	0.35	913	39.38	mod-sensitive	h	0.75	29.54	0.032	228
Thomas Pond	Raymond	716	72	644	0.35	225	6.97	mod-sensitive	h	0.75	5.23	0.023	56
Berry Pond	Readfield	1307	100	1207	0.25	302	8.73	mod-sensitive	m	1.00	8.73	0.029	75
Bog Pond	Readfield	1230	120	1110	0.2	222	7.12	mod-sensitive	m	1.00	7.12	0.032	56
Carlton Pond	Readfield	1383	400	983	0.25	246	16.93	mod-sensitive	h	0.75	12.70	0.052	61
Echo Lake	Readfield	311	30	281	0.3	84	6.41	good	h	1.00	6.41	0.076	21
Little Cobbossee Lake	Readfield	533	50	483	0.2	97	4.07	poor restorable	m	0.50	2.04	0.021	24
Lovejoy Pond	Readfield	1158	100	1058	0.3	317	23.08	mod-sensitive	h	0.75	17.31	0.055	79
Maranacook Lake, South Basin	Readfield	2908	250	2658	0.25	665	46.15	mod sensitive	h	0.75	34.61	0.052	166
Maranacook Lake, North Basin	Readfield	6604	750	5854	0.25	1464	61.65	mod-sensitive	h	0.75	46.24	0.032	366
Messalonskee Lake	Readfield	2915	150	2765	0.25	691	53.05	mod-sensitive	h	0.75	39.79	0.058	173
Shed Pond	Readfield	316	30	286	0.25	72	2.2	mod-sensitive	m	1.00	2.20	0.031	18
Torsey Lake	Readfield	1094	150	944	0.25	236	12.12	mod-sensitive	h	0.75	9.09	0.039	59
Flagstaff Lake	Redington Twp	17731	0	17731	0.15	2660	159.7	mod-sensitive	h	0.75	119.78	0.045	665
Redington Pond	Redington Twp	4519	0	4519	0.15	678	35.1	mod-sensitive	h	0.75	26.33	0.039	169
Chickawaukie Lake	Rockland	333	66	267	0.35	93	5.02	mod-sensitive	h	0.75	3.77	0.040	23
Chickawaukie Pond	Rockport	1321	132	1189	0.3	357	20.2	mod-sensitive	h	0.75	15.15	0.042	89
Lilly Pond	Rockport	150	25	125	0.3	38	1.74	poor-restorable	m	0.50	0.87	0.023	9
Crawford Pond	Rockport	336	20	316	0.2	63	4.38	mod-sensitive	h	0.75	3.29	0.052	16
Grassy Pond	Rockport	961	100	861	0.25	215	8.51	mod-sensitive	m	1.00	8.51	0.040	54
Hosmer Pond	Rockport	303	100	203	0.2	41	2.42	mod-sensitive	m	1.00	2.42	0.060	10
Maces Pond	Rockport	516	55	461	0.25	115	4.36	mod-sensitive	m	1.00	4.36	0.038	29
Mirror Lake	Rockport	753	175	578	0.2	116	9.48	mod-sensitive	h	0.75	7.11	0.062	29
Rocky Pond	Rockport	153	10	143	0.25	36	1.45	mod-sensitive	m	1.00	1.45	0.041	9
Tolman Pond	Rockport	2463	350	2113	0.25	528	17.02	mod-sensitive	m	1.00	17.02	0.032	132
Moosehead Lake	Rockwood Strip	4079	400	3679	0.3	1104	90.2	good	h	1.00	90.20	0.082	276
Long Pond, North Basin	Rome	3689	500	3189	0.35	1116	86.61	poor restorable	h	0.50	43.31	0.039	279

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North Pond, Little	Rome	1067	250	817	0.25	204	8.55	mod-sensitive	m	1.00	8.55	0.042	51
Great Pond	Rome	7198	800	6398	0.3	1919	150.5	mod-sensitive	h	0.75	112.87	0.059	480
Long Pond, South Basin	Rome	1097	80	1017	0.25	254	24.43	poor restorable	h	0.50	12.22	0.048	64
North Pond	Rome	242	20	222	0.25	56	3.28	mod-sensitive	m	1.00	3.28	0.059	14
Watson Pond	Rome	454	40	414	0.2	83	4.25	mod-sensitive	h	0.75	3.19	0.038	21
Whittier Pond	Rome	2115	200	1915	0.2	383	12.74	mod-sensitive	h	0.75	9.56	0.025	96
Bunker Pond	Roxbury	326	10	316	0.15	47	2.58	mod-sensitive	m	1.00	2.58	0.054	12
Ellis Pond	Roxbury	3496	230	3266	0.2	653	26.68	mod-sensitive	m	1.00	26.68	0.041	163
Swains Pond	Rumford	84	2	82	0.15	12	0.81	mod-sensitive	m	1.00	0.81	0.066	3
Curtis Bog	Sabattus	1045	450	595	0.25	149	9.72	mod-sensitive	m	1.00	9.72	0.065	37
Jimmy Pond	Sabattus	798	40	758	0.15	114	4.63	mod-sensitive	m	1.00	4.63	0.041	28
Loon Pond	Sabattus	190	10	180	0.25	45	2.4	mod-sensitive	m	1.00	2.40	0.053	11
Sabattus Pond	Sabattus	565	200	365	0.25	91	5.29	poor-restorable	m	0.50	2.65	0.029	23
Sutherland Pond	Sabattus	227	12	215	0.25	54	2.18	mod-sensitive	m	1.00	2.18	0.041	13
Moosehead Lake	Sand Bar Tract a	3061	250	2811	0.3	843	67.64	good	h	1.00	67.64	0.080	211
U. Sandy River Pond	Sandy River Plar	1287	100	1187	0.2	237	8.11	mod-sensitive	h	0.75	6.08	0.026	59
Rangeley Lake	Sandy River Plar	6629	1100	5529	0.25	1382	121.2	good	h	1.00	121.23	0.088	346
Long Pond	Sandy River Plar	3066	1000	2066	0.25	517	34.72	good	h	1.00	34.72	0.067	129
Saddleback Lake	Sandy River Plar	2147	350	1797	0.25	449	13.38	mod-sensitive	h	0.75	10.04	0.022	112
Bauneg Beg	Sanford	5446	750	4696	0.35	1644	34.42	m-sens	m	1.00	34.42	0.021	411
Estes Lake	Sanford	5127	775	4352	0.35	1523	41.58	mod-sensitive	m	1.00	41.58	0.027	381
Number One Pond	Sanford	4484	650	3834	0.3	1150	40.28	mod-sensitive	m	1.00	40.28	0.035	288
Estes Lake, Upper Basin	Sanford	3165	700	2465	0.35	863	20.5	mod-sensitive	m	1.00	20.50	0.024	216
Moosehead Lake	Sapling Twp.	1275	150	1125	0.2	225	28.17	good	h	1.00	28.17	0.125	56
Indian Pond	Sapling Twp.	16207	2000	14207	0.15	2131	334.4	good	h	1.00	334.43	0.157	533
Doliff Pond	Searsmont	143	10	133	0.2	27	0.92	mod-sensitive	m	1.00	0.92	0.035	7
Lawry Pond	Searsmont	2263	200	2063	0.2	413	16.71	mod-sensitive	m	1.00	16.71	0.040	103
Levenseller Pond	Searsmont	219	40	179	0.25	45	2.09	mod-stable	m	1.25	2.61	0.058	11
Little Pond	Searsmont	158	70	88	0.2	18	2.13	mod-sensitive	m	1.00	2.13	0.121	4
Quantabacook Lake	Searsmont	6807	700	6107	0.25	1527	61.62	mod-sensitive	m	1.00	61.62	0.040	382
Ruffingham Meadow Pond Pond	Searsmont	1798	400	1398	0.2	280	10.82	mod-stable	m	1.25	13.53	0.048	70
Sennebec Pond	Searsmont	14161	1500	12661	0.2	2532	126.6	mod-sensitive	h	0.75	94.96	0.038	633
Tilden Pond	Searsmont	217	25	192	0.2	38	2.02	mod-stable	m	1.25	2.53	0.066	10
Unnamed Pond, drains to Quantabacook L. wetland	Searsmont	128	12	116	0.2	23	1.12	mod-sensitive	m	1.00	1.12	0.048	6
Cain Pond	Searsport	454	25	429	0.2	86	3.66	mod-sensitive	m	1.00	3.66	0.043	21
Halfmoon Pond	Searsport	380	40	340	0.25	85	5.79	mod-sensitive	h	0.75	4.34	0.051	21

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McClure Pond	Searsport	593	85	508	0.25	127	5.71	mod-sensitive	m	1.00	5.71	0.045	32
Swan Lake	Searsport	2132	200	1932	0.25	483	36.49	mod-sensitive	h	0.75	27.37	0.057	121
Peabody Pond	Sebago	1151	115	1036	0.35	363	21.69	mod-sensitive	h	0.75	16.27	0.045	91
Sebago Lake	Sebago	12214	2400	9814	0.3	2944	364.5	outstanding	h	0.50	182.23	0.062	736
Barker Pond	Sebago	1062	100	962	0.25	241	15.01	mod-sensitive	h	0.75	11.26	0.047	60
Browns Pond	Sebago	659	60	599	0.25	150	5.71	mod-sensitive	m	1.00	5.71	0.038	37
Cold Rain Pond	Sebago	34	0	34	0.2	7	0.28	mod-sensitive	h	0.75	0.21	0.031	2
Hancock Pond	Sebago	1025	100	925	0.3	278	17.7	mod-sensitive	h	0.75	13.28	0.048	69
Mariner Pond	Sebago	2379	500	1879	0.25	470	16.69	mod-sensitive	m	1.00	16.69	0.036	117
Perley Pond	Sebago	81	2	79	0.25	20	0.99	mod-sensitive	m	1.00	0.99	0.050	5
Southeast Pond	Sebago	1312	100	1212	0.25	303	12.12	mod-sensitive	m	1.00	12.12	0.040	76
Woods Millpond	Sebago	266	15	251	0.2	50	1.54	mod-sensitive	m	1.00	1.54	0.031	13
Mousam Lake, North Basin	Shapleigh	4665	550	4115	0.35	1440	71.94	mod-sensitive	h	0.75	53.96	0.037	360
Mousam Lake, South Basin	Shapleigh	1205	250	955	0.3	287	13.56	mod-sensitive	h	0.75	10.17	0.035	72
East Pond	Smithfield	1492	130	1362	0.25	341	29.96	poor restorable	m	0.50	14.98	0.044	85
Great Pond	Smithfield	1267	275	992	0.25	248	26.5	mod-sensitive	h	0.75	19.88	0.080	62
North Pond	Smithfield	6100	530	5570	0.25	1393	82.7	mod-sensitive	m	1.00	82.70	0.059	348
Little Pond	Smithfield	29	9	20	0.2	4	0.28	mod-sensitive	m	1.00	0.28	0.070	1
N. Basin, Damariscotta Lake	Somerville	4628	463	3702	0.2	740	54.81	mod-sensitive	h	0.75	41.11	0.055	185
Long Lake	St. Agatha	11003	600	10403	0.2	2081	161.3	mod-sensitive	h	0.75	120.98	0.058	520
Sebago Lake	Standish	10743	3200	7543	0.35	2640	320.6	outstanding	h	0.50	160.29	0.061	660
Adams Pond	Standish	32	3	29	0.2	6	0.24	mod-sensitive	m	1.00	0.24	0.041	1
Bonney Eagle Lake	Standish	1981	400	1581	0.3	474	14.86	mod-sensitive	m	1.00	14.86	0.031	119
Duck Pond	Standish	93	5	88	0.25	22	0.9	mod-sensitive	m	1.00	0.90	0.041	6
Halfmoon Pond	Standish	54	10	44	0.25	11	0.55	mod-sensitive	m	1.00	0.55	0.050	3
Little Watchic Pond	Standish	1037	150	887	0.25	222	8.44	mod-sensitive	m	1.00	8.44	0.038	55
Otter Ponds #2	Standish	34	2	32	0.3	10	0.55	mod-sensitive	h	0.75	0.41	0.043	2
Otter Ponds #3	Standish	14	1	13	0.3	4	0.3	mod-sensitive	m	1.00	0.30	0.077	1
Rich Mill Pond	Standish	1981	500	1481	0.25	370	12.3	mod-sensitive	m	1.00	12.30	0.033	93
Snake Pond	Standish	39	3	36	0.25	9	0.39	mod-sensitive	m	1.00	0.39	0.043	2
Watchic Pond	Standish	2228	300	1928	0.35	675	33.89	mod-sensitive	h	0.75	25.42	0.038	169
Keewaydin Lake	Stoneham	2463	1600	863	0.3	259	26.12	good	h	0.75	19.59	0.076	65
Nash Pond	Strong	123	10	113	0.2	23	0.88	mod-sensitive	m	1.00	0.88	0.039	6
Porter Lake	Strong	1114	150	964	0.25	241	14.02	good	h	1.00	14.02	0.058	60
Taylor Hill Pond	Strong	748	100	648	0.2	130	5.38	mod-sensitive	m	1.00	5.38	0.042	32
Flanders Pond	Sullivan	3560	900	2660	0.25	665	40.5	mod-sensitive	m	1.00	40.50	0.061	166
Abbotts Pond	Sumner	190	40	150	0.15	23	1.67	mod-sensitive	h	0.75	1.25	0.056	6

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Cushman Pond	Sumner	86	20	66	0.15	10	0.85	mod-sensitive	h	0.75	0.64	0.064	2
Labrador Pond	Sumner	2159	250	1909	0.2	382	15.76	mod-sensitive	m	1.00	15.76	0.041	95
Little Labrador Pond	Sumner	931	110	821	0.2	164	5.95	mod-sensitive	m	1.00	5.95	0.036	41
Moose Pond	Sumner	2018	100	1918	0.15	288	12.01	mod-sensitive	m	1.00	12.01	0.042	72
North Pond	Sumner	951	30	921	0.2	184	10.98	good	h	1.00	10.98	0.060	46
Pleasant Pond	Sumner	956	30	926	0.2	185	19.31	mod-sensitive	m	1.00	19.31	0.104	46
Shagg Pond	Sumner	74	15	59	0.15	9	0.68	mod-sensitive	h	0.75	0.51	0.058	2
Washburn Pond	Sumner	66	12	54	0.15	8	0.59	mod-sensitive	h	0.75	0.44	0.055	2
Lower Patten Pond	Surry	1838	180	1658	0.25	415	27.07	good	h	1.00	27.07	0.065	104
Gold Stream Pond	Surry	1386	100	1286	0.2	257	10.18	mod-sensitive	m	1.00	10.18	0.040	64
Toddy Pond	Surry	1265	150	1115	0.25	279	19.24	good	h	1.00	19.24	0.069	70
Upper Patten Pond	Surry	1233	125	1108	0.2	222	11.88	mod-sensitive	h	0.75	8.91	0.040	55
Swan Lake	Swanville	2994	300	2694	0.25	674	51.22	m-sens	h	0.75	38.42	0.057	168
Nichols Pond	Swanville	118	0	118	0.25	30	1.16	mod-sensitive	h	0.75	0.87	0.029	7
Webber Pond	Sweden	205	35	170	0.25	43	1.89	mod-sensitive	m	1.00	1.89	0.044	11
Black Pond	Sweden	1198	125	1073	0.2	215	8.37	mod-sensitive	m	1.00	8.37	0.039	54
Highland Lake	Sweden	1457	90	1367	0.3	410	22.95	mod-sensitive	h	0.75	17.21	0.042	103
Keys Pond	Sweden	1235	130	1105	0.35	387	15.23	good	h	1.00	15.23	0.039	97
Kezar Pond	Sweden	2174	200	1974	0.25	494	28.75	mod-sensitive	m	1.00	28.75	0.058	123
Little Moose Pond	Sweden	289	10	279	0.2	56	3.52	good	h	1.00	3.52	0.063	14
Little Pond	Sweden	71	5	66	0.2	13	0.74	mod-sensitive	m	1.00	0.74	0.056	3
Moose Pond, Basin 1	Sweden	3135	250	2885	0.25	721	35.34	mod-sensitive	h	0.75	26.51	0.037	180
Stearns Pond	Sweden	3565	300	3265	0.25	816	34.94	mod-sensitive	h	0.75	26.21	0.032	204
Narraguagus Lake	T16 MD	1235	160	1075	0.2	215	11.7	mod-sensitive	h	0.75	8.78	0.041	54
Spectacle Pond	T16 MD	509	20	489	0.2	98	6.08	mod-sensitive	m	1.00	6.08	0.062	24
Mud Lake	T17R4	5715	286	5429	0.15	814	88.02	m-sens	m	1.00	88.02	0.108	204
Millinocket Lake	T1R8 WELS	4190	200	3990	0.25	998	53.31	good	h	1.00	53.31	0.053	249
Pemadumcook Chain	T1R8 WELS	1519	150	1369	0.2	274	197.9	mod-sensitive	h	0.75	148.44	0.542	68
Millinocket Lake	T1R9 WELS	3165	500	2665	0.25	666	40.28	good	h	1.00	40.28	0.060	167
Pemadumcook Chain	T1R9 WELS	8789	500	8289	0.2	1658	1143	mod-sensitive	h	0.75	857.12	0.517	414
West Pond	T3ND	2110	105	2005	0.2	401	42.71	good	h	1.00	42.71	0.106	100
Nicatous Lake	T3ND	3629	363	3266	0.2	653	63.76	mod-sensitive	h	0.75	47.82	0.073	163
Green Pond	T3R1 NBPP	536	20	516	0.2	103	5.38	mod-sensitive	m	1.00	5.38	0.052	26
Number Three Pond	T3R1 NBPP	2804	600	2204	0.2	441	23.41	mod-sensitive	m	1.00	23.41	0.053	110
Chesuncook, Caribou Lake	T3R13	6822	200	6622	0.15	993	111.9	mod-sensitive	h	0.75	83.89	0.084	248
West Pond	T40MD	1326	66	1260	0.2	252	26.85	good	h	1.00	26.85	0.106	63
Pleasant Lake	T6 R1 NBPP	3864	400	3464	0.15	520	47.4	mod-sensitive	h	0.75	35.55	0.068	130

Appendix C

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Shaw Lake	T6 R1 NBPP	360	50	310	0.15	47	2.75	mod-sensitive	m	1.00	2.75	0.059	12
Long Pond	T7R9 NWP	3286	170	3116	0.2	623	37.88	mod-sensitive	h	0.75	28.41	0.046	156
Baskahegan Lake	T8 R3 NBPP	12762	1300	11462	0.15	1719	127.5	mod-sensitive	m	1.00	127.51	0.074	430
Moosehead Lake	Taunton and Ray	2295	100	2195	0.25	549	50.73	good	h	1.00	50.73	0.092	137
Martin Pond	The Forks	714	71	643	0.2	129	4.96	m-sens	h	0.75	3.72	0.051	32
Moxie Pond	The Forks	5488	700	4788	0.2	958	50.11	mod-sensitive	h	0.75	37.58	0.039	239
Brassua Lake	Tomhegan Twp.	4899	200	4699	0.22	1034	53.29	mod-sensitive	h	0.75	39.97	0.039	258
Baskahegan Lake	Topsfield	9772	1800	7972	0.15	1196	97.63	mod-sensitive	m	1.00	97.63	0.082	299
Upper Richardson	Township C	6412	321	6091	0.2	1218	147.6	good	h	1.00	147.55	0.121	305
Lower Richardson Lake	Township C	7039	300	6739	0.2	1348	218.1	good	h	1.00	218.11	0.162	337
Hodgdon Pond	Tremont	227	25	202	0.25	51	2	mod-sensitive	m	1.00	2.00	0.040	13
Seal Cove Pond	Tremont	1766	1000	766	0.25	192	20.83	mod-sensitive	h	0.75	15.62	0.082	48
Carlton Pond	Troy	7445	750	6695	0.2	1339	42.68	mod-sensitive	m	1.00	42.68	0.032	335
Plymouth Pond	Troy	5342	650	4692	0.2	938	27.82	mod-sensitive	m	1.00	27.82	0.030	235
Round Pond	Troy	489	20	469	0.2	94	3.59	mod-sensitive	m	1.00	3.59	0.038	23
Unity Pond	Troy	8366	1300	7066	0.2	1413	85.37	poor-restorable	m	0.50	42.69	0.030	353
Bear Pond	Turner	222	25	197	0.25	49	2.31	mod-sensitive	m	1.00	2.31	0.047	12
Black Pond	Turner	12	0	12	0.3	4	0.13	mod-sensitive	m	1.00	0.13	0.036	1
Crystal Pond	Turner	284	20	264	0.25	66	3.04	mod-sensitive	h	0.75	2.28	0.035	17
Frog Pond	Turner	88	15	73	0.2	15	0.55	mod-sensitive	m	1.00	0.55	0.038	4
Lake Auburn	Turner	160	8	152	0.3	46	3.74	good	h	1.00	3.74	0.082	11
Lard Pond	Turner	106	42	64	0.3	19	0.85	mod-sensitive	m	1.00	0.85	0.044	5
Lily Pond	Turner	252	40	212	0.2	42	2.16	mod-sensitive	m	1.00	2.16	0.051	11
Little Wilson Pond	Turner	827	120	707	0.25	177	7.27	mod-sensitive	h	0.75	5.45	0.031	44
Mud Pond	Turner	1519	300	1219	0.2	244	8.11	mod-sensitive	m	1.00	8.11	0.033	61
Mud Pond	Turner	44	3	41	0.2	8	0.39	mod-sensitive	m	1.00	0.39	0.048	2
Mud Pond	Turner	29	2	27	0.25	7	0.39	mod-sensitive	h	0.75	0.29	0.043	2
Pleasant Pond	Turner	570	100	470	0.3	141	8.48	mod-sensitive	h	0.75	6.36	0.045	35
Round Pond	Turner	24	5	19	0.35	7	0.35	mod-sensitive	m	1.00	0.35	0.053	2
Sandy Bottom Pond	Turner	59	8	51	0.3	15	0.74	mod-sensitive	m	1.00	0.74	0.048	4
The Basin	Turner	34	10	24	0.2	5	0.13	mod-sensitive	m	1.00	0.13	0.027	1
Crawford Pond	Union	3659	350	3309	0.25	827	47.84	mod-sensitive	h	0.75	35.88	0.043	207
Lermond Pond	Union	148	30	118	0.35	41	2.93	good	h	1.00	2.93	0.071	10
Little Medomak Pond	Union	135	10	125	0.2	25	1.43	mod-sensitive	h	0.75	1.07	0.043	6
Medomak Pond	Union	4835	450	4385	0.25	1096	32.63	mod-sensitive	m	1.00	32.63	0.030	274
Round Pond	Union	5517	400	5117	0.25	1279	55.23	mod-sensitive	m	1.00	55.23	0.043	320
Sennebec Pond	Union	1702	170	1532	0.25	383	15.21	mod-sensitive	h	0.75	11.41	0.030	96

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Seven Tree Pond	Union	2748	300	2448	0.3	734	35.52	mod-sensitive	h	0.75	26.64	0.036	184
Unity Pond	Unity	2270	500	1770	0.25	443	23.17	poor restorable	m	0.50	11.59	0.026	111
Webber Pond	Vassalboro	5169	300	4869	0.25	1217	77.17	poor rest	m	0.50	38.59	0.032	304
Threemile Pond	Vassalboro	1299	350	949	0.25	237	15.19	poor-restorable	m	0.50	7.60	0.032	59
China Lake, West Basin	Vassalboro	1430	125	1305	0.25	326	31.15	poor restorable	h	0.40	12.46	0.038	82
Pattee Pond	Vassalboro	1079	250	829	0.25	207	9.45	mod-sensitive	m	1.00	9.45	0.046	52
Spectacle Pond	Vassalboro	686	40	646	0.25	162	9.21	good	h	1.00	9.21	0.057	40
Threecornered Pond	Vassalboro	1662	350	1312	0.25	328	13	poor restorable	m	0.50	6.50	0.020	82
Black Pond	Vienna	889	150	739	0.15	111	6.43	mod-sensitive	m	1.00	6.43	0.058	28
Boody Pond	Vienna	182	50	132	0.15	20	1.25	mod-sensitive	h	0.75	0.94	0.047	5
Crowell Pond	Vienna	4825	500	4325	0.2	865	29.87	mod-sensitive	m	1.00	29.87	0.035	216
Davis Pond	Vienna	150	50	100	0.2	20	1.25	mod-sensitive	m	1.00	1.25	0.063	5
Egypt Pond	Vienna	284	35	249	0.2	50	2.71	mod-sensitive	h	0.75	2.03	0.041	12
Flying Pond	Vienna	3133	500	2633	0.25	658	50.51	mod-sensitive	h	0.75	37.88	0.058	165
Kidder Pond	Vienna	249	50	199	0.2	40	1.87	mod-sensitive	m	1.00	1.87	0.047	10
Kimball Pond	Vienna	106	20	86	0.25	22	1.43	good	h	1.00	1.43	0.067	5
Long Pond, North Basin	Vienna	973	200	773	0.25	193	22.88	poor restorable	h	0.50	11.44	0.059	48
Parker Pond	Vienna	1156	60	1096	0.25	274	19.13	mod-sensitive	h	0.75	14.35	0.052	69
Whittier Pond	Vienna	252	15	237	0.2	47	2.29	mod-sensitive	m	1.00	2.29	0.048	12
Duckpuddle Pond	Waldoboro	3575	400	3175	0.25	794	32.08	mod-sensitive	m	1.00	32.08	0.040	198
Havener Pond	Waldoboro	383	50	333	0.25	83	3.55	mod-sensitive	m	1.00	3.55	0.043	21
Kalers Pond	Waldoboro	365	165	200	0.25	50	4.36	mod-sensitive	h	0.75	3.27	0.065	13
Little Medomak Pond	Waldoboro	610	70	540	0.25	135	6.37	mod-sensitive	h	0.75	4.78	0.035	34
Medomak Pond	Waldoboro	1734	200	1534	0.25	384	11.7	mod-sensitive	m	1.00	11.70	0.031	96
North Pond	Waldoboro	130	10	120	0.2	24	1.8	mod-sensitive	m	1.00	1.80	0.075	6
Pemaquid Pond	Waldoboro	420	120	300	0.25	75	6.39	mod-sensitive	h	0.75	4.79	0.064	19
Round Pond	Waldoboro	175	20	155	0.2	31	1.76	mod-sensitive	m	1.00	1.76	0.057	8
Sidensparker Pond	Waldoboro	936	100	836	0.25	209	9.39	mod-sensitive	m	1.00	9.39	0.045	52
Tobias Pond	Waldoboro	22	5	17	0.25	4	0.19	mod-sensitive	m	1.00	0.19	0.045	1
Unnamed Pond,drains to Sidensparker	Waldoboro	496	40	456	0.2	91	3.96	mod-sensitive	m	1.00	3.96	0.043	23
Cobbossee Lake	Wales	5735	600	5135	0.25	1284	108.7	poor restorable	m	0.50	54.36	0.042	321
Sabattus Pond	Wales	3741	500	3241	0.25	810	34.92	poor-restorable	m	0.50	17.46	0.022	203
Graham Lake	Waltham	10195	500	9695	0.25	2424	146.8	mod-stable	m	1.25	183.46	0.076	606
South Pond	Warren	4860	420	4440	0.25	1110	47.65	mod-sensitive	m	1.00	47.65	0.043	278
N. Basin, Damariscotta Lake	Washington	9463	946	8517	0.2	1703	112.1	mod-sensitive	h	0.75	84.04	0.049	426
Muddy Pond	Washington	91	9	82	0.2	16	1.14	mod-sensitive	m	1.00	1.14	0.071	4

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Crystal Pond	Washington	444	35	409	0.2	82	5.62	mod-sensitive	h	0.75	4.22	0.052	20
Iron Pond	Washington	158	0	158	0.2	32	1.58	mod-sensitive	h	0.75	1.19	0.038	8
Medomak Pond	Washington	9916	1000	8916	0.2	1783	66.89	mod-sensitive	m	1.00	66.89	0.038	446
Mill Pond	Washington	1008	40	968	0.2	194	7.18	mod-sensitive	m	1.00	7.18	0.037	48
Sheepscot Lake	Washington	929	30	899	0.2	180	10.34	good	h	1.00	10.34	0.058	45
Spring Pond	Washington	46	0	46	0.2	9	0.5	mod-sensitive	h	0.75	0.38	0.041	2
Travel Pond	Washington	289	15	274	0.15	41	1.76	mod-sensitive	m	1.00	1.76	0.043	10
Unnamed Pond (Hibberts Gore)	Washington	51	30	21	0.2	4	0.33	mod-sensitive	m	1.00	0.33	0.079	1
Washington Pond	Washington	1789	200	1589	0.2	318	14.75	mod-sensitive	h	0.75	11.06	0.035	79
Bartlett Pond	Waterboro	2234	284	1950	0.25	488	13.2	m-sens	m	1.00	13.20	0.027	122
Ford Mill Pond (Midas# 6841)	Waterboro	1025	154	871	0.3	261	6.57	mod-sensitive	m	1.00	6.57	0.025	65
Shaker Pond	Waterboro	9421	1200	8221	0.3	2466	66.12	mod-sensitive	m	1.00	66.12	0.027	617
Killick Pond	Waterboro	1957	300	1657	0.25	414	11.92	mod-stable	h	1.00	11.92	0.029	104
Little Ossipee Lake	Waterboro	2984	400	2584	0.3	775	35.5	good	h	1.00	35.50	0.046	194
Bear Pond	Waterford	5275	744	4531	0.3	1359	62.22	mod-sensitive	h	0.75	46.67	0.034	340
Bog Pond	Waterford	284	28	256	0.2	51	3.13	mod-sensitive	m	1.00	3.13	0.061	13
Cabbage Yard Pond	Waterford	259	13	246	0.2	49	1.54	mod-sensitive	m	1.00	1.54	0.031	12
Crystal Lake	Waterford	862	43	819	0.25	205	19.11	mod-sensitive	h	0.75	14.33	0.070	51
Duck Pond	Waterford	308	15	293	0.2	59	2.97	mod-sensitive	m	1.00	2.97	0.051	15
Highland Lake	Waterford	42	0	42	0.25	11	0.63	mod-sensitive	h	0.75	0.47	0.045	3
Island Pond	Waterford	679	130	549	0.25	137	6.3	mod-sensitive	h	0.75	4.73	0.034	34
Jewett Pond	Waterford	395	30	365	0.25	91	3.41	mod-sensitive	m	1.00	3.41	0.037	23
Keoka Lake	Waterford	3644	772	2872	0.3	862	42.88	mod-sensitive	h	0.75	32.16	0.037	215
Little Moose Pond	Waterford	924	74	850	0.25	213	11.28	good	h	1.00	11.28	0.053	53
Long Lake	Waterford	1265	126	1139	0.3	342	17.7	mod-sensitive	h	0.75	13.28	0.039	85
Mcwain Pond (Long Pond)	Waterford	2406	240	2166	0.25	542	31.53	mod-sensitive	h	0.75	23.65	0.044	135
Middle Pond	Waterford	39	20	19	0.25	5	0.39	mod-sensitive	h	0.75	0.29	0.062	1
Mud Pond	Waterford	1655	83	1572	0.2	314	13.23	mod-sensitive	m	1.00	13.23	0.042	79
Papoose Pond	Waterford	155	50	105	0.3	32	2.2	mod-sensitive	h	0.75	1.65	0.052	8
Sebago Lake	Waterford	13232	800	12432	0.3	3730	394.8	outstanding	h	0.50	197.41	0.053	932
Speck Pond 1	Waterford	4	0	4	0.2	1	0.06	mod-sensitive	m	1.00	0.06	0.075	0
Speck Pond 2	Waterford	22	6	16	0.2	3	0.24	mod-sensitive	m	1.00	0.24	0.075	1
Stearns Pond	Waterford	551	50	501	0.2	100	5.4	mod-sensitive	h	0.75	4.05	0.040	25
Whitney Pond	Waterford	39	0	39	0.2	8	0.28	mod-sensitive	m	1.00	0.28	0.036	2
Mt Blue Pond	Weld	96	0	96	0.1	10	0.85	mod-sensitive	h	0.75	0.64	0.066	2
Webb Lake	Weld	30771	15000	15771	0.25	3943	299.7	mod-sensitive	h	0.75	224.74	0.057	986
Houghton Pond	West Bath	84	5	79	0.25	20	0.79	mod-sensitive	m	1.00	0.79	0.040	5

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Lily Pond	West Bath	575	50	525	0.25	131	2.73	mod-sensitive	m	1.25	3.41	0.026	33
Campbell Pond	West Bath	103	8	95	0.25	24	0.99	mod-sensitive	m	1.00	0.99	0.042	6
Highland Lake	Westbrook	385	90	295	0.35	103	4.71	mod-sensitive	h	0.75	3.53	0.034	26
Faulkner Lake	Weston	516	40	476	0.15	71	4.6	mod-sensitive	m	1.00	4.60	0.064	18
Clary Lake	Whitefield	2340	250	2090	0.25	523	25.07	mod-sensitive	m	1.00	25.07	0.048	131
Givens (Longfellow) Pond	Whitefield	93	20	73	0.25	18	1.03	mod-sensitive	m	1.00	1.03	0.056	5
Joice Pond	Whitefield	200	25	175	0.25	44	2.29	mod-sensitive	m	1.00	2.29	0.052	11
Little Dyer Pond	Whitefield	1245	250	995	0.2	199	9.7	mod-sensitive	m	1.00	9.70	0.049	50
Tinkham Pond	Whitefield	66	5	61	0.2	12	0.63	mod-sensitive	m	1.00	0.63	0.052	3
Togus Pond (Lower)	Whitefield	699	300	399	0.25	100	7.01	mod-sensitive	m	1.00	7.01	0.070	25
Weary Pond	Whitefield	311	20	291	0.2	58	3.26	mod-sensitive	m	1.00	3.26	0.056	15
Eastern Lake	Whiting	192	20	172	0.15	26	1.85	mod-sensitive	m	1.00	1.85	0.072	6
Gardiner Lake	Whiting	1961	200	1761	0.25	440	43.39	good	h	1.00	43.39	0.099	110
Holmes Pond	Whiting	2060	200	1860	0.15	279	14.42	mod-sensitive	m	1.00	14.42	0.052	70
Indian Lake	Whiting	593	60	533	0.25	133	8	mod-sensitive	h	0.75	6.00	0.045	33
Josh Pond	Whiting	1564	100	1464	0.2	293	13.64	mod-sensitive	m	1.00	13.64	0.047	73
Little Lake	Whiting	793	50	743	0.15	111	7.36	mod-sensitive	m	1.00	7.36	0.066	28
Orange Lake	Whiting	1670	160	1510	0.2	302	23.59	mod-sensitive	h	0.75	17.69	0.059	76
Roaring Lake	Whiting	1598	100	1498	0.15	225	12.23	mod-sensitive	m	1.00	12.23	0.054	56
Second Lake	Whiting	311	20	291	0.15	44	3.17	mod-sensitive	h	0.75	2.38	0.054	11
Sunken and Rocky Lakes	Whiting	2154	150	2004	0.2	401	27.03	mod-sensitive	m	1.00	27.03	0.067	100
Unnamed Pond	Whiting	158	10	148	0.15	22	1.41	mod-sensitive	m	1.00	1.41	0.064	6
Western Lake	Whiting	180	10	170	0.15	26	1.76	mod-sensitive	m	1.00	1.76	0.069	6
Badger Pond	Willimantic	383	10	373	0.15	56	3.08	mod-sensitive	m	1.00	3.08	0.055	14
Big Benson Pond	Willimantic	296	5	291	0.2	58	5.02	good	h	1.00	5.02	0.086	15
Big Greenwood Pond	Willimantic	321	10	311	0.2	62	7.38	mod-sensitive	h	0.75	5.54	0.089	16
Fourth Davis Pond	Willimantic	165	7	158	0.15	24	1.71	mod-sensitive	m	1.00	1.71	0.072	6
Garcock Pond	Willimantic	51	1	50	0.15	8	0.46	mod-sensitive	m	1.00	0.46	0.061	2
Grindstone Pond	Willimantic	145	5	140	0.15	21	1.74	mod-sensitive	h	0.75	1.31	0.062	5
Horseshoe Pond	Willimantic	420	10	410	0.15	62	4.6	mod-sensitive	m	1.00	4.60	0.075	15
Mud Greenwood Pond	Willimantic	224	45	179	0.15	27	2.27	mod-sensitive	h	0.75	1.70	0.063	7
Onawa Lake	Willimantic	143	5	138	0.2	28	1.56	good	h	1.00	1.56	0.057	7
Poverty Pond	Willimantic	338	10	328	0.15	49	3.41	mod-sensitive	m	1.00	3.41	0.069	12
Sebec Lake	Willimantic	23432	2000	21432	0.2	4286	324.8	good	h	1.00	324.77	0.076	1072
Second Davis Pond	Willimantic	266	15	251	0.2	50	2.09	mod-sensitive	m	1.00	2.09	0.042	13
Squankin Pond	Willimantic	17	0	17	0.15	3	0.15	mod-sensitive	m	1.00	0.15	0.059	1
Third Davis Pond	Willimantic	1593	60	1533	0.15	230	9.67	mod-sensitive	m	1.00	9.67	0.042	57

Appendix C

Per Acre Phosphorus Allocations for Selected Maine Lakes

Updated 11/8/10

Lake Name	Town in which development is located	Direct Watershed Area in Town (acres) **DDA**	Area not available for development (acres) **ANAD**	Area available for development (acres) **AAD**	**GF**	Expected developed area (acres) **D**	(lbP/y) **F**	Water Quality Category **WQC**	**LOP**	**C**	**FC**	Per acre phosphorus allocation (lb/acre/yr) **P**	Small Watershed Threshold (acres) **SWT**
Pease Pond	Wilton	854	80	774	0.25	194	7.96	mod-sensitive	m	1.00	7.96	0.041	48
Unnamed Pond	Wilton	434	0	434	0.15	65	2.88	mod-sensitive	m	1.00	2.88	0.044	16
Varnum Pond	Wilton	847	80	767	0.25	192	11.79	good	h	1.00	11.79	0.061	48
Wilson Pond	Wilton	8048	970	7078	0.25	1770	72.1	mod-sensitive	h	0.75	54.08	0.031	442
Sebago Lake	Windham	1356	271	1084	0.35	380	40.5	outst	h	0.50	20.25	0.053	95
Pettingill Pond	Windham	360	60	300	0.35	105	3.35	mod-sensitive	h	0.75	2.51	0.024	26
Little Sebago L., Main Basin	Windham	590	75	515	0.35	180	9.19	mod-sensitive	h	0.75	6.89	0.038	45
Little Sebago L., Hunger Bay	Windham	748	180	568	0.35	199	13.91	mod-sensitive	h	0.75	10.43	0.052	50
Highland Lake	Windham	2194	300	1894	0.4	758	26.87	mod-sensitive	h	0.75	20.15	0.027	189
Chaffin Pond	Windham	79	10	69	0.35	24	0.94	mod-sensitive	m	1.00	0.94	0.039	6
Forest Lake	Windham	1040	100	940	0.3	282	10.05	mod-sensitive	m	1.00	10.05	0.036	71
Little Duck Pond	Windham	261	25	236	0.3	71	2.49	mod-sensitive	m	1.00	2.49	0.035	18
Lower Mud Pond	Windham	46	23	23	0.25	6	0.35	mod-sensitive	m	1.00	0.35	0.061	1
Panther Pond	Windham	71	3	68	0.3	20	1.1	mod-sensitive	h	0.75	0.83	0.040	5
Tarkill Pond	Windham	234	60	174	0.35	61	2.18	mod-sensitive	m	1.00	2.18	0.036	15
Upper Mud Pond	Windham	61	5	56	0.25	14	0.39	mod-sensitive	m	1.00	0.39	0.028	4
Fox Pond	Windsor	103	15	88	0.2	18	0.94	mod-sensitive	m	1.00	0.94	0.053	4
Givens (Longfellow) Pond	Windsor	49	15	34	0.25	9	0.55	mod-sensitive	m	1.00	0.55	0.065	2
Long Pond	Windsor	1546	500	1046	0.25	262	17.37	mod-sensitive	m	1.00	17.37	0.066	65
Moody Pond	Windsor	281	75	206	0.2	41	2.71	mod-sensitive	m	1.00	2.71	0.066	10
Mud Pond	Windsor	439	200	239	0.2	48	3.41	mod-sensitive	m	1.00	3.41	0.071	12
Savade Pond	Windsor	820	250	570	0.25	143	7.8	mod-sensitive	h	0.75	5.85	0.041	36
Threecornered Pond	Windsor	138	20	118	0.2	24	1.08	poor-restorable	m	0.50	0.54	0.023	6
Threemile Pond	Windsor	2750	600	2150	0.25	538	32.1	poor-restorable	m	0.50	16.05	0.030	134
Togus Pond (Lower)	Windsor	1712	700	1012	0.25	253	17.22	mod-sensitive	m	1.00	17.22	0.068	63
Wellman Pond	Windsor	237	100	137	0.2	27	1.6	mod-sensitive	m	1.00	1.60	0.058	7
Long Pond (Long, Caribou, &	Winn	254	10	244	0.2	49	3.19	mod-sensitive	m	1.00	3.19	0.065	12
Birch Harbor Pond	Winter Harbor	259	25	234	0.25	59	2.53	mod-sensitive	m	1.00	2.53	0.043	15
Apple Valley Lake	Winthrop	982	98	884	0.25	221	6.39	mod-sensitive	m	1.00	6.39	0.029	55
Annabessacook Lake	Winthrop	4477	600	3877	0.3	1163	66.61	poor restorable	m	0.50	33.31	0.029	291
Berry Pond	Winthrop	2080	150	1930	0.25	483	13.91	mod-sensitive	m	1.00	13.91	0.029	121
Carlton Pond	Winthrop	108	0	108	0.25	27	1.32	mod-sensitive	h	0.75	0.99	0.037	7
Cobbossee Lake	Winthrop	2248	250	1998	0.3	599	42.62	poor restorable	h	0.50	21.31	0.036	150
Dexter Pond	Winthrop	390	90	300	0.25	75	3.32	mod-sensitive	m	1.00	3.32	0.044	19
Kezar Pond	Winthrop	205	70	135	0.3	41	1.85	mod-sensitive	m	1.00	1.85	0.046	10
Little Cobbossee Lake	Winthrop	531	120	411	0.25	103	4.05	poor restorable	m	0.50	2.03	0.020	26
Lower Narrows Pond	Winthrop	862	40	822	0.25	206	14.88	good	h	1.00	14.88	0.072	51

Appendix C

Per Acre Phosphorus Allocations for Selected Maine Lakes

Updated 11/8/10

Lake Name	Town in which development is located	Direct Watershed Area in Town (acres) **DDA**	Area not available for development (acres) **ANAD**	Area available for development (acres) **AAD**	**GF**	Expected developed area (acres) **D**	(lbP/y) **F**	Water Quality Category **WQC**	**LOP**	**C**	**FC**	Per acre phosphorus allocation (lb/acre/yr) **P**	Small Watershed Threshold (acres) **SWT**
Maranacook Lake South Basin	Winthrop	2814	340	2474	0.25	619	44.69	mod-sensitive	h	0.75	33.52	0.054	155
Maranacook Lake North Basin	Winthrop	177	5	172	0.2	34	1.65	mod-sensitive	h	0.75	1.24	0.036	9
Unnamed Pond (5313)	Winthrop	706	50	656	0.25	164	4.16	mod-sensitive	m	1.00	4.16	0.025	41
Upper Narrows Pond	Winthrop	2545	220	2325	0.25	581	29.39	mod-sensitive	h	0.75	22.04	0.038	145
Wilson Pond	Winthrop	808	50	758	0.25	190	9.19	mod-sensitive	h	0.75	6.89	0.036	47
Dresden Bog	Wiscasset	294	0	294	0.2	59	3.1	mod-sensitive	m	1.00	3.10	0.053	15
Gardiner Pond	Wiscasset	400	40	360	0.25	90	4.01	mod-sensitive	m	1.00	4.01	0.045	23
Nequasset Pond	Wiscasset	845	120	725	0.25	181	7.54	mod-sensitive	h	0.75	5.66	0.031	45
North Pond	Woodstock	1126	220	906	0.2	181	11.64	mod-sensitive	h	0.75	8.73	0.048	45
South Pond	Woodstock	138	15	123	0.2	25	2.11	mod-sensitive	h	0.75	1.58	0.064	6
Bryant Pond	Woodstock	1868	300	1568	0.25	392	25.68	mod-sensitive	h	0.75	19.26	0.049	98
Big Concord Pond	Woodstock	1317	150	1167	0.2	233	10.78	mod-sensitive	h	0.75	8.09	0.035	58
Shagg Pond	Woodstock	743	50	693	0.2	139	6.83	mod-sensitive	h	0.75	5.12	0.037	35
Nequasset Pond	Woolwich	7432	600	6832	0.25	1708	66.34	mod-sensitive	h	0.75	49.76	0.029	427

Worksheet 1
PPB calculations

Project name: ______________________________

Lake name: ______________________________

Town name: ______________________________

Standard Calculation

Watershed per acre phosphorus budget (Appendix C):	**PAPB**	________	lbs P/acre/year
Total acreage of development parcel:	**TA**	________	acres
NWI wetland acreage:	**WA**	________	acres
Steep slope acreage:	**SA**	________	acres
Existing developed area		________	acres
Project acreage: A = TA - (WA + SA)	**A**	________	acres
Project Phosphorus Budget: PPB = P x A	**PPB**	________	**lbs P/year**

Small Watershed Adjustment

If Project Acreage (A) is greater than the threshold acreage for the small watershed threshold (SWT, from pertinent lake and town info in the table in Appendix C), calculate an alternative PPB using the analysis below and use this value if it is less than the the Standard Calculation PPB.

Small Watershed Threshold (Appendix C):	**SWT**	________	acres
Project acreage:	**A**	________	acres
Allowable increase in town's share of annual phosphorus load to lake (Appendix C):	**FC**	________	lbs P/year
Area available for development (Appendix C):	**AAD**	________	acres
Ratio of A to AAD (R=A/AAD)	**R**	________	
If R < 0.5, Project Phosphorus Budget PPB = [(FC x R)/2] + [FC/4]	**PPB**	________	**lbs P/year**
If R> 0.5, Project Phosphorus Budget PPB = FC x R	**PPB**		**lbs P/year**

1-15-09

Worksheet 2
Pre-PPE and Post-PPE Calculations

Calculate phosphorus export from development for before and after treatment
Use as many sheets as needed for each development type (commercial, roads, residential lots, etc.)

Project name:____________________________ **Development type**: ________________ Sheet # __________

Land Surface Type or Lot #(s) with description	Acres or # of lots	Export Coefficient from Table 3.1 Table 3.2	Pre-treatment Algal Av. P Export (lbs P/year)	Treatment Factor for BMP(s) from Chapter 6	Post-treatment Algal Av. P Export (lbs P/year)	Description of BMPs
			0	1	0	
			0	1	0	
			0	1	0	
			0	1	0	
			0	1	0	
			0	1	0	
			0	1	0	
			0	1	0	
			0	1	0	
			0	1	0	
		Total Pre-PPE (lbs P/year)		**Total PostPPE (lbs P/year)**		

Appendix D: Worksheet 3 - Mitigation credit

Project name:______________________________ **Development type:** ______________________ Sheet # ___________

Mitigation credit when a pre-existing source is being eliminated

Mitigation Source Area Land Use	Acres	Export Coefficient (lbs P/acre/year)	Modifier	Pre-treatment Historical P Export (lbs P/year)	Treatment Factor for Historical BMP(s) (1.0 if no BMPs)	Historical P Export (lbs P/year)			Mitigation Credit (bs P/year)	Comments
			0.5	0	1	0			0	
			0.5	0	1	0			0	
			0.5	0	1	0			0	
				Total source elimination mitiagion credit (SEC)					**0**	**lbs P/year**

Mitigation credit when a pre-existing source is treated by a new BMP

Mitigation Source Area Land Use	Acres	Export Coefficient (lbs P/acre/year)	Modifier	Pre-treatment Historical P Export (lbs P/year)	Treatment Factor for Historical BMP(s) (1.0 if no BMPs)	Historical P Export (lbs P/year)		Treatment Factor for New BMP(s) Chapter 6	Mitigation Credit (bs P/year)	Comments
			0.5	0	1	0	1 -		0	
			0.5	0	1	0	1 -		0	
			0.5	0	1	0	1 -		0	
				Total source treatment mitiagion credit (STC)					**0**	**lbs P/year**

TOTAL MITIGATION CREDIT (SEC + STC)	**0**	**lbs P/year**

Worksheet 4
Project Phosphorus Export Summary

Summarizing the project's algal available phosphorus export (PPE)

Project name: ____

Project Phosphorus Budget - Worksheet 1	**PPB**	0.00	lbs P / year
Total Pre-Treatment Phosphorus Export - Worksheet 2	**Pre-PPE**	0.00	lbs P / year
Total Post-Treatment Phosphorus Export - Worksheet 2	**Post-PPE**	0.00	lbs P / year
Total Phosphorus Mitigation Credit - Worksheet 3	**TMC**	0.00	lbs P / year
Project Phosphorus Export (Post-PPE - TMC)	**PPE**	0.00	lbs P / year

Is the Project Phosphorus Export sufficiently reduced? (PPE< PPB)

If PPE is less than or equal to PPB - the project meets its phosphorus budget (YES). If PPE is more than PPB (NO) - more reduction in phosphorus export is required or a compensation fee can be paid

YES

Is the Post-Treatment Phosphorus Export *LESS* than 40% of the Pre-Treatment Export? *Equivalent to more than 60% removal efficiency (Post-PPE < 40% Pre-PPE)*

*If **YES**, in some waterhseds the compensation fee is an available option. If **NO**, a compensation fee is not an option. PPE must be further reduced.*

NOT APPLICABLE

When Post-PPE is less than 40% of Pre-PPE, a compensation fee may be appropriate at the cost of $25,000 per pound of phosphorus over budget. The compensation fee option is only available in some lake watersheds. Check with the DEP project manager or with the DEP Division of Watershed Management to see if the watershed in which the project is located is eligible before proposing a project that incorporates a compensation fee.

The following compensation fee must be paid
$25,000*(PPE-PPB)

NOT APPLICABLE

Appendix E
Alternative Method for Small Commercial-type Developments Located Within Designated Growth Areas

It can be difficult for densely developed projects on small parcels to meet their phosphorus budgets. Because of the density of high phosphorus producing surfaces like parking lots and lawns, the stormwater draining these projects carries relatively large amounts of phosphorus. The small parcel size, however, means that the phosphorus budget for the parcel will also be small. As a result, highly intensive phosphorus control measures, which are often fairly costly, may be required for the project to meet its phosphorus budget.

In these cases it may cost less to develop outside the designated growth area where land is more readily available for larger parcel sizes (and hence larger project phosphorus budgets) and for less intensive, and less expensive, phosphorus control measures like natural wooded buffers. If a municipality is concerned that the phosphorus budget will counter local planning efforts by being a disincentive for locating development within designated growth areas, they may request that the department allow commercial developers within their designated growth areas to use an alternative means of defining the project phosphorus budget. This alternative is described below.

To prevent sprawl and encourage building within designated growth areas, a municipality may request that projects with no more than 1.0 acre of impervious surfaces (building, parking, driveways, both paved and gravel) located on a small parcel with less than 5 acres within an area specifically designated for commercial growth in the municipality's DEP approved comprehensive plan be allowed to calculate the site's PPB as follows:

Alternative PPB Calculation for a Small Commercial-type Development
(as defined by having less than 1 acre of impervious area and on a parcel that is less than 5 acres and located within a designated growth area)

The alternative PPB shall be the lesser of the following:
A. Alternative PPB = PPB as calculated (using Worksheet 1) multiplied by 5, or
B. Alternative PPB = Project's proposed impervious area multiplied by 0.5 lb per acre

Example 2: PPB for Small Commercial Development

Problem:

'Parking for Rent' is proposing a one acre impervious parking lot on a 1.5 acre lot within the identified growth zone of a watershed with a phosphorus allocation of 0.03 lb/acre/year. The proposed treatment is through a buffer. Calculate the Project Phosphorus Budget.

Solution:

The standard PPB would be 1.5 acre X 0.03 lb/acre/year = 0.045 lb P /year. However, since the project is a small commercial-type development with no more than 1 acre of impervious area and on a parcel that is less than 5 acres and is located in a municipality's designated growth area, the alternative method for calculating the PPB may be used upon request by the municipality. The alternative PPB calculation is the lesser of:

Option A.

Standard PPB (as calculated on Worksheet 1) X 5 = 0.045 lb P /year X 5 = 0.225 lb P /year

Option B.

Project's Proposed Impervious Area X 0.5 lb P /acre / year = 1 acre X 0.5 = 0.5 lb P /year

Thus, the PPB is 0.225 lb P /year as in Option A.

Lake Stormwater Phosphorus Compensation Fee Program

Development projects subject to the Maine Stormwater Management Law located in eligible lake watersheds may satisfy permit requirements for phosphorus reduction by paying a compensation fee into a Lakes Stormwater Phosphorus Compensation Fund for that same eligible lake watershed. The development project needs to be designed to provide at least 60% reduction in off-site export of phosphorus required by the permit. The fee rate is $25,000 per pound of phosphorus.

Compensation fund monies are used to implement Stormwater Compensation Projects reduce phosphorus export from existing high phosphorus export land uses in the lake watershed.

DEP authorized 7 entities (listed below) to serve as Stormwater Compensation Fee Administrators (SAs) to receive compensation fees from developers and use the monies to develop and implement Stormwater Compensation Projects within their respective service areas. DEP receives and manages any fees collected for lakes outside of the service areas of the SAs.

- Androscoggin Valley Soil & Water Conservation District
- Cumberland County Soil & Water Conservation District
- Cobbossee Watershed District
- Kennebec County Soil & Water Conservation District
- Lakes Environmental Association
- Penobscot County Soil & Water Conservation District
- York County Soil & Water Conservation District

Materials

- Lake Stormwater Phosphorus Compensation Fee Option: Procedures and Limitations (August 20, 2010) describes the compensation fee option and lists eligible lakes.

- Lake Stormwater Compensation Fee Program: General Guidance (October 2012), provides guidance for Stormwater Administrators on management and use of funds to develop and implement Stormwater Compensation Projects.

Contact

For more information contact:

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Division of Environmental Assessment, Bureau of Land & Water Quality

Chapter 1
Introduction

Based on the shortcomings of traditional BMPs discussed in Volume I, Chapter 2, Maine DEP has restructured its use of BMPs to focus on meeting four major objectives:

1. **Effective pollutant removal:** BMPs must effectively remove the fine particles that carry much of the nutrient and heavy metal load, as well as dissolved pollutants, and hydrocarbons. BMPs that only remove coarse sediments are no longer available.

2. **Cooling:** BMPs discharging within a stream, brook or river watershed must effectively cool down (22°C or cooler) stormwater runoff before discharging it to adequately protect aquatic life. This may also be accomplished through measures to avoid heating of the stormwater.

3. **Channel protection:** BMPs discharging within a stream, brook or river watershed must slowly release stormwater runoff from a site to avoid destabilization and resulting sedimentation of receiving stream channels. This can also be accomplished through site planning and operation that minimizes the volume and rate of discharge of stormwater by minimizing impervious area, maximizing infiltration and evapo-transpiration, and maximizing time of concentration of storm flows.

4. **Flood control:** Traditional flood control detention for large, infrequent storms will still be necessary for some sites to avoid flooding of downstream infrastructure.

These objectives are discussed further in Volume I, Chapter 1. DEP is recommending four types of BMPs that if sized appropriately, will provide effective pollutant removal, cooling and channel protection. In some instances they may also provide flood control benefits without the need for a pond structure. The purpose of this volume is to provide information on these BMPs, as well as other BMPs that may be used for pretreatment and quantity control. The BMPs covered in this manual are outlined below:

BMPs to Control Flooding - These BMPs can be used to control peak flows from a development. Peak control BMPs are discussed in the following chapter(s):

Chapter 3: Peak Control/ Detention Structures

BMPs to Meet Water Quality Objectives (Pollutant Removal, Cooling & Channel Protection) - These four BMPs are recommended to meet the BMP standards for discharges to river, stream and brook watersheds and can also be used to meet phosphorus standards for lakes. The proper design of these BMPs will meet objectives for pollutant removal, cooling and channel protection. Water quality BMPs to meet water quality objectives are discussed in the following chapter(s):

Chapter 4: Wet Ponds
Chapter 5: Buffers
Chapter 6: Infiltration BMPs
Chapter 7: Filtration BMPs

Conveyance and Distribution BMPs - These BMPs can be used to help convey and control flows entering one of the four water quality BMPs. Conveyance and distribution BMPs are discussed in the following chapter(s):

Chapter 8: Conveyance and Distribution BMPs
- Vegetated Swales
- Flow Splitter
- Level Spreader

Separator BMPs - Separator BMPs are primarily designed as pretreatment devices to remove sediment and oil and grease from runoff before it discharges into one of the four water quality BMPs. Separator BMPs are discussed in the following chapter(s):

Chapter 9: Separator BMPs
- Water Quality Inlet
- Oil/Grit and Oil/Water Separator
- Proprietary Systems

Low Impact Development (LID) BMPs - LID can be used to minimize the impacts of development during the planning phase, which can minimize the need for structural BMPs. It is important to limit the size of an area draining to a LID BMP and to treat at the source. LID BMPs are discussed in the following chapter(s):

Chapter 10: Low Impact Development (LID)
- Planning for LID
- LID Techniques

Operation and Maintenance - Operation and maintenance is crucial to the performance of any BMP. This needs to be incorporated into the design phase to be most effective. Operation and maintenance criteria are discussed in the following chapter(s):

Chapter 11: Designing for Operation and Maintenance

Table 1-1 summarizes the applicability of each BMP. Alternative stormwater management systems to the four proposed by DEP may be used if they will provide equivalent pollutant removal, cooling and channel protection. DEP also strongly encourages the incorporation of low impact development site planning concepts with any development. LID may reduce the scale and need for structural BMPs.

Table 1-1: Best Management Practice Type Selection Matrix

BMP Type	Best Management Practice	Selection Criteria: Drainage Area (Acres)					Soil Hydrologic Group				Depth to High Water Table/ Depth to Bedrock		Land Area		Applicability					Design Restrictions						
		0-5	5-10	10-25	25-50	50+	A	B	C	D	0-3 ft	3+ ft	Requires Large Land Area	Requires Small Land Area	Peak Control (Flood Control Standard)	WQ Control (BMP Standard)	Pretreatment	Conveyance	Distribution	Proximity to Wells (ft)	Proximity to Property Lines	Wetland, Stream, Lake, River Setback	Upgradient Building Setback	Downgradient Building Setback	Steep Slope (>3:1) Setback	Slope
Detention Basin	Detention Basin			●	●	●	●	●	●	●	○	●	●		●					100'	25'	75'	20'	50'	50'	
Wet Pond	Wet Pond			●	●	●		●	●	●	●	●	●		●	●				300'	25'	75'	20'	100'	50'	
Buffer	Vegetated Buffer with Slope Lip Level Spreader	●					●	●	●	○	●	●	●		○	●										<15%
	Adjacent to Downhill Side of Road	●					●	●	●	●	●	●	●		○	●										<20%
	Ditch Turn-Out	●					●	●	●	○	●	●	●		○	●										<15%
	Adjacent to Residential, Large Pervious or Small Impervious	●					●	●	●	○	●	●	●		○	●										<15%
Infiltration	Drywell	●					●	●				●		●		●				300'	25'	25'	10'	100'		
	Infiltration Trench	●	●				●	●				●	●			●				300'	25'	75'	20'	100'		
	Infiltration Basin		●	●	●		●	●				●	●		●	●				300'	25'	75'	20'	100'		
Filter	Vegetated Soil Filter		●				●	●	●	●		●		●		●				100'	25'	75'	20'	25'	25'	
	Bioretention Cell	●					●	●	●	●		●		●		●				100'	25'	75'	20'	25'	25'	
Conveyance and Distribution	Vegetated Swales						●	●	●	●							●	●								
	Flow Splitter	●	●	●	●	●	●	●	●	●									●							
	Level Spreader	●					●	●	●	●									●							
Separator BMPs	Water Quality Inlet	●					●	●	●	●							●	○	○							
	Oil/Grit and Oil/Water Separator	●					●	●	●	●							●	○	○							
	Proprietary Systems	●					●	●	●	●							●	○	○							
LID	LID	●	●	●	●	●	●	●	●	●	●	●		●	○	●		●	○							

● Applicable ○ May be applicable with careful design

Chapter 2
Stormwater Hydrology

This Chapter deals with selected topics related to hydrologic modeling practice in Maine. A detailed discussion of hydrologic principles is not included here. Users of this manual should have a working knowledge of applied hydrology, including familiarity with the Rational Method, SCS TR-20 and SCS TR-55 methodology.

Persons without a background in hydrology should refer to the engineering hydrology texts listed in the bibliography. Persons without a working knowledge of the hydrologic principles of stormwater runoff should not be preparing or reviewing the engineering designs for the measures discussed in this document.
This manual is not an exhaustive and detailed design manual for stormwater hydrology information. Information is provided herein to provide a qualified designer with consistent and current data and information to incorporate into a design or analysis.

To assist designers, as well as to provide a standardized database for runoff estimating, selected hydrologic data is provided in this Chapter and in Appendix A. This material includes rainfall intensity duration data and curves, runoff coefficients for the Rational Method, and other data pertinent to Maine and useful in employing the methodologies discussed.

IMPORTANT

Refer to Volume I, Chapter 2 for more information on DEP's four stormwater management objectives, including:

- Effective Pollutant Removal
- Cooling
- Channel Protection
- Flood Control

Chapter Contents:

2.1 Controlling Peak Discharges & Runoff Volumes

The effects of urbanization on runoff are discussed in Volume I, Chapter 1 and Chapter 2. In summary, urbanization increases the volume and rate of runoff from the watershed, which in turn creates higher stream flows during rain events. Higher flows can cause flooding and have adverse effects on natural streams. The stream channel experiences higher flows more frequently and for longer durations. Under natural conditions, a stream experiences bankfull discharge about once every two years, while in moderately developed watersheds, bankfull discharge may occur as frequently as three to four times annually (Schueler, 1987; also see Leopold et. al., 1964 and Andersen, 1970). This may occur even when peak flow rates are controlled because of the increased runoff volume after development. These higher velocity flows cause stream banks to erode and the channel to widen. Eroded sediment is deposited in slower downstream reaches. The frequency of these channel disturbances limits the quality of the habitat in the stream channel, especially for organisms with longer life cycles.

Base flow in streams is also affected by changes in hydrology from urbanization. A large part of base flow is supplied by shallow infiltration. As shallow infiltration is reduced by increased impervious cover, the volume of water available for base flow in streams is reduced. These changes in hydrology, combined with increased pollutant loadings, can have a dramatic effect on the aquatic ecosystem in urban streams.

With regard to urbanization's effects on runoff volumes and peak flows, one goal of stormwater management is to manipulate post development flows to minimize their impacts on downstream (and upstream) capacity and stability. One of the ways to accomplish this objective is to use hydraulic structures to control discharges to approximate original conditions.

To most effectively approximate the original conditions, both the peak discharge rate of runoff as well as the total runoff volume need to be controlled.

Peak rates can be controlled by detention. As shown in Figures 2-1 and 2-2, to effectively control peak rates to pre-development levels, detention structures should be designed with multi-stage discharge structures (such as multiple ori-

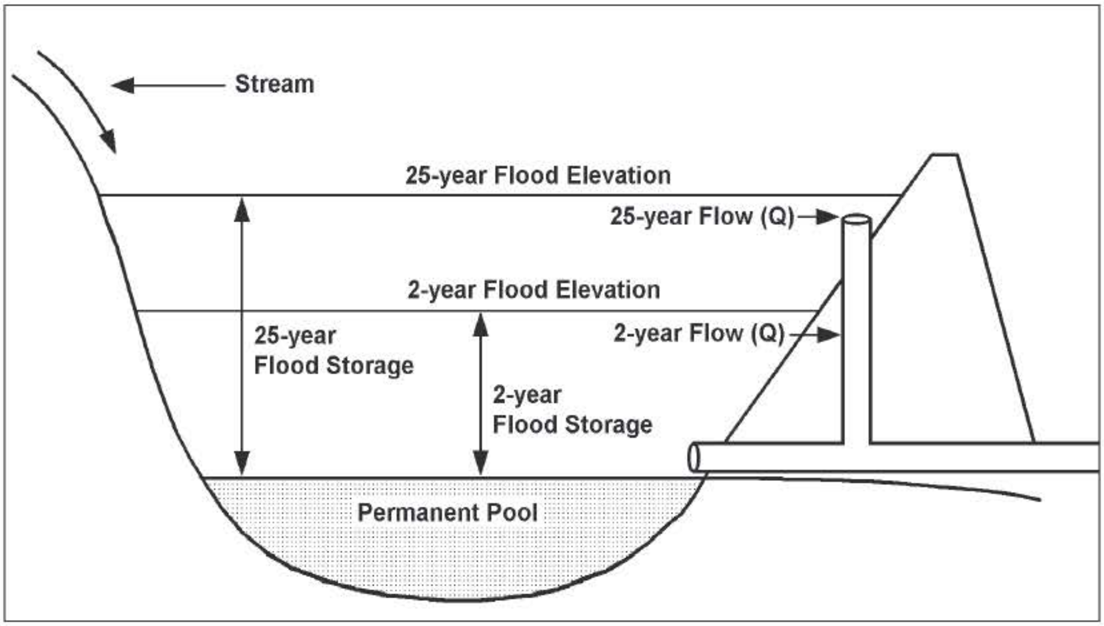

Figure 2-1. Schematic of Multi-Stage Discharge Detention Structure

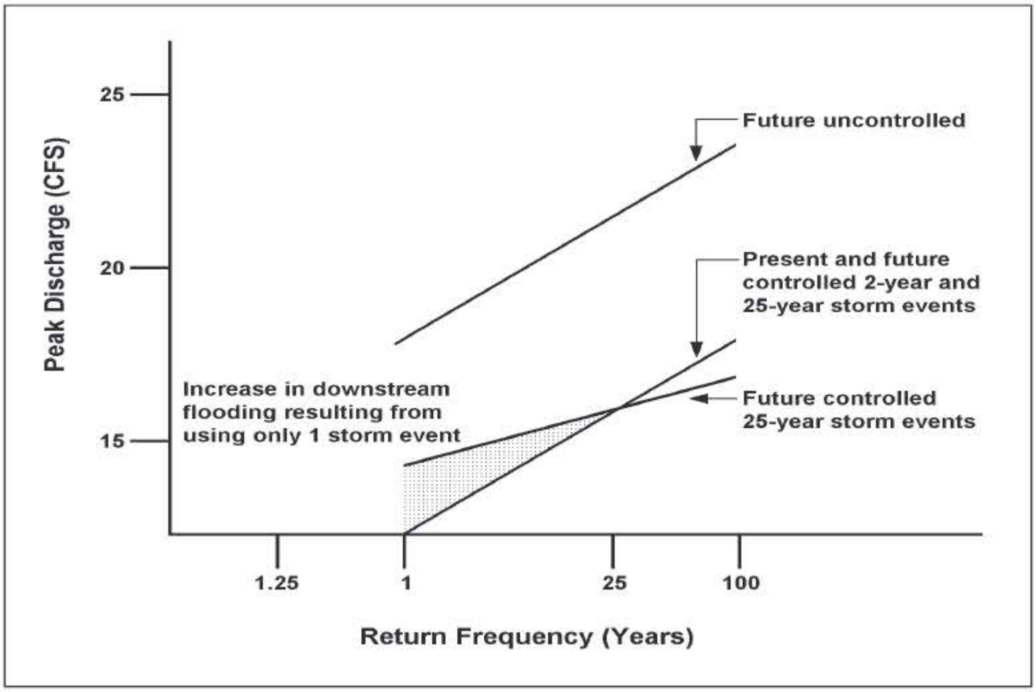

Figure 2-2. Frequency Discharge Curve

fice/weir combinations, or single V-notch weirs) to "bracket" the range of design flows of concern (e.g., 2-year, 10-year, and 25-year frequency events).

Duplicating pre-development runoff volume requires application of infiltration practices. This option is frequently limited or prohibited by site soils constraints and local water quality issues. Thus, where volume reduction is not an option, it is important to incorporate extended detention of the more frequent, potentially channel shaping storms into BMPs to minimize exposure of the stream channel to erosive flows. Schueler (1987, Appendix B of that publication) presents a preliminary methodology for estimating excess storage required to mimic pre-development bankfull flooding frequency.

Other tools available for managing stormwater include grading and channelization practices to lengthen travel times in drainage systems, grading to flatten slopes to increase time of concentration, and downstream modifications to pro vide for capacity and stability to carry increased flows.

2.2 Factors Affecting Runoff

The following material comments on selected factors that affect runoff. It is intended to establish some conventions in the terminology used in this document, and to highlight particular design issues relative to the factors discussed.

1. **Watershed/Drainage Area**: The term watershed is used qualitatively to identify the geographic area of land draining to a stream or other waterbody at a given location. The term catchment is also used. To describe a watershed, one needs to know its area, slopes, drainage characteristics of soils, cover, shape, and hydrography.

   The term drainage area is used to refer to the planimetric dimensions of the watershed. That is, it is a quantitative term, and refers to the measured area of the watershed (e.g., the drainage area of XYZ stream is 381 acres).

Care should be taken when delineating watershed boundaries to show and account for all areas outside the project area that are a part of each watershed.

2. **Rainfall:** To fully describe a precipitation event, four parameters must be used. They are the amount, the duration, the distribution, and the return frequency. For example, a fully described storm would be: 4.5 inches of rain, of 24 hour duration, having a type III distribution and a return frequency of 10 years.

a. *Rainfall Amounts:* Rainfall is typically recorded in total rainfall received in a 24 hour period. Applicable data for Maine is reported in Table 2-1. Rainfall amounts for shorter time frames are typically recorded by intensity (depth per unit time) and this data is presented in Intensity-Duration curves (as shown in Appendix A).

b. *Storm Duration:* The storm duration is the length of time from the beginning of rainfall to the point when there is no more additional accumulation of precipitation. Storm durations can be quantified in terms of minutes, hours and days, but usually no greater than five days. The duration of a storm is necessary for estimating the rate of runoff discharge. Accurate distributions for actual storms must rely on automatic recording rain gages located at major airports or National Weather Service (NWS) stations.

c. *Rainfall Distribution:* Rainfall intensity is a depth of rainfall per unit of time, usually expressed in inches per hour. Storms will contain many intensities, grouped either randomly (as in a real storm), or in a set sequence (as in a synthetic storm).

Rainfall intensity varies with time during a given storm for different geographical regions and for different locations specific to a region. The Soil Conservation Service (SCS), with the assistance of the National Weather Service, has developed four synthetic 24-hour rainfall time distribution curves for the United States. These include types I, IA, II and III (SCS NEH 4, SCS TR-55) included in Table 2-2. The type II and type III storm distributions as shown in Figure 2-3, are applicable within Maine.

Rainfall is also spatially distributed during a given event. However, for design of most stormwater management facilities, common practice assumes that rainfall is uniformly distributed over the entire contributing watershed. This assumption does not necessarily apply to large, complex watersheds, for which SCS TR-20 or an equivalent model allowing this flexibility should be used.

Table 2-1
24 Hour Duration Rainfalls for Various Return Periods
Natural Resources Conservation Service County Rainfall Data

County	Storm Type	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	100-Yr	500-Yr	Annual	
		Return Interval or Frequency								
Androscoggin		2.5	3.0	3.9	4.6	5.4	6.5	7.8	45.3	
Aroostook C		2.1	2.1	3.2	3.6	4.2	5.0	5.9	36.1	(Presque Isle Area)
Aroostook N	S	2.0	2.3	3.0	3.5	4.0	4.8	5.7	36.1	(Fort Kent Area)
Aroostook S	E	2.2	2.5	3.3	3.8	4.4	5.3	6.4	39.0	(Houlton Area)
Cumberland NW	E	2.8	3.3	4.3	5.0	5.8	6.9	8.3	43.4	(NW of St. Route 11)
Cumberland SE		2.5	3.0	4.0	4.7	5.5	6.7	8.1	44.4	(SE of St. Route 11)
Franklin	N	2.4	2.9	3.7	4.2	4.9	5.9	7.0	45.6	
Hancock	O	2.4	2.7	3.6	4.2	4.9	6.0	7.2	45.2	
Kennebec	T	2.4	3.0	3.8	4.4	5.1	6.1	7.2	41.7	
Knox-Lincoln	E	2.5	2.9	3.8	4.4	5.1	6.2	7.4	46.1	
Oxford E	S	2.5	3.0	4.0	4.6	5.3	6.4	7.6	43.0	(E of St. Route 26)
Oxford W		3.0	3.5	4.5	5.2	6.0	7.1	8.4	43.8	(W of St. Route 26)
Penobscot N	1	2.2	2.5	3.3	3.8	4.4	5.4	6.4	41.5	(N of Can. -Atl. Rwy)
Penobscot S		2.4	2.7	3.5	4.1	4.8	5.8	6.9	39.5	(S of Can. -Atl. Rwy)
Piscataquis N	A	2.2	2.5	3.3	3.8	4.4	5.3	6.3	38.5	(N of Can. - Atl. Rwy)
Piscataquis S	N	2.3	2.6	3.4	4.0	4.6	5.5	6.6	41.0	(S of Can. - Atl. Rwy)
Sagadahoc	D	2.5	3.0	3.9	4.6	5.4	6.5	7.8	45.3	
Somerset N		2.2	2.5	3.3	3.8	4.4	5.3	6.3	37.3	(N of Can. - Atl. Rwy)
Somerset S		2.4	2.7	3.5	4.1	4.7	5.7	6.8	39.5	(S of Can. - Atl. Rwy)
Waldo	2	2.5	2.8	3.7	4.3	4.9	6.0	7.1	47.2	
Washington		2.4	2.5	3.4	4.0	4.8	5.9	7.1	44.2	
York		2.5	3.0	4.0	4.6	5.4	6.6	7.8	46.7	

NOTES: REVISED 4/10/92 Lew P. Crosby
24-HR DURATION RAINFALL

SOURCES: 24-HR. DATA - TP 40
ANNUAL DATA - CDAN

Note 1: [1]Use ***Type II*** for Oxford County (with the exception of towns listed below) and Penobscot County (with the exception of towns listed below) and all Main counties not listed below)

Note 2: [2]Use ***Type III*** for York, Cumberland, Androscoggin, Sagadahoc, Kennebec, Waldo, Knox, Piscataquis, Somerset, Franklin, Aroostook, Lincoln, Hancock, Washington Counties; the following Oxford County Towns: Porter, Brownfield, Hiram, Denmark, Oxford, Hebron, Buckfield and Hartford; and the following Penobscot County Towns: Dixmont, Newburgh, Hampden, Bangor, Veazie, Orono, Bradley, Clifton, Eddington, Holden, Brewer, Orrington, Plymouth, Etna, Carmel, Hermon, Glenburn, Old Town, Milford and Greenfield.

Table 2-2
Rainfall Distribution Comparisons for Maine

(DA = Drainage Area)
Numbers refer to percent of total 24 hour precipitation.

Duration	Uniform	Type I For DA >3 sq. mi	Type II[1] For DA <3 sq. mi	Type III[2] For DA <3 sq. mi
6 Min.	0.4%	6.0%	11.25%	8.4%
15 Min.	1.0%	21.0%	38.0%	31.0%
1 Hour	4.2%	28.0%	43.0%	40.0%
2 Hour	8.3%	37.0%	54.0%	50.0%
3 Hour	12.5%	43.0%	58.0%	57.0%
6 Hour	25.0%	57.0%	70.0%	71.0%
12 Hour	50.0%	75.0%	84.0%	86.0%
24 Hour	100.0%	100.0%	100.0%	100.0%

Source: SCS & NWS, NEH-4 and TR-20

d. <u>*Return Period/Frequency:*</u> The return period (sometimes referred to as frequency) of a hydrologic event is the expected (or average) value of the recurrence interval (time between occurrences) of an event equal to or greater than a given magnitude. For example, in Portland, Maine, the return period between storm events with rainfall equal to or greater than 4.7 inches (24-hour storm duration) is 10 years. Alternatively stated, 4.7 inches is the 10-year frequency, 24-hour duration storm for Portland. The probability of a hydrologic event occurring in a given year is the inverse of the return period. Thus, the 10-year frequency storm has a 0.10 probability of being equaled or exceeded in any given year, and the 100-year frequency storm has a 0.01 probability of being equaled or exceeded in any given year. The reader is referred to hydrologic texts from more extensive discussions of frequency analysis (and associated risk analysis).

Note that different types of hydrologic events can have different return periods (or frequencies). For example, the 100-year frequency storm is a rainfall event. The 100-year flood is a peak stage or runoff event. A common assumption of hydrologic estimating methods is that the flood event corresponds with the rainfall event of the same frequency. This is not always true; for instance, a relatively minor storm accompanied by a spring snow melt can result in a relatively major flood event. A flood event may also result from a coastal surge cause by high winds, independent of rainfall.

Severity of a hydrologic event varies inversely with its return period; that is, very severe storms occur less frequently than moderate storm events. The choice of a storm frequency for designing a hydraulic structure can be based on analyzing the risk of damages from storms of greater severity compared to the costs of initial construction.

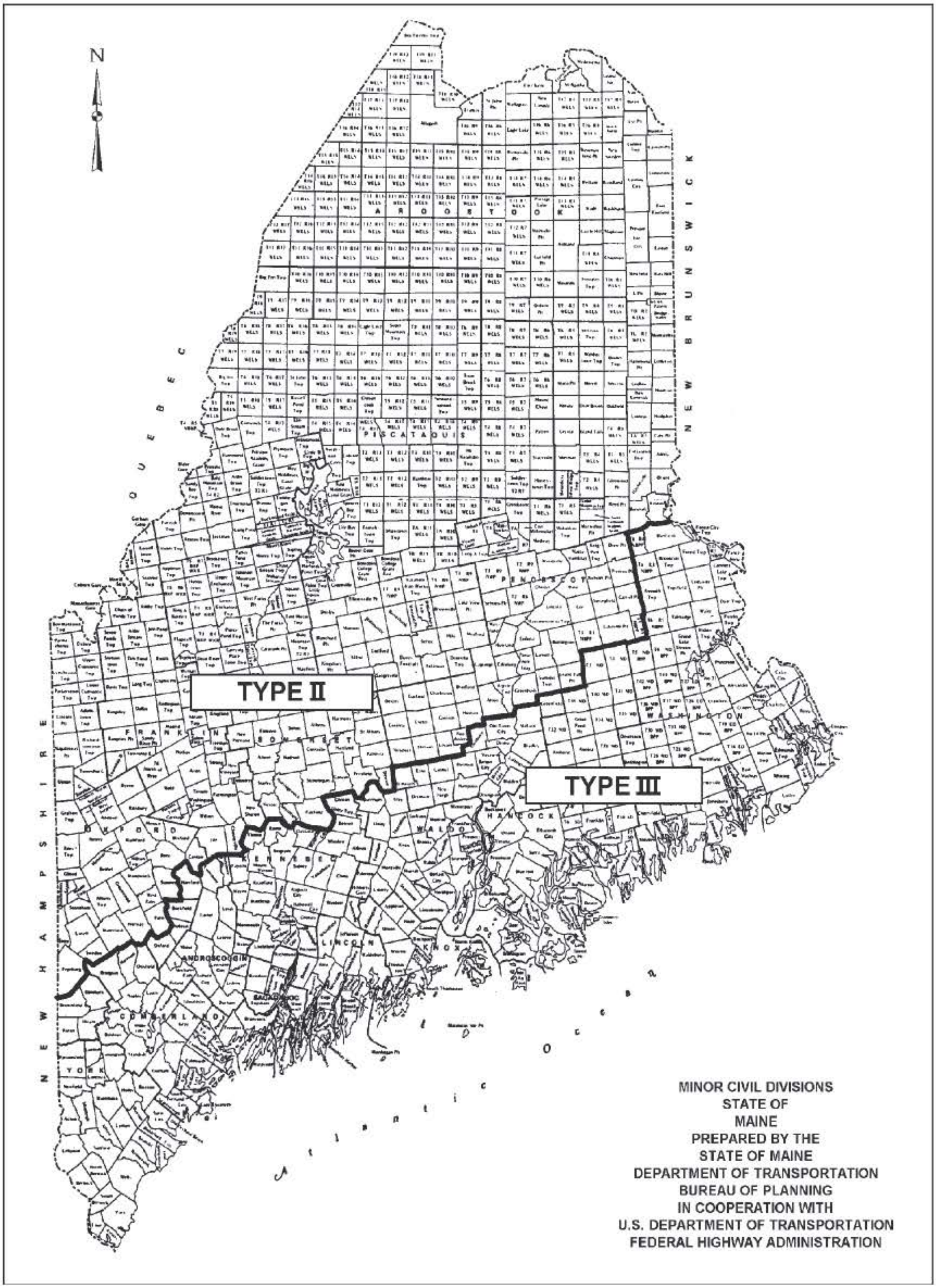

Figure 2-3. Type II and Type III Storm Distributions in Maine

The following is recommended for conventional practice in Maine:

- Piped conveyance systems (storm drains) are designed for the 10-year frequency storm. Culverts under roadways and other major drainage structures are designed for the 25-year storm. The Department of Transportation (DOT) may require design for the 50 or 100-year storm.

- Detention structures are designed to control the 2-year, 10-year, and 25-year frequency discharges. (Ideally, detention structures would control all frequency storms, including "expected" storm events like the 3-month or 6-month storm.)

- Detention structures designed to provide channel protection detention must have principal spillways capable of providing extended detention of 12 hours for runoff from a 2-hour storm of a 1-year frequency.

- Areas that will be inundated during the 25-year frequency storm must be identified and, presumably, suitable for temporary inundation. Structures (residential buildings, public roads, water treatment facilities, etc.) must not be located in areas subject to inundation during a 100-year storm.

- Emergency spillways from detention structures must be designed to independently convey the routed runoff from at least the 25-year, 24-hour storm while maintaining at least one foot of freeboard between the peak storage elevation and the top of the embankment crest. This, in addition to the principal spillway, should provide an adequate margin of safety for conveyance of a 100-year event. A routed 100-year storm is acceptable for other hydrologic methods such as TR-20.

- Designers should note that local ordinances or MEMA/FEMA standards may require sizing of pipes and structures for larger return periods (i.e., less frequent storms).

e. _Rainfall Intensity - Duration - Frequency Relationships:_ In designing stormwater management facilities, the designer usually selects one or more "design storms". The most common approach is to use a design storm that relates the rainfall intensity, duration, and frequency (return period). Intensity-duration-frequency (IDF) curves are developed to describe this relationship, based on frequency analyses of rainfall event data at specific locations (some sources publish the data in the form of depth duration frequency maps, e.g., NOAA 35 and TP 40). Rainfall IDF data for Maine has been assembled from a number of sources. This data is included in Appendix A. The designer is referred to the hydrology literature for a more detailed discussion of the derivation of these IDF relationships. The Maine Department of Transportation Highway Design Guide, January 1994 has IDF curves for selected locations in Maine.

3. **Soils**: Soil characteristics affect the volume and rate of storm runoff. Some hydrologic estimating methods specifically account for soil types (SCS NEH-4, SCS TR-55); others may not (e.g., some references for the runoff coefficient used in the Rational Method do not relate the coefficient to soil type). The choice of a hydrologic model for a specific application may be governed by the extent to which the model accounts for soil conditions.

An extensive description of soil characteristics and relationship to hydrology is not offered here. If a hydrologic model does include a parameter for soil conditions, the following should be considered:

a. *Antecedent Moisture Conditions (AMC):* The SCS models include soils runoff curve numbers based on average antecedent moisture conditions (AMC-II). In some cases, the analysis of dry (AMC-I) or wet (AMC-III) soil conditions prior to the design storm may be warranted. For design purposes, the curve numbers for AMC-II which are built into the models should always be used unless there are specific design criteria specifying otherwise. For analysis purposes where data from TR-20 or other runoff models is being calibrated with actual storm data, an adjustment of the curve number (CN) based on differing mousier conditions (AMC) may be warranted. Any adjustment in CN due to AMC changes must be made with caution and only with proper professional judgement. Tables are provided in Appendix A relative to adjustment based on AMC, and the designer should refer to SCS NEH-4 for guidance on how to apply AMC adjustments.

The definition of each antecedent moisture condition is as follows (SCS NEH-4):

Condition I Soils are dry but not to wilting point; satisfactory cultivation has taken place.

Condition II Average Conditions (Base Values in TR-55 and TR-20).

Condition III Heavy rainfall, or light rainfall and low temperatures, have occurred within the last 5 days; saturated soil.

Table 2-3 gives seasonal rainfall limits for these antecedent moisture conditions.

Table 2-3
Total Five Day Antecedent Rainfall
(inches)

AMC	Dormant Season	Growing Season
I	Less than 0.5	Less than 1.4
II	0.5 - 1.1	1.4 - 2.1
III	Over 1.1	Over 2.1

Source: Browne, 1990; SCS TP-149

b. *Hydrologic Soil Group:* The hydrologic soil group (HSG) reflects the infiltration rate of the soil, the permeability of any restrictive layer(s), and the moisture-holding capacity of the soil profile to a depth of 60 inches. The infiltration rate of the soil affects runoff. Generally, the higher the rate of infiltration, the lower the quantity of stormwater runoff. Fine textured soils such as clay produce a greater rate of runoff than coarse grained soils such as sand. The hydrologic soil groups are:

HSG A (Low runoff potential) Soils having a low runoff potential and high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels and having a high rate of water transmission (greater than 0.30 in./hr.).

HSG B Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in./hr.).

HSG C Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission (0.05-0.15 in/hr.)

HSG D (High runoff potential) Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential,

soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission (less than 0.05 in/hr.)
Source: NEH-4

c. *Changes in Site Soils:* When a site is extensively reworked (i.e., cuts or fills in excess of 60 inches), the hydrologic group associated with the original surficial soils may not apply to the newly graded surface. The designer may need to adjust curve numbers to account for new soils conditions, as well as new cover conditions, to obtain realistic estimates of runoff for this scenario.

d. *Seasonal High Water Table (HWT):* The depth to the groundwater may be determined by the mottles present in the soil horizon. Mottling can be identified from the organic streaking, concretions, and color differentiations or from other morphological features indicative of a seasonal water table. The mottles are caused by the alternation of saturated and unsaturated soil conditions. During saturation, iron and manganese become reduced and exhibit subdued shades of grays, greens or blues. When the soil is unsaturated, the oxygen combines with iron and manganese to develop brighter soil colors such as yellows and reddish browns. Soils that experience seasonally fluctuating water tables usually exhibit alternating streaks, spots or blotches of bright-oxidized colors mixed with reduced dull or subdued colors. The longer a soil is saturated, the greater is the percentage of color that will be subdued.

4. **Surface Cover**: The type of surface or ground cover and its condition also affect runoff volume, as they influence the infiltration rate of the soil. For example:

- Fallow land yields more runoff than forests or grassland for the same soil type.

- Leaf litter and decomposing organic matter maintain the soil's infiltration potential while a bare soil may become sealed by the impact of falling rain. Also, vegetation and foliage retain some of the falling rain and increase the amount evaporated into the atmosphere. Foliage also transpires moisture into the atmosphere and creates a moisture deficiency in the soil which must be replaced by rainfall prior to the occurrence of runoff.

- Vegetation and litter also form barriers along the path of flowing water, decreasing its velocity and reducing the peak rate of runoff. This duff layer also maintains the microtopography of the forest floor.

- Covering areas with impervious surfaces, such as parking areas, reduces infiltration and surface storage, thereby increasing the size of runoff volumes and peak discharges.

5. **Modeling Soil and Cover Types:** When modeling stormwater runoff, a mathematical representation of the combination of soil type and surface cover is often used. In the SCS models (TR-20 and TR-55), the selection of curve numbers (CNs) to represent soil-cover complex types is fairly standardized. For the Rational Method, there are a number of sources offering tables of runoff coefficients ("C"), and the designer has a fair degree of discretion in choosing a value. In order to promote consistency in practice in Maine, this manual recommends that the runoff coefficients used should compare to those published by the ASCE in the most recent manual of practice for stormwater management and as shown in Appendix A. These values should be used for return periods of 2-10 years. Higher values should be used for longer return periods when infiltration and other losses have a smaller effect on runoff. However, alternative methods of determining "C" may be appropriate in some instances (e.g., using methods which yield "C" values corresponding to SCS Curve Numbers).

6. **Time of Concentration and Travel Time:** The Time of Concentration (Tc) is the time required for water to travel from the hydraulically most remote part of the watershed to the point of analysis at the lower end of the watershed. This longest time may or may not be the longest physical distance. Travel Time (Tt) is the time it takes water to travel from one location in the watershed to another. A Tc is determined by summing the Tts along the flow path from the most remote point (time-wise) of a watershed. A Travel Time may be the time water flows from one point to another as sheet flow, shallow concentrated flow, or open channel or conduit flow. A Tc will generally contain a sheet flow component, probably have a shallow concentrated flow component, and may have an open channel or conduit flow component. These components are described as follows:

a. *Sheet flow*: Sheet flow (less than 0.1 foot deep) is flow over a plane surface, which usually occurs in the headwaters of watersheds. With sheet flow, the friction value (Manning's "n") is an effective roughness coefficient that includes the effect of raindrop impacts; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment (SCS, 1986).

Reference is made to SCS Technical Note N4 (SCS, 1986) for limitations as to length of sheet flow. In Maine, the length of sheet flow is seldom greater than 150 feet. A distance of up to a maximum of 300 feet may be possible in a well maintained, slightly sloped paved parking area or a slightly sloped grassed lawn. An on-site inspection (preferably during a runoff event) is the only way to validate the length of sheet flow.

b. *Shallow Concentrated Flow:* After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. In practice, sheet flow probably becomes shallow concentrated flow after a much shorter distance. The point at which shallow concentrated flow occurs should be justified on the basis of a site inspection (for existing conditions), or design grades (for proposed conditions).

c. *Open Channel or Non-pressure Conduit Flow:* Open channel flow may be assumed where channels are visible on aerial photographs or where blue lines (indicating streams) appear on USGS quadrangle sheets. However, the beginning point of the channels is often much higher in the watershed and its location should be verified by an actual site inspection or by survey data. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation. Conduit flow Tts are used only if the discharge is fully contained in the conduit under non-pressure flow. Pipes flowing under pressure cannot be modeled as conduit flow.

2.3 Factors Affecting Runoff

The selection and design of stormwater management practices requires estimates of flow volumes, peak discharges, and detention storage requirements. For some projects, not only must the outlet of a particular watershed be examined but also the downstream effects of changes at the site must be evaluated. A number of methods are available to model hydrologic parameters. These methods are discussed in the following pages, and Data Sheets describing several methods are presented in Appendix B.

A number of public domain and proprietary computer programs are now available, which incorporate one or more of the methodologies discussed here. Appendix C contains brief descriptions of a number of these programs.

2.3.1 Water Quality Volume

The water quality volume is that initial volume (depth) of runoff that is considered to carry the bulk of pollutants deposited since the last runoff event. This is generally defined as a given depth of runoff distributed over the watershed.

Studies have indicated that the first one-inch of runoff carries 90% of the pollution load from a storm. Other research has shown that smaller precipitation events between 0.5 and 1.5 inches of rainfall (approximately the runoff resulting from a 1-year, 24-hour storm event) are responsible for about 75% of the runoff pollutant discharges; larger rainfall amounts (i.e., a 10-year storm event) are associated with drainage design and are responsible for only small portions of annual pollutant discharges (Pitt, 1994). This latter research concludes that treating the initial amount of runoff is effective not because of the first flush, but because the first 0.5 inch of runoff from all storms accounts for almost all of the total annual runoff from most land uses.

It is important to note that the above is only valid for areas with existing impervious area. Developing sites with exposed soils have a high potential for erosion when under construction during larger storms.

Several of the water quality Best Management Practices outlined in Volume III are designed to treat the water quality volume of stormwater runoff and their design should be based on the above criteria.

WATER QUALITY VOLUME DESIGN CRITERIA FOR STORMWATER MANAGEMENT TREATMENT SYSTEMS:

Stormwater management facilities must be designed to treat the first 1 inch of runoff from impervious surfaces and 0.4 inch from landscaped areas.

2.3.2 Runoff Volume and Peak Rate (Single Event)

Many different methods of computing peak rates and volumes of runoff for storm events have been developed. Common methods used in Maine are listed below, with a short description of limitations. Table 2-4 summarizes the recommended applications of these methods. (Adapted from MPCA, 1989):

1. **Rational Method:** The Rational Method establishes an empirical formula that is commonly used in urban areas for computing peak rates of runoff for designing drainage structures. It is useful in estimating runoff on relatively small areas such as roof tops and parking lots. Use of the rational equation should be limited to drainage areas less than 20 acres (Amer. Public Works Assn., 1974) with generally uniform cover type and grade. However, some practitioners dislike using the Rational Method even on the smallest of drainage areas. The most serious drawback of the Rational Method is that it gives only the peak discharge and provides no information about the time distribution of the storm runoff so is therefore not usable for simulation modeling. Furthermore, selecting variables for the Rational Method is more an art of judgment than a precise account of the antecedent moisture condition or an aerial distribution of rainfall intensity (USEPA, 1976). Modifications of the Rational Method have similar limitations (Amer. Public Works Assn. 1974).

2. **TR-20:** The SCS TR-20 computer program is a full hydrographic routing model which uses hydrologic soil cover complexes (runoff curve numbers) to determine runoff volumes as well as unit hydrographs to determine peak rates of discharge. Factors included in the method are 24 hour rainfall amount, a specific rainfall distribution, runoff curve numbers, time of concentration, travel time and drainage area. This method divides the watershed into subareas, completes an outflow hydrograph for each, and then combines

Table 2-4
Selection Criteria for Runoff Calculation Methods
(MPCA, 1989 and modified by Maine DEP)

Output Requirements	Drainage Area	Appropriate Method
Peak discharge only	Up to 20 acres	1 2 4 5
	Up to 2000 acres	2 3 4 5
	Up to 20 sq. miles	2 3
Peak discharge and runoff volume	Up to 2000 acres	2 3 4 5
	Up to 20 sq. miles	2 3
Runoff hydrograph	Up to 20 sq. miles	2 3

1. Rational Method
2. SCS TR-20 Method
3. COE HEC-1 Method
4. SCS TR-55 Tabular Method
5. SCS TR-55 Graphical Method

and routes each subarea to the outlet. It is especially useful for measuring the effects of changed land use in part of a watershed. It can also be used to determine the effects of structures and combinations of structures, including channel modification, at different locations in a watershed. This procedure should be used with caution for drainage areas less than 50 acres or individual drainage areas more than 20 square miles. It may be used on watersheds up to 391 square miles in area, assuming subdivision of the total watershed into relatively homogeneous sub-watersheds of less than 20 square miles each, and routing through all subareas to the study point. It is very useful for large drainage basins, especially when there are a series of structures or detention basins and several tributaries are to be studied.

3. **HEC-1:** The United States Army Corps of Engineers method, HEC-1, provides an evaluation similar to SCS TR-20. Like TR-20, it can be used on both simple and complex watersheds. HEC-1 requires the input of more complex data than TR-20, but provides greater flexibility in calibrating a rainfall-runoff model with actual stream gauge records. A disadvantage could exist in small rugged watersheds where actual runoff documentation is not available. In an area where all soils have been mapped by SCS, the SCS runoff curve number method may offer more accurate results.

4. **TR-55 Tabular Method:** The SCS TR-55 Tabular Method is an approximation of the more detailed SCS TR-20 method. The Tabular Method divides the watershed into subareas, completes an outflow hydrograph for each, and then combines and routes each subarea to the outlet. It is especially useful for measuring the effects of changed land use in a part of a watershed. It can also be used to approximate the effects of a single structure, including channel modification, at the bottom of a watershed. The Tabular Method should not be used when large changes in the curve number occur among subareas within a watershed and when runoff volumes are less than about 1.5 inches for curve numbers less than 60. This method should also not be used if there is a considerable amount of natural detention within or above the study watershed. For most watershed conditions, however, this procedure is adequate to determine the effects of urbanization on peak rates of discharge for subareas up to approximately 2000 acres in size.

5. **TR-55 Graphical Method:** The SCS TR-55 Graphical Method calculates peak discharge and runoff volumes using an assumed unit hydrograph and a thorough, but rapid, evaluation of the soils, slope, and surface cover characteristics of the contributing watershed. This method is recommended for use in the design of erosion and sediment control measures. When more detail and accuracy are required or when an accurate simulation of natural conditions is required, one of the other appropriate methods should be used.

The methods identified in the foregoing discussion (particularly, the Rational method, SCS TR-20 and SCS TR-55 methods) are widely used in Maine for site development related analyses. Other estimation methods are available, and may be useful for particular applications or to cross check results. For example, the Maine Department of Transportation has developed a Highway Design Guide (MDOT, 1990) which prescribes the use of five methods for estimating peak discharges (including the Rational Method). These methods and the limits of their applicability are listed in Table 2-5. The reader should refer to Chapter 12 of the Highway Design Guide and selected references for a further description of the alternative methods. The Maine Geologic Survey also utilizes several methods for large drainage areas (over five square miles) which are typically used to quantify stream flows.

To assist the designer in selection and application of methods for estimating runoff and peak discharge, "Data Sheets" on selected methods are provided in Appendix B. However, the designer should consult the primary references for these methods as well as the applicable reviewing authority prior to final selection and application to a particular project.

Table 2-5
Maine Department of Transportation
Application of Hydrologic Methods for Peak Flow

Method	Drainage Area*	Slope*	Note No.
Potters	>10 acres	N/A	1
BPR 1021	1 to 1000 acres	N/A	1
Bensons	>10 acres	50’-150’/mi	1
Rational	0 to 200 acres	N/A	2
USGS	>100 acres	2’-300’/mi	1

** Do not use a hydrologic method outside of the parameters indicated.*

NOTES:

1. The methods indicated apply to Urban areas only when the discharge originates outside the built up portion of an Urban area, such as a brook whose drainage originates in a Rural area but passes through an Urban area. They do not apply when drainage originates within the built up portion of an Urban area.

2. The Rational Method is a primary tool for use in determining discharge from areas within an Urban area but also will have limited use in Rural areas.

2.3.3 Frequency vs. Discharge Analysis

The before and after runoff analysis is normally depicted graphically with hydrographs. But a plot on log probability paper helps in ease of comprehension and error checking. As shown in Figure 2-2, you observe a lower line representing the pre-condition frequency discharge behavior of the subject watershed. The post condition frequency discharge behavior is shown above. The difference in the peak discharges between the two lines is the increase in flooding. This type of plot shows the reason and need for controlling a "family" of storms to mimic predevelopment conditions.

Flood control is simply the addition of sufficient storage behind a detention pond that lowers the upper line to the lower line. At least one small storm frequency (usually the 2-yr.) and one large storm frequency (usually the 25-yr.) is sufficient to approximate the range of runoff values, although an intermediate storm (such as the 10-yr.) provides a more complete hydrologic model.

The frequency discharge analysis for the before (pre) and after (post) condition should be depicted for project areas of vital interest, at the lower project boundary and at restricted downstream areas of potential flood damage.

2.3.4 Flood Routing/Storage Estimating

Flow routing is a procedure for determining the time and magnitude of flow at a downstream point on a watercourse from known or assumed hydrographs at one or more points upstream (Chow, 1988). If the flow is a flood, the procedure is known as flood routing. A number of methods have been developed for routing hydrographs through hydrologic systems. The reader is referred to the basic hydrology references for detailed presentations of the theory and methodologies of routing.

Flood routing is used in some of the runoff estimation methods (SCS TR-20, HEC-1) to obtain peak flows at different points along a water course. Flood routing is also of importance in modeling the effects of ponded areas on the outflow from a watershed, and for the sizing of detention facilities.

SCS TR-55 includes a graphic methodology to determine detention storage requirements using the output of the Graphical and Tabular runoff estimation procedures. This method is based on the investigation of average storage and routing effects of many structures using the Storage Indicator Method of reservoir routing. This method is approximate, and should not be used to perform final design if an error in storage of 25 percent (oversized storage) cannot be tolerated (USDA/SCS, 1986). A routing method should be used to properly size outlet structures designed for multiple storms.

A number of commercially available computer software packages have been developed which incorporate the SCS-TR-20 or HEC-1 procedures, or other routing methods. See Appendix C.

The Modified Rational Method, while not a true routing procedure, can be used for preliminary design of detention storage for watersheds up to 20 or 30 acres.

2.4 Hydrologic Data for Maine

Appendix A presents hydrologic data applicable to Maine. The information is drawn from a number of sources (as cited) and is presented for the convenience of the designer. The designer assumes any responsibility for selection and application of this data for specific projects.

Selected References

ASCE. 1992 *Design and Construction of Urban Stormwater Management Systems.* ASCE - Manuals and Reports on Engineering Practice No. 77. American Society of Civil Engineers and the Water Environment Federation. New York, NY.

Benson, M.A. *Factors Influencing The Occurrence of Floods in a Humid Region of Diverse Terrain* (Benson's Method), W.S.P. 1580-B.

Browne, F.X. 1990. "Stormwater Management". In *Standard Handbook of Environmental Engineering* (R.A. Corbitt, ed.). McGraw-Hill Publishing Co., New York. pp. 7.1 to 7.135.

Chow, V.T., D.R. Maidment, and L.W. Mays. 1988. *Applied Hydrology*. McGraw-Hill Publishing Co., New York.

MDOT. 1990. Drainage Design Chapter 12. *Maine Highway Design Guide*, Highway Design Division, Maine Department of Transportation, Augusta, Maine.

Potter, W.P. 1957. *Peak Flows - New England Hill and Lowland, Area B2, Peak Flows from Adirondack - White Mountain - Maine Woods, Area B3, and Glacial Sandstone and Shale Area.* (Potters Method), Bureau of Public Roads.

SCS TP-149. *A Method for Estimating Volume and Rate of Runoff in Small Watersheds.* TP-149, U.S. Department of Agriculture, Soil Conservation Service, Washington DC.

SCS NEH-4. *National Engineering Handbooks, Section 4, "Hydrology".* U.S. Department of Agriculture, Soil Conservation Service, Washington DC.

SCS TR-20. *Project Formulation - Hydrology*. Technical Release 20, US Department of Agriculture, Soil Conservation Service, Washington DC.

SCS TR-55. *Urban Hydrology for Small Watersheds.* Technical Release 55, U.S. Department of Agriculture, Soil Conservation Service, Washington DC.

USGS. 1975. *A Technique for Estimating the Magnitude and Frequency of Floods in Maine*. Open-File Report 75-292, United States Geological Survey.

Wanielista, M.P. 1983. *Water Quantity and Quality Control.* Ann Arbor Press.

Wanielista, M.P. 1990. *Hydrology and Water Quantity Control*, John Wiley and Sons, Inc., New York

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Chapter 3
Peak Flow Control/ Detention Basins

Peak flow control generally involves the use of a detention structure to temporarily store excess runoff and gradually release it over a period of time to the receiving watercourse. Typically, a detention facility is designed to control outflow at a rate no greater than the pre-development peak discharge rate.

Generally, detention facilities will not significantly reduce the total volume of runoff, but will redistribute the rate of runoff over a period of time by providing temporary "live" storage of a certain amount of stormwater. The purpose is to reduce downstream flooding and erosion problems. The most common detention structure is the dry detention basin, although wet ponds can also be used for peak flow control. This chapter focuses on detention basins, since their primary function is peak control, with little water quality benefit. Wet ponds are discussed in Chapter 4 for use as both water quality and peak flow control.

3.1 General Description

IMPORTANT

Detention basins may only be used for water quantity control. They must be combined with other water quality BMPs to receive credit for water quality improvements.

A detention basin is an impoundment designed to temporarily store runoff and release it at a controlled rate. A dry detention basin is normally designed for quantity control or peak flow control and pollutant removal is only a minimal benefit. Although detention basins are effective at controlling peak discharge rates leaving a site, they may do little to limit increases in flow rates further downstream and, in some cases, may actually increase the peak flows at some points.

This Chapter discusses the design of detention basins for quantity control and extended detention for stream channel protection.

Chapter Contents:

Other BMPs presented in this manual (i.e., wet ponds, buffers, infiltration and underdrained soil filters) must be used for water quality improvements. Figure 3-1 shows a typical detention basin.

3.2 Site Suitability Criteria

1. **Drainage Area:** Four acres of drainage are recommended for each acre-foot of storage in the basin.

2. **Depth to Groundwater:** The bottom of the constructed basin, including any underdrain soil filters shall be one foot above the seasonal high groundwater table.

3. **Bedrock:** Bedrock close to the surface may prevent excavation.

3.3 General Design and Construction Criteria

1. **Basins on Slopes:** When basins are created by cutting and filling a slope, care should be taken that the seasonal groundwater table on the slope above the basin is not exposed, thus creating a seasonal spring. Controlling the groundwater flow or spring flow into a basin may be accomplished by the proper installation of a subsurface interceptor drainage system. To prevent destabilization from groundwater seepage, riprap may be needed.

2. **Inlet and Outlet Locations:** Provide one distinct area of inlet flow and one distinct area of outlet flow in the basin. The inlet and outlet should be as far apart as possible. Runoff should have to travel the longest distance possible through the basin before being discharged. The shallow and narrow end of the basin should be located near the inlet and the deeper and wider end near the outlet.

3. **Inlet Design:** The inlet must be designed with riprap or other energy dissipater, such as a baffle below the inflow structure to reduce erosive forces and pretreatment to remove sediment. Sediment forebays shall be designed with a minimum length to width ratio of 2:1.

IMPORTANT

1. Runoff should travel the longest distance through the basin before being discharged.
2. Sediment forebays shall be designed with a minimum length to width ratio of 2:1.
3. Provide a maintenance right-of-way to the basin for access by heavy equipment. Maintenance access shall be planted with grass and at least 10 feet wide with a maximum slope of 15% and a maximum cross slope of 3%.
4. The maximum grade of the emergency spillway may not exceed 20% unless a non-flexible lining such as riprap is used to control erosion within the spillway.
5. A geotechnical engineer must design and submit a report on any embankment over 10' high or posing a significant hazard to downstream property or life.
6. A safety bench must be designed into all embankments greater than 10 feet high.
7. Construction of basins must be complete with side slopes and banks stabilized with grass or conservation mix seeding before allowing the basin to fill with water.
8. Basins must be vegetated by the end of the growing season or construction postponed till the next season.
9. Avoid introduction of invasive species.

4. **Relationship to Groundwater:** The basin bottom should be located above the seasonal high groundwater table to avoid standing water in the basin.

5. **Scour:** Energy dissipation should be provided at the inlet and outlet to prevent scour and reduce the velocity of stormwater. The velocity of flow through the inlet sediment control structure and basin should not exceed 2.5 feet per second.

6. **Provisions for Sediment Disposal:** Reservation of land on site for construction sediment disposal should be considered. These sites should be located such that water draining from the material could not flow directly to the water resources being protected.

7. **Access:** Maintenance access shall be planted with grass and at least 10 feet wide with a maximum slope of 15% and a maximum cross slope of 3%. This access should never cross the emergency spillway, unless the spillway has been designed for that purpose. An easement may be required.

8. **Sediment Pretreatment:** Pretreatment devices such as grassed swales, underdrained swales, filter strips, filter fabric and sediment traps shall be provided to minimize the discharge of sediment to the basin. Pretreatment structures shall be sized to hold an annual sediment loading or be routinely cleaned. An annual sediment load shall be calculated using a predicted sand application rate of 500 lbs/acre for sanding of roadways, parking areas and access drives within the subcatchment area, a sand density of 90 lbs per cubic foot and assuming a minimum frequency of ten sandings per year.

9. **Principal Spillways:** Principal spillways shall be designed to control runoff from the 24-hour storms of the 2-year, 10-year, and 25-year frequencies such that the peak flows of stormwater from the project site do not exceed the peak flows of stormwater prior to undertaking the project.

   a. *Piping Materials:* Piping should be constructed of materials with a service life corresponding to the anticipated design life of the basin and its embankment. Reinforced concrete pipe is often recommended in a freshwater environment, but other materials may also be determined to be suitable.

   b. *Outlet Protection:* Outflow from the basin must be directed to a stable channel. The channel should remain shaded when cold water fisheries may be impacted. The channel may need to be riprapped to prevent erosion. Riprap should be designed in accordance with the Maine Erosion and Sediment Control BMP Manual, 2003.The discharge onto a buffer needs to be spread through a level spreader designed appropriately to discharge runoff as a sheet flow. See Chapter 5 for correct design and sizing.

To obtain an annual sediment volume, perform the following calculation:

$$\underset{\text{(acres)}}{\textit{Area to be sanded}} \times 500\ \frac{\textit{pounds}}{\textit{acre-storm}} \div 90\ \frac{\textit{pounds}}{ft^3} \times 10\ \frac{\textit{storms}}{\textit{year}} = \frac{\textit{cubic feet of}}{\textit{sediment/yr}}$$

3.4 Surface Detention Basin Design Criteria

In addition to the general design and construction criteria, the following criteria apply to surface detention basins.

1. **Basin Slopes:** Basin side slopes must be no steeper than 2:1. Flatter slopes provide easier access and maintenance (mowing) of the basin. At a minimum, one side slope, interior or exterior, must be 3:1, such that the combined interior and exterior embankment should total 5:1 (2:1 + 3:1).

2. **Basin Shape:** Provide a long and narrow basin shape, with a minimum length to width ratio of 2:1, 3:1 is best. Length to width ratio can be increased by designing an irregularly shaped basin or by using baffles to create a longer path of flow. The basin should be narrowest at the inlet and widest at the outlet.

3. **Inlet Protection:** Prevention of scour at the inlet is necessary to reduce maintenance problems and prevent damage to basin floor vegetation. Provide energy dissipation at the inlet in accordance with practices outlined in the Maine Erosion and Sediment Control BMPs Handbook (March 2003).

4. **Emergency Spillways:** Emergency spillways shall be designed to independently convey the routed runoff from at least the 25-year, 24-hour storm while maintaining at least one foot of freeboard between the peak storage elevation and the top of the embankment crest and to safely convey the 100-year storm without overtopping the embankment. Overflow must discharge to a stable channel or established wetland area.

   a. _Location:_ Emergency spillways must be located on undisturbed, non-fill soil wherever possible. If the spillway must be located on fill soils, then it must be horizontally offset at least 20 feet from the principal outlet and be designed with a riprap lining, reinforced-turf lining, or a non-flexible lining.

   b. _Exit channel grade:_ The maximum grade of the spillway's exit channel may not exceed 20% unless a non-flexible lining is used to control erosion within the channel. Vegetation, reinforced turf, riprap, and modular blocks are considered flexible linings. All linings must be evaluated for stability at the channel grade chosen. There shall be no large woody species growing in the emergency spillway that could interfere with its function.

   c. _Flow depth:_ The design flow depth in the exit channel may not exceed one-half the d50 stone size for channels lined with riprap and three inches for channels lined with un-reinforced vegetation. The channel shall be designed to remain stable through the full range of design flows.

4. **Embankments:** Embankments must be designed by a professional engineer registered in the State of Maine. The embankment must be designed to meet engineering standards for foundation preparation, fill compaction, seepage control, and embankment stability. Standards for small embankment ponds and basins can be found in Section G-2 of the Maine Erosion and Sediment Control BMPs Handbook (March 2003). The design must include an investigation of the subsurface conditions at the proposed embankment location to evaluate settlement potential, groundwater impacts, and the need for seepage controls. The department will require the submittal of a geotechnical report from a geotechnical engineer for any embankment over 10 feet in effective height or posing a significant hazard to downstream property or life.

   a. _Key:_ Embankments must be keyed into undisturbed subsurface soils.

   b. _Crest elevation:_ The minimum elevation of the top of the settled embankment must be at least one foot above the peak water surface in the basin with the emergency spillway flowing at design depth for the design storm routed through just the emergency spillway.

c. *Crest width:* The minimum crest width for any embankment must be as shown in the following table:

Effective Height of Embankments (feet)	Crest Width (feet)
Less than 10	6
10-15	8
15-20	10
20-25	12
25-35	14
More than 35	15

d. *Fill Material:* Fill must be free of frozen soil, rocks over six inches, and sod, brush, stumps, tree roots, wood, or other perishable materials. Embankment fills less than 10 feet in fill height must be compacted using compaction methods that would reasonably guarantee that the fill density is at least 90% of the maximum density as determined by standard proctor (ASTM-698). All embankment fills more than 10 feet in fill height must be compacted to at least 90% of the maximum density as determined by standard proctor (ASTM-698) and must have their density verified by field density testing.

e. *Slopes:* The embankment's slopes may not be steeper than 2:1. For safety reasons and to promote vegetation growth, a gradually sloped embankment around the basin perimeter is recommended. Flatter slopes provide easier access and maintenance (mowing) of the basin. At a minimum, one side slope, interior or exterior, must be 3:1, such that the combined interior and exterior embankment should total 5:1 (2:1 + 3:1). Riprap can also be installed around the edge of the basin in accordance with SCS guidance.

5. **Construction:** Construction can be started no later than September 1 or earlier than June 1. If sideslopes and banks cannot be revegetated and stabilized by the end of the growing season, basin construction should be delayed to the following growing season. Construction of basins should be planned so as not to take more than 1 to 2 weeks, excluding major weather delays. Seeding must occur by September 15 or other stabiliziation measure must be implemented in preparation for the winter season.

6. **Discharge to Basin:** Do not discharge stormwater to the basin until the basin is fully stabilized or provide a sediment barrier at the outlet.

7. **Floor Compaction:** Provide a means to prevent soil compaction on the floor of the basin during construction.

8. **Soil Amendment:** If the basin soil needs amendment to support vegetation, the added material needs to be at least 6 inches thick with the bottom 3 inches rotottilled into the native soils. Wood waste compost and other highly organic material work best.

9. **Naturalized Basins:** Naturalized basins shall be used in lieu of conventional detention basins wherever feasible. In addition to conventional design criteria, the following design criteria shall be followed to achieve the maximum benefit:

a. *Low Flow Channel:* Construct basin to have a natural low flow channel with turf reinforcement material to remove pollutants and prevent erosion.

b. *Landscaping:* Incorporate a naturally landscaped area at the ground surface. The ground surface around the basin shall be large enough to be in scale with the overall landscaped area. The purpose is to filter and soften views from residential areas. Group trees or shrubs to avoid a spotty effect. A minimum of six inches of topsoil with at least 6% organic content shall be provided for all planting ground cover beds or lawn areas.

c. *Vegetation:* Plant all areas of the naturalized basin, including basin floors, side slopes, berms, impoundment structures, or other earth structures, with suitable vegetation such as naturalized meadow plantings or lawn grass specifically suited for storm water basins. Suggested plants include:

i. Grasses: Big Blue Stem, Switchgrass and wildflower mixes. In wet areas, plant Sweetflag, Yellow Iris and Soft Rush for color and texture.

ii. Shrubs: Red Chokeberry (Aronia arbutifolia), Silky Dogwood (Cornus ammomum), Arrowwood (Viburnun Dentatum), Cranberrybush (Viburnum trilobum).

iii. Trees: Red Maple (Acer rubrum), River Birch (Betula nigra), Sweetgum (Liquidambar styraciflua), various Willows. Trees may not be planted below the pool area of the basin. If shrubs are used, they must be adapted to wet or moist soils conditions.

d. *Mulch:* Mulch all shrub beds located within the pool area with a non-floating type mulch over a weed barrier material.

e. *Maintenance Access:* Blend access area in with the surrounding landscape to the extent feasible.

f. *Basin Shape:* The perimeter of all basins shall be curvilinear so that from most edges of the basin, the whole basin will not be in view. A more traditionally shaped (oval or rectangular) basin may be permitted when conditions

IMPORTANT
Design Tips - Vegetation

Seed mixtures must be appropriately selected for the soil type, moisture content, the amount of sun exposure, and the level of use as found at the site. Examples are as follows:

Lots of sun and mostly dry:	Creeping red or tall fescue, perennial rye grass and clover
Shady areas:	Creeping red fescue, Kentucky bluegrass, Canada bluegrass
Wetlands:	Creeping red fescue, Reed canary grass, Timothy
Steep slopes:	Crownvetch, clover
Naturalized basins:	
Grasses:	Big Blue Stem, Switchgrass and wildflower mixes. In wet areas, plant Sweetflag, Yellow Iris and Soft Rush for color and texture
Shrubs:	Red Chokeberry (Aronia arbutifolia), Silky Dogwood (Cornus ammomum), Arrowwood (Viburnun Dentatum), Cranberrybush (Viburnum trilobum)
Trees:	Red Maple (Acer rubrum), River Birch (Betula nigra), Sweetgum (Liquidambar styraciflua), various Willows. Trees may not be planted below the pool area of the basin. If shrubs are used, they must be adapted to wet or moist soils conditions

The mixture should include some annual rye for quicker green-up. Apply at the approximate rate of 0.5 -1 lbs per 1,000 SF (30-50 lbs per acre). Contact your Soil and Water Conservation District for specific mixtures.

such as topography, parcel size, or other site conditions warrant. Basins shall follow natural landforms to the greatest extent possible or be shaped to mimic a naturally formed depression.

10. **Vegetation:** Plant all areas of the basin, including basin floors, side slopes, berms, impoundment structures, or other earth structures, with grasses such as naturalized meadow plantings or lawn grass specifically suited for stormwater basins. Six inches of loam or composted wood waste or fine erosion control mix should be added if necessary to amend onsite soils.

    Particular care must be used to avoid the unintended introduction of invasive species such as purple loosestrife (Lythrum salicaria) and common reed (Phragmites australis). It is recommended that a qualified wetland biologist be consulted when planning the revegetation of a basin.

11. **Principal Spillways:**

    a. *Trash Racks:* All basin outlets must have a trash rack to control clogging by debris and to provide safety to the public. The surface area of each rack must be at least four times the outlet opening it is protecting. The spacing between rack bars must be no more than six inches or one-half the dimension of the smallest outlet opening behind it, whichever is less. Trash racks should be inclined to be self-cleaning.

    b. *Seepage Controls:* All pipes that extends through an embankment should have anti-seep collars or filter diaphragms to control the migration of soil materials and, so, prevent potential embankment failure from "piping" within the backfill soil along the conduit. All smooth outlet pipes greater than eight inches and all corrugated outlet pipes greater than 12 inches must have seepage controls to prevent the migration of soil along the outside of the pipe.

    c. *Anti-floatation:* All outlets employing a riser structure must be designed to prevent the riser floating.

3.5 Subsurface Detention Basin Design Criteria

In addition to the general design and construction criteria, the following criteria apply to subsurface detention basins.

1. **Emergency Spillways:** Emergency spillways shall be designed to independently convey the routed runoff from at least the 25-year, 24-hour storm. Overflow must discharge to a stable channel or established wetland area.

2. **Pretreatment:** All subsurface systems must include pretreatment for the removal of sediments prior to entering the detention structure.

3. **Observation Wells:** Subsurface detention systems must have an observation port for monitoring sediment levels and determining when rehabilitation is necessary. This should be installed to the bottom of the system. The observation well shall be a 4-inch diameter, perforated PVC pipe fitted with a removable yet securable well cap, foot plate, and rebar anchor. Set the observation well prior to backfilling with the stone fill.

4. **Access Ports:** Access to the subsurface system must be provided to allow for the removal of accumulated sediments.

3.6 Maintenance Criteria

1. **Maintenance Agreement:** A legal entity should be established with responsibility for inspecting and maintaining any detention basin. The legal agreement establishing the entity should list specific maintenance responsibilities (including timetables) and provide for the funding to cover long-term inspection and maintenance.

2. **Inlet & Outlet Inspections:** The inlet and outlet of the basin should be checked periodically to ensure that flow structures are not blocked by debris. Inspections should be conducted monthly during wet weather conditions from March to November. It is important to design flow structures so that they can be easily inspected for debris blockage, and that corrective action can be taken even during storm conditions.

3. **Erosion & Instability:** Basins should be inspected annually for erosion, destabilization of side slopes, embankment settling and other signs of structural failure, and loss of storage volume due to sediment accumulation. Corrective action should be taken immediately upon identification of problems.

4. **Embankment Maintenance:** Embankments should be maintained to preserve their integrity as impoundment structures, including, but not necessarily limited to, vegetative maintenance (mowing, control of woody vegetation), rodent control, erosion control and repair, and outlet control structure maintenance and repair. Basins should be mowed no more than twice a year during the growing season to maintain maximum grass heights less than 12 inches. All accumulated trash and debris shall be removed.

5. **Sediment Removal:** Sediment should be removed from the pretreatment structure at least annually and from the basin when necessary.

6. **Observation Wells, Measure of Sediment Accumulation, and Points of Access for Sediment Removal:** Observation wells and access points to allow for the inspection and removal of accumulated sediment must be included in the design of subsurface systems. The maintenance plan must provide for removal of sediment from the infiltration system.

7. **Improving Maintenance:** A shallow detention basin designed to be used for other purposes, such as recreation, is more likely to be well-maintained.

Selected References

Maine DEP. 2003. *Maine Erosion and Sediment Control BMPs*. Bureau of Land and Water Quality and Maine Department of Environmental Protection.

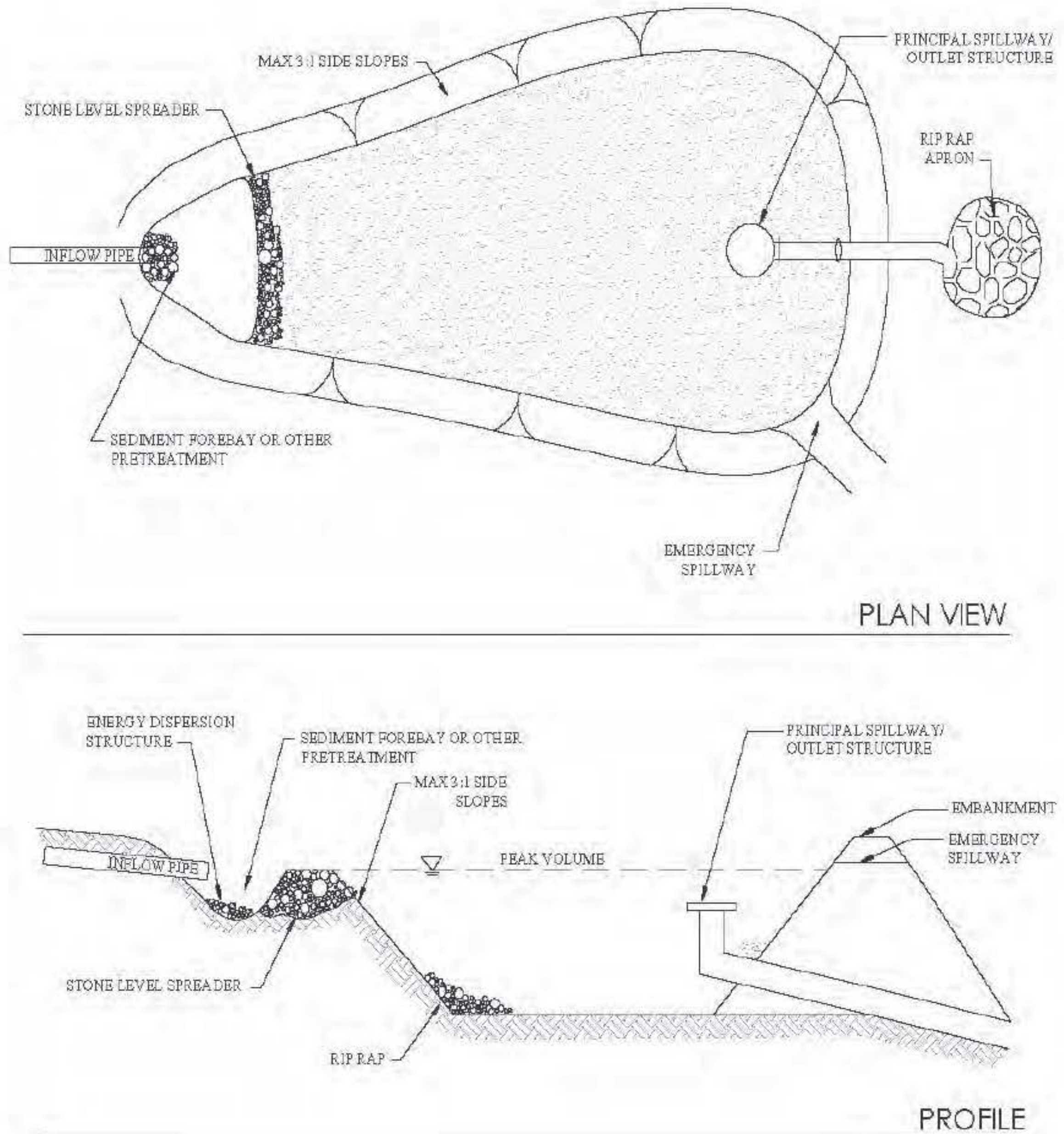


FIGURE 3-1. TYPICAL DETENTION BASIN

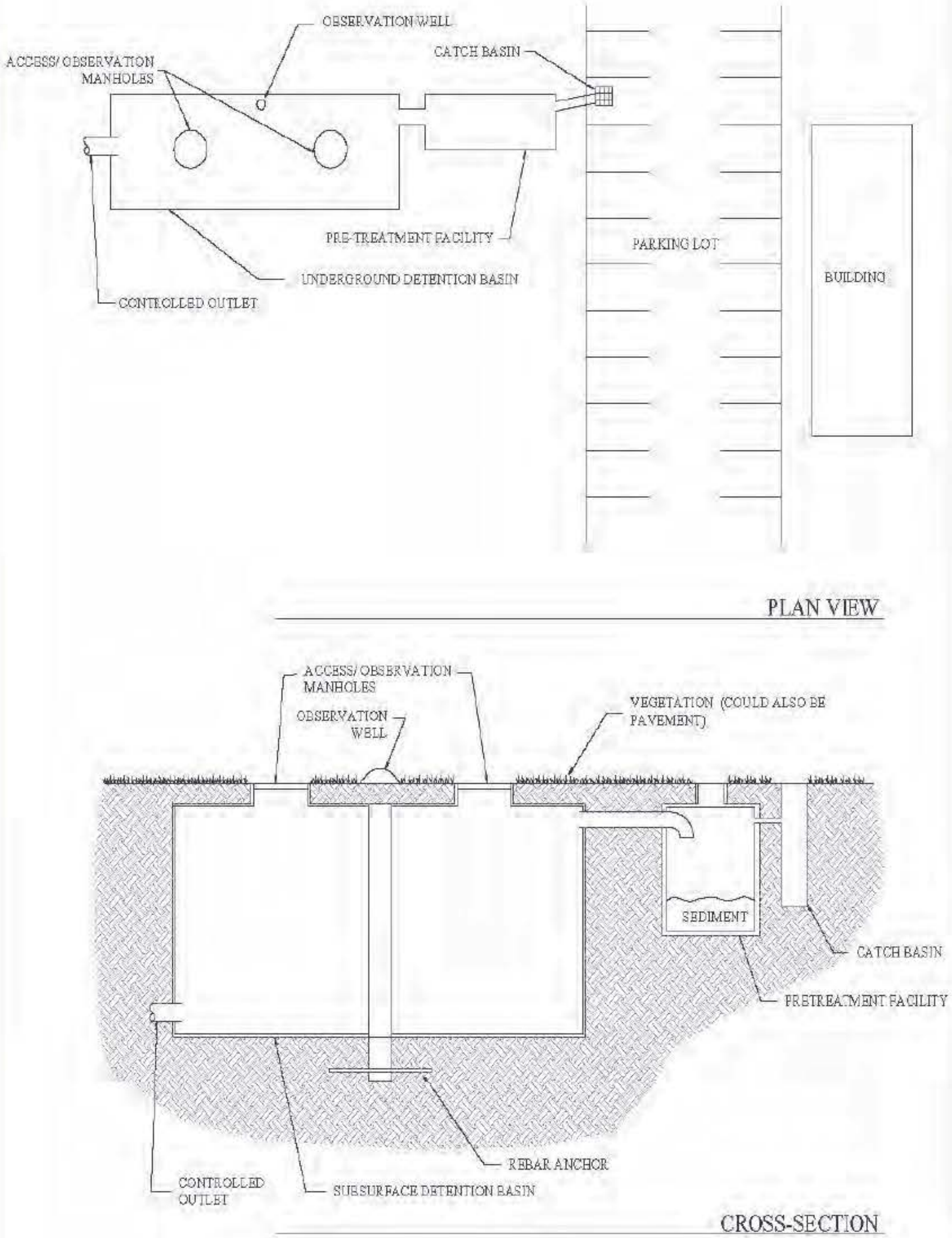


FIGURE 3-2. TYPICAL SUBSURFACE DETENTION BASIN

Chapter 4
Wet Ponds

4.1 General Description

IMPORTANT

An underdrained gravel trench outlet is required for all discharges within a stream, brook or river watershed. The channel protection volume must be discharged solely through the underdrained gravel trench. Direct discharges to a lake, major river or tidal water may be discharged through standard outlet structures.

Wet ponds are stormwater detention impoundments that have a permanent pool of water and have the capacity to temporarily store storm water runoff while it is released at a controlled rate. They can be designed to provide flood control as well as water quality treatment. Properly sized and maintained, wet ponds can achieve high rates of removal for a number of urban pollutants, including sediment and the pollutants associated with sediment, such as trace metals, hydrocarbons, BOD, nutrients, and pesticides. They also provide some treatment of dissolved nutrients, through biological processes within the pond (Schueler, 1987, MPCA, 1989). The addition of an underdrained gravel trench in the bench area around the permanent pool allows for slow, extended release of stormwater without risk of blockage and effective cooling to avoid thermal impacts. A typical wet pond meeting the Department's BMP standards for water quality and flooding standards for peak flow rates is shown in Figures 4-1 and 4-2. The underdrained gravel trench outlet is required when used to meet the BMP standards discharging to a stream, river or brook. The designer should refer to the referenced material for a more extensive discussion of removal efficiencies and how they compare with other BMPs.

Chapter Contents:

4.2 Site Suitability Criteria

1. **Wildlife Habitat:** If the pond will be used as wildlife habitat or need to enhance habitat, a larger contributing watershed may need to be considered so that flow is sufficient to maintain pool volume. Schueler (1987) suggests that wet ponds for wildlife habitat located in watersheds less than 20 acres should have a reliable water source and a clay liner.. Some guidance on minimum watershed area to sustain a pond with average runoff is given in SCS (1982).

2. **Depth to Bedrock:** Wet ponds should not be located on fractured bedrock because runoff may seep into fractures which may discharge pollutants directly to groundwater. A one foot minimum separation distance is recommended and/or a clay or geosynthetic liner should be provided.

3. **Permanent Flow:** Wet ponds should not be constructed in areas that receive continuous discharge from a spring. Permanent flow into a pond may not allow the detention time needed for pollutant removal to occur.

4. **Location in Stream Channels:** Wet ponds should not be located in existing stream channels because of the impact to aquatic life and a reduction in efficiency of the wet pond.

5. **Location in Wetlands:** Wet ponds must not be located in wetlands without the appropriate permits from DEP and the Army Corps of Engineers. DEP recommends contacting the Army Corps of Engineers early in the design phase if any wet pond is proposed in a wetland as it may not be permitted.

4.3 Design and Construction Criteria

4.3.1 General Criteria

1. **Release of Channel Protection Volume:** The channel protection volume, equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's non-impervious developed area, must be discharged through an underdrained gravel trench outlet over a 24 hour to 36 hour period. When designing for flood control, the pond needs to control the peak from the 2, 10 and 25-year storms.

2. **Permanent Pool Volume:** When designed to meet the BMP standard, the permanent pool must be sized in accordance with criteria to meet the BMP standard provided below. When designed to meet the phosphorus standard, the permanent pool volume is adjusted for any given treatment factor using the equation found in Chapter ___ in Volume II.

IMPORTANT
Performance Criteria for Project in the Direct Watershed of a Lake Where the Phosphorus Standard is Applied

When used to meet phosphorus allocations in lake watersheds, adjust the sizing of the wet pond in accordance with Volume II of this manual.

3. **Soils:** The site for a proposed wet pond should have suitable soils to prevent excessive seepage and compaction to avoid migration of fine soil particles. A wetpond on Group A soils will infiltrate and should be designed as an infiltration structure.

4. **Highly Permeable Soils:** Installation of ponds in highly permeable soils may result in seepage, such that the pool level will have

large fluctuations and the permanent pool may even be totally lost during a dry period. Even though the pond may dry up during the summer months due to the small volume of runoff, pollutant removal will be high if runoff infiltrates through the pond bottom or evaporates rather than discharging through the outlet. There are two design options for ponds which are to be constructed in Hydrologic Group A or B soils that do not normally hold water, or the BMP should be designed as an infiltration bed.

a. *Pond Lining:* The bottom of the pond can be lined with a synthetic membrane or impermeable soil such as clay to prevent water loss (however, see discussion of clay soils, below).

b. *Natural Clogging:* The pond can act as an infiltration basin until clogging of the bottom with sediment and organic material prevents infiltration and creates a wet pond. In this case, standards for separation from bedrock and seasonal high water table provided in the infiltration basin discussion should be used in designing the pond.

5. **Clay Soils:** Installation of ponds in clay soils may be problematic. Outflow from the pond may pick up fine soil particles and carry them to the receiving water course. This is particularly of concern for phosphorus control in sensitive lake watersheds. If construction in clay soils is unavoidable, measures should be taken to prevent this problem, such as:

- Use of erosion control matting on sides and bottom of pond until aquatic vegetation is established.

- Lining the pond with a soil filter media that is not susceptible to resuspension (a filter fabric may be required between this material and the clay).

6. **Ponds on Slopes:** When ponds are created by cutting and filling a slope, care should be taken that the seasonal groundwater table on the slope above the pond is not exposed, thus creating a seasonal spring. Controlling the groundwater flow or spring flow into a pond may be accomplished by the proper installation of a subsurface interceptor drainage system.

7. **Wildlife Habitat:** If designed for wildlife habitat, the wet pond should have an irregular shoreline and a combination of shallow and deep areas.

8. **Permanent Pool Depth:** Wet ponds must have a mean depth of 3 feet or more to prevent turbulent resuspension of sediments. Mean depth should be no greater than 10 feet and maximum depth of the pond no greater than 15 feet to avoid thermal stratification and associated release of phosphorus from sediments. Mean depth is defined as the pond volume (measured at one foot below permanent pool elevation) divided by the surface area at that elevation.

9. **Pond Shape to Promote Plug Flow:** Plug flow is accomplished when the flow of water entering the pond does not mix with the water already in the pond but acts to push out all or some of the existing water in the pond. The following measures must be incorporated into design to promote plug flow:

a. *Flow Path:* The inlet and outlet should be as far apart as possible. Runoff should have to travel the longest distance possible through the pond before being discharged.

b. *Inlet and Outlet Locations:* Provide one distinct area of inlet flow and one distinct area of outlet flow in the pond. The shallow and narrow end of the pond should be located near the inlet and the deeper and wider end near the outlet.

c. *Pond Shape:* Provide a long and narrow pond shape, with a minimum length to width ratio of 2:1, 3:1 would be best. Narrowness is important to minimize wind mixing, which can stir up phosphorus from sediments and release it to outflow. Length-to-width ratio can be increased by designing an irregular shaped pond or by using baffles to create a longer path of flow. The elevation of permanent pool volume can be up to 6 inches over the top of the baffles without destroying plug flow.

d. *Number of Ponds:* Provide two or more ponds in a series for the most effective treatment. The first pond experiences some mixing as incoming runoff meets still water, but water is pushed into subsequent ponds at a steady rate that minimizes mixing and promotes plug flow. Multiple ponds also restrict wind-generated mixing of the total volume of the ponds. Simple overflow outlets should be installed between ponds to ensure that water is released from the top of the pool. This upper layer of water contains less sediment than lower layers.

10. **Relationship to Groundwater:** The elevation of the pond outlet should be at least 1 foot above the highest elevation of the seasonal high groundwater table in the area to be flooded by the pond.

11. **Inlet Design:** If runoff enters the pond via a pipe, the invert of the inlet pipe should be located within 1 foot of the permanent pool elevation to reduce mixing of incoming runoff with the permanent pool and to reduce erosion at the inlet. It is best to avoid submerged inlets because deposition can occur in the pipeline or ice buildup can block the pipe opening. Prevention of scour at the inlet is necessary to reduce maintenance problems and prevent damage to basin floor vegetation. Provide energy dissipation at the inlet in accordance with practices outlined in the Maine Erosion and Sediment Control BMPs Handbook (March 2003).

12. **Scour:** Energy dissipation should be provided at the inlet and outlet to prevent scour and reduce the velocity of stormwater. The velocity of flow through the inlet sediment control

IMPORTANT
Design Tips

- The mean depth of the permanent pool is calculated as the pond volume measured at one foot below the permanent pool elevation divided by the surface area at that elevation.
- Wet ponds shall be designed with a minimum length to width ratio of 2:1; 3:1 would be best.
- Provide a maintenance right-of-way to the pond for access by heavy equipment. Maintenance access shall be planted with grass and at least 10 feet wide with a maximum slope of 15% and a maximum cross slope of 3%.
- The maximum grade of the emergency spillway may not exceed 20% unless a non-flexible lining is used to control erosion within the spillway.
- The design flow depth in the emergency spillway may not exceed one-half the d50 stone size for channels lined with riprap and 3" for channels lined with un-reinforced vegetation.
- A geotechnical engineer must design and submit a report on any embankment over 10' high or posing a significant hazard to downstream property or life.
- A safety bench should be designed into all embankments.
- Construction of ponds must be complete with side slopes and banks stabilized with grass or conservation mix seeding before allowing the pond to fill with water.
- Ponds must be vegetated by the end of the growing season or construction postponed till the next season.
- Avoid introduction of invasive species. A qualified wetland biologist should be consulted when planning the vegetation of a wet pond.

structure and pond should not exceed 2.5 feet per second.

13. **Provisions for Sediment Disposal:** Reservation of land on site for construction sediment disposal should be considered. For sensitive lake watersheds, DEP requires two sites to be reserved for on-site disposal of sediment excavated from the wet pond(s). These sites should be located such that water draining from the material could not flow directly to the water resources being protected.

14. **Access:** Maintenance access shall be planted with grass and at least 10 feet wide with a maximum slope of 15% and a maximum cross slope of 3%. This access should never cross the emergency spillway, unless the spillway has been designed for that purpose.

15. **Sediment Pretreatment:** Pretreatment devices such as grassed swales, underdrained swales, filter strips, filter fabric and sediment traps shall be provided to minimize the discharge of sediment to the wet pond. Pretreatment structures shall be sized to hold an annual sediment loading. An annual sediment load shall be calculated using a sand application rate of 500 lbs/acre for sanding of roadways, parking areas and access drives within the subcatchment area, a sand density of 90 lbs per cubic foot and assuming a minimum frequency of ten sandings per year. To obtain an annual sediment volume, perform the calculation below.

16. **Emergency Spillways:** Emergency spillways shall be designed to independently convey the routed runoff from at least the 25-year, 24-hour storm while maintaining at least one foot of freeboard between the peak storage elevation and the top of the embankment crest and to safely convey the 100-year storm without overtopping the embankment. Overflow must discharge to a stable channel or established wetland area.

    a. *Location:* Emergency spillways must be located on undisturbed, non-fill soil wherever possible. If the spillway must be located on fill soils, then it must be horizontally offset at least 20 feet from the principal outlet and be designed with a riprap lining, reinforced-turf lining, or a non-flexible lining.

    b. *Exit channel grade*: The maximum grade of the spillway's exit channel may not exceed 20% unless a non-flexible lining is used to control erosion within the channel. Vegetation, reinforced turf, riprap, and modular blocks are considered flexible linings. All linings must be evaluated for stability at the channel grade chosen. There shall be no large woody species growing in the emergency spillway that could interfere with its function.

    c. *Flow depth:* The design flow depth in the exit channel may not exceed one-half the d50 stone size for channels lined with riprap and three inches for channels lined with un-reinforced vegetation. The channel shall be designed to remain stable through the full range of design flows.

17. **Embankments:** Embankments must be designed by a professional engineer registered in the State of Maine. The design must include an investigation of the subsurface conditions at the proposed embankment location to evaluate settlement potential, groundwater impacts, and the need for seepage controls. The department will require the submittal of a geotechnical report from a geotechnical engineer for any embankment over 10 feet in effective height or posing a significant hazard to downstream property or

To obtain an annual sediment volume, perform the following calculation:

$$\underset{\text{(acres)}}{\text{Area to be sanded}} \times 500\,\frac{\text{pounds}}{\text{acre-storm}} \div 90\,\frac{\text{pounds}}{\text{ft}^3} \times 10\,\frac{\text{storms}}{\text{year}} = \text{cubic feet of sediment/yr}$$

life. Standards for small embankment ponds and basins can be found in Section G-2 of the Maine Erosion and Sediment Control BMPs Handbook (March 2003).

a. _Crest elevation:_ The minimum elevation of the top of the settled embankment must be at least one foot above the peak water surface in the basin with the emergency spillway flowing at design depth for the design storm routed through just the emergency spillway.

b. _Crest width:_ The minimum crest width for any embankment must be as shown in the following table:

Effective Height of Embankment (feet)	Crest Width (feet)
Less than 10	6
10-15	8
15-20	10
20-25	12
25-35	14
more than 35	15

c. _Key:_ Embankments must be keyed into undisturbed subsurface soils.

d. _Fill Material:_ Fill must be free of frozen soil, rocks over six inches, and sod, brush, stumps, tree roots, wood, or other perishable materials. Embankment fills less than 10 feet in fill height must be compacted using compaction methods that would reasonably guarantee that the fill density is at least 90% of the maximum density as determined by standard proctor (ASTM-698). All embankment fills more than 10 feet in fill height must be compacted to at least 90% of the maximum density as determined by standard proctor (ASTM-698) and must have their density verified by field density testing.

e. _Slopes:_ The embankment's slopes may not be steeper than 2:1. Flatter slopes provide easier access and maintenance (mowing) of the basin. At a minimum, one side slope, interior or exterior, must be 3:1, such that the combined interior and exterior embankment should total 5:1 (2:1 + 5:1). For safety reasons and to promote the growth of rooted aquatic plants, a gradually sloped bench of 10:1 (H:V) slope around the pond perimeter is recommended. This bench should extend into the pool at least 10 feet (for very small ponds, a 5-foot bench would be sufficient). The bench reduces the potential for accidental falls into the pond and makes it easier to climb out. The underdrained gravel filter bench can be designed to also serve as the safety bench. If it is not possible for a shallow bench to extend around the pond, thorny bushes can be planted to discourage access. Riprap can also be installed around the edge of the pond in accordance with SCS guidance. The inlet area of the pond should be located within the flat bench area.

IMPORTANT
Design Tips - Vegetation

Seed mixtures must be appropriately selected for the soil type, moisture content, the amount of sun exposure, and the level of use as found at the site. Examples are as follows:

Lots of sun and mostly dry:	Creeping red or tall fescue, perennial rye grass and clover
Shady areas:	Creeping red fescue, Kentucky bluegrass, Canada bluegrass
Wetlands:	Creeping red fescue, Reed canary grass, Timothy
Steep slopes:	Crownvetch, clover

The mixture should include some annual rye for quicker green-up. Apply at the approximate rate of 0.5 -1 lbs per 1,000 SF (30-50 lbs per acre). Contact your Soil and Water Conservation District for specific mixtures.

18. **Vegetation:** Aquatic plants shall be used to stabilize the pond, control sedimentation and utilize nutrients. Appropriate species should be carefully selected for different sections of the pond. Appropriate plants should be chosen to stabilize the sides and bottom of the pond, as well as the safety bench. Prior to filling the ponds, side slopes and banks must be stabilized with grass or conservation mix seeding to prevent erosion. Creation of a marsh environment at the pond inlet will help to trap sediment. If the inlet has a sump, aquatic plants can be planted upstream of the sump to help retain sediments in the sump. Fertilizer should not be used in or around the pond except when necessary to establish new vegetation. Allowing for natural invasion along the safety bench or planting native species may encourage healthier growth than planting species not already found on site. Also, use of foreign species is not recommended because of the potential for introducing nuisance plants to the water course receiving the wet pond discharge.

    Particular care must be used to avoid the unintended introduction of invasive species such as purple loosestrife (Lythrum salicaria) and common reed (Phragmites australis). It is recommended that a qualified wetland biologist be consulted when planning the revegetation of a wet pond.

19. **Pond Drain:** If elevations allow, a manually controlled drain should be provided to dewater the pond over a 24 hour period without harming downstream water courses. This will facilitate removing accumulated sediment at periodic (but infrequent) intervals. The drain should be locked to prevent accidental draining of the pond.

20. **Construction:** Construction of wet ponds should be timed so that the ponds do not fill up with water until their construction is substantially finished. Construction of ponds should be planned so as not to take more than 1 to 2 weeks, excluding major weather delays. Construction can be started no later than September 1 or earlier than June 1. If sideslopes and banks cannot be revegetated and stabilized by the end of the growing season, pond construction should be changed to the following year. Seeding or stabilization must occur by September 15 in preparation for the winter season.

4.3.2 Criteria to Meet the BMP Standards

IMPORTANT
Performance Criteria for Discharges Where the BMP Standard is Applied

- The permanent pool must hold a volume equal to 1.5 inches times subcatchment's impervious area plus 0.6 inches times subcatchment's non-impervious developed area.
- The channel protection volume must be designed to detain 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's non-impervious developed area.
- The channel protection volume must be discharged through an underdrain gravel trench over a 24 to 36 hour period.
- The underdrain trench outlet must be sized to provide effective cooling of the stormwater runoff to 60 degrees Fahrenheit.

1. **Permanent Pool Volume:** The permanent pool must be designed to hold a volume equal to 1.5 inches times the subcatchment's impervious area plus 0.6 inch times the subcatchment's non-impervious developed area. If the total volume is split fairly evenly between two ponds in series, the total permanent pool volume required may be reduced by 10%. If three ponds are used, the allowed reduction is 20%.

2. **Channel Protection Volume:** Wet ponds must be designed to detain, above the permanent pool, a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area unless the pond discharges directly to a major river, lake or tidal water. This volume must be released over a 24 to 36 hour period. The design engineer is responsible for developing and specifying a design that meets the performance criteria based on site specific characteristics.

3. **Cooling:** When designed to meet the BMP standard, the underdrain trench outlet must be sized to provide effective cooling of the stormwater runoff to 60 degrees Fahrenheit. The underdrained outlet design should provide adequate cooling of stormwater runoff before discharging it.

4. **Outlet:** The channel protection volume must be discharged solely through an underdrained gravel trench outlet having a single outlet with a diameter no greater than eight inches unless the pond discharges directly to a major river, lake or tidal water. Additional storage for flood control may be discharged through traditional pond outlets, flood control outlets, at an elevation above the permanent pool and channel protection volume storage. For all discharges within a stream, brook or river watershed, an underdrain gravel filter must be provided. For direct discharge into a major river segment, coastal watershed or lake, a standard pond outlet may be provided.

5. **Underdrained Gravel Trench:** The underdrain trench design is intended to meet the slow release of the channel protection volume over a 24 to 36 hour period and to provide adequate cooling of stormwater runoff from a wet pond. The site design engineer is responsible for developing and specifying a design that meets the performance criteria based on site specific characteristics.

a. *Bench Elevation:* The bench must be set at the permanent pool elevation such that the channel protection volume will be stored between the bench surface elevation and the elevation of any flood control or emergency spillway outlets.

b. *Pond Bench and Gravel Trench:* The gravel trench must be excavated in a pond bench having a minimum width of eight feet. The trench must be four feet wide and at least 2 feet from the pond side edge of the bench and must be located at or near the end of the pond, furthest from the principal inflow.

c. *Trench Sizing:* The trench must have a length of 3 feet for every 1000 cubic feet of channel protection volume.

d. *Trench Dimensions:* The gravel trench must be 4 feet wide and at least 3 feet deep. The pipe underdrain system should have at least 2 feet of gravel cover and six inches below the drainage pipe.

e. *Geotextile Fabric:* A geotextile fabric with suitable characteristics must be placed between the gravel trench and adjacent soil. The fabric will prevent the surrounding soil from migrating into the trench and clogging the outlet. Use an appropriate geotextile design manual to choose a fabric that is compatible with the surrounding soil for the purposes stated above. Overlap seams should be a minimum of 12 inches.

f. *Underdrain Pipe:* The underdrain piping should be 6 inch diameter with slotted, rigid schedule 40 PVC or SDR35 pipe.

g. *Gravel Bed:* The gravel bedding should be a clean well draining gravel. Recommended specification is the gravel meeting MEDOT specification 703.22 Type B Underdrain Backfill materials with at least 10% passing the #50 sieve. MEDOT specifications for underdrain backfill material are provided in the following table:

MEDOT Specifications for Underdrains (ME DOT #703.22)	
Sieve Size	% by Weight
Underdrain Type B	
1"	90-100
1/2"	75-100
#4	50-100
#20	15-80
#50	0-15
#200	0-5
Underdrain Type C	
1"	100
3/4"	90-100
3/8"	0-75
#4	0-25
#10	0-5

h. *Orifice:* If the gravel does not provide 24 to 36 hours of maximum detention or the gravel (MEDOT specification 703.22 Type B) does not have at lease 10% passing the #50 sieve or if the sieve analysis is unavailable, then an orifice shall be provided at the outlet to control the release of flows. The orifice should be sized and modeled as a function of the required channel protection volume (CPV) release rate. The following table shows examples of possible pond orifices for channel protection volumes. These sizes are provided for guidance only and because of the small orifice sizes, the engineer is responsible for developing a design that meets the performance criteria based on the site specific characteristics and the required drainage time.

Example Pond Outlet Orifice			
CPV (cu ft)	Orifice Diameter (in)	CPV (cu ft)	Orifice Diameter (in)
8000-9500	1 3/2	24000-26500	2 3/2
9500-11000	1 1/2	26500-29000	2 1/2
11000-13000	1 5/8	29000-32000	2 5/8
13000-15000	1 3/4	32000-35000	2 3/4
15000-17000	1 7/8	35000-38000	2 7/8
17000-19000	2	38000-41500	3
19000-21500	2 1/8	41500-45000	3 1/8
21500-24000	2 1/4	45000-48500	3 1/4

i. *Outlet clogging:* The pond outlet or orifice shall be designed to prevent clogging and to allow access to the underdrain outlet for inspection and maintenance. This may be accomplished by having the underdrain discharge to a concrete sump outlet structure with the orifice built into this structure.

j. *Alternative Outlets:* A 4-inch gate valve on the structure may be used in lieu of a standard orifice. This would allow for adjustment for site specific conditions. The engineer is responsible for designing an outlet structure that meets the release and cooling criteria previously presented.

6. **Pond Outlet:** All pond discharges must outlet to a stable natural channel or an area capable of withstanding concentrated flows and saturated conditions without eroding.

7. **Overflow:** If the pond is used for a project which does not need to provide peak flow control, the overflow from the pond may either be discharged uncontrolled through a broad crest weir or a standard outlet. If the pond needs to retain peak flows for flood control, then a standard outlet for peak control needs to be provided. Discharge from the pond needs to be directed to a stable channel or an area capable to withstand concentrated flows.

4.3.3 Criteria for Standard Outlets and Peak Control

Standard Outlets: Flood control outlets shall be designed to control runoff from the 24-hour storms of the 2-year, 10-year, and 25-year frequencies such that the peak flows of stormwater from the project site do not exceed the peak flows of stormwater prior to undertaking the project. The bottom peak flow control structure must be no lower than the maximum elevation of the channel protection volume if that treatment is required.

1. **Discharge from Pond Surface:** The flood control outlet should be of the simple overflow type to discharge the clarified water from near the surface of the pool.

2. **Piping Materials:** Piping should be constructed of materials with a service life corresponding to the anticipated design life of the pond and its embankment. Reinforced concrete pipe is often recommended in a freshwater environment, but other materials may also be determined to be suitable.

3. **Trash Racks:** All pond outlets must have a trash rack to control clogging by debris and to provide safety to the public. The surface area of each rack must be at least four times the outlet opening it is protecting. The spacing between rack bars must be no more than six inches or one-half the dimension of the smallest outlet opening behind it, whichever is less. Trash racks should be inclined to be self-cleaning.

4. **Seepage Controls:** All pipes that extend through an embankment should have anti-seep collars or filter diaphragms to control the migration of soil materials and to prevent potential embankment failure from "piping" within the soil backfill along the conduit. All smooth outlet pipes greater than eight inches and all corrugated outlet pipes greater than 12 inches must have seepage controls to prevent migration of soil along the outside of the pipe.

5. **Anti-floatation:** All outlets employing a riser structure must be designed to prevent the riser floating.

6. **Outlet Protection:** Outflow from the pond must be directed to a stable channel. The channel should remain shaded when cold water fisheries may be impacted. The channel may need to be riprapped to prevent erosion. Riprap should be designed in accordance with the Maine Erosion and Sediment Control BMP Manual, 2003.

4.3.4 Maintenance Criteria

1. **Maintenance Agreement:** A legal entity should be established with responsibility for inspecting and maintaining a wet pond. The legal agreement establishing the entity should list specific maintenance responsibilities and provide for the funding to cover long-term inspection and maintenance.

2. **Clearing Inlets and Outlets:** The inlet and outlet of the pond should be checked periodically to ensure that flow structures are not blocked by debris. All ditches or pipes connecting ponds in series should be checked for debris that may obstruct flow. Inspections should be conducted monthly during wet weather conditions from March to November. It is important to design flow structures that can be easily inspected for debris blockage.

3. **Gravel Trench Outlet Inspection:** The gravel trench outlet should be inspected after every major storm in the first few months to ensure proper function. Thereafter, the gravel trench should be inspected at least once every six months. Inspection consists of verifying that the pond is slowly emptying through the gravel filter for a short time (12-24 hours) after a storm and that potentially clogging material such as accumulations of decaying leaves are not preventing discharge through the gravel.

4. **Gravel Replacement:** The top several inches of the gravel in the outlet trench must be replaced with fresh material when water ponds above the permanent pool for more than 72 hours. The removed sediments should be disposed of in an acceptable manner.

5. **Inspecting Ponds for Instability and Erosion:** Wet ponds should be inspected annually for erosion, destabilization of side slopes, embankment settling and other signs of structural failure. Corrective action should be taken immediately upon identification of problems.

6. **Maintenance Dredging:** Wet ponds lose 0.5-1.0% of their volume annually due to sediment accumulation. Dredging is required when accumulated volume loss reaches 15%, or approximately every 15-20 years.

Selected References

Maine DEP. 2003. *Maine Erosion and Sediment Control BMPs.* Bureau of Land and Water Quality and Maine Department of Environmental Protection.

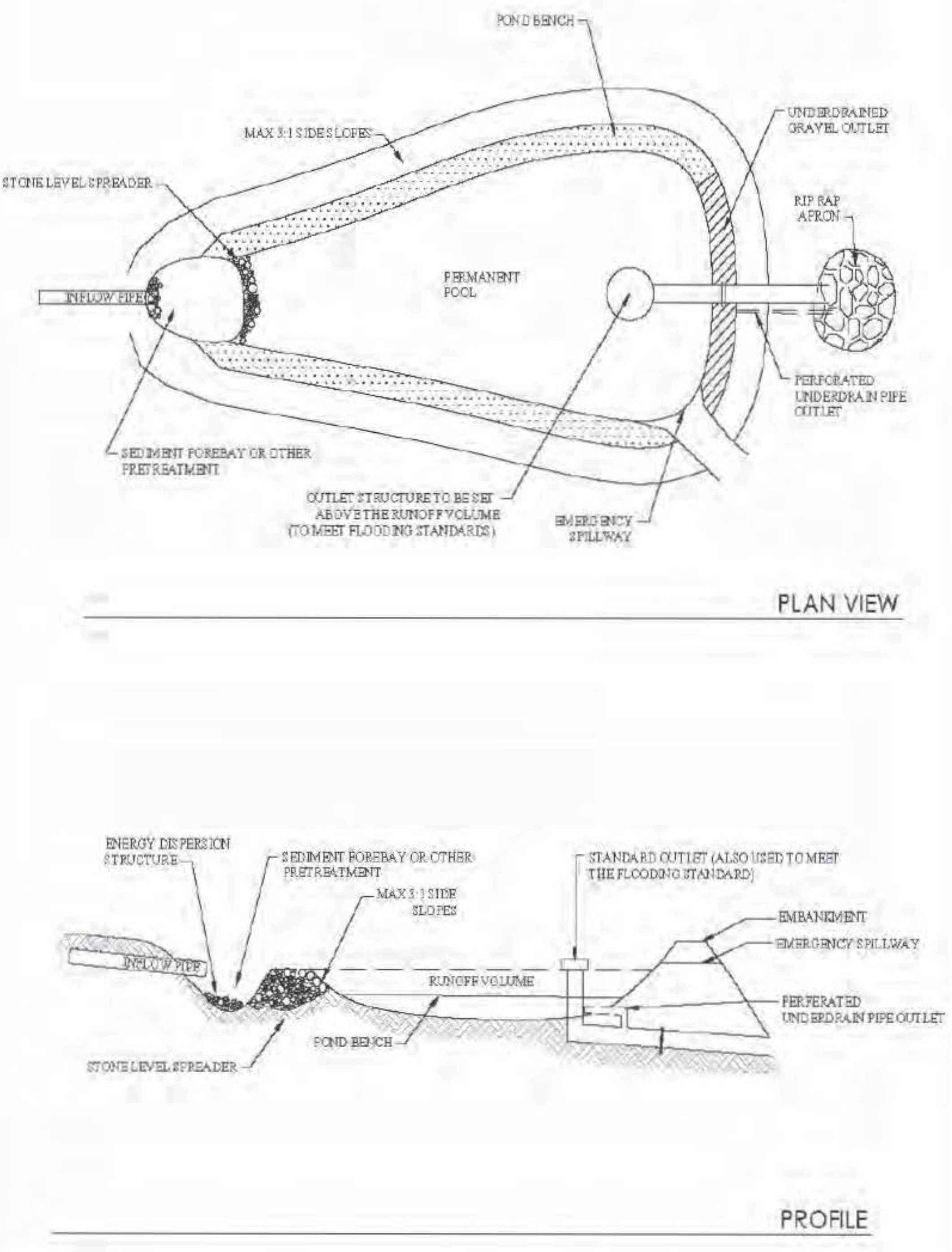
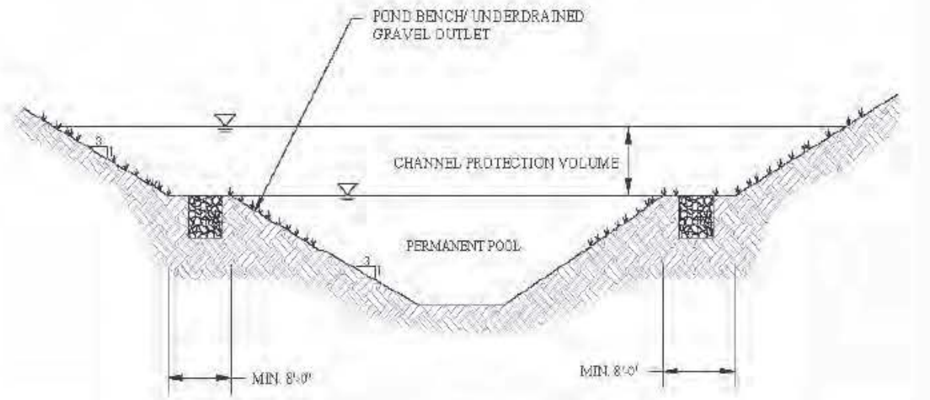
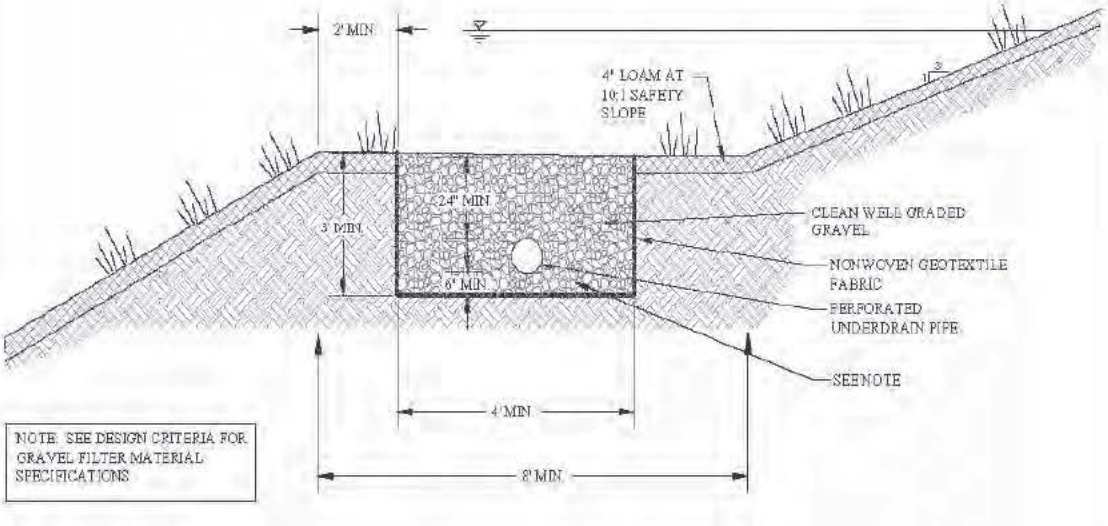


FIGURE 4-1. TYPICAL WET POND WITH UNDERDRAIN OUTLET



CROSS - SECTION



POND BENCH UNDRAINED GRAVEL FILTER DETAIL

FIGURE 4-2. TYPICAL WET POND WITH UNDERDRAIN OUTLET

Section 5.0
VEGETATED BUFFERS

REVISED JUNE 2 010

5.1.1 General Description

Buffer strips are natural, undisturbed strips of natural vegetation or planted strips of close-growing vegetation adjacent to and downslope of developed areas. As stormwater runoff travels over the buffer area, vegetation slows the runoff and traps particulate pollutants. They are also effective for phosphorus removal when designed in accordance with this manual. The effectiveness of buffers for pollutant removal depends on the flow path length and slope of the buffer berm length, the soil permeability, the size of drainage area, and the type and density of vegetation. Also critical to the performance of buffer strips is the distribution of water flowing over it. If water is allowed to concentrate because of poor grading or uneven runoff distribution, the buffer will be short-circuited and have only minimal benefit. The irregular microtopography of undisturbed buffers provides small areas within which runoff can pool, encouraging infiltration and reducing the amount of runoff.

Buffers are used to treat runoff from relatively small amounts of impervious Buffers are used to treat runoff from relatively small amounts of impervious area, as typically found in residential developments and small commercial and industrial sites. This type of BMP requires minimal maintenance and provides an aesthetically pleasing area.

IMPORTANT

There are four types of BMP buffers approved by DEP:

- Buffer adjacent to residential, largely pervious or small impervious areas: This buffer is for smaller areas where the flow enters the buffer as sheet flow.
- Buffer with stone bermed level lip spreaders: This buffer is used for larger, developed areas and uses a level spreader to create sheet flow onto the buffer.
- Buffer adjacent to the downhill side of a road: This buffer is used for flow from a roadway when it directly enters the buffer as sheet flow.
- Ditch turn-out buffer: This buffer is used to divert roadway runoff collected in a ditch into a buffer as sheet flow.
- Buffer downgradient of a single family residential lot. This buffer has a reduced size to allow for a reduced pollutant loading.

Chapter Contents:

This manual describes four different BMP buffers, each of which is appropriate for specific situations. This chapter is set up to present general design, construction and maintenance criteria applicable to all buffers up front, followed by specific design criteria for each buffer type.

IMPORTANT

Use the buffer sizing tables in this Chapter to size buffers to meet BMP standards. When used to meet phosphorus allocations in lake watersheds, adjust the sizing of the buffers in accordance with Volume II of this manual.

IMPORTANT
Design Tips - All Buffers

- Buffers shall be directly adjacent to areas being treated.
- Buffer slope must be less than 15%.
- Runoff must enter the buffer as sheet flow.
- Manipulate sites to maximize buffer flow path length.
- Only continuous flow path length may be counted for treatment.
- Flow paths of runoff through a buffer must be parallel or diverging; they must not converge.

5.1.2 General Size Suitability Criteria

1. **Drainage Area:** The required size and type of buffer used is dependent on the size and land use of the area draining to it. Generally speaking, the smaller the area draining to a buffer, the more effective it is likely to be.

2. **Location:** Buffers are located downslope of developed areas and along waterways. They should be located directly adjacent to areas for which they are providing treatment. Use of buffers may be limited by location of suitable septic areas, building sites, roads, and driveways. Site planning should provide for the location of buffers as part of the overall development scheme, with consideration of the design criteria listed below. In sensitive lake watersheds requiring phosphorus controls, preliminary planning will need to include determination of the allowable phosphorus export from the site.

5.1.3 General Design and Construction Criteria

1. **Maximum Slope:** The buffer's slope must be less than 15% to be included in the calculation of buffer flow path length. Areas with slopes greater than 15% are too steep to be effective as a treatment buffer but should be left undisturbed. The buffer must have a relatively uniform slope so that stormwater does not concentrate in channels.

2. **Distribution of runoff over the buffer:** To be treated, runoff must enter the buffer as sheet flow and cannot be allowed to channelize. Buffers will not treat shallow concentrated or channelized flow. In most cases wooded and non-wooded natural buffers take advantage of the natural micro topography, (the small depressions and mounds of natural ground) to store runoff and allow for

maximum infiltration.

3. **Separation from streams:** Buffers must not be interrupted by intermittent or perennial stream channels or other drainage ways.

4. **Restabilization of buffers used for sediment control during construction:** If a buffer has been used to trap sediment during construction, the sediment must be removed and the original topography, ground cover and vegetation reestablished. Otherwise, sediment accumulations may cause runoff to concentrate in certain locations. It is advisable to protect buffer strips with wood waste berm sedimentation barriers during the construction process.

5. **Pretreatment for buffers with "bare soil" contributing areas:** To prevent a heavy sediment loading from damaging the buffer, sites that will have areas of bare soil for a long time can not utilize this BMP without first pre-treating the runoff with a sediment control BMP.

6. **Buffer dimensions**: Buffer flow path length depends to some extent on the proposed layout, and may be limited by the location of roads, driveways, building sites, and suitable septic system locations. Overall site design and individual lot configuration can be manipulated to maximize buffer flowpath length while minimizing interference with developed areas. The longer the buffer flow path length, the more effective the buffer is. Only continuous flow path length may be counted. A second buffer separated from the first by a developed area may not be included. The buffer berm length will vary depending on the soil type and vegetative cover of the buffer. Buffer sizing is addressed under each of the four buffer BMPs discussed in this manual.

7. **Topography:** The topography of a buffer area must be such that stormwater runoff will not concentrate as it flows across a buffer, but will remain well distributed. Flow paths of runoff through a buffer must not converge, but must be essentially parallel or diverging. This should be confirmed in the field for each area designated as a buffer.

8. **Vegetative cover:** The vegetative cover type of a buffer must be either forest or meadow. In most instances the sizing of a buffer varies depending on vegetative cover type.

   a. Forest buffer: A forest buffer must have a well distributed stand of trees with essentially complete canopy cover, and must be maintained as such. A forested buffer must also have an undisturbed layer of duff covering the mineral soil. Activities in a buffer that disturb the duff layer are prohibited.
   b. Meadow buffer: A meadow buffer must have a dense cover of grasses, or a combination of grasses and shrubs or trees. A buffer must be maintained as a meadow with a generally tall stand of grass, not as a lawn. It must not be mown more than twice per calendar year. If a buffer is not located on natural soils, but is constructed on fill or reshaped slopes, a buffer surface must either

be isolated from stormwater discharge until a dense sod is established, or must be protected by a three inch layer of erosion control mix or other wood waste material approved by the department before stormwater is directed to it. Vegetation must be established using an appropriate seed mix.

c. Mixed meadow and forest buffer:
If a buffer is part meadow and part forest, the required sizing of a buffer must be determined as a weighted average, based on the percent of a buffer in meadow and the percent in forest, of the required sizing for meadow and forest buffers.

9. **Deed restrictions and covenants:** Areas designated as buffers must be identified on site plans and protected from disturbance by deed restrictions and covenants. Refer to Appendix D for suggested templates for deed restrictions and conservation easements.

5.1.4 General Maintenance Criteria

1. **Mowing:** Meadow buffers may be mown no more than twice per year. They may not be maintained as a lawn.

2. **Inspection Frequency:** Buffers should be inspected annually for evidence of erosion or concentrated flows through or around the buffer. All eroded areas should be repaired, seeded and mulched. A shallow stone trench should be installed and maintained as a level spreader to distribute flows evenly in any area showing concentrated flows.

3. **Access and Use:** Buffers should not be traversed by all-terrain vehicles or other vehicles. Activities within buffers should be conducted so as not to damage vegetation, disturb any organic duff layer, and expose soil.

4. **Model Maintenance Plan:** The following techniques should be followed to maintain the integrity of buffers from initial planning through post-construction (Schueler, 1994):

a. Planning Stage
i. Require buffer limits to be present on all clearing/grading and erosion control plans
ii. Record all buffer boundaries on official maps and site plans.
iii. Clearly establish acceptable and unacceptable uses for the buffer, and include in deed restrictions and conservation easements.
iv. Establish clear vegetation targets and management rules for the buffer.
v. Provide incentives for owners protect buffers through perpetual conservation easements rather than deed restrictions.

b. Construction Stage
i. Pre-construction stakeout of buffers to define the Limit of Disturbance (LOD).
ii. Set LOD based on drip-line of the forested buffer.
iii. Conduct pre-construction meeting to familiarize contractors and foremen with LOD and buffer limit.
iv. Mark the LOD with silt fence barrier, signs or other methods to exclude construction equipment.

c. Post-Development Stage

i. Mark buffer boundaries with permanent signs (or fences) describing allowable uses.
ii. Educate property owners/homeowner associations on the purpose, limits and allowable uses of the buffer.
iii. Conduct periodic "buffer walks" to inspect the condition of the buffer network (using volunteers, where possible).
iv. Replant unused meadow buffers with trees and shrubs, if possible.

Selected References

Maine DEP, 1992. Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development. Maine Department of Environmental Protection, Augusta, Maine.
MPCA, 1989. Protecting Water Quality in Urban Areas: Best Management Practices for Minnesota. Minnesota Pollution Control Agency, Division of Water Quality, St. Paul, Minnesota.
Schueler, T.R, 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments, Washington, District of Columbia.
Simon, John, 2004. DEP Filter Buffer Study Reports (produced for DEP).
Wong, S.L. and McCuen, R.M., 1982. “The Design of Vegetative Buffer Strips for Runoff and Sediment Control.” Tidewater Administration, Department of Natural Resources, Annapolis, Maryland

5.2.1 Buffer Adjacent to Residential, Largely Pervious or Small Impervious Areas

A buffer adjacent to residential, largely pervious or small impervious areas is for small developments where runoff enters the buffer as sheet flow without the aid of a level spreader. Figure 5-1 shows a typical buffer of this type. It may only be used when it is located immediately downhill of the developed area and runoff enters as sheet flow. This design is not appropriate for treating large impervious areas because, even if pavement is graded evenly, it is likely that some concentration of runoff will occur as the stormwater travels across large areas of pavement. Only runoff from the following areas may be treated using this type of buffer:

• A single family residential lot draining to buffer;
• A developed area with less than 10% imperviousness where the flow path over the portion of the developed area for which treatment is being credited does not exceed 150 feet; or
• An impervious area of less than one acre, where the flow path across the impervious area does not exceed 100 feet.

In addition to the general design and construction criteria, provided in the beginning of this Chapter, the following criteria must also be applied in the design and construction of a buffer adjacent to residential, largely pervious or small impervious areas.

1. **Slope:** A buffer meeting this standard is not allowed on natural slopes in excess of 15%.

2. **Soil Restrictions:** A buffer meeting this standard is not allowed on Hydrologic Soil Group D soils except that a forested buffer is allowed if the D soils in a buffer are not wetland soils.

3. **Buffer Sizing:** Sizing depends only on the soil type and vegetative cover type of a buffer. Tables 5-1 and 5-2 indicate the required buffer flow path length based on soil types and vegetative cover types. Buffers described by this Chapter must be located downhill of the entire developed area for which it is providing stormwater treatment, such that all runoff from the entire developed area has a flow path through the buffer at least as long as the required length of flow path.

IMPORTANT
Design Tips–Buffer Adjacent to Residential, Largely Pervious or Small Impervious Areas

• Buffers adjacent to residential, largely pervious or small impervious areas are for small developments. They are not appropriate for treating large impervious areas.
• Runoff must enter the buffer as sheet flow without the aid of a level spreader.
• The buffer must be located downhill of the developed area.

Table 5-1 Required Buffer Flow Path Length Per Soil and Vegetative Cover Types with 0-8% Buffer Slope		
Hydrologic Soil Group of Soil in Buffer	Length of Flow Path for a Forested Buffer (feet)	Length of Flow Path for a Meadow Buffer (feet)
A	45	75
B	60	85
C Loamy Sand or Sandy Loam	75	100
C Silt Loam, Clay Loam or Silty Clay Loam	100	150
D Non-Wetland	150	Not Applicable

Table 5-2 Required Buffer Flow Path Length Per Soil and Vegetative Cover Types with 9-15% Buffer Slope		
Hydrologic Soil Group of Soil in Buffer	Length of Flow Path for a Forested Buffer (feet)	Length of Flow Path for a Meadow Buffer (feet)
A	54	90
B	72	102
C Loamy Sand or Sandy Loam	90	120
C Silt Loam, Clay Loam or Silty Clay Loam	120	180
D Non-Wetland	180	Not Applicable

5.2.2 Buffer with Stone Bermed Level Lip Spreader

A buffer with stone bermed level lip spreaders consists of a bermed level spreader followed by a buffer. Runoff is directed behind the stone berm, which is constructed along the contour at the upper margin of a buffer area. The runoff then spreads out behind the berm so that it seeps through the entire length of the berm and is evenly distributed across the top of a buffer as sheet flow. Figure 5-2 shows a typical buffer with stone bermed level lip spreader. This type of buffer must be used when treating stormwater runoff from any of the following:

- An impervious area greater than one acre;
- Impervious areas where the flow path across the impervious area exceeds 150 feet; or
- Developed areas, including lawns and impervious surfaces, where runoff is concentrated, intentionally or unintentionally, so that it does not run off in well-distributed sheet flow when it enters the upper end of a buffer, except that road ditch runoff may be treated using a ditch turn out buffer.

In addition to the general design and construction criteria, provided in the beginning of this Chapter, the following criteria must also be applied in the design and construction of a buffer with stone bermed level lip spreaders.

1. **Stone berm specifications:** The berm must be well-graded and contain some small stone and gravel so that flow through the berm will be restricted enough to cause it to spread out behind the berm. The stone berm must be at least 1.5 feet high and 2.0 feet across the top with 2:1 side slopes constructed along the contour and closed at the ends. Unless otherwise approved by the department, the design must include a shallow, 6-inch deep trapezoidal trough with a minimum bottom width of three feet, and with a level downhill edge excavated along the contour on the uphill edge of the stone berm.

2. **Stone size:** The stone must be coarse enough that it will not clog with sediment. Stone for stone bermed level lip spreaders must consist of sound durable rock that will not disintegrate by exposure to water or weather. Fieldstone, rough quarried stone, blasted ledge rock or tailings may be used. The rock must be well-graded within the limits provided in Table 5-3 or as approved by the department..

3. **Slope:** A buffer meeting this standard is not allowed on natural slopes in excess of 15% unless a buffer has been evaluated using a site specific hydrologic buffer design model approved by the department, and measures have been included to ensure that runoff remains well-distributed as it passes through a buffer.

4. **Soil Restrictions:** A buffer meeting this standard is not allowed on Hydrologic Soil Group D soils that are identified as wetland soils.

5. **Buffer sizing:** The required size of a buffer area below the stone bermed

level lip spreader varies with the size and imperviousness of the developed area draining to a buffer, the type of soil in the buffer, the slope and vegetative cover type. Table 5-4 and 5-5 indicate the required berm length per acre of impervious area and lawn draining to a buffer for a given length of flow path through a buffer. Required berm length varies by the Hydrologic Soil Group of the soils in a buffer and by the length of flow path through a buffer. If more than one soil type is found in a buffer, the required sizing of a buffer must be determined as weighted average, based on the percent of a buffer in each soil type, of the required sizing for each soil type buffer. Alternative sizing may be allowed if it is determined by a site-specific hydrologic buffer design model approved by the department.

IMPORTANT
Design Tips - Buffer with Stone Bermed Level Lip Spreader

- Stone berm must be well-graded and contain small stone and gravel to force flows to spread out behind the berm.
- Stone berm must be at least 1.5' high and 2.0' across the top with 2:1 side slopes.
- Provide a shallow, 6" deep trapezoidal trough with a minimum bottom width of 3' along uphill edge of berm.
- Buffer with stone berm not allowed on Hydrologic Soil Group D soils identified as wetland soils.
- Required berm length varies by the Hydrologic Soil Group of the soils in a buffer and by the length of flow path.

Table 5-3
Berm Stone Size

Sieve Designation (Metric)	Sieve Designation (US Customary)	Percent By Weight Passing Square Mesh Sieves
300 mm	12 in	100
150 mm	6 in	84-100
75 mm	3 in	68-83
25.4 mm	1 in	42-55
4.75 mm	No. 4	8-12

NOTE: *The following tables were developed using a 1.25 inch, 24 hour storm of type III distribution, giving a maximum unit flow rate of less than 0.009 cfs per foot.*

Table 5-4
Required Berm and Flow Path Length of a Buffer with 0-8% Slope and a Stone Bermed Level Lip Spreader

Hydrologic Soil Group	Length of Flow Path through Buffer (feet)	Berm Length for a Forested Buffer (feet)		Berm Length for a Meadow Buffer (feet)	
		Per acre of impervious area	Per acre of lawn	Per acres of impervious area	Per acre of lawn
Soil Group A	75	75	25	125	35
	100	65	20	75	25
	150	50	15	60	20
Soil Group B	75	100	30	150	45
	100	80	25	100	30
	150	65	20	75	25
Soil Group C sandy loam or loamy sand	75	125	35	150	45
	100	100	30	125	35
	150	75	25	100	30
Soil Group C silt loam, clay loam or silty clay loam	100	150	45	200	60
	150	100	30	150	45
Soil Group D non-wetland	150	150	45	200	60

Table 5-5 Required Berm and Flow Path Length of a Buffer with 9-15% Slope and a Stone Bermed Level Lip Spreader					
Hydrologic Soil Group	Length of Flow Path through Buffer (feet)	Berm Length for a Forested Buffer (feet)		Berm Length for a Meadow Buffer (feet)	
		Per acre of impervious area	Per acre of lawn	Per acre of impervious area	Per acre of lawn
Soil Group A	75	90	30	150	42
	100	78	24	90	30
	150	60	18	72	24
Soil Group B	75	120	36	180	54
	100	96	30	120	36
	150	78	24	90	30
Soil Group C sandy loam or loamy sand	75	150	42	180	54
	100	120	36	150	42
	150	90	30	120	36
Soil Group C silt loam, clay loam or silty clay loam	100	180	54	240	72
	150	120	36	180	54
Soil Group D non-wetland	150	180	54	240	72

5.2.3 Buffer Adjacent to the Down Hill Side of a Road

A buffer adjacent to the down hill side of a road consists of a buffer directly adjacent to a roadway. The road must be parallel to the contour of the slope. It may only be used when the runoff from the road surface and shoulder sheets immediately into the buffer. In no instance may runoff from areas other than the adjacent road surface and shoulder be directed to these buffers. Figure 5-3 shows a typical buffer adjacent to the down hill side of a road.

In addition to the general design and construction criteria, provided in the beginning of this Chapter, the following criteria must also be applied in the design and construction of buffers adjacent to the down hill side of a road.

IMPORTANT
Design Tips - Buffer Adjacent to the Down Hill Side of a Road

The in slope of the roadbed may only be included as part of a meadow buffer if it is designed and constructed to allow infiltration.

1. **Slope:** A buffer meeting this standard is not allowed on natural slopes in excess of 20%.
2. **Soil Restrictions**: A buffer meeting this standard is not allowed on soils identified as wet-land soils.
3. **Buffer Sizing:** Sizing depends only on the vegetative cover type of a buffer and the number of travel lanes draining to a buffer. Table 5-6 indicates the required buffer flow path length based on the number of travel lanes draining to the buffer and whether the buffer is forested or meadow.
4. **Inclusion of inslope**: The inslope of the roadbed may be included as part of a meadow buffer only if it is designed and constructed to allow infiltration. Design and construction to allow infiltration includes, but is not limited to, the inslope fill material being a sandy loam or coarser soil texture having slopes no steeper than 4:1; loaming and seeding to meadow grasses; and maintaining a buffer area as a meadow buffer.

Table 5-6
Required Buffer Flow Path Adjacent to the Down Hill Side of a Road

	Length of Flow Path for a Forested Buffer (feet)	Length of Flow Path for a Meadow Buffer (feet)
One travel lane draining to buffer	35	50
Two travel lanes draining to buffer	55	80

5.2.4 Ditch Turnout Buffer

A ditch turn-out buffer is used to divert runoff collected in a roadside ditch into a buffer. It consists of a combination of check dams and bermed level lip spreaders used to divert concentrated ditch flows into a buffer as sheet flow.

Runoff backs up behind the check dam and is directed over a stone berm that spreads flows out so that it is evenly distributed across the top of a buffer as sheet flow. Figure 5-4 shows a typical ditch turn-out buffer.

In addition to the general design and construction criteria, provided in the beginning of this Chapter, the following criteria must also be applied in the design and construction of a ditch turn-out buffer.

1. **Drainage Area:** No areas other than the road surface, road shoulder and road ditch may be directed into the buffer. No more than 400 ft of road and ditch may be treated in any ditch turn-out buffer, and no more than 250 feet may be treated if more than one travel lane is draining to the ditch.

2. **Distribution of runoff over the buffer:** The turnout should extend into the side ditch or cut slope in a manner that it intercepts the ditch runoff and carries it into the buffer area. The buffer end of the turnout must be level and equipped with a stone bermed level spreader.

3. **Stone berm specifications:** The stone berm to which the ditch turn-out delivers the runoff must be at least 20 feet in length and must be constructed along the contour. It must be at least one- foot high and two feet across the top with 2:1 side slopes.

4. **Stone size:** Stone for the berm must consist of sound durable rock that will not disintegrate by exposure to water or weather. Fieldstone, rough quarried stone, blasted ledge rock or tailings may be used. The rock must be well graded with a median size of approximately 3 inches and a maximum size of 6 inches

5. **Slope:** A buffer meeting this standard is not allowed on natural slopes in excess of 15%.

6. **Soil Restrictions:** A buffer meeting this standard is not allowed on Hydrologic Soil Group D soils with wetlands.

7. **Buffer sizing:** The required size of a buffer area below the turnout's stone bermed level lip spreader varies with the type of soil in a buffer area, the slope of a buffer, the length of road ditch draining to a buffer and the vegetative cover type within a buffer. Tables 5-7 and 5-8 indicate the required length of the flow path through a buffer for various vegetative covers and ditch lengths. If two travel lanes drain to the ditch, as in the case of a super elevated road, the length of flow path indicated for 400 feet of road must be used, but no more than 250 feet of ditch may drain to each turn-out.

Table 5-7 Required Buffer Flow Path Length Per Length of Road or Ditch with 0-8% Buffer Slope			
Hydrologic Soil Group of Soil in Buffer	Length of Road or Ditch Draining to a Buffer (feet)	Length of Flow Path for a Forested Buffer (feet)	Length of Flow Path for a Meadow Buffer (feet)
A	200	50	70
	300	50	85
	400	60	100
B	200	50	70
	300	50	85
	400	60	100
C Loamy Sand or Sandy Loam	200	60	100
	300	75	120
	400	100	Not applicable
C Silt Loam, Clay Loam or Silty Clay Loam	200	75	120
	300	100	Not applicable
D Non-wetland	200	100	150

Table 5-8 Required Buffer Flow Path Length Per Length of Road or Ditch with 9-15% Buffer Slope			
Hydrologic Soil Group of Soil in Buffer	Length of Road or Ditch Draining to a Buffer (feet)	Length of Flow Path for a Forested Buffer (feet)	Length of Flow Path for a Meadow Buffer (feet)
A	200	60	84
	300	60	102
	400	72	120
B	200	60	84
	300	60	102
	400	72	120
C Loamy Sand or Sandy Loam	200	72	120
	300	90	144
	400	120	Not applicable
C Silt Loam, Clay Loam or Silty Clay Loam	200	90	144
	300	120	Not applicable
D Non-wetland	200	120	180

5.2.5 Buffer Downgradient of a Single Family Residential Lot

In addition to the general design and construction criteria, provided in the beginning of this Chapter, the following criteria must also be applied in the design and construction of a ditch turn-out buffer. This design applies only to buffers adjacent to single family residential lot development where:

- The buffer is located immediately downhill of the developed area;
- Runoff enters the buffer as sheet flow without a level spreader; and
- The flow path over the portion of the developed area for which treatment is being credited does not exceed 150 feet.

1. **Slope:** To meet this alternative design, a buffer is not allowed on natural slopes in excess of 15%.

2. **Soil Restrictions:** Such a buffer is allowed on Hydrologic Soil Group D soils only if it is forested and non-wetland.

3. **Buffer Sizing:** The table below indicates the required buffer flow path length based on soil types and vegetative cover types. Buffers must be located downhill of the entire developed area for which they are providing stormwater treatment; and with no converging contour, such that all runoff from the developed area passes in sheet flow through the buffer for a distance at least as long as the required length of flow path.

4. **General Criteria:** In addition, buffers must conform to the general design, construction and maintenance criteria described in this Chapter.

5. **Minimum sizing for phosphorus standard:** If this buffer standard is being used to meet the phosphorus standard and its size is being adjusted to provide a specific treatment factor, the minimum sizing for this type of buffer is a flow path of 35 feet

Required minimum length of flow path through the buffer Based on a slope no greater than 15%		
Hydrologic soil	**For a forested buffer (feet)**	**For a meadow buffer (feet)**
A	35	50
B	45	60
C Loamy Sand or Sandy Loam	50	70
C Silt Loam, Clay Loam or Silty Clay Loam	70	100
D Non wetland	100	Not Applicable

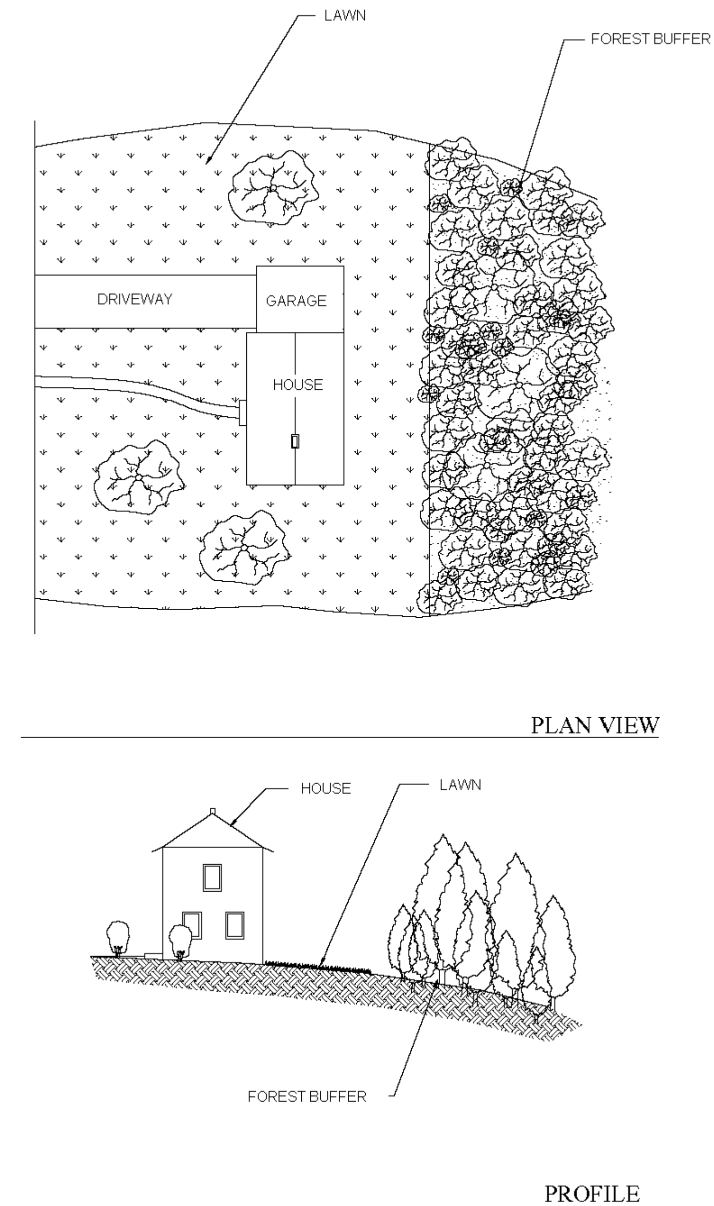


FIGURE 5-1. BUFFER ADJACENT TO RESIDENTIAL AREAS

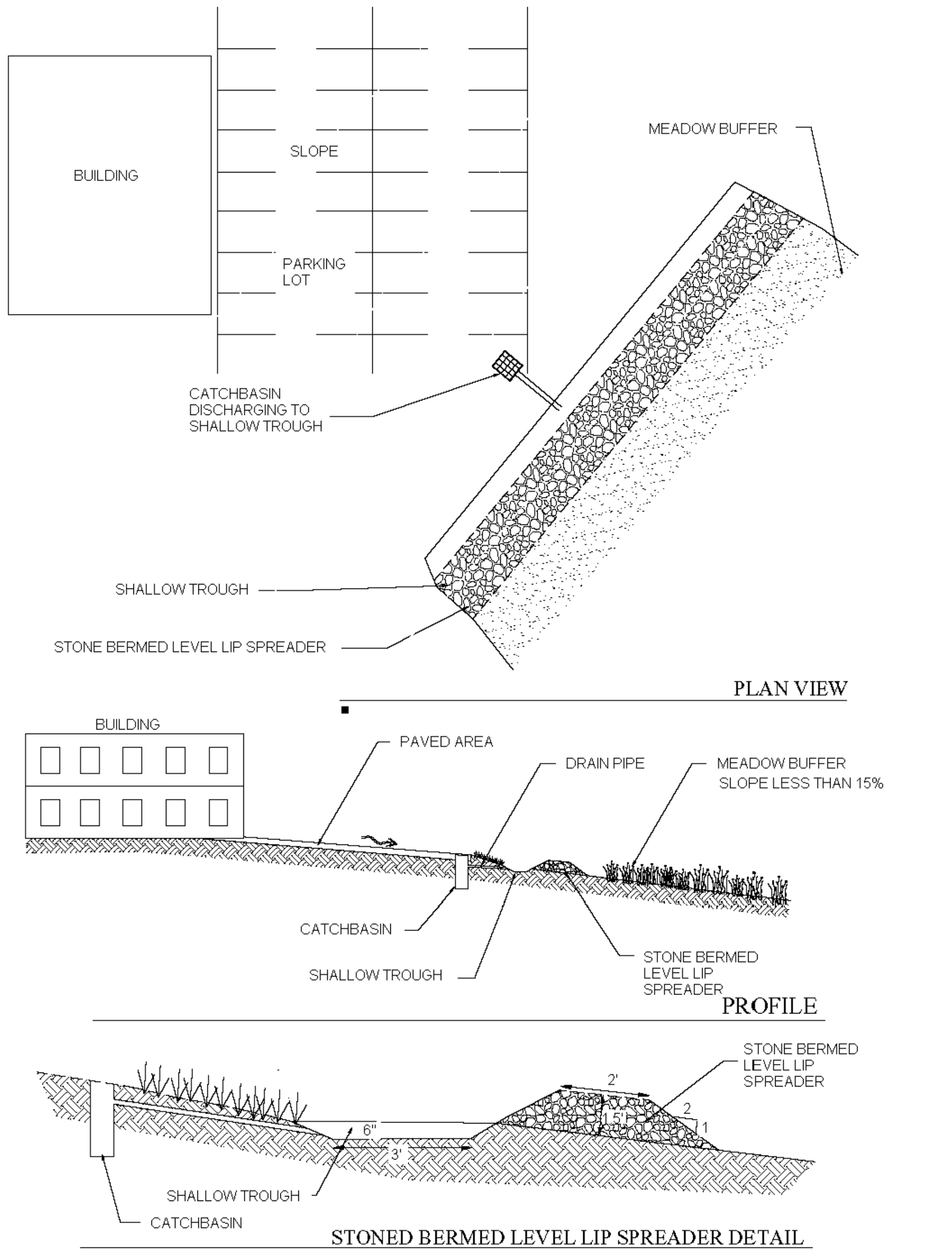


FIGURE 5-2. BUFFER WITH STONE BERMED LEVEL LIP SPREADER

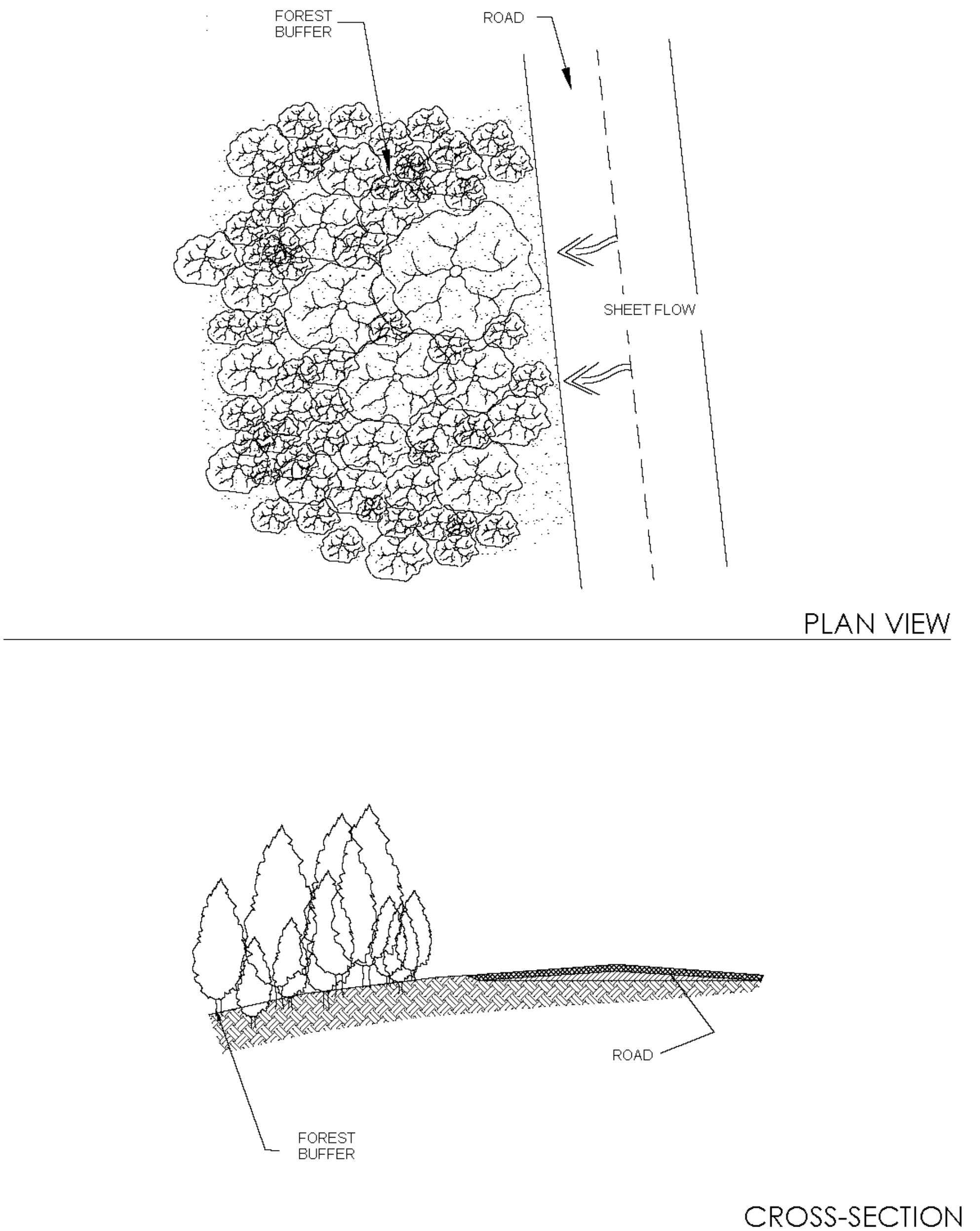


FIGURE 5-3. BUFFER ADJACENT TO THE DOWNHILL SIDE OF A ROAD

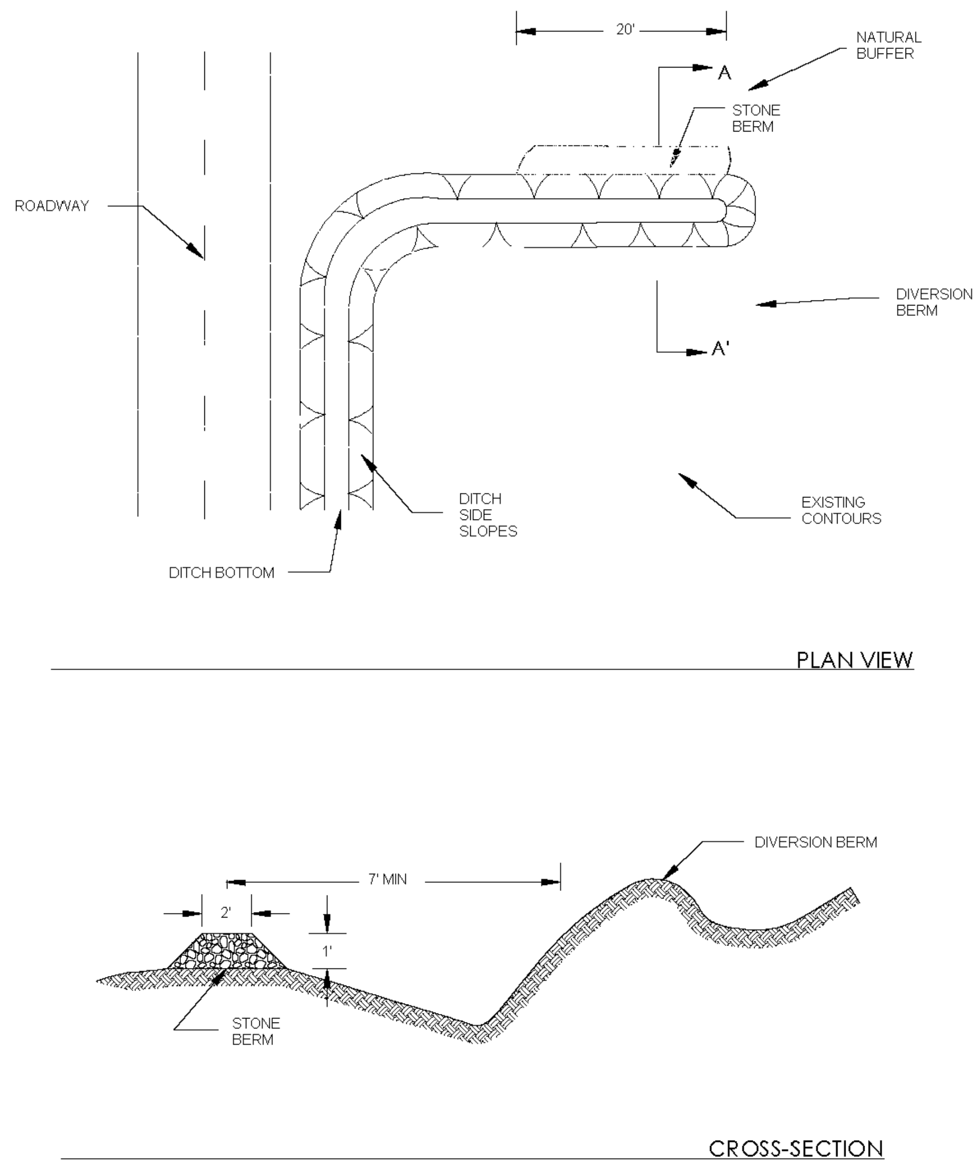


FIGURE 5-4. TYPICAL DITCH TURNOUT BUFFER

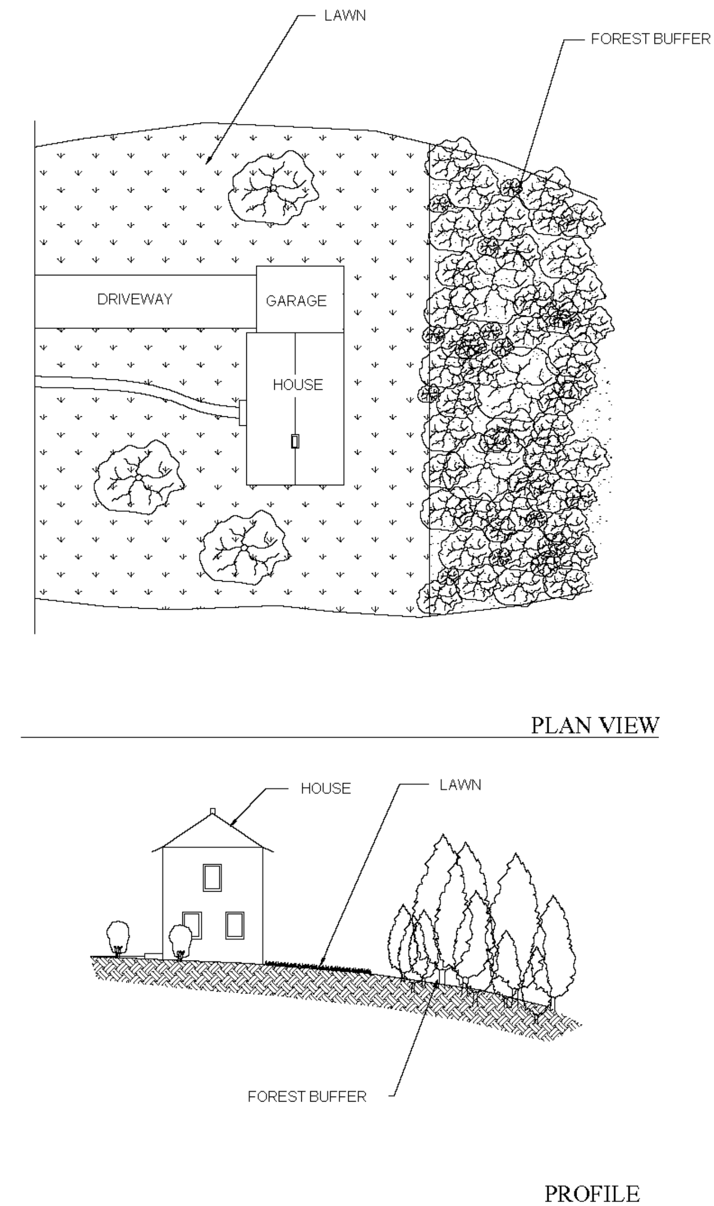


FIGURE 5-1. BUFFER ADJACENT TO RESIDENTIAL AREAS

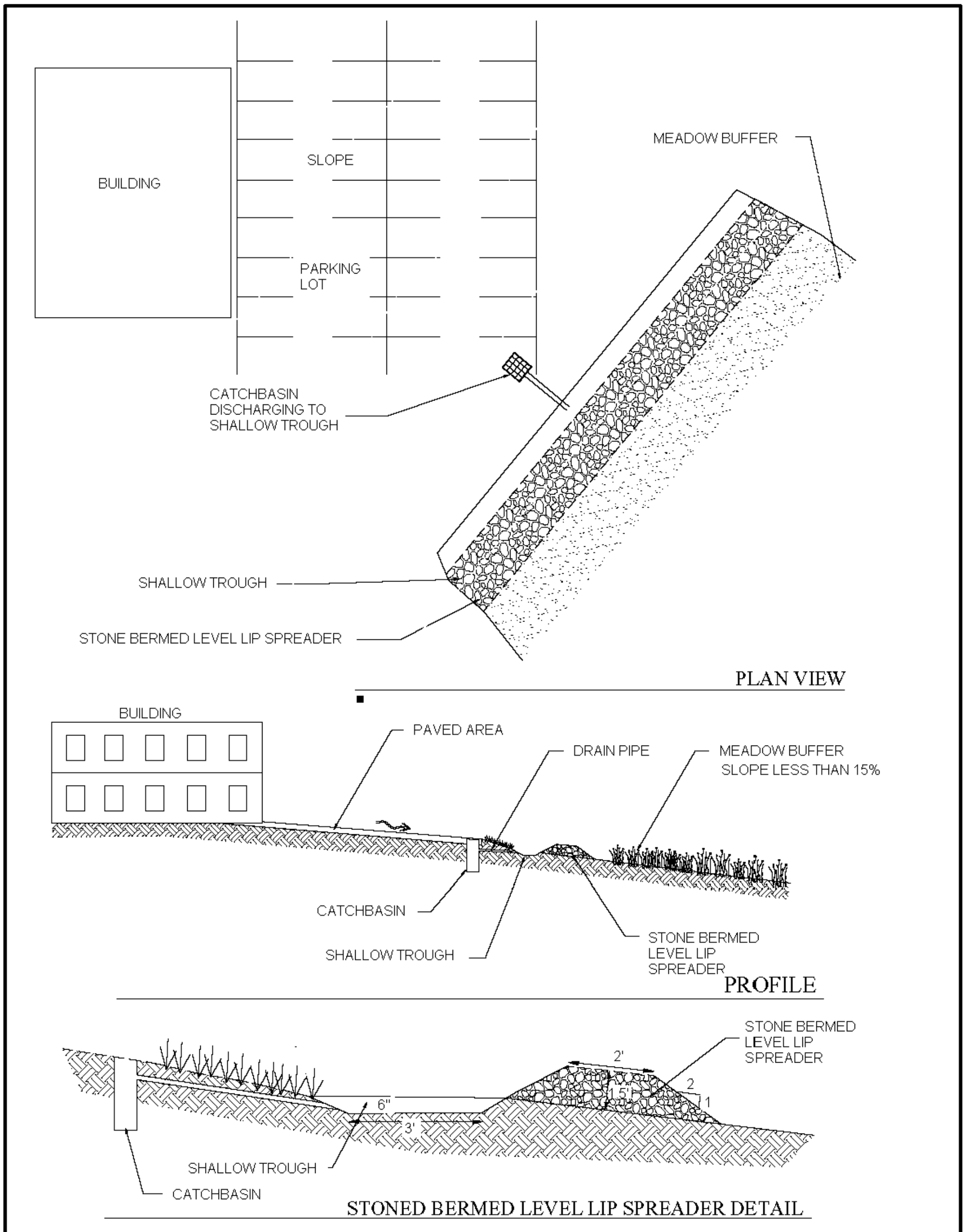


FIGURE 5-2. BUFFER WITH STONE BERMED LEVEL LIP SPREADER

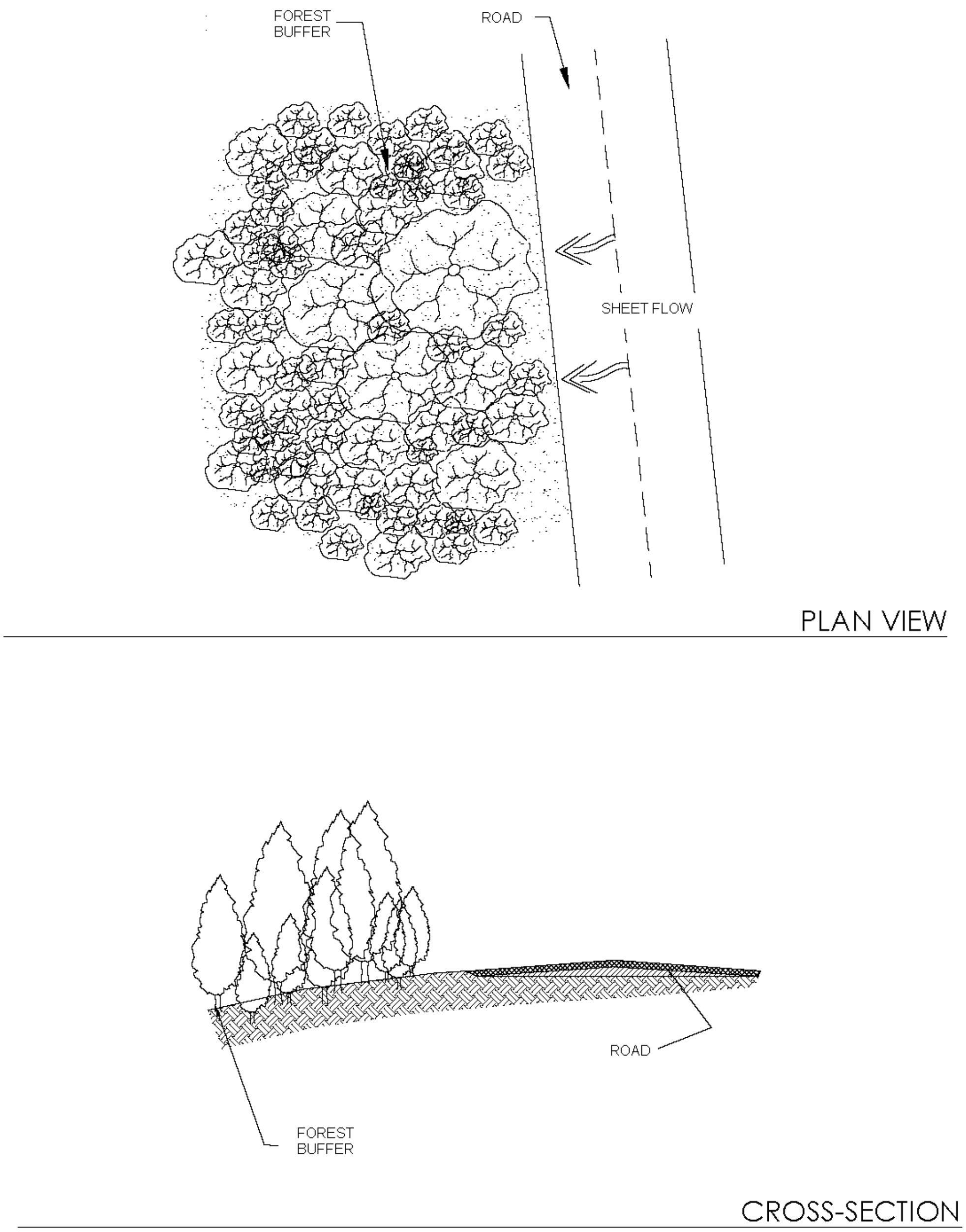


FIGURE 5-3. BUFFER ADJACENT TO THE DOWNHILL SIDE OF A ROAD

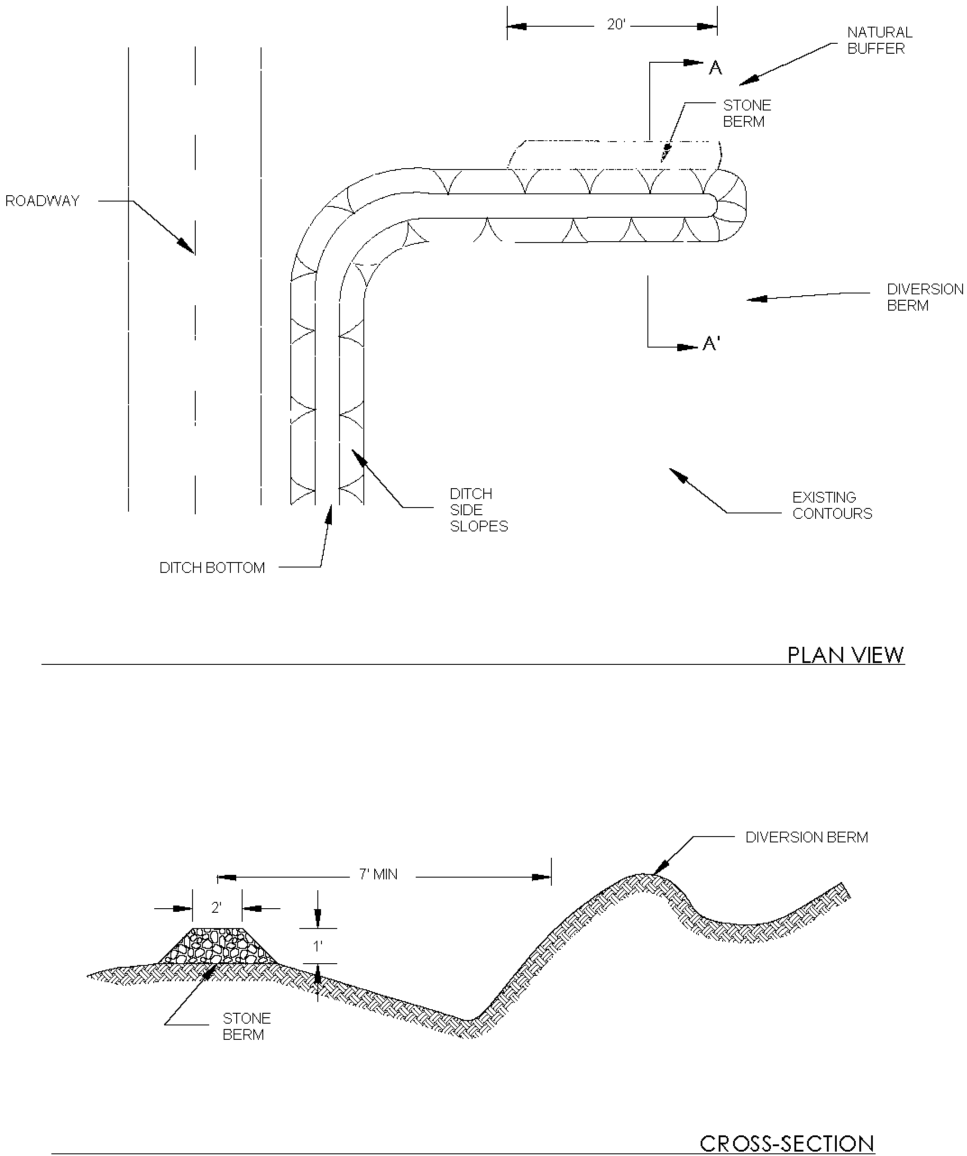


FIGURE 5-4. TYPICAL DITCH TURNOUT BUFFER

Chapter 6
Infiltration BMPs

6.1 General Criteria

IMPORTANT Performance Criteria for Projects in the Direct Watershed of a Lake Where the Phosphorus Standard is Applied

When used to meet phosphorus allocations in lake watersheds, adjust the sizing of the infiltration system in accordance with Volume II of this manual.

6.1.1 General Description

Infiltration measures control stormwater quantity and quality, by retaining all or part of runoff on-site and discharging it into the ground. Infiltration is designed to occur at the surface (as in infiltration basins and to a degree vegetated swales and buffers), or in subsurface systems (e.g., infiltration trenches and infiltrators).

The basic function of an infiltration system is to remove a portion of runoff from the total runoff volume of the site and treatment comes about through absorption, straining, microbial decomposition in the soil and trapping of particulate matter within pretreatment areas. Pretreatment to remove sediments grease and oils is required prior to discharge to the infiltration measure. Possible pretreatment measures include filter strips, swales with check dams, sand filters, sediment traps, grease and oil traps, and sediment basins.

Groundwater does risk contamination with infiltration practices and some long-term studies of pollutant migration through soils beneath infiltration practices have shown a downward movement of pollutants (Schueler, 1987; MPCA, 1989). Possible excep-

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tions include soluble pollutants such as nitrate, chloride, and gasoline (Schueler, 1987). More recent studies have documented the extent of groundwater and soil contamination at various facilities and provide specific guidance for varying contamination risks. See, for example, Pitt (1994), Wilde (1994), National Research Council (1994) and Miller (1996). Infiltration systems should not be used if the intercepted runoff is anticipated to contain pollutants that can affect groundwater quality, such as hydrocarbons, nitrate, and chloride.

This manual describes three common Infiltration BMPs, each of which is appropriate for specific situations. These types include:

- Dry Well: This infiltration BMP is used to temporarily store and infiltrate prefiltered runoff from a very limited contributing area.
- Infiltration Trench: This BMP is suitable for treating runoff from small drainage areas (less than 10 acres). Installations around the perimeter of parking lots, between residential lots, and along roads are most common.
- Infiltration Basin: This BMP is suitable for treating and controlling runoff from drainage areas of 5 to 50 acres in size. Installations serving a large commercial development, a residential subdivision, an industrial subdivision, or a gravel-mining site are most common.

In addition to these infiltration techniques, there are several Low Impact Design (LID) techniques that rely on infiltration. The major difference is that the LID techniques use smaller infiltration systems to disperse infiltration throughout a site, rather than an end-of-pipe technique such as the infiltration trench and basin.

IMPORTANT
Performance Criteria

Infiltration areas must retain a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area and infiltrate this volume into the ground.

6.1.2 General Site Suitability Criteria

1. **Site Slopes**: Infiltration shall not be located on slopes greater than 20%.
2. **Soil Permeability:** The permeability of the soil at the depth of the base of the proposed infiltration system must be no less than 0.50 inches per hour and no greater than 2.41 inches per hour. Permeability must be shown to be reasonably consistent across the proposed infiltration area and shall be determined by in-place well or permeameter testing, by analyses of soil gradation, or other means acceptable to the department.
3. **Siting in Fill Soils:** Do not install infiltration systems in a newly filled area or a site designated as "made land" without a geotechnical evaluation of the subgrade stability and permeability rates.
4. **Industrial Sites:** Infiltration devices should not be used in manufacturing and industrial areas because of the high potential for soluble and toxic pollutants and petroleum products.
5. **Construction Sites:** Construction site runoff should not be directed to infiltration areas because of the high concentration of suspended solids, which will clog infiltration surfaces.

6.1.3 General Design and Construction Criteria

1. **Sizing:** Infiltration systems must be designed to retain a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area and infiltrate this volume into the ground.

2. **Site Construction:** Infiltration practices may not be used as sediment control devices during site construction. Plans must clearly indicate how sediment will be prevented from entering the infiltration device during construction.

3. **Dry Weather Effluent:** Dry weather storm drain effluent should not be directed to infiltration areas due to probable high concentrations of heavy metals, pesticides, pathogens, and other pollutants.

4. **Combined Sewer Overflows:** Combined sewage overflows should not be directed to infiltration areas because of their high pathogen concentrations and high clogging potential.

5. **Snowmelt:** Snowmelt runoff from areas subject to or adjacent to road traffic or parking should not be directed to infiltration areas because of the high concentrations of salts.

6. **Soil Amendment:** If amending soils to meet permeability, the added soils must be at least six inches thick, with the bottom three inches tilled into the native soil.

7. **Stone Porosity:** A porosity value of 0.4 shall be used in the design of stone reservoirs for infiltration practices.

8. **Time for Drainage:** The infiltration system must drain completely within 72 hours following the runoff event. Complete drainage is necessary to maintain aerobic conditions in the underlying soil to favor bacteria that aid in pollutant attenuation (Schueler, 1987)

IMPORTANT
Design Tips

- Pretreatment to remove sediments is required for all infiltration systems. Pretreatment must be designed to store an annual volume of sediment.
- Soil permeability at the depth of the proposed infiltration system must be between 0.50 and 2.41 in/hr.
- Soil permeability must be determined by in-place well or permeameter testing, soil gradation or other means acceptable to DEP.
- Infiltration systems must drain completely within 72 hours following the runoff event.
- Maintenance is critical to system performance. Sediment must be removed at least annually.
- The bottom of the infiltration system must be at least three feet above the elevation of the seasonal high water table.
- Infiltration systems serving one acre or more of impervious area must be located in areas with more than five feet of saturated overburden above the bedrock surface.
- Stormwater infiltration may not affect the direction of groundwater flows.
- Infiltration of stormwater may not cause mounding.
- Overflow must be provided to a stable discharge location.
- Setback to the components of an offsite subsurface wastewater disposal system must be at least 100 feet or the setback distances may be require approval from the local plumbing inspector or the Department of Human Services' Division of Health Engineering.

and to allow the system to recover its storage capacity before the next storm event.

9. **Emergency Drainage:** A means to dewater the infiltration system in the event of failure should be provided. This will allow for easier repair of the system.

10. **Separation From Seasonal High Water Table:** The bottom of the infiltration system, including any stone layer or other material below the depth of any manufactured components of the system, must be at least three feet above the elevation of the seasonal high water table.

11. **Separation from bedrock:** Infiltration systems serving one acre or more of impervious area must be located in areas with more than five feet of saturated overburden above the bedrock surface, as measured during the seasonal low water table. This restriction does not apply to runoff from areas of non-asphalt roofing on structures in which no manufacturing or processing occurs, other than for home-based industries. Separation from bedrock and depth to the water table may be demonstrated by means of test pits, borings, or similar invasive explorations, or by non-invasive geophysical methods such as seismic surveys.

12. **Impact on Depth to Groundwater:** Infiltration of stormwater may not increase the elevation to the seasonal high water table beneath a surface-irrigation site, land-disposal area for septage or other waste, or other waste or wastewater management facility, without approval by the DEP and, if applicable, the Department of Health Human Services.

13. **Impact on Groundwater Flow:** Stormwater infiltration may not affect the direction of groundwater flows so as to impair any groundwater monitoring programs or cause the migration of existing contaminated groundwater that would result in unreasonable adverse impact on the quality of surface water, groundwater, or drinking water supplies.

14. **Mounding and Seepage:** Infiltration of stormwater may not cause effects that will adversely affect the stability of slopes in the vicinity of the activity. A qualified professional shall assess the potential for seepage and reduction in slope stability, and submit a report of findings, including logs of test borings or other subsurface explorations, modeling, or other means of analysis as determined to be necessary and applicable.

15. **Conveyance of Overflow:** Infiltration systems must include measures to convey overflow to a stable discharge location.

16. **Access:** Access to any infiltration area must be controlled during and after construction to prevent compaction of the soil. Limit access to the site to only that equipment needed to construct the infiltration system. Avoid placement of heavy objects or traffic on stone areas or chamber areas not H-20 rated.

17. **Setback from Water Supplies:** Unless otherwise approved by the DEP and the Department of Health and Human Services' Drinking Water Program, if applicable, locate the infiltration system at least 300 feet from any private water supply well, outside the delineated contributing area of a public water supply well, and as far downgradient of any water supply well as practical.

18. **Setback from Water Supply Lines:** Site the basin at least ten feet from any water supply conduit.

19. **Setback from Wastewater Disposal Systems:** An infiltration system is considered a major watercourse for the purposes of Table 700.2 of the Maine Subsurface Wastewater Disposal Rules, 144A CMR 241, for determining applicable setbacks from the relevant components of an offsite subsurface wastewater disposal system. Additional setback distances may be required by the local

plumbing inspector or the Department of Human Services' Division of Health Engineering. Allowance for lesser setbacks for onsite disposal systems or other disposal systems owned or controlled by the developer may be requested from the department, the Department of Human Services, and the local plumbing inspector. Infiltration systems must be located as far downgradient of any component of a subsurface wastewater disposal system as practical.

20. **Setback from Steep Slopes:** 50 feet from downhill slopes greater then 3:1.

21. **Setbacks from Flood Plains:** 10 feet from a 10 year floodplain.

22. **Setback from Property Lines:** At least 25 feet from the property line.

23. **Observation Wells:** Subsurface infiltration systems must have an observation well for monitoring recovery and determining when rehabilitation is necessary, unless the system uses an accessible manhole-type structure. The observation well shall be a 4-inch diameter, perforated PVC pipe fitted with a removable yet securable well cap, foot plate, and rebar anchor. Set the observation well prior to backfilling with the stone fill.

24. **Geotextile Lining:** A geotextile fabric with suitable characteristics must be placed between any stone layer and adjacent soil. The fabric will prevent the surrounding soil from migrating into the system and reducing its storage capacity. Use an appropriate geotextile design manual to choose a fabric that is compatible with the surrounding soil for the purposes stated above. The filter fabric should be free of tears, punctures, and other damage. Overlap seams a minimum of 12 inches.

25. **Stone Fill:** Stone fill shall be clean, washed, 1½ -inch to 3-inch aggregate.

26. **Sediment Pretreatment:** Pretreatment devices such as grassed swales, underdrained swales, filter strips, and sediment traps shall be provided for all infiltration systems to minimize the discharge of sediment to the infiltration system. Pretreatment structures shall be sized to hold an annual sediment loading. An annual sediment load shall be calculated using a sand application rate of 500 lbs/acre for sanding of roadways, parking areas, and access drives within the subcatchment area, a sand density of 90 lbs per cubic foot and a minimum frequency of ten sandings per year.

27. **Petroleum Pretreatment:** Infiltration systems receiving runoff from areas of asphalt or concrete paving must include sump skimmers, sorbent booms, or similar devices to remove petroleum products from runoff.

28. **Fill Placement:** Limit fill compaction to the work necessary to spread the fill to a uniform depth within the structure. Do not drive rollers or other equipment over the fill to compact it.

29. **Landscaping:** For subsurface systems, cover the fabric with twelve inches of soil and revegetate. Do not leave a depression above the infiltration system to collect water. The drip-line of any existing or newly planted trees shall not extend over the infiltration system. New trees shall be planted away from the well to account for future crown and root growth. Any newly established trees (seedlings) in the vicinity of the infiltration system shall be removed to prevent roots from intruding into the system.

To obtain an annual sediment volume, perform the following calculation:

$$\text{Area to be sanded (acres)} \times 500\,\frac{\text{pounds}}{\text{acre-storm}} \div 90\,\frac{\text{pounds}}{ft^3} \times 10\,\frac{\text{storms}}{\text{year}} = \text{cubic feet of sediment/yr}$$

30. **Insulation:** Unlike wastewater disposal systems, which are less likely to freeze due to the effluent temperature and also to biological activity, the components of a stormwater infiltration system may be susceptible to freezing if located above the depth of frost penetration. The designer should consider the need for incompressible insulation for shallow system components.

6.1.4 General Maintenance Criteria

Preventive maintenance is vital for the long-term effectiveness of an infiltration system. Since infiltration is less conspicuous than most BMPs, it is easy to overlook during maintenance inspections. The following criteria apply to all infiltration systems.

1. **Fertilization:** Fertilization of the area over the infiltration bed should be avoided unless absolutely necessary to establish vegetation.

2. **Snow Storage Prohibited:** Snow removed from any on-site or off-site areas may not be stored over an infiltration area, with the exception of storage on pavement alternatives approved by the department.

3. **Monitoring and Inspections:** Inspect the infiltration system several times in the first year of operation and at least annually thereafter. Conduct the inspections after large storms to check for surface ponding at the inlet that may indicate clogging. Water levels in the observation well should be recorded over several days after the storm to ensure that the system drains within 72 hours after filling.

4. **Pollution-Control Devices:** Pollution-control devices such as oil-water separators, skimmers, and booms must be inspected regularly to determine if they need to be cleaned or replaced.

5. **Sediment Removal and Maintenance of System Performance:** Sediment must be removed from the system at least annually to prevent deterioration of system performance. The pre-treatment inlets should be checked periodically and cleaned out when accumulated sediment occupies more than 10% of available capacity. This can be done manually or by a vacuum pump. Inlet and outlet pipes should be checked for clogging. Accumulated grease and oil from separator devices should be removed frequently and disposed of in accordance with applicable state and local regulations. The system must be rehabilitated or replaced if its performance is degraded to the point that applicable stormwater standards are not met.

6. **Pretreatment Buffer Strips:** If a grass buffer strip is used in conjunction with the infiltration BMP it should be inspected regularly. Growth should be vigorous and dense. Bare spots or eroded areas should be repaired and/or re-seeded or re-sodded. Watering and/or fertilization should be provided during the first few months after the strip is established, and may periodically be needed in times of drought. Grass filter strips should be mowed regularly to prevent the uncontrolled growth of briars and weeds. Filter strips in residential or commercial areas will need to be mowed more frequently, but filter strip performance will be impaired if the grass is cut too short. Lawn clippings should be removed to prevent them from clogging the BMP.

7. **Observation Wells, Measure of Sediment Accumulation, and Points of Access for Sediment Removal:** Observation wells to determine the system's performance and access points to allow for the removal of accumulated sediment must be included in the design of infiltration systems. Dry wells and infiltration basins must have staff gauges, marked rods, or similar instrumentation to measure the accumulation of sediment and determine how quickly the system drains after a storm. The maintenance plan must indicate the expected rate of drainage

of the infiltration system and provide for removal of sediment from the infiltration system.

8. **Groundwater Monitoring:** Groundwater quality monitoring may be required as part of the system maintenance to demonstrate that pollutant removal practices are effective. Groundwater quality monitoring will generally be required for activities infiltrating water from areas of heavy turf-chemical use, such as golf courses and certain athletic fields, and large connected impervious areas, such as parking lots and runways. Groundwater quality monitoring will generally not be required for systems infiltrating water from lawn areas and other vegetated areas, residential developments, playing fields, and roofs of residential and commercial structures.

9. **Groundwater Testing:** Groundwater should be analyzed quarterly for indicator parameters such as pH, specific conductance, dissolved oxygen, and chloride. Zinc has been found to be a stabile heavy metal and should also be measured quarterly; it tends to appear anywhere from two to ten years after operation of large systems. Sampling for diesel-range and gasoline range organics, BTEX and MTBE, should be performed if draining large impervious areas of urbanized areas.

10. **Deed:** A commitment to regularly maintain privately-owned trenches will have to be legally conditioned in the property deed, development permit, or home-owner association agreement.

6.2 Types of Infiltration BMPs

6.2.1 Dry Well

A dry well is a small, stone-filled pit, or structure surrounded by stone, typically 3 to 12 feet deep, used to temporarily store and infiltrate pre-filtered runoff from a very limited contributing area. Figure 6-1 shows drawings of typical dry wells.

Runoff is stored in the structure and/or void spaces in the stone fill. Runoff enters the dry well by an inflow pipe, inlet grate, or by surface infiltration, and infiltrates through the bottom and sides of the pit. When a dry well is properly sited and designed, most runoff pollutants will become bound to the soil under the well while the water percolates to the groundwater table.

A dry well is best suited for receiving roof runoff via a building's gutter and downspout system. Because of their small size and low cost, dry wells are particularly suited for use within a subdivision of single-family homes. Except for a screen or grate at the head of the downspout, no pretreatment measures precede treatment within a dry well for roof runoff. Dry wells can also be used in combination with catch basins on roadways to promote infiltration of smaller storms, while providing conveyance of larger storms. These can be designed with deep sumps to capture sediments, while still providing for infiltrating through the walls above the sump. Dry wells are a simple and effective technique used to promote LID.

Design and Construction Criteria

In addition to the general design and construction criteria discussed in the beginning of this chapter, the following criteria must also be applied in the design and construction of dry wells.

1. **Setback from Foundations:** Locate dry wells at least 10 feet from the building foundation and at least 100 feet from buildings downslope from the device.

2. **Setback from Natural Resources:** Site the dry well at least 25 feet away from any wetland, stream, river, lake, or coastal estuary.

3. **Overflow Measures:** Design and build the dry well to include measures for controlling overflow. In a roof-drain application, a surcharge pipe can outlet to a splash block or directly onto the lawn. In a leaching catch basin, pipes can be used to connect one structure to another, allowing larger storms to be discharged as they would with standard catch basins. In any case, avoid discharging the well overflow to driveways, streets, or parking lots.

4. **Gutters and downspouts:** Construct the dry well during the installation of the roof gutters and downspouts. A coarse screen or grate should be installed at the inlet of the downspout or along the length of the gutter to prevent leaves and debris from clogging the inlet to the dry well.

5. **Inlet Connection:** The runoff diverted to the dry well should enter through below-ground pipes to avoid intercepting any sediment from surface runoff. Pipes should enter any open structure through a clamped watertight boot or be securely mortared in place where they enter the structure. Pipes should enter as close as practicable to the top of the dry well.

Maintenance

In addition to the general maintenance criteria discussed in the beginning of this chapter, the following criteria must also apply to the maintenance of dry wells. Maintenance of a dry well for roof top runoff requires cleaning the gutters of debris that may clog the downspout. If dry wells are used on single-family homes, this cleaning will usually be left to each homeowner. There is no reliable estimate about the length of time a dry well will function before clogging. It is probable that the longevity of the well is 10 to

15 years, depending on how often the gutters are cleaned, the type of roofing material, and the choice of filter fabric used to line the well.

1. **Gutter Cleaning:** Remove any leaves, seeds, and other debris from the roof's gutters every spring and every fall. A coarse screen or grate should be installed at the head of each downspout leading to the dry well. Replace the screen or grate if it is broken.

2. **Rehabilitation:** Clogging of a dry well is likely to occur at the bottom of the well. Relieve this clogging by excavating away the turf and soil over the well; removing the existing stone and perforated pipe; and rebuilding the dry well. Dig out the soil at the bottom of the dry well and replace it with a six-inch layer of clean sand. The old stone in the dry well can be reused if it is washed prior to reinstalling it in the well. To minimize the eventual cost of rehabilitation, the dry well should be located in a lawn area as close as possible to the ground surface.

6.2.2 Infiltration Trench

An infiltration trench is a stone-filled excavation used to temporarily store runoff so that it can infiltrate into the ground. There are two types of infiltration trenches: surface trenches and underground trenches. A surface trench is open at the ground surface, exposing the trench's top layer of stone. An example of a surface trench is shown in Figure 6-2. Runoff enters this trench as overland flow after pretreatment through a filter strip or vegetated buffer. Turf or pavement covers an underground trench. An example of an underground trench is shown in Figure 6-3. Runoff enters the trench in a solid pipe; it is distributed within the trench by perforated pipe. Pipes or manhole structures may be incorporated into infiltration trenches to increase the storage capacity while minimizing the footprint of the infiltration system. When a trench is properly sited and designed, most runoff pollutants will become bound to the soil under the trench while the runoff water percolates to the groundwater table.

An infiltration trench is suitable for treating runoff from small drainage areas (less than 10 acres). Installations around the perimeter of parking lots, between residential lots, and along roads are most common. Infiltration trenches can also be incorporated beneath a vegetated swale to increase its infiltration ability.

Design and Construction Criteria

In addition to the general design and construction criteria discussed in the beginning of this chapter, the following criteria must also be applied in the design and construction of Infiltration Trenches.

1. **Site Slopes:** The surface grade at the trench site should be 20% or less for an underground trench and 5% or less for a surface trench.

2. **Setback from Foundations:** Locate the trench at least 20 feet from any foundation located upslope from the trench and at least 100 feet from any foundation located downslope from the trench. Designers should always evaluate the possible effects of mounding to determine if greater setbacks are required.

3. **Setback from Natural Water Bodies:** Site the trench at least 75 feet away from any wetland, stream, river, lake, or coastal estuary.

4. **Erosion Control:** Construct the infiltration trench after the trench's drainage area is stabilized with vegetation and erosion controls are installed to prevent sediment from reaching the trench. An infiltration trench receiving flow from an unstabilized site will have its working life greatly reduced and may even clog prior to the completion of the development. The contractor should use sod to vegetate the filter strip surrounding a surface trench. If hydroseeding or hand broadcasting must be used, then the contractor should install a sediment barrier between the filter strip and trench until the filter strip is fully vegetated. The contractor should install a pretreatment drop-inlet sediment filter around the pretreatment inlet to an underground trench. Keep the inlet filter in place until the trench's drainage area is fully stabilized with pavement and vegetation.

5. **Trench Grade:** The grade of the trench bottom and trench base should be as close to 0% as possible. Always install the trench parallel to elevation contours.

6. **Filter Fabric Installation:** Line the trench with geotextile fabric so that the cloth will completely surround the stone-filled reservoir; it should extend from the bottom of the trench to within six to twelve inches of the surface. The cut width of the fabric should include sufficient material to have a twelve inch overlap at the top of the enclosed stone. If overlaps are required between rolls of fabric, then the upstream roll should lap a minimum of two feet over the downstream roll to provide a shingled effect.

Maintenance

In addition to the general maintenance criteria discussed in the beginning of this chapter, the following criteria must also be applied to maintain infiltration trenches. There is no reliable estimate about the length of time an infiltration trench will function before clogging. It is probable that the effective lifetime of a trench is 10 to 15 years, depending on the maintenance of the pretreatment BMPs, the choice of filter fabric to line the trench, and the amount of fines in the sediment load to the trench. One study (Galli, 1993) found that slightly over half were not functioning as designed within 5 years. Proper design and long term maintenance is crucial to extend the life of an infiltration trench.

1. Maintaining a Surface Trench

a. *Inlet Maintenance:* Remove any fallen leaves and other debris from the trench's surface inlet at least every fall after leaf drop and every spring after snow melt. If left in place, the trash and leaves will clog the trench inlet.

b. *Rehabilitation:* Clogging in a surface trench is most likely to occur near the top of the trench between the top layer of stone and the protective layer of filter fabric. Relieve this surface clogging by carefully removing the top layer of stone, removing the clogged filter fabric, installing new fabric, and replacing the top layer of stone. If the old stone is reused, it should be washed to remove any fine sediment prior to being placed back in the trench.

2. Maintaining a Subsurface Trench

a. *Inlet Maintenance:* Check the pretreatment inlets to an underground trench at least annually and clean-out any sediment, trash, oil, and grease when these materials deplete more than 10% of the inlet structure's capacity.

b. *Rehabilitation:* Clogging of an underground infiltration trench is likely to occur at the bottom of the trench. Relieve this clogging by excavating away any pavement, turf, and soil over the trench; removing the existing stone and perforated pipe,; and rebuilding the trench. Scarify the soil at the bottom of the trench with a tiller or dig-out this soil and replace it with a six-inch layer of sand. The old stone in the trench can be reused if it is washed prior to reinstalling it in the trench.

6.2.3 Infiltration Basin

An infiltration basin is a water impoundment, typically 3 to 12 feet deep, constructed over permeable soil to infiltrate runoff into the ground. The basin drains dry between storm events and, unlike a detention basin, is not specifically designed to release any stormwater as surface flow except for flows from larger storms. As a structural safety measure, however, the basin will usually have an emergency spillway to pass peak flows during extreme storm events. When a basin is properly sited and designed, most runoff pollutants will become bound to the soil under the basin before the runoff water percolates to the groundwater table.

When the subsoils are appropriate, an infiltration basin can be suitable for treating and controlling runoff from drainage areas of 5 to 50 acres in size. Installations serving a large commercial development, a residential subdivision, an industrial subdivision, or a gravel mining site are most common. However, some commercial and industrial sites may have contaminants that may not be treatable by soil filtration. In these cases, infiltration should be avoided in favor of other BMPs.

Figure 6-4 shows a typical infiltration basin.

Design and Construction Criteria

In addition to the general design and construction criteria discussed in the beginning of this chapter, the following criteria must also be applied in the design and construction of infiltration basins.

1. **Site Slopes:** The surface grade at the basin site should be 5% or less.

2. **Setback from Foundations:** Locate the basin at least 20 feet from any foundation located upslope from the basin and at least 100 feet from any foundation located downslope from the basin.

3. **Setback from Natural Water Bodies:** Site the trench at least 75 feet away from any wetland, stream, river, lake, or coastal estuary.

4. **Siting on Heavily Used Areas:** Sites that will receive heavy use (such as playing fields) should not be considered for infiltration basins due to the limited infiltration capacity of compacted surface soils.

5. **Off-line Siting:** A basin designed for water quality treatment is usually located off-line from the stormwater system using a flow splitter. This helps prevent the "first flush" runoff flowing into the basin from being diluted and pushed out the emergency spillway by the remaining runoff. Refer to Chapter 8, Section 8.2 for a typical flow-splitter design.

6. **Storage Volume:** The required volume of runoff to be stored in an infiltration basin consists of the volume to be treated by infiltration as outlined in the General Design Criteria applicable to all infiltration systems, plus additional capacity if it is to be used to control peak discharges from storms exceeding the magnitude of the infiltration design storm. The basin storage volume should be intentionally oversized to account for the eventual total loss of infiltration capability (Galli, 1993). To control peak rates of storm flows, only the volume in a pond above an outlet structure can be utilized on a long-term basis.

7. **Storage Depths:** Maryland (1984) indicates the maximum depth for a required recovery time can be found using the following equation:

   $d_{max} = f\ T_p$

   where d_{max}=maximum storage depth (inches)

   f=final permeability rate of the basin area (inches per hour)

   T_p=maximum allowable ponding time (hours).

The final permeability rate is determined from field percolation tests.

8. **Emergency Spillway:** The infiltration basin should have an emergency spillway to convey overflow during extreme storm events. The spillway may be either a stone-lined or vegetated channel or a riser outlet. As a minimum, the spillway should be able to convey a flow equal to the 25-year, 24-hour peak inflow out of the basin and into a drainage way which will remain stable under these conditions while maintaining one foot of embankment freeboard above the water elevation in the basin. Spillways should be constructed on original ground (not embankment fill).

9. **Side Slopes:** Design the basin's side slopes to be no steeper than 3H:1V. The side slopes should be well-vegetated with species that can tolerate inundation and flooding for up to one week.

10. **Basin Floor:** Design the basin floor to be flat (0% slope) to develop a uniform ponding depth. This will ensure that the full infiltrative area of the basin will be used for each storm. There is some evidence that maintaining microtopography (small mounds and depressions) on the basin's floor will help delay clogging by concentrating sedimentation in the depressions. The floor should be prepared with one of the following linings.

    a. *Coarse Sand or Pea Gravel:* The filter layer can be replaced or cleaned when it becomes clogged. The minimum depth to bedrock or high groundwater table must be measured from the bottom of this sand or gravel layer. The sand or gravel should be at least 6 inches thick.

    b. *Grass Turf:* If grass is used to vegetate the basin floor, it should consist of species that can survive inundation for up to one week and still provide a dense, vigorous turf layer. Root growth by grass continually opens up new drainage paths within the soil and, so, helps delay clogging of the basin floor.

    c. *A Layer of Coarse Organic Material (erosion control mix or composted mulch):* These materials should be tilled into the soil. The basin floor should then be soaked or inundated for a brief period and allowed to dry. This induces the rapid decay of organic material, increasing the soil's permeability and its ability to remove soluble pollutants from the runoff.

11. **Embankment Design:** Most infiltration basins need an embankment to have sufficient storage capacity and still maintain a three-foot separation between the basin floor and the seasonal high groundwater table. The embankment must be designed to meet engineering standards for foundation preparation, fill compaction, seepage control, and embankment stability. Standards for small embankment ponds and basins can be found in Section G-2 of the Maine Erosion and Sediment Control BMPs Handbook (March 2003).

12. **Inlet Protection:** Prevention of scour at the inlet is necessary to reduce maintenance problems and prevent damage to basin floor vegetation. Provide energy dissipation at the inlet in accordance with practices outlined in the Maine Erosion and Sediment Control BMPs Handbook (March 2003).

13. **Erosion Control:** Construct the infiltration basin after its drainage area is stabilized with vegetation and erosion controls that will prevent sediment from reaching the basin. An infiltration basin receiving flow from an unstabilized site will have its working life greatly reduced and may even clog prior to the completion of the development. Thus, using an infiltration basin as a temporary sediment basin during construction is not recommended.

Maintenance

In addition to the general maintenance criteria discussed in the beginning of this chapter, the following criteria must also be applied in the maintenance of infiltration basins. Infiltration basins do not have long life spans. Sixty to one hundred percent of basins studied could no longer infiltrate runoff after five years (Schueler, 1992b). Because of the fragile nature and extremely high failure rate of infiltration basins, water quality can generally be controlled more reliably with other BMPs (Galli, 1993).

1. **Basin Inspections:** Inspections of infiltration basins should be conducted on a semi-annual basis. In addition, brief inspections should always be conducted following major storms. Timely maintenance of infiltration basins is critical, as poor maintenance practices can result in loss of infiltration capacity. Records should be kept of all maintenance operations to help plan future work and identify problem areas.

2. **Drainage Area Inspections:** Inspect the basin's drainage area semi-annually for eroding soil and other sediment sources. Repair eroding areas using appropriate erosion control BMPs immediately. Control sediment sources, such as stockpiles of winter sand, by removing them from the basin's drainage area or surrounding them with sediment control BMPs.

3. **Mowing:** A basin with a turf lining should have its side-slopes and floor mowed at least twice a year to prevent woody growth. Mowing operations may be difficult since the basin floor may remain wet for extended periods. If a low maintenance vegetation is used, basin mowing can be performed in the normally dry months. Clippings should be removed to minimize the amount of organic material accumulating in the basin.

4. **Pedestrian Access:** Limit access to turf lined basins to passive recreational activities (such as an employee lunch area). Do not use the basin for a playing field, as heavy foot traffic can compact the soil surface.

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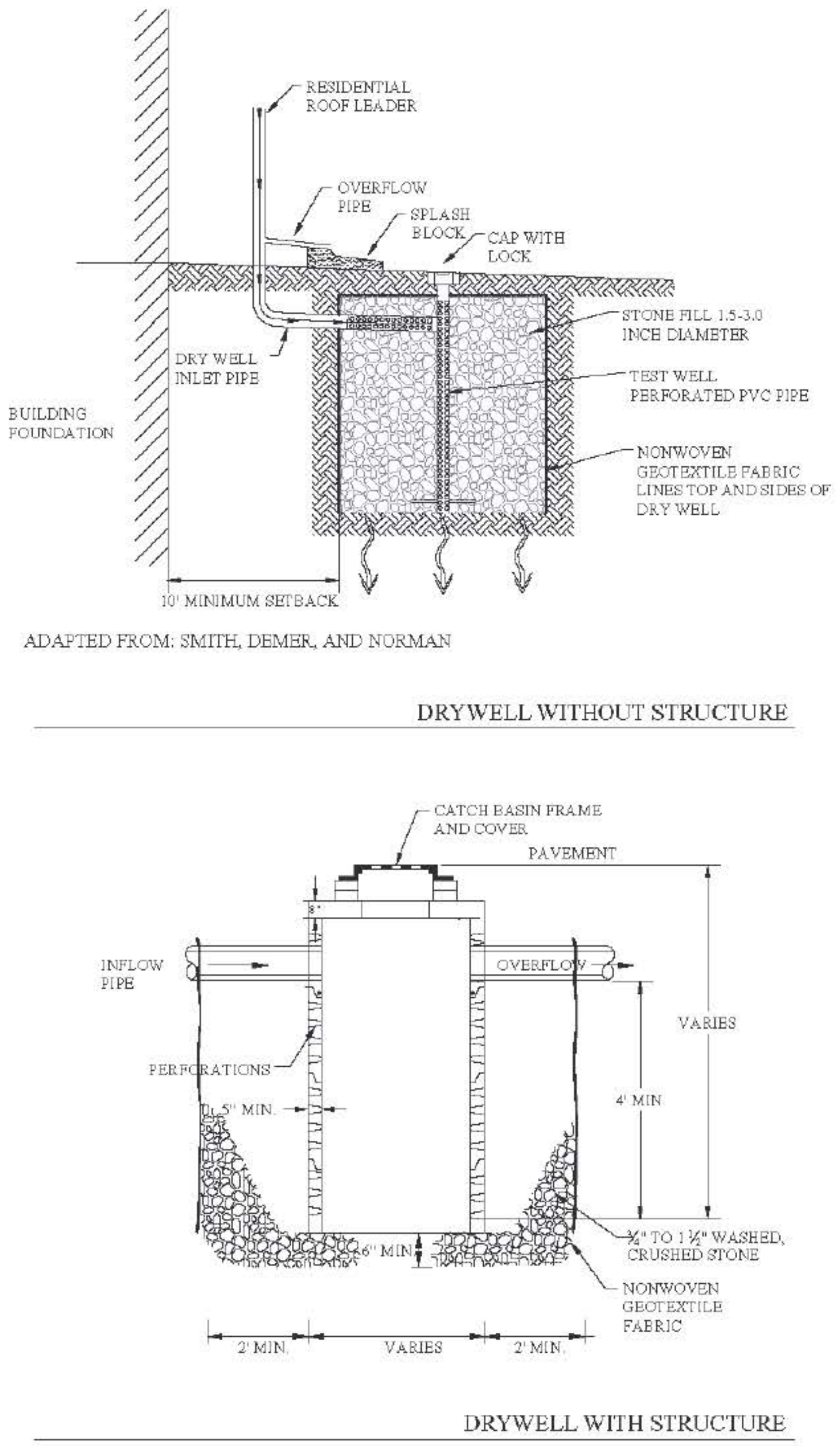


FIGURE 6-1. TYPICAL DRYWELL

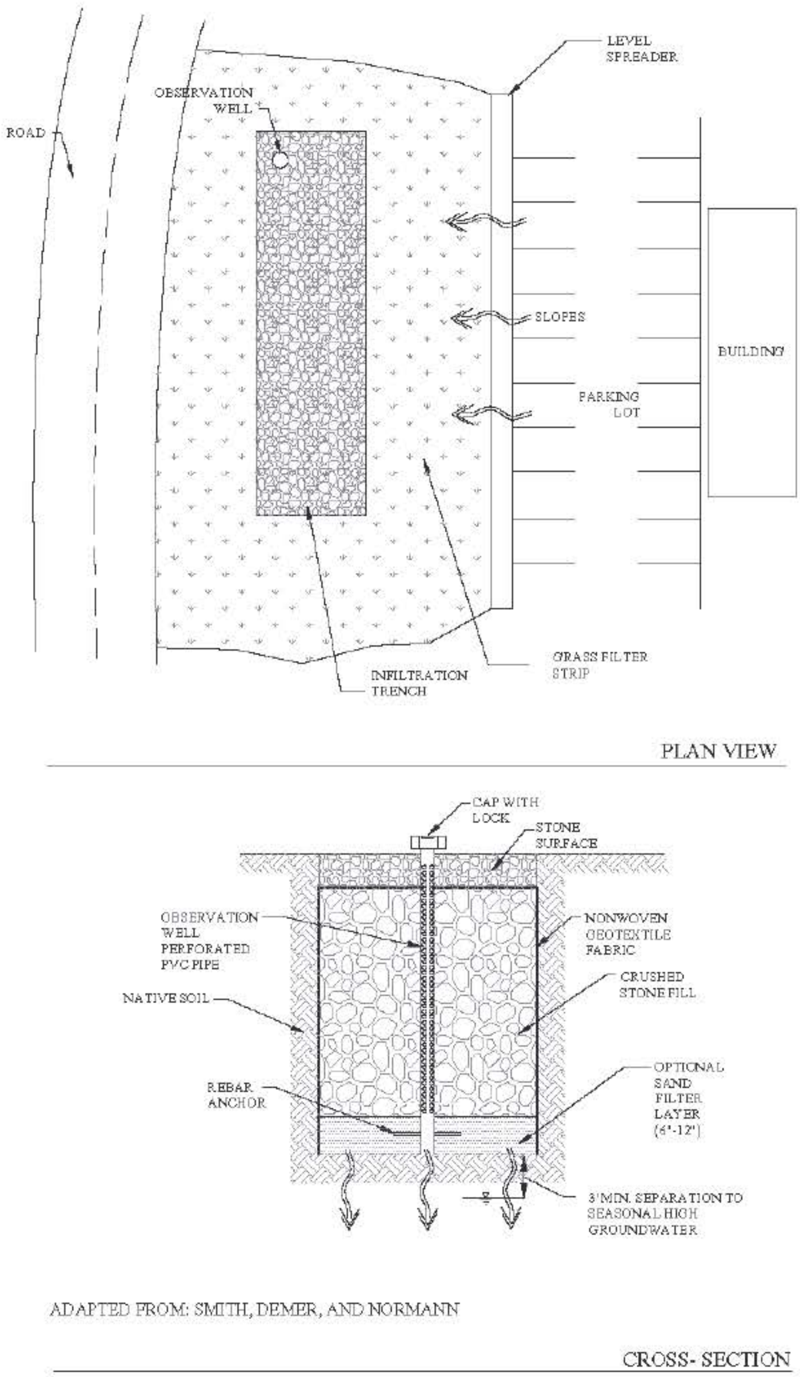


FIGURE 6-2. TYPICAL SURFACE INFILTRATION TRENCH

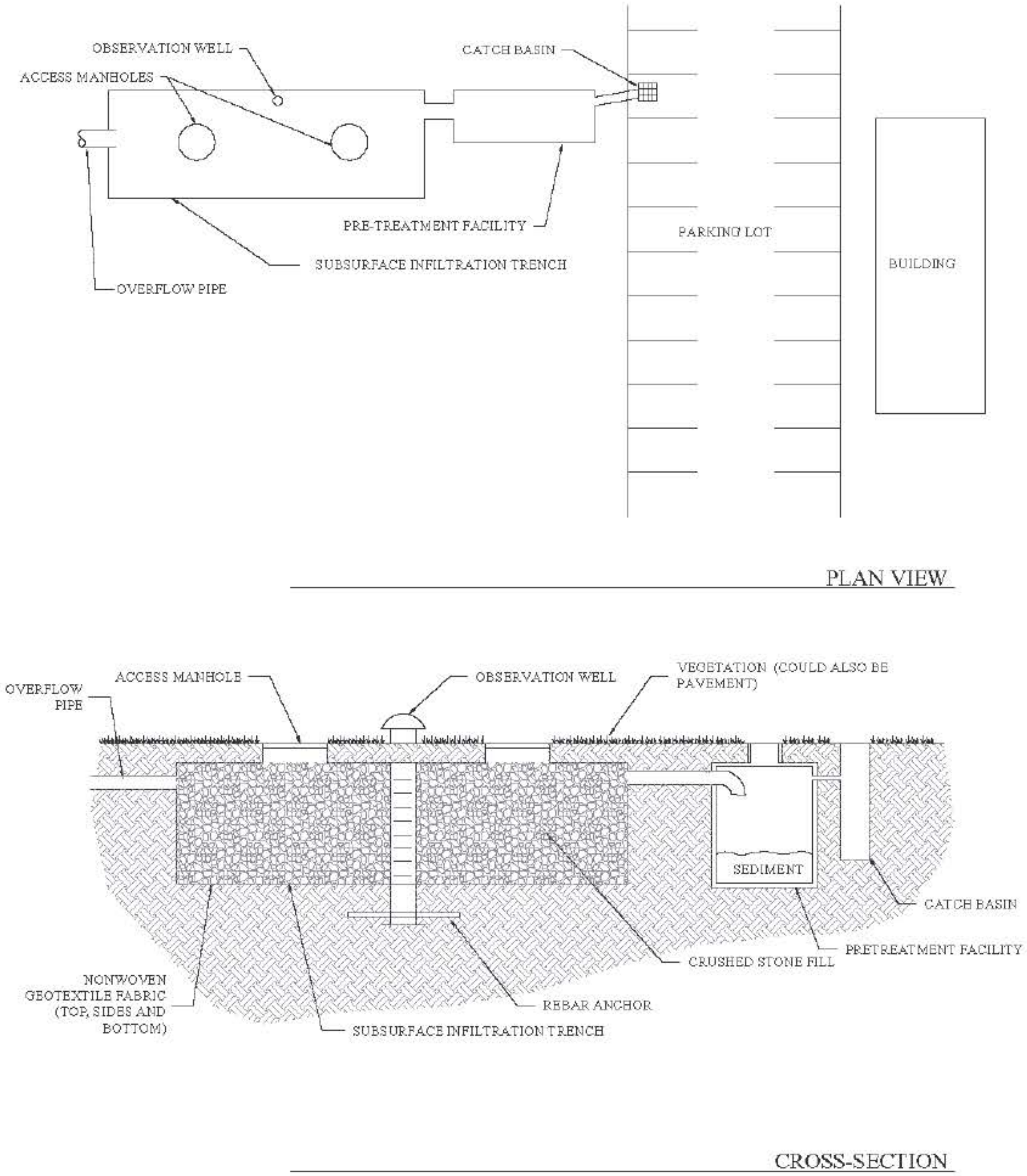


FIGURE 6-3. TYPICAL SUBSURFACE INFILTRATION TRENCH

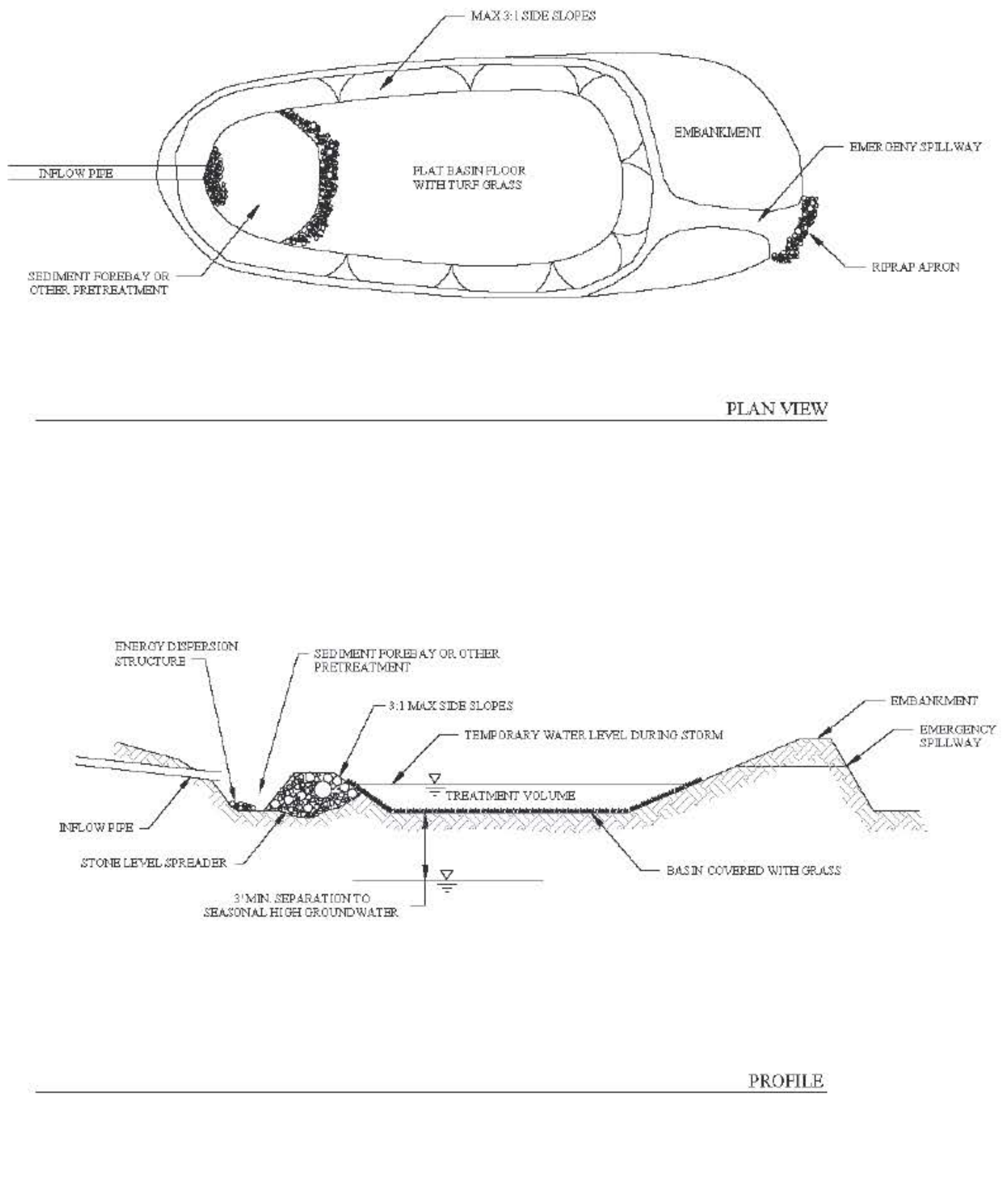


FIGURE 6-4. TYPICAL INFILTRATION BASIN

Chapter 7.0
Filtration BMPS

June 2009

Filtration BMPs, particularly vegetated organic soil filter media BMPs, have been shown to be very effective at removing a wide range of pollutants from stormwater runoff. Soil filters can be designed and constructed using common materials; however, some manufacturers have developed proprietary filter media and structures that may also be used with DEP approval. This chapter discusses the design and construction of underdrained soil filters.

Underdrained soil filters provide quality treatment and channel protection as the underdrain piping system slowly releases the discharge of runoff. This prevents downgradient channel erosion associated with more frequent increased flow volumes. It also cools the runoff, reducing thermal impacts to receiving streams.

Underdrained soil filter structures must detain a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area. Upgradient areas should be directed away from the filter basin. This surface area of a grass filter bed should represent no less than the sum of 5% of the impervious area and 2% of the landscaped area draining into it. For a bioretention cell, the surface area needs to be at least 8% of the impervious area and 3% of the landscaped area. When used to meet phosphorus allocation in lake watersheds, the sizing of the underdrain filter structures need to be adjusted in accordance with Volume II of this BMP manual.

DEP strongly encourages the use of Low Impact Development (LID) techniques and recommends the use of small underdrained soil filter basins dispersed throughout a site with a maximum drainage area of 0.75 to 1.0 acre for each individual filter.

The soil filter should be designed to drain the channel protection or water quality volume within 24 to 48 hours. If flood control is also required, detention within the structure or in parallel must be provided.

The peak storage depth within the filter structure may not exceed 18 inches if grassed and 6 inches if planted with landscaping plants. Storage and detention for flooding conditions and to meet the 2, 10 and 25-year peak control is allowed within the structure and over the channel protection volume provided that it will drain within 12 hours.

Chapter Content:

Filter basins may be constructed as infiltration or underdrained soil filters depending on site soils; however, the design standards and requirements for infiltration provided in Chapter 6 of Volume III of the Maine BMP Manual must be followed. Soils must be able to infiltrate the pooled water within 12 hours, requiring an infiltration rate of greater than 0.5 to 1.5 inch per hour depending on the depth of water. In very permeable soils that have a permeability rate of 2.41 inch per hour or greater and where the groundwater table is deeper than the bottom of the basin, an impermeable liner will be required to protect the groundwater from contamination.

Underdrained soil filter basins must be planted with plant species that are tolerant of draught conditions with frequent inundation. Mulching is required. See Appendix B of Volume I for appropriate plant species for Maine. A landscape designer or architect should be involved to select the appropriate plants for conditions at the site.

7.0.1 Description of an Underdrain Soil Filter BMP

Vegetated underdrained soil filters control stormwater quality by capturing and retaining runoff and passing it through a filter bed comprised of a specific soil media. Soil filters having a mixture of silty sand and organic matter achieve the highest removal rates and therefore are the focus of this Chapter. These filters can remove a wide range of pollutants from stormwater, including suspended sediment, phosphorus, nitrogen, metals, hydrocarbons and some dissolved pollutants.

Once through the soil media, the runoff is collected in a perforated underdrain pipe and discharged to the receiving water. The filter and underdrain provides for slow release of smaller storm events, minimizing stream channel erosion and cooling of the discharge. There are several types of filters and these will be discussed individually and in more details in the following sections.

Vegetated soil filters are usually located in close proximity to the origin of the stormwater runoff and it is anticipated that these facilities would most often be scattered throughout a residential area or along the downhill edge of smaller parking areas.

7.0.2 Site Suitability Criteria

Drainage Area: The size of the underdrained soil filter and storage capacity over the filter is based on the size and land use within the area draining to the structure.
Depth to Groundwater: In most instances, the bottom of the underdrained soil filter should be above the seasonal high groundwater table and should always be below the invert of the underdrain pipe.
Bedrock: Bedrock close to the surface may require blasting or an impermeable liner to prevent fast infiltration and the potential of contaminating the deep groundwater table.
Test Pits: One test pit shall be excavated for filter bed area to identify the depth to groundwater and bedrock
Infiltration: Vegetated soil filters can be designed to infiltrate water into the groundwater below or to filter the water through the bioretention soil media and collect it in an underdrain located beneath the soil media. In Maine, the most typical use of vegetated soil filters will be with an underdrained soil filter structure because natural soils are rarely suitable for infiltration

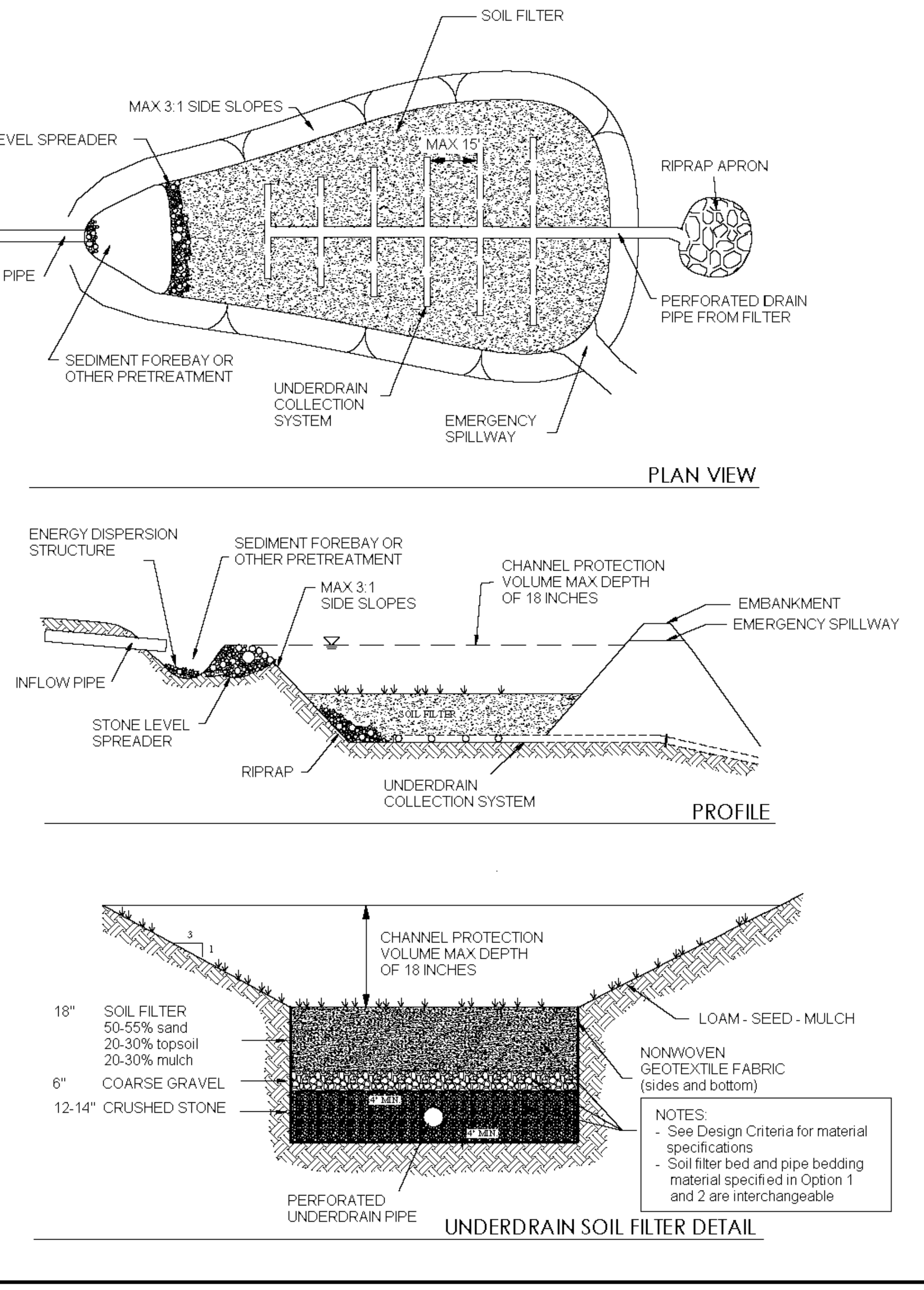


FIGURE 7-1. VEGETATED UNDERDRAIN SOIL FILTER FIELD (OPTION 1)

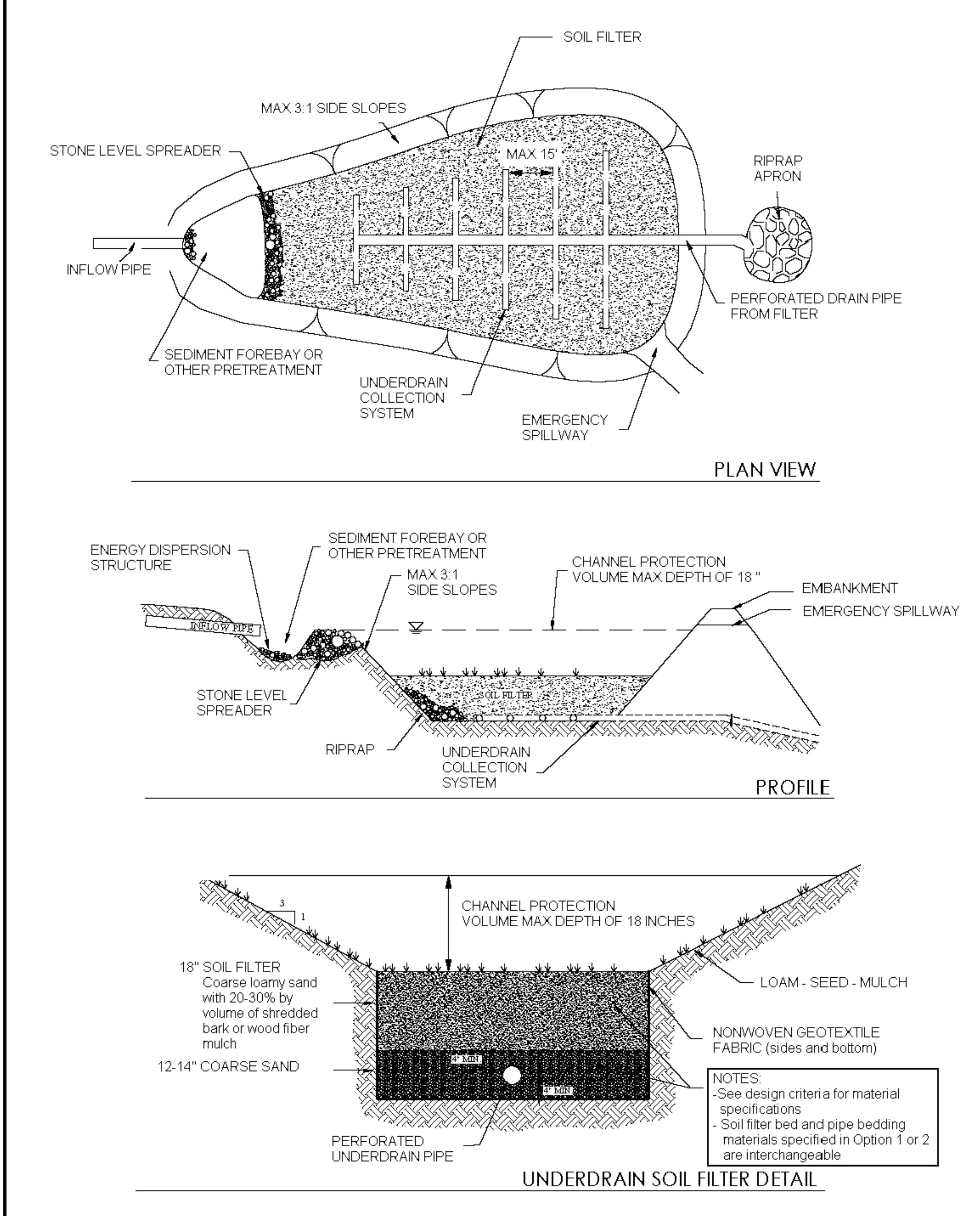


FIGURE 7-2. VEGETATED UNDERDRAIN SOIL FILTER FIELD (OPTION 2)

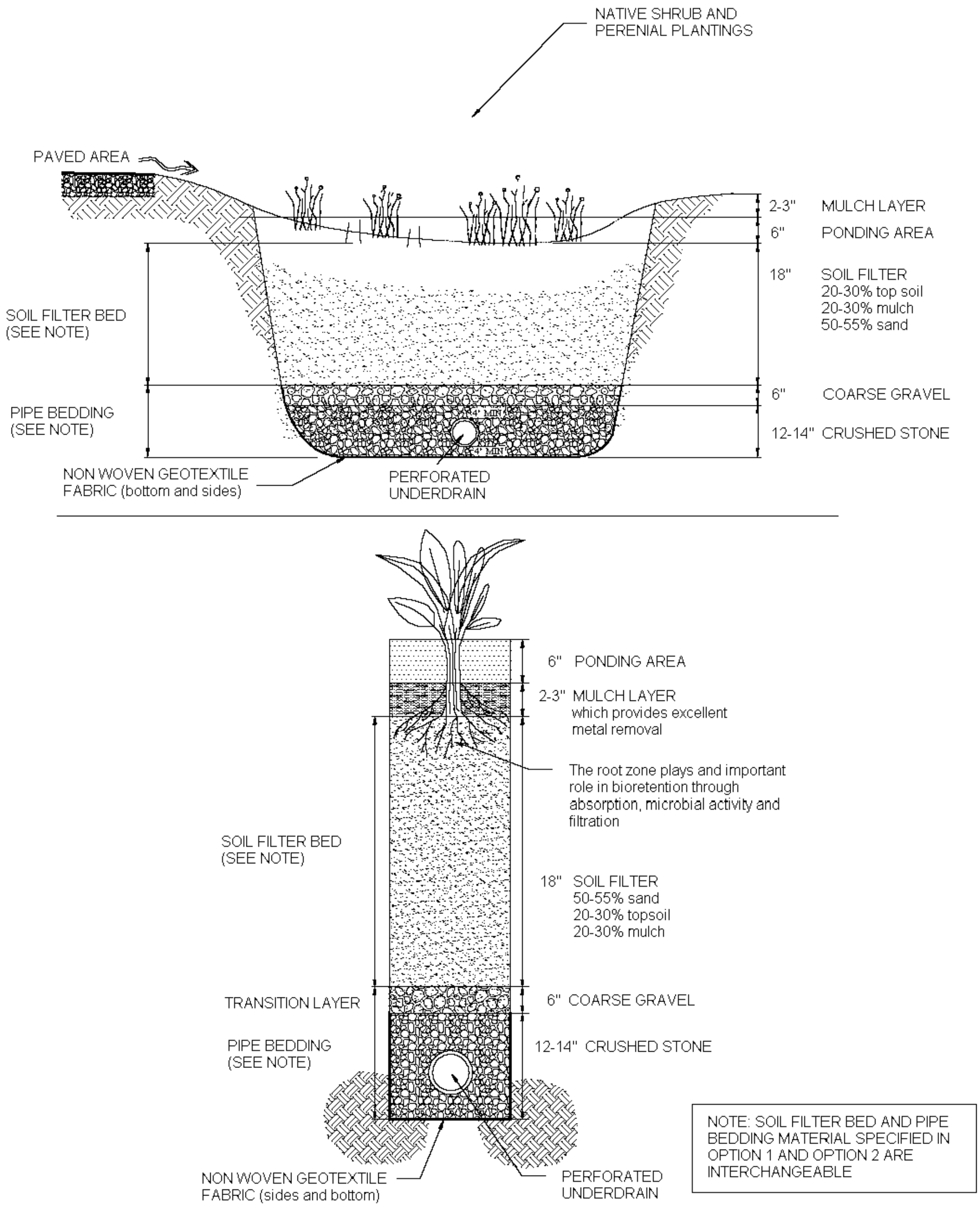


FIGURE 7-3. TYPICAL BIORETENTION CELL (OPTION 1)

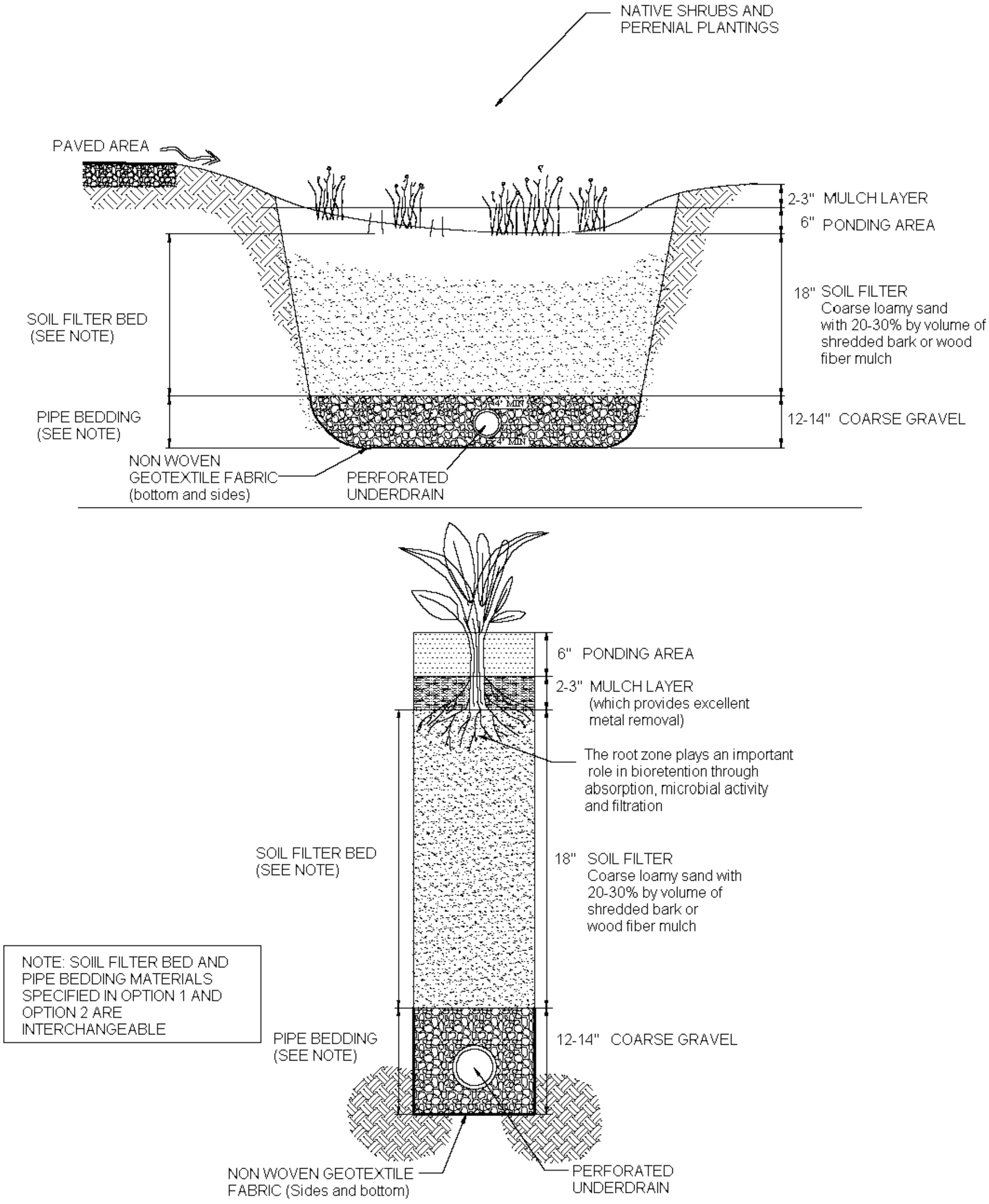


FIGURE 7-4. TYPICAL BIORETENTION CELL (OPTION 2)

7.1.1 Description

Vegetated underdrained soil filters control stormwater quality by capturing and retaining runoff and passing it through a filter bed comprised of a specific soil media. Soil filters having a mixture of silty sand and organic matter achieve the highest removal rates as they can remove a wide range of pollutants from stormwater, including suspended sediment, phosphorus, nitrogen, metals, hydrocarbons and some dissolved pollutants. Once through the soil media, the runoff is collected in a perforated underdrain pipe and discharged downstream. The filter structure provides for the slow release of smaller storm events, minimizing stream channel erosion, and cooling the discharge. Vegetated soil filters are usually located in close proximity to the origin of the stormwater runoff and should be scattered throughout a residential area or along the downhill edge of smaller parking areas.

Underdrained soil filters provide quantity control and channel protection as the underdrain releases the discharge of runoff, which protects streams from channel erosion associated with more frequent increased flow volumes. The slow discharge also cools the runoff, reducing thermal impacts to receiving streams. If flood control is required, detention within the structure or in parallel to must be provided.

Underdrained soil filter structures must detain a runoff volume equal to the sum of 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area. This surface area of a grass filter bed should represent no less than the sum of 5% of the impervious area and 2% of the landscaped area draining into it, with other upgradient areas directed away from the basin.

When used to meet the phosphorus allocation in lake watersheds, the sizing of the underdrain filter structures needs to be adjusted in accordance with Volume II of this BMP manual.

The peak storage depth of the channel protection volume within a grassed filter structure may not exceed 18 inches and should be designed to drain dry within 24 to 48 hours.

Storage and detention for flooding conditions and to meet the 2, 10 and 25-year peak flow control is allowed within the structure and over the channel protection volume provided that it will drain within 12 hours.

The underdrained soil filters must be planted with plant species that are tolerant of draught conditions with frequent inundation. Full vegetation must be achieved within the first year following construction.

7.1.2 Site Suitability Criteria

Drainage Area: The size of the underdrained soil filter and storage capacity over the filter is based on the size and land use within the area draining to the structure.

Depth to Groundwater: In most instances, the bottom of the underdrained soil filter should be above the seasonal high ground-water table.

Test Pits: One test pit shall be excavated in the area of the filter bed to identify the depth to groundwater and bedrock.

Bedrock: If bedrock is close to the surface an impermeable liner may be required to prevent rapid injection and contamination of the groundwater within fractures in the bedrock. If the basin does not have one foot of soil overburden between bedrock and the bottom of the underdrain layer, the basin must be lined with an impermeable geomembrane (not with clay).

Permeable Soils: In soil group A and, in some cases, soil group B, an underdrained filter basin should be designed as an infiltration basin provided that the design and siting criteria from Appendix D of Chapter 500 (Stormwater Management Rules) can be met. Otherwise, a low permeability liner (not clay) must be used.

7.1.3 General Design Criteria

The following design criteria apply to all underdrained soil filters.

Treatment Volume: An underdrained soil filter must detain and filter a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area. Other upgradient areas should be directed away from the filter basin.

Filter Area: The area of the filter (surface area of the filter) must be no less than the sum of 5% of the impervious area and 2% of the landscaped area draining to the filter.

Basin Size: The size of a filter bed should not exceed 3000 sq. ft in basin bottom area or have more than 2.5 acres of subwatershed draining to the structure. Larger sizes are difficult to construct and maintain.

Construction Components: Underdrained filters are constructed in excavated holes that are at least three feet deep and consist of, from bottom up:

- A geotextile fabric between natural soils and constructed media. An impermeable membrane may be required if groundwater contamination is a concern.
- A 12 to 14 inch base of coarse clean stone or coarse gravel in which a 4 to 6 inch perforated underdrain pipe system is bedded.
- A gravel transition layer, if necessary.
- 18-inch layers of uncompacted soil filter media.
- A surface cover of grass and mulch.
- Depression for surface stormwater storage

Impoundment Depth: The peak water quality storage depth may not exceed 18 inches over a grass filter that must drain dry in no less than 24 and no more than 48 hours. Storage over the treatment volume may be provided to control peak flows from the 2, 10 and 25 year storms and meet the flooding standards but must drain within 12 hours.

Outlet: The channel protection volume must be discharged solely through an underdrained vegetated soil filter bed with a network of underdrain pipe having a single outlet with a diameter no greater than eight inches. A manually adjustable valve may be installed to control the outflow rate from the underdrain pipe to obtain the required 24 to 48 hour release time.

Underdrain Outlet: Each underdrain system must discharge to an area capable of withstanding concentrated flows and saturated conditions without eroding.

Sediment Pretreatment: Pretreatment devices such as grassed swales, grass or meadow filter strips and sediment traps shall be provided to minimize the discharge of sediment to the underdrained soil filter. Pretreatment structures shall be sized to hold an annual sediment loading calculated using a sand application rate of 50 cubic feet per acre per year for sanding of roadways, parking areas and access drives within the subcatchment area.

Access: Where needed, a maintenance access shall be planned for and maintained that is at least 10 feet wide with a maximum slope of 15% and a maximum cross slope of 3%. This access should never cross the emergency spillway, unless the spillway has been designed for that purpose. An easement for long-term access may be needed.

7.1.3 Specific Design Criteria

Underdrain Pipe: Proper layout of the pipe underdrain system is necessary to effectively drain the entire filter area. There must be at least one line of underdrain pipe for every eight feet of filter area's width. The slope of the installed underdrain pipe must be positive. The underdrain piping should be 4" to 6" slotted, rigid schedule 40 PVC or SDR35. Structure joints shall be sealed so that they are watertight. Underdrain pipes must be placed no further than 15 feet apart.

Pipe Bedding and Transition Zone: The 4 to 6 inch diameter perforated underdrain pipe(s) must be bedded in 12 to 14 inches of underdrain material with at least 4 inches of material beneath the pipe and 4 inches above. Two options for pipe bedding are provided below; however Option 1 is preferred:

OPTION 1 - Drainage Layer: The underdrain material consists of well graded, clean, coarse gravel meeting the MEDOT specification 703.22 Underdrain Type B for Underdrain Backfill (see Table 7.1). The material must contain less than 5% fines passing the #200 sieve. No transition zone is necessary since the drainage pipe is bedded in less pervious gravel and this design is acceptable for areas where the head or depth to seasonal high groundwater is close to the bottom of the drainage layer.

OPTION 2 – Drainage Layer with Transition None: The underdrain bedding material must consist of 12 inches of crushed stone meeting the MEDOT specification 703.22 Underdrain Type C for Underdrain Backfill Material (see Table 7.1). As a transition zone, a 6 inch layer of well graded, clean, coarse gravel meeting the MEDOT specification 703.22 Underdrain Type B for Underdrain Backfill Material (see Table 7.1) is needed above the crushed stone bedding. The amount of fines passing the #200 sieve in the gravel should be preferably less than 5%.

Soil Filter Bed: The soil filter must be at least 18 inches deep on top of the gravel underdrain pipe bedding and must extend across the bottom of the entire filter area. This soil mixture shall be a uniform mix, free of stones, stumps, roots, or other similar objects larger than two inches. No other materials or substances that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations can be mixed within the filter.

Filter Bed: Two options are provided for the treatment portion of the basin.

OPTION 1- Soil Filter Media: Soil media must consist of a silty sand soil or soil mixture combined with 20% to 25% by volume (no less than 10% by dry weight) of a moderately fine shredded bark or wood fiber mulch.

TABLE 7.1 Maine DOT Specifications for Underdrains (MEDOT #703.22)

Sieve Size	% by Weight
UNDERDRAIN - TYPE B	
1”	90-100
½”	75-100
#4	50-100
#20	15-80
#50	0-15
#200	0-5
UNDERDRAIN - TYPE C	
1”	100
¾”	90-100
3/8”	0-75
#4	0-25
#10	0-5

Other organic sources must be approved by the department; however an agricultural source is not acceptable for the organic component of the media.

The resulting mixture must have no less than 8% passing the 200 sieve and shall have a clay content of less than 2%. The system must be designed to drain the surface storage volume in no less than 24 hours and no more than 48 hours.

TABLE 7.2 Maine DOT Specifications for Aggregate (MEDOT #703.01)	
Sieve Size	**% by Weight**
3/8”	100
#4	95-100
#8	80-100
#16	50-85
#30	25-60
#60	10-30
#100	2-10
#200	0-5

As an example, the mixture may contain by volume the following:

- *50% of sand (MEDOT #703.01 contains insufficient fine for the media)*
- *20% of loamy topsoil*
- *30 % of composted woody fibers and fine shredded bark, superhumus or equivalent(adjusted for mineral soil content)*

OPTION 2 – Layered System with Topsoil
Because of its coarseness, a filter media mixed from different sources may lack nutrients, may be unable to retain moisture, and maybe be devoid of micro-organisms (such as fungus, bacteria and nematodes) which are found in a natural soil and which benefit the germination and establishment of vegetation. Natural soils will contain these important organisms and provide superior filtration. Option 2 provides for a layered system that takes advantage of the characteristics of natural soils. The different layers from the bottom up are:
Optional hay layer**:** A layer of hay can be placed to separate the drainage layer from the treatment layer above to prevent subsidence or plugging of the sand/gravel/stone layer and/or pipe.
Filter Layer: A 12 inches layer of loamy coarse sand which is loosely installed should meet the grain size specifications of Table 7.3.
Topsoil: The surface of the basin should be covered with 6 inches of non-clayey, loamy topsoil such as USDA loamy sand topsoil with 5-8% humified organic matter and meeting the specifications provided in Table 7.4. Topsoil from the development may be appropriate but should be tested for organic content and clay content (hydrometer test). The soil must be screened, loose, friable, and shall be free from admixtures of subsoil, refuse, stones (greater than 2 inches in diameter), clogs, root and other undesirable foreign matter. The topsoil should be gently mixed within the filter layer to provide continuity for deep root penetration. The teeth of a backhoe, a hand rake, a shovel or rototilling 2-3 inches may be used as a way to create a loosened transition.

TABLE 7.3 Specifications for Loamy Coarse Sand	
Sieve #	**% Passing by Weight**
10	85-100
20	70-100
60	15-40
200	8-15
200 clay size	<2.0

TABLE 7.4 Specifications for Sandy Loam to Fine Sandy Loam	
Sieve #	**% Passing by Weight**
4	75-95
10	60-90
40	35-85
200	20-70
200 clay size	< 2.0

Clay Content: Use of soils with more than 2 % clay content could cause failure of the system and care should be taken, especially in areas where the predominant soil contains marine clay, that the sand and topsoil used in the mixture have very little or no clay content.

Filter Permeability: The filter must be permeable enough to insure drainage within 48 hours maximum, yet have sufficient fines to insure filtration of fine particles and removal of dissolved pollutants. The design may either rely on the soil permeability, if known, to provide the slow release of the water treatment volume over a minimum of 24 hours, or may insure this rate by installing a constrictive orifice or valve on the underdrain outlet. In determining the permeability of the media, the percent fines of the mixture and the level of

compaction should be considered. Generally, the soil media should be only lightly compacted between 80 and 82% standard proctor (ASTM D698) and shall have a permeability of 2.4 in/hr to 4 in/hr.
Gradation testing: Gradation tests, including hydrometer testing for clay content, and permeability testing of the soil filter material, shall be performed by a qualified soil testing laboratory and submitted to the project engineer for review before placement and compaction.

Geotextile Fabric: A geotextile fabric with suitable characteristics may be placed between the sides of the filter layer and adjacent soil. The fabric will prevent the surrounding soil from migrating into and clogging the filter and clogging the outlet. Overlap seams must be a minimum of 12 inches. Do not wrap fabric over the top of the pipe bedding as it will cause clogging and will prevent flows out of the filter. The geotextile fabric shall be Mirafi 170n or equivalent.

Rock Forebay: A rock forebay is recommended to reduce flow velocity into the basin. It shall remain clear of sediment until the upgradient tributary area is fully vegetated

Vegetation: The soil filter surface must be planted with a grass species that is tolerant of frequent inundation and well drained soils. Upon seeding, the soil filter shall be mulched with hay or an erosion control blanket but must not be fertilized. An appropriate seed mixture should contain the following or be an approved equivalent conservation type mixture:

Creeping red fescue	20 lbs/acre
Tall fescue	20 lbs/acre
Birdsfoot trefoil	8 lbs/acre
Total	48 lbs/acre

7.1.4 Construction Criteria

Basin excavation: The area of the basin may be excavated in preparation of the installation of the underdrain and can be used for a sediment trap from the site during construction. After excavation of the basin, the outlet structure and piping system must be installed at the appropriate elevation and protected with a sediment barrier. If the basin is to be used as a sediment trap, the sides of the embankments must be mulched and maintained to prevent erosion.

Compaction of soil filter: Filter soil media and underdrain bedding material must be compacted to between 90 and 92% standard proctor. The bed should be installed in at least 2 lifts of 9 inches to prevent pockets of loose media.

Outlet Discharge Outflow of the filter basin underdrain can be controlled by a constrictive orifice or a valve (2” plastic ball valve, type 346, with a ball valve handle extension, type 615, with a three-piece valve box installed over the valve). Upon completion of the installation of the soil filter media and the establishment of 90% of grass cover over the filter media, the contractor shall flood the vegetated basin to the design elevation with clean water and adjust the outflow to obtain a 24 hour to 32 hour release time.

Construction Sequence: Erosion and sedimentation from unstable subcatchments is the most common reason for filter failure. Not heeding the construction sequencing criteria is likely to result in the need to replace the soil filter. The soil filter media and vegetation must not be installed until the area that drains to the filter has been permanently stabilized with pavement or other structure, 90% vegetation cover, or other permanent stabilization. Otherwise, the runoff from the contributing drainage area must be diverted around the filter until stabilization is completed unless the Department has determined, on a case-by-case basis, that sufficient measures are being taken to prevent erosion of material from the unstable catchment area and deposition on the filter.
Remedial Loam Cover: If vegetation is not established within the first year, the contractor may install a 2-3 inch layer of sandy loam topsoil (with less than 2% clay as tested via hydrometer test) on the surface of the grass filter and reseed/mulch.

Construction Oversight: Inspection of the filter basin shall be provided for each phase of construction by the design engineer with required reporting to the DEP. At a minimum, inspections will occur:

- After preliminary construction of the filter grades and once the underdrain pipes are installed but not backfilled;
- After the drainage layer is constructed and prior to the installation of the filter media;
- After the filter media has been installed and seeded;
- After one year to inspect health of the vegetation and make corrections; and
- All material used for the construction of the filter basin will be approved by the design engineer after tests by a certified laboratory show that they are passing DEP specifications.

Testing and Submittals: The contractor shall identify the location of the source of each component of the filter media. All results of field and laboratory testing shall be submitted to the project engineer for confirmation. The contractor shall:

- Submit samples of each type of material to be blended for the mixed filter media and samples of the underdrain bedding material. Samples must be a composite of three different locations (grabs) from the stockpile or pit face. Sample size required will be determined by the testing laboratory.
- Perform a sieve analysis conforming to ASTM C136 (Standard test method for sieve analysis of fine and coarse aggregates; 1996a) on each type of the sample material. The resulting soil filter media mixture MUST have 8% to 12% by weight passing the #200 sieve, a clay content of less than 2% (determined hydrometer grain size analysis) and have 10% dry weight of organic matter.
- Perform a permeability test on the soil filter media mixture conforming to ASTM D2434 with the mixture compacted to 90-92% of maximum dry density based on ASTM D698.

7.1.5 Maintenance Criteria

During the first year, the basin will be inspected semi-annually and following major storm events.
Debris and sediment buildup shall be removed from the forebay and basin as needed.
Mowing of a grassed basin can occur semi-annually to a height no less than 6 inches.
Any bare area or erosion rills shall be repaired with new filter media or sandy loam then seeded and mulched.
Maintaining good grass cover will minimize clogging with fine sediments and if ponding exceeds 48 hours, the top of the filter bed must be rototilled to reestablish the soil's filtration capacity.

Maintenance Agreement: A legal entity should be established with responsibility for inspecting and maintaining any underdrained filter. The legal agreement establishing the entity should list specific maintenance responsibilities (including timetables) and provide for the funding to cover long-term inspection and maintenance.

Soil Filter Inspection: The soil filter should be inspected after every major storm in the first year to be sure it is functioning properly. Thereafter, the filter should be inspected at least once every six months to ensure that it is draining within 48 hours following a one inch storm or greater. And that following a storms that fill the system to overflow, it drains in no less than 36 to 6o hours. If the system drains too fast, an orifice may need to be added on the underdrain outlet or, if already present, may need to be modified.

Soil Filter Replacement: The top several inches of the filter shall be replaced with fresh material when water ponds on the surface of the bed for more than 72 hours. The removed sediments should be disposed of in an acceptable manner.

Sediment Removal: Sediment and plant debris should be removed from the pretreatment structure at least annually.

Mowing: If mowing is desired, only hand-held string trimmers or push-mowers are allowed on the filter (no tractor) and the grass bed should be mowed no more than 2 times per growing season to maintain grass heights of no less than 6 inches.

Fertilization: Fertilization of the under-drained filter area should be avoided unless absolutely necessary to establish vegetation.

Harvesting and Weeding: Harvesting and pruning of excessive growth will need to be done occasionally. Weeding to control unwanted or invasive plants may also be necessary. Add new mulch only as necessary for bioretention cell

7.2.1 Description

A bioretention cell is a type of underdrained soil filter designed to collect, infiltrate/filter, and treat moderate amounts of stormwater runoff using conditioned planting soil beds, gravel underdrained beds and vegetation within shallow depressions. The major difference between an underdrained grassed soil filter and a bioretention cell is the vegetation. A typical grassed underdrained soil filter may be planted with grass, whereas a bioretention cell is planted with a variety of shrubs and perennials whose roots assist with the passing of water and uptake of pollutants. Studies have shown that bioretention cells are capable of reducing sediment, nutrients, oil and grease, and trace metals.

Like grassed filters, bioretention cells control stormwater quality by capturing and retaining runoff and passing it through a filter bed comprised of a specific soil media. Once through the soil media, the runoff is collected in a perforated underdrain pipe and discharged downstream. The filter structure provides for the slow release of smaller storm events, minimizing stream channel erosion, and cooling the discharge. Bioretention cells are usually located in close proximity to the origin of the stormwater runoff and should be scattered throughout a residential area or along the downhill edge of smaller parking areas.

Bioretention cells with an underdrained soil filter must detain a runoff volume equal to the sum of 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area. This surface area of a bioretention cell should represent no less than the sum of 7% of the impervious area and 3% of the landscaped area draining into it, with other upgradient areas directed away from the basin.

When used to meet the phosphorus allocation in lake watersheds, the sizing of the underdrain filter structure needs to be adjusted in accordance with Volume II of this BMP manual.

The peak storage depth of the channel protection volume within a bioretention cell structure may not exceed 6 inches and should be designed to drain dry within 24 to 48 hours. Storage and detention for flooding conditions is not allowed within the structure and over the channel protection volume because of the potential impact to the plants in the basin. An independent structure must be provided.

The basin must be planted with plant species that are tolerant of draught and wet conditions. Full plant cover must be achieved within the first year following construction.

Figures 7.3 and 7.4 show two pipe bedding options for constructing bioretention cell meeting DEP's criteria.

7.2.2 Site Suitability Criteria

Drainage Area: The size of the basin and storage capacity over the filter is based on the size and land use within the area draining to the structure. Areas not needing treatment should be diverted away from a biocells.

Depth to Groundwater: In most instances, the bottom of the filter should be above the seasonal high groundwater table.

Test Pits: One test pit shall be excavated in the area of the filter bed to identify the depth to groundwater and bedrock.

Bedrock: If bedrock is close to the surface, an impermeable liner may be required to prevent rapid injection and contamination of the groundwater within fractures in the bedrock. If the basin does not have one foot of soil overburden between bedrock and the bottom of the underdrain layer, the basin must be lined with an impermeable geomembrane (not with clay).

Permeable Soils: If a system is located in an area where the soil is highly permeable (i.e. Soil Group A and some Soil Group B soils), the filter basin will *not* need a liner and will *not* need to be designed as an infiltration system per the requirements of Chapter 6 of this manual if the developed area draining to it:

- Contains less than one acre of imperious area.
- Consists only of roof.
- Is a single family residential subdivision, or
- Is not a facility that has a high turnover parking, that stocks hazardous products or that provides industrial or vehicle services and maintenance.

7.2.3 General Design Criteria

The following design criteria apply to all underdrained bioretention cells.

Treatment Volume: A bioretention cell soil filter must detain and filter a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area. Other upgradient areas should be directed away from the filter basin.

Filter Area: The area of the filter (surface area of the filter) must be no less than the sum of 7% of the impervious area and 3% of the landscaped area draining to the filter.

Basin Size: The size of a filter bed should never exceed 2000 sq. ft in basin bottom area or have more than one acre of subwatershed draining to the structure. Larger sizes are difficult to construct and maintain.

Construction Components: Underdrained filters are constructed in excavated holes that are at least three feet deep and consist of, from bottom up:

- A geotextile fabric between natural soils and constructed media. An impermeable membrane may be required if groundwater contamination is a concern.
- A 12 to 14 inch base of coarse clean stone or coarse gravel in which a 4 to 6 inch perforated underdrain pipe system is bedded.
- 18-inch layers of uncompacted soil filter media.
- A selection of plants and 2-3 inches of wood mulch.
- Depression for surface stormwater storage

Impoundment Depth: The peak water quality storage depth may not exceed 6 inches over plants that will sustain frequent draught and inundation that must drain dry in no less than 24 and no more than 48 hours. Due to the deeper root zones of the plants and increased evapotranspiration potential, one third of the soil filter volume may be included as storage volume when designing bioretention cells. Storage over the treatment volume to control peak flows for the flooding standards can not be provided because of potential damage to the vegetation. The overflow outlet must be no more than 6 inches above the filter bottom.

Outlet: The channel protection volume must be discharged solely through the underdrained filter bed with a network of underdrain pipe having a single outlet with a diameter no greater than six inches. Each underdrain system must discharge to an area capable of withstanding concentrated flows and saturated conditions without eroding.

Sediment Pretreatment: Pretreatment devices such as grassed swales, grass or meadow filter strips and sediment traps shall be provided to minimize the discharge of sediment to the underdrained soil filter.

Access: Where needed, a maintenance access shall be planned for and maintained that is at least 10 feet wide with a maximum slope of

15% and a maximum cross slope of 3%. This access should never cross the emergency spillway, unless the spillway has been designed for that purpose. An easement for long-term access may be needed.

7.2.4 Specific Design Criteria

Underdrain Pipe: Proper layout of the pipe underdrain system is necessary to effectively drain the entire filter area and the slope of the installed underdrain pipe must be positive. There must be at least one line of underdrain pipe for every eight feet of filter area's width. The underdrain piping should be 4" to 6" slotted, rigid schedule 40 PVC or SDR35. Structure joints shall be sealed so that they are watertight. Underdrain pipes must be placed no further than 15 feet apart.

Pipe Bedding: The 4 to 6 inch diameter perforated underdrain pipe(s) must be bedded in 12 to 14 inches of underdrain material with at least 4 inches of material beneath the pipe and 4 inches above. The underdrain material consists of well graded, clean, coarse gravel meeting the MEDOT specification 703.22 Underdrain Type B for Underdrain Backfill (see Table 7.1). The material must contain less than 5% fines passing the #200 sieve.

Soil Filter Bed: The soil filter must be at least 18 inches deep on top of the gravel underdrain pipe bedding and must extend across the bottom of the entire filter area. This soil mixture shall be a uniform mix, free of stones, stumps, roots, or other similar objects larger than two inches. No other materials or substances that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations can be mixed within the filter. Two options are available for the filter bed.

OPTION 1- Soil Filter Media: Soil media must consist of a silty sand soil or soil mixture combined with 20% to 25% by volume (no less than 10% by dry weight) of a moderately fine shredded bark or wood fiber mulch. Other organic sources must be approved by the department; however an agricultural source is not acceptable for the organic component of the media.

The resulting mixture must have no less than 8% passing the 200 sieve and shall have a clay content of less than 2%. The system must be designed to drain the surface storage volume in no less than 24 hours and no more than 48 hours.

TABLE 7.1 Maine DOT Specifications for Underdrains (MEDOT #703.22)

Sieve Size	% by Weight
UNDERDRAIN - TYPE B	
1”	90-100
½”	75-100
#4	50-100
#20	15-80
#50	0-15
#200	0-5
UNDERDRAIN - TYPE C	
1”	100
¾”	90-100
3/8”	0-75
#4	0-25
#10	0-5

TABLE 7.2 Maine DOT Specifications for Aggregate (MEDOT #703.01)

Sieve Size	% by Weight
3/8”	100
#4	95-100
#8	80-100
#16	50-85
#30	25-60
#60	10-30
#100	2-10
#200	0-5

As an example, the mixture may contain by volume the following:

- *50% of sand (MEDOT #703.01 contains insufficient fine for the media and must be amended)*
- *20% of loamy topsoil*

- *30 % of composted woody fibers and fine shredded bark, superhumus or equivalent*

OPTION 2 – Layered System with Topsoil
Because of its coarseness, a filter media mixed from different sources may lack nutrients, may be unable to retain moisture, and maybe be devoid of micro-organisms (such as fungus, bacteria and nematodes) which are found in a natural soil and which benefit the germination and establishment of vegetation. Natural soils will contain these important organisms and provide superior filtration. Option 2 provides for a layered system that takes advantage of the characteristics of natural soils. The different layers from the bottom up are:
***Optional hay layer*:** A layer of hay can be placed to separate the drainage layer from the treatment layer above to prevent subsidence or plugging of the sand/gravel/stone layer and/or pipe.
Filter Layer: A 12 inches layer of loamy coarse sand which is loosely installed should meet the grain size specifications of Table 7.3.
Topsoil: The surface of the basin should be covered with 6 inches of non-clayey, loamy topsoil such as USDA loamy sand topsoil with 5-8% humified organic matter and meeting the specifications provided in Table 7.4. Topsoil from the development may be appropriate but should be tested for organic content and clay content (hydrometer test). The soil must be screened, loose, friable, and shall be free from admixtures of subsoil, refuse, stones (greater than 2 inches in diameter), clogs, root and other undesirable foreign matter. The topsoil should be gently mixed within the filter layer to provide continuity for deep root penetration. The teeth of a backhoe, a hand rake, a shovel or rototilling 2-3 inches may be used as a way to create a loosened transition.

Clay Content: Use of soils with more than 2 % clay content could cause failure of the system and care should be taken, especially in areas where the predominant soil contains marine clay, that the sand and topsoil used in the mixture have very little or no clay content.

Filter Permeability: The filter must be permeable enough to insure drainage within 48 hours maximum, yet have sufficient fines to insure filtration of fine particles and removal of dissolved pollutants. The design may either rely on the soil permeability, if known, to provide the slow release of the water treatment volume over a minimum of 24 hours, or may insure this rate by installing a constrictive orifice or valve on the underdrain outlet. In determining the permeability of the media, the percent fines of the mixture and the level of compaction should be considered. Generally, the soil media should be only lightly compacted between 80 and 82% standard proctor (ASTM D698) and shall have a permeability of 2.4 in/hr to 4 in/hr.

Gradation testing: Gradation tests, including hydrometer testing for clay content, and permeability testing of the soil filter material, shall be performed by a qualified soil testing laboratory and submitted to the project engineer for review before placement and compaction.

Geotextile Fabric: A geotextile fabric with suitable characteristics may be placed between the sides of the filter layer and adjacent soil. The fabric will prevent the surrounding soil from migrating into and clogging the filter and clogging the outlet. Overlap seams must be a minimum of 12 inches. Do not wrap fabric over the top of the pipe bedding as it will cause clogging and will prevent flows out of the filter. The geotextile fabric shall be Mirafi 170n or equivalent.

Plant Species: The soil filter surface must be planted with plants that are tolerant of well drained soils and frequent inundation. Native plants should be chosen for their tolerance to urban runoff, pollutant loading, temperature and pH. A list of appropriate plant species has been provided in Appendix B of Volume I. A landscape designer or architect should be involved to select the appropriate plants for site conditions. Beware of invasive plant species. Upon planting, the soil filter shall be mulched with but must not be fertilized.

Mulch: Individual planting shall be mulched with 2-3 inches of cover. Acceptable mulch must be well aged, uniform in color, and free of foreign material including plant root material.

Rock Forebay: A rock forebay is recommended to reduce flow velocity into the basin. It shall remain clear of sediment until the upgradient tributary area is fully vegetated.

7.2.5 Construction Criteria

Construction Sequence: Erosion and sedimentation from unstable subcatchments is the most common reason for filter failure. Not heeding the construction sequencing criteria is likely to result in the need to replace the soil filter. The soil filter media and vegetation must not be installed until the area that drains to the filter has been permanently stabilized with pavement or other structure, 90% vegetation cover, or other permanent stabilization. Otherwise, the runoff from the contributing drainage area must be diverted around the filter until stabilization is completed unless the Department has determined, on a case-by-case basis that sufficient measures are being taken to prevent erosion of material from the unstable catchment area and deposition on the filter.

Basin excavation: The area of the basin may be excavated in preparation of the installation of the underdrain and can be used for a sediment trap from the site during construction. After excavation of the basin, the outlet structure and piping system must be installed at the appropriate elevation and protected with a sediment barrier. If the basin is to be used as a sediment trap, the sides of the embankments must be mulched and maintained to prevent erosion.

Compaction of soil filter: Filter soil media and underdrain bedding material must be compacted to between 90 and 92% standard proctor. The bed should be installed in at least 2 lifts of 9 inches to prevent pockets of loose media.

Outlet Discharge: The Overflow of the filter basin shall be placed no more than 6 inches above the filter media. The outlet of the underdrain must discharge to an area that is stable to prevent erosion.

Remedial Cover: If sedimentation has occurred within the first year, the organic mulch must be removed and replaced with a fresh a 2-3 inch layer of fresh mulch.

Construction Oversight: Inspection of the filter basin shall be provided for each phase of construction by the design engineer with required reporting to the DEP. At a minimum, inspections will occur:

- For all material used for the construction of the filter basin will be approved by the design engineer after tests by a certified laboratory show that they are passing DEP specifications.
- After preliminary construction of the filter grades and once the underdrain pipes are installed but not backfilled;
- After the drainage layer is constructed and prior to the installation of the filter media;
- After the filter media has been installed, planted and mulched, and
- After one year to inspect health of the vegetation and make corrections.

Testing and Submittals: The contractor shall identify the location of the source of each component of the filter media. All results of field and laboratory testing shall be submitted to the project engineer for confirmation. The contractor shall:

- Submit samples of each type of material to be blended for the mixed filter media and samples of the underdrain bedding material. Samples must be a composite of three different locations (grabs) from the stockpile or pit face. Sample size required will be determined by the testing laboratory.
- Perform a sieve analysis conforming to ASTM C136 (Standard test method for sieve analysis of fine and coarse aggregates; 1996a) on each type of the sample material. The resulting soil filter media mixture MUST have 8% to 12% by weight passing the #200 sieve, a clay content of less than 2% (determined

hydrometer grain size analysis) and have 10% dry weight of organic matter.

- Perform a permeability test on the soil filter media mixture conforming to ASTM D2434 with the mixture compacted to 90-92% of maximum dry density based on ASTM D698.

7.2.6 Maintenance Criteria

During the first year, the basin will be inspected semi-annually and following major storm events.

- Debris and sediment buildup shall be removed from the forebay and basin as needed. Any bare area or erosion rills shall be repaired with new filter media or sandy loam then planted and mulched.
- A healthy plant cover will minimize clogging with fine sediments and if ponding exceeds 48 hours, the filter bed must be rototilled and reestablished.

Maintenance Agreement: A legal entity should be established with responsibility for inspecting and maintaining any biocells. The legal agreement should establish the entity, list all specific maintenance responsibilities (including timetables) and provide for the funding to cover long-term inspection and maintenance.

Filter Inspection: The soil filter should be inspected after every major storm in the first year to be sure it is functioning properly and that the plants are establishing. Thereafter, the filter should be inspected at least once every six months to ensure that it is draining within 48 hours following a one inch storm or greater.

Soil Filter Replacement: The mulch shall be replaced with fresh material on a yearly basis.

Sediment Removal: Sediment and plant debris should be removed from the pretreatment structure at least annually. Removed sediments should be disposed of in an acceptable manner.

Fertilization: Fertilization of the under-drained filter area should be avoided unless absolutely necessary to establish vegetation.

Harvesting and Weeding: Harvesting and pruning of excessive growth will need to be done occasionally. Weeding to control unwanted or invasive plants may also be necessary. Plants that are not thriving must be replaced.

Section 7.3
Underdrained Subsurface Sand Filter BMP

June 2010

7.3.1 Description

Subsurface soil filters including a detention/retention bed of chambers may only be approved as an alternative BMP design on a case-by-case basis as they generally require much more care in their design, construction and maintenance. Subsurface sand filters are viewed as having a higher risk of failure and should not be considered unless all other alternatives have been considered and deemed impracticable because of the compaction necessary for bearing strength that is usually required of subsurface systems, because there is no vegetation to insure long term permeability, to provide evapo-transpiration or a long-term source of organic matter; and because there is no track record on this type of system (only on sand filters).

StormTech Isolator Row

The StormTech Isolator Row system is designed as part of the sites overall detention/retention system and provides the pretreatment requirement as it is mandatory for a subsurface sand filter BMP. The fabric-wrapped chambers provide for settling and filtration of contaminants including: sediment, metals and hydrocarbons as stormwater rises in the Isolator Row and ultimately passes through the filter fabric. Sediments are captured in the Isolator Row protecting the storage areas of the adjacent stone and chambers from sediment accumulation and the open bottom chambers allow stormwater to flow vertically out of the chambers. The chambers and the surrounding aggregate are designed to store the stormwater runoff and release the runoff at attenuated rates. This detention of the runoff in the chambers and aggregate also cools the runoff reducing the thermal impacts downstream of the system.

A subsurface soil filter must meet the following criteria:

1. Drainage Area: The drainage area contributing to a subsurface underdrained sand filter is sized based on the storage capacity over the filter and within the structure.
2. Depth to Groundwater: The bottom of the underdrain sand filter should be one foot above the seasonal high groundwater table at a minimum.
3. Bedrock: The top of bedrock may be no closer than 1 foot from the bottom of the underdrained sand filter.

7.3.2 General Design and Construction Criteria

Treatment Volume: An underdrained subsurface filter must detain a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment vegetated area.

Impoundment Depth: The peak surface storage depth within the chamber system for the water quality volume may not exceed 18 inches. Additional storage may be provided for the volume of runoff needing detention to meet the flooding standards.

System Size: The surface area of the sand filter bed and chamber system must be at least equal to 5% of the impervious area draining to it and 2 % of the landscaped area.

Outlet: The treatment volume must be discharged solely through an underdrain sand bed and underdrain piping system having a single outlet with a diameter no greater than eight inches or through a proprietary filter

system approved by the Department.
Site Stabilization: The site must be completely stabilized before construction of the subsurface sand filter is to begin.
Erosion Control: Prevent sediment from reaching the Isolator Row during construction until the site is stabilized is extremely important. An Isolator Row receiving sediment from an unstabilized site will have accumulated sediment that may affect the design flow rates of the Isolator Row and require cleaning prior to system use.
Construction Components: Underdrained chamber systems are constructed in an excavated area that is at least 5 ft deep and consisting of the following:

- A geotextile fabric between the natural subbase soils and constructed media.
- A 12 to 14 inch base of coarse clean stone with a system of 4 to 6-inch perforated drainage pipe.
- A layer of well compacted sand filter media at least 18 inches thick,
- Transition layers, as needed, to provide separation between the different gradation (between the drainage layer, the soil filter bed and the chamber backfill) without using geotextiles which have been found to clog.

7.3.3 Specific Design Criteria

Underdrain Pipe: Proper layout of the pipe underdrain system is necessary to effectively drain the entire filter area. There must be at least one line of underdrain pipe for every eight feet of the filter area's width. The underdrain piping should be 4" to 6" slotted, rigid schedule 40 PVC or SDR35. An orifice may be needed to ensure that the channel protection volume is slowly released over 24 to 36 hours.
Pipe Bedding and Transition Zone: The underdrain pipe(s) must be bedded in a minimum of 12 of underdrained material with at least 4 inches of material beneath the pipe and 4 inches above. The underdrain bedding material must consist of clean gravel meeting the MEDOT specification 703.22 Underdrain Type C for Underdrain Backfill Material (see Table 7.1). Crushed stone bedding material may be used; however it will need to be covered with a 6 inch layer of well graded, clean, coarse gravel meeting the MEDOT specification 703.22 Underdrain Type B for Underdrain Backfill Material (see Table 7.1). Fines passing the #200 sieve in the gravel should be no more than 5% (preferably 2%). Underdrain pipes should be placed 8 feet apart.

TABLE 7.1 Maine DOT Specifications for Underdrains (MEDOT #703.22)

Sieve Size	% by Weight
UNDERDRAIN - TYPE B	
1”	90-100
½”	75-100
#4	50-100
#20	15-80
#50	0-15
#200	0-5
UNDERDRAIN - TYPE C	
1”	100
¾”	90-100
3/8”	0-75
#4	0-25
#10	0-5

TABLE 7.2 Maine DOT Specifications for Aggregate (MEDOT #703.01)

Sieve Size	% by Weight
3/8”	100
#4	95-100
#8	80-100
#16	50-85
#30	25-60
#60	10-30
#100	2-10
#200	0-5

Sand Filter Bed: The sand filter must be at least 18 inches deep on top of the gravel underdrain pipe bedding and must extend across the bottom of the entire filter area. This sand material shall be a uniform mix, free of stones, stumps, roots, or other similar objects larger than two inches. The preferred material should have minimal clay content but contain between 8% and 10% fines passing the #200 sieve but should meet the other specifications in Table 7.2 for sieve size 3/8" to #100. The material should drain within 24 and 48 hours after compaction. The material will need to be submitted to a rigid testing protocol to insure adequate permeability at the anticipated level of compaction (92 to 95% Proctor). The permeability of the material will decrease due to compaction and the amount of fines may be adjusted to maintain the expected drainage time.

Pre-Treatment: Pre-treatment will be required and will include the StormTech Isolator Row or an equally effective sediment removal technology and additional pre-treatment for hydrocarbons by a combination of gravity (floatation) or absorption. A 5-year maintenance contract for regular seasonal inspection of the system and for cleaning the pretreatment device will be required. Pretreatment must include a strategy to attenuate hydrocarbons, often located in the catchbasins that drain to the filter.

7.3.2 Site Suitability Criteria

Drainage Area: The required number of Isolator Row chambers is based on the size and land use within the area draining to the chambers.

Depth to Groundwater: The bottom of the underdrain sand filter should be one foot above the seasonal high groundwater table at a minimum.

Bedrock: The top of bedrock may be no closer than 1 foot from the bottom of the underdrained sand filter.

Outlet: The channel protection volume is discharged through an outlet control structure. This structure is typically a standard manhole with a weir plate controlling the release rate from the chamber system via a series of orifices or weir crests. The outlet plate is designed based on a stage discharge relationship preventing downstream channel erosion. The outlet plate is designed to obtain the required 24 to 48 hour release time. The system outlet must discharge to an area capable of withstanding concentrated flows and saturated conditions without eroding.

Hydrocarbon Pretreatment: Pretreatment devices or practices such as sump skimmers, sorbent booms, or other similar devices shall be provided in catchbasins to minimize the discharge of hydrocarbons to the subsurface chamber system when the function of the draining area is a likely source of hydrocarbons (i.e. parking lots, roads, etc.).

7.3.3 Pretreatment Isolator Row General Design Criteria

The following design criteria apply to the designing treatment with the StormTech Isolator Row if used for pretreatment:

Treatment Flow Rate: The treatment flow rate for the StormTech Isolator Row system is the projected one year peak flow rate for the drainage area feeding the Isolator Row.

Sizing the Isolator Row: The treatment flow rate for the Isolator Row varies based on the chamber system specified. The treatment flow rates for the StormTech chambers are: 0.1 cfs for the SC-310 chamber, 0.2 cfs for the SC-740/DC-780 chambers, and 0.3 cfs for the MC-3500 chamber. To determine the number of Isolator Row chambers, the one year peak flow rate must be divided by the specific flow rate of the specified chamber. For example, a one year peak flow rate of 1.9 cfs would require 1.9/0.2 = 9.5 (rounded up to 10) SC-740 chambers in the Isolator Row (a minimum of 10 chambers). Additional Isolator Row chambers are acceptable based on site conditions and chamber bed layout.

Access/Diversion Structure: An adequately sized structure placed directly in front of the Isolator Row is required for inspection and maintenance. This structure will have a weir or elevation overflow manifold installed and should be a minimum of 48 inches to allow access to the Isolator Row. The actual size of the structure will vary based on the weir design, pipe sizes, pipe angles and flow rate over the weir. StormTech recommends additional access structures when the length of the Isolator Row exceeds 50 feet. The structure may be added at the opposite end of the Isolator Row or inline with the Isolator Row at every 50 foot interval.

Multiple Isolator Rows: If inlets enter the detention/retention system at multiple locations an Isolator Row is required for each inlet point. If length of the number of chambers required exceeds the available length a second Isolator Row can be placed adjacent to the first Isolator Row however, a separate access structure is required for each additional row.

Isolator Row Flow Control Elevation: The elevation of this weir/manifold is typically set between the elevations of the midpoint of the chamber and the top of the chamber.

Overflow: It is required to have an overflow on the Isolator Row directed towards additional storage chambers or a suitable location (direct to outlet, other storage devices, etc.)

Filter composition: Two layers of a woven geotextile fabric meeting AASHTO M288 specifications are placed between the stone and the Isolator Row chambers. This tough geotextile provides a media for stormwater filtration and provides a durable surface for maintenance operations. It is also designed to prevent scour of the underlying stone and remain intact during high pressure jetting. A layer of either woven or non-woven geotextile is required over the top of the SC-310 and SC-740 chambers to provide filtration for flow passing through the sidewalls of the chambers. This layer of fabric is optional for the DC-780 and MC-3500 chambers.

Connection Pipes: The connection pipes between the Isolator Row and the access/diversion structure are 12" for the SC-310 chambers and 24" for the SC-740, DC-780, and MC-3500 chambers.

7.6.4 Chamber System Construction Criteria

Manufactures Specifications: Install the chamber system in accordance with the manufacturer's written installation instructions.

Excavation: The area of the basin may be excavated in preparation of the installation of the system. After excavation of the basin, the outlet structure and piping system must be installed at the appropriate elevation and protected with a sediment barrier. Excavation must be free of standing water. Dewatering measures must be taken if required.

Site Preparation: Prepare the chamber bed's subgrade soil as outlined in the engineer's drawings.

Requirement for subgrade soil bearing capacity should meet or exceed the chamber manufacturer's allowable subgrade soil bearing capacity.

Aggregate Backfill around the Chamber System: Clean, crushed, angular stone with a nominal size distribution of ¾ to 2 inches is required around the chambers. Stone designations meeting AASHTO M43 Nos. 3, 357, 4, 467, 5, 56, and 57 are acceptable. Granular fill above the stone is required per the manufactures specifications. Fills meeting AASHTO M43 Nos. 3, 357, 4, 467, 5, 56, 57, 6, 67, 68, 7, 78, 8, 89, 9, and 10 are acceptable.

Construction Sequence: Erosion and sedimentation from unstable subcatchments could be a source of sediment entering the pre-treatment device. The runoff from the contributing drainage area must be diverted around the work area until stabilization is completed

Construction Oversight Inspection during and after construction and until the site is

Erosion Control:

Measures are to be taken to prevent sediment from reaching the Isolator Row during construction until the site is stabilized. An Isolator Row receiving sediment from an unstabilized site will have accumulated sediment that may affect the design flow rates of the Isolator Row and require cleaning prior to system use.

stabilized must be performed by the manufacturer's representative.

7.4.4 Maintenance Criteria

During the first year, the subsurface structure will be inspected semi-annually and following major storm events.

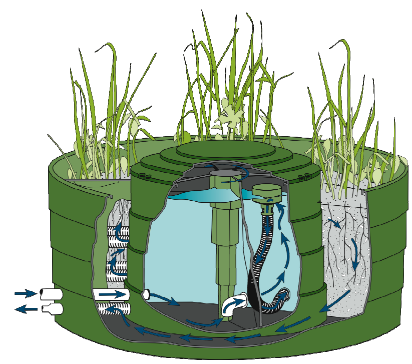
Maintenance Agreement: A legal maintenance agreement between the owner and an approved maintenance operator should be established with the specific descriptions of the responsibility of each for inspecting and maintaining any underdrained filter. The legal agreement establishing the entity should list specific maintenance activities (including timetables) and provide for the funding to cover long--term inspection and maintenance.

Soil Filter Inspection: Inspection ports will need to be installed within the underdrain gravel layer. At least one port needs to be installed per 500 square feet of subsurface structure. The system should be inspected after every major storm in the first few months to ensure proper function. Thereafter, the filter should be inspected at least once every six months to ensure that it is draining within 24 hours to 36 hours.

Pre-treatment device: Cleaning of the pre-treatment device shall be done as needed and identified by the entity holding the maintenance agreement as mandated under contract. Debris and sediment buildup within the Isolator Row fabric shall be removed as needed utilizing a Jet-Vac system. A routine inspection schedule needs to be established for each individual site based on site specific variables such as land use (i.e. road, industrial, commercial, residential, etc.) anticipated pollutant load, percent imperviousness, etc. The filter should be inspected at least once every six months to ensure that it is draining within 24 hours to 36 hours; however the inspection can be adjusted based upon previous observations of sediment deposition. When the average depth of sediment throughout the length of the Isolator Row exceeds 3 inches, clean-out must be performed.

Section 7.4
StormTreat Filter BMP

7.4.1 Description



The StormTreat Systems structure is a manufactured device designed to manage stormwater quality by capturing, retaining and passing runoff through a series of sedimentation chambers and a biofilter. The sedimentation chambers trap the majority of larger particles such as suspended solids and skim and retain floating pollutants including oil and other hydrocarbons. The biofilter is comprised of a specific soil media planted with wetland plants and is designed to remove a wide range of pollutants from stormwater including total suspended solids, phosphorus, nitrogen, metals, bacteria, hydrocarbons and some dissolved pollutants. Once through the structures, the treated effluent is discharged slowly downstream through an outlet control valve. The slow release of detained stormwater results in high pollutant removal performance, flow rate reduction, reduced stream channel erosion, as well as cooling, reducing thermal impacts to receiving streams. StormTreat structures are usually located in close proximity to the origin of stormwater runoff and an up gradient storage structure is generally required to detain the total water quality volume of runoff to be treated through the structure. Multiple StormTreat tanks may be installed in parallel to meet specific sizing and performance criteria. The tank is constructed of durable recycled polyethylene and has a 9.75ft diameter and 4ft depth.

Filter structures must detain a runoff volume equal to the sum of 1.0-inch times the subcatchment's impervious area plus 0.4-inch times the subcatchment's landscaped developed area. The system should be designed to process the total water quality volume within 72 hours.

When used to meet the phosphorus allocation in lake watersheds, sizing and flow rate of the filter structure needs to be adjusted in accordance with Volume II of this BMP manual.

Storage and detention for flooding conditions and to meet the 2, 10 and 25-year peak flow control must be provided in parallel to a StormTreat structure.

The StormTreat structure must be planted with plant species that are tolerant of drought conditions and frequent inundation. Establishment of vegetation must be achieved within the first year following construction.

A stormwater treatment system that uses a combination of upstream storage draining to StormTreat structures is considered an approved alternative to the General Standard BMPs provided it is designed, installed and maintained in accordance with the following criteria.

7.4.2 Site Suitability Criteria

Drainage Area: The required number of StormTreat units and upstream detention capacity is based on the size and land use within the area draining to the structure.

Outlet: The channel protection volume must be discharged through a pipe manifold system having a single outlet with a diameter no greater than eight inches. A manually adjustable valve should be installed to control the flow rate from the outlet pipe to obtain the required 72-hour maximum release time. The system must discharge to an area capable of withstanding concentrated flows and saturated conditions without eroding.

Sediment Pretreatment: Pretreatment devices such as grassed swales, grass or meadow filter strips and sediment traps shall be provided to minimize the discharge of sediment to the StormTreat System. Pretreatment structures shall be sized to hold annual sediment loading calculated using a sand application rate of 50 cubic feet per acre per year for sanding of roadways, parking areas and access drives within the subcatchment area.

Access: Where needed, a maintenance access shall be planned for and maintained that is at least 10 feet wide with a maximum slope of 15% and a maximum cross slope of 3%. This access should never cross the emergency spillway, unless the spillway has been designed for that purpose. An easement for long-term access may be needed.

7.4.3 General Design Criteria

Treatment Volume: The sum of the volume of upstream detention and available detention volume in the StormTreat tank(s) must be equal to at least the sum of 1.0 inch of runoff from the impervious areas that drain to the system and 0.4 inches of runoff from the landscaped areas that drain to the system referred to as the water quality volume (WQV).

Sizing System: The system must have at least one StormTreat tank per 1155 cubic feet of stored and treated volume. To determine the number of StormTreat tanks required divide the WQV in cubic feet from above by 1155 and round up. For example: On a site with 1-acre of contributing impervious surface and 1-inch of rainfall the WQV is 3630 cubic feet. Divide 3630 by 1155 and you get 4 StormTreat tanks required. (Always round up to next whole number to assure WQV is processed in 72 hours or less).

Tanks in Parallel: If more than one tank is required they should be arranged in parallel, connected using a 4 inch diameter pvc inflow pipe manifold from the upstream storage and a 2 inch diameter pvc outflow pipe manifold to the outlet.

Discharge elevation: The invert elevation of the bypass spillway or diversion for upstream storage should be 42 to 45 inches above the elevation of the StormTreat tank(s) bottom.

Flow Control: A valve must be located at the end of the outflow manifold to control flow rate of the system. The valve must be set, by actual field measurement, so that the flow discharged from the system is equal to 2.0 gallons per minute per tank when the elevation of water in the system is 2.5 feet above the bottom of the tank(s).

Filter composition: The stone in the bio-filtration chamber of the StormTreat tank consists of clean 3/8-inch rice or natural bank run stone (not crushed). The stone must be washed thoroughly to remove fines to ensure maximum life of the filter and to prevent system failure due to clogging. Stone should be visually inspected prior to filling of StormTreat tanks to assure absence of fines.

Pretreatment: The 25% reduction in the required treatment volume that is available for underdrained soil filters if an approved pre-treatment device is installed upstream of the filter is not available for StormTreat Systems.

7.4.4 Specific Design Criteria

Filter Permeability: The filter media must be permeable enough to insure drainage within 72 hours maximum. The design may either rely on the soil permeability, if known, to provide the slow release of the water quality volume over a minimum of 24 hours, or may ensure this rate by installing a constrictive orifice or flow control valve on the outlet. In determining the permeability of the media, the percent fines of the mixture and the level of compaction should be considered.

Vegetation: The bio-filter surface must be planted with a plant species that is tolerant of drought, frequent inundation and well-drained soils such as soft stem bulrush and burreed (sparganium). The plants are maintained between storms by 6 inches of water in the bottom of the wetland basin, assured by the outlet pipe elevation, which provides for soil moisture though capillary action during dry periods.

7.4.5 Construction Criteria

Manufacturers Specifications:
Install the StormTreat Systems structures in accordance with the manufacturer's specifications at:
http://www.stormtreat.com/configuration/installations.php

Excavation: The area of the basin may be excavated in preparation for the installation of the StormTreat structure and can be used for a sediment trap from the site during construction. After excavation of the basin, the StormTreat tank(s), outlet structure and piping manifolds must be installed at the appropriate elevation and protected with a sediment barrier. If the basin is to be used as a sediment trap, the sides of the embankments must be mulched and maintained to prevent erosion.

Outlet Discharge: Outflow from the StormTreat structure should be controlled using a 2-inch plastic control ball valve (type 346). If necessary, a valve handle extension (type 615) may be used. Also, if the outflow valve is easily accessible, tamper resistance should be ensured using a three-piece valve box installed over the valve.

Adjusting Outflow Rate: The following procedure may be used to set the outflow rate:

1. Close outlet valve.
2. Cap the inflow pipe into the first settling chamber in each StormTreat tank to prevent backflow.
3. Fill the tank(s) with clean water to 2.5 feet above the tank bottom.
4. Open the valve so that the required flow is met.
5. Flow shall be determined by a volumetric flow measurement with a known volume container and a stopwatch.

Finished Elevation: Finished grade outside the tank rim shall be at or just below the rim elevation. Grade should never be above the tank rim without implementation of erosion control measures to assure sediment does not enter the filter media.

Backfill: Fill for the area surrounding the tanks shall be native soils if available or gravel or crushed stone if used as a detention/infiltration basin.

Construction Sequence: Erosion and sedimentation from unstable subcatchments is the most common reason for filter failure. Not heeding the construction sequencing criteria is likely to result in the need to replace the filter media. Stabilization or diversion techniques must be employed to avoid erosion and to assure fines do not enter the filter media until stabilization is completed or the Department has approved, on a case-by-case basis, that appropriate measures were taken to prevent erosion of material from the unstable catchment area and deposition on the filter.

Construction Oversight: Inspection of the installation shall be provided for each phase of construction by the design engineer and vendor with required reporting to the DEP. At a minimum, inspections will occur:
• After preliminary construction of the excavation grades and once the tanks are installed and inlet and outlet manifolds are connected prior to backfilling.
• After the tanks have been installed, backfilled and vegetated.
• During outflow regulation and valve setting.
• After one year to inspect vegetation uptake and flow rate and make corrections.

Inflow Adjustment:
The inlet control valve shall be adjusted so that the flow from the outlet control structure is 10 gallons per minutes

- Close the inlet valve.
- Plug the 2 inlet pipes to the outlet control structure.
- Fill the structure with clean water to the elevation of the bulkhead orifice.
- Open the valve so that the required flow is met.
- Flow shall be determined by a volumetric flow measurement with a known volume container and a stopwatch.

7.4.6 Maintenance Criteria

Provide maintenance to the StormTreat System structures per the manufacturer's recommendations at: http://www.stormtreat.com/configuration/maintenance.php

During the first year, the basin should be inspected semi-annually and following major storm events. Recommended maintenance procedures for the first year are as follows:

- Watering may be necessary to aid plant establishment if rainfall intervals are longer than one week.
- Debris and weeds shall be removed from the bio-filter area as needed.
- Tank lids should be removed and sediment depth checked and recorded.
- Maintenance schedule should be designed based on the sediment loading of the first maintenance visits.
- Sediment should be removed at or before reaching a depth of 5 inches.
- Outflow rate should be checked and reset if necessary.
- Biofilter plants should be trimmed or harvested periodically to a minimum height of 6 inches.

Maintenance Agreement: A legal entity should be established with responsibility for inspecting and maintaining any StormTreat structures. The legal agreement establishing the entity should list specific maintenance responsibilities (including timetables) and provide for the funding to cover long-term inspection and maintenance.

Pretreatment Maintenance: Sediment and plant debris should be removed from the pretreatment structure at least annually.

Fertilization: Fertilization of the planting on the structure must be avoided.

Contact for more information:

StormTreat Systems, Inc.
Phone: 508-833-1033
Email: info@stormtreat.com
www.stormtreat.com

Section 7.5
Filterra Bioretention Systems

7.5.1 Product Description

The Filterra® bioretention filtration system is a self-contained stormwater treatment system. The technology packages soil media, plants and drainage infrastructure similar to those found in typical bioretention best management practices (BMPs) into a specially designed, pre-fabricated concrete housing (Figure 1). The Filterra® is a flow-through system, intended to provide decentralized, distributed stormwater treatment control within a wide range of urbanized settings. The Filterra® technology is well-suited for incorporation into Low Impact Development (LID) site and stormwater treatment design. The Filterra® technology is capable of providing effective removal of suspended sediments, nutrients, heavy metals, and TPH from treated stormwater flows. For more information, please review a Whitepaper on the Filterra® technology at www.filterra.com.

Figure 1. Filterra® Bioretention Stormwater Treatment System

The Filterra® design is based on the principles of traditional bioretention technologies such as filter strips and rain gardens. Bioretention systems and similar micro-scale controls are intended to enhance the treatment capacity of developed landscapes and reduce reliance on larger downstream controls such as detention basins. They may provide significant treatment over the entire course of a typical runoff event if designed, sited, installed and maintained appropriately. Bioretention technologies operate similarly to under drain filters in terms of particulate settling, filtration, adsorption and absorption of pollutants. Unit treatment processes more specific to bioretention include nutrient uptake, transpiration and other measures associated with the vegetation and root structure.

The Filterra® technology is intended to address common problems and limitations of typical bioretention systems, providing an easily-installed, easily-maintained, standardized bioretention design. In terms of installation, maintenance and functionality, the Filterra® also shares similarities with common sand or sand/organic filtration technologies. The most critical element of the Filterra® design is the specialized soil media, composed to optimize the flow-through rates and treatment capacity of the system. The top of the Filterra® system is typically enclosed, with a tree frame and grate incorporated into the lid to accommodate the specified vegetation and maintenance access. To help improve uniformity and consistency of performance, Americast offers comprehensive, customized sizing and installation guidance to Filterra® customers and an extensive on-site maintenance service.

7.5.2 Design and Installation Criteria

The Filterra® system is considered an approved alternative to the General Standard BMPs described in the Chapter 500 Stormwater Manual Rules when it is designed as a stormwater treatment train that uses a combination of Filterra® systems draining in series to a StormTech Isolator Row (and chamber system when channel protection volume attenuation is required). It must be designed, installed and maintained in accordance with the following criteria.

1. The Filterra® system is installed with the inlet slot invert slightly below pavement grade. Captured flows percolate through the mulch; plant and soil filter media and eventually discharge via a perforated under-drain to an adjacent StormTech Isolator Row (Figure 2). Several inches of headspace is provided above the mulch surface layer to permit ponding of flows during high-intensity runoff events, and to collect trash and debris.

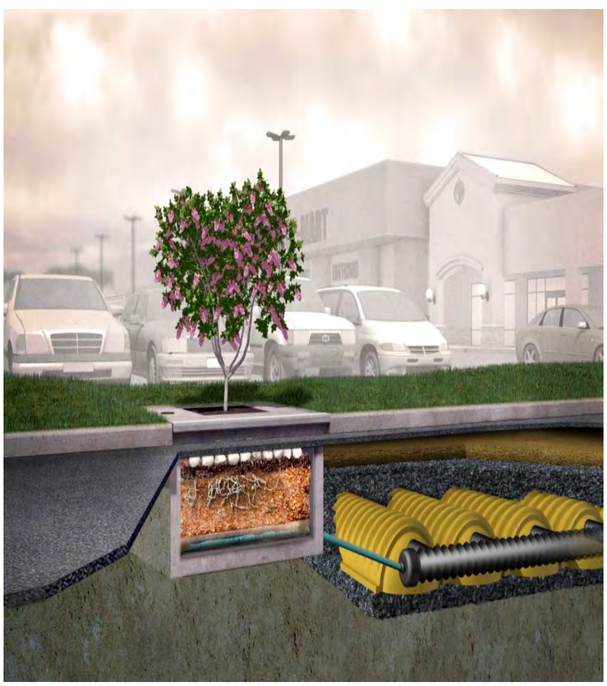


Figure 2. Typical Filterra® Design and Installation

2. When designed with the standard curb inlet design, the Filterra® will be configured "off-line" with the surface elevation at the Filterra® system being up gradient of an overflow inlet. In the grated inlet design, the Filterra® system will incorporate an internal bypass and does not require an overflow inlet. More specific installation information is provided in the Filterra® Installation, Operation and Maintenance (IOM) Manual also found on the Filterra® website. The applicant must demonstrate that the design meets all the manufacturer's specifications and shall be reviewed by the manufacturer prior to submission for DEP approval. Review and approval of the design by the manufacturer will be sufficient to demonstrate conformance with the manufacturer's specifications.

3. The Filterra® system will be configured in series upstream of a StormTech Isolator Row. The treated and bypass flow will be combined and directed to the Isolator Row which shall be sized to treat the flow from a 1-year, 24-hour storm event.

4. For proper trash collection ensure a minimum 4" and maximum 6" Filterra® throat opening depth. Positive drainage of each Filterra® system's effluent treatment pipe is required to prevent free standing water from accumulating in the system or under drain. This could occur due to tidal influences or improper connection of Filterra's® effluent pipe to the StormTech Isolator Row.

6. Plans and the completed Filterra® Project Information Form located in the Filterra® DAKit must be sent to Americast for Filterra® placement review. Plans sheets should include grading, drainage areas, stormwater schedules or profiles, landscape sheets and Filterra® detail sheets. This review is mandatory for warranty to apply and helps ensure that each Filterra® system operates efficiently to maximize performance and minimize maintenance.

7. The Filterra® Bioretention System(s) shall be delivered to the site with the engineered filter media and plumbing fully installed. The Filterra® shall be delivered sealed, preventing debris and sediment from entering the system during construction. The boards on top of the lid and boards sealed in the system's throat must **NOT** be removed prior to "activation". The activation of the system includes removal of the internal wooden forms and protective mesh cover, installation of plant(s) and mulch layers as necessary. Activation of the Filterra® unit is performed ONLY by the Supplier (Americast or its authorized dealer). The activation process cannot commence until the project site is fully stabilized and cleaned (full landscaping, grass cover, final paving and street sweeping completed), minimizing the risk of construction materials contaminating the Filterra® system.

8. A list of appropriate plants for use with the Filterra® system is provided on the Filterra® website. Use of native species may reduce the need for additional irrigation of the Filterra® vegetation. Each Filterra® must receive adequate irrigation to ensure survival of the living system during periods of drier weather. This may be achieved through a piped system, gutter flow or through the tree grate. In general, irrigation needs should be the same as that of the surrounding landscaping, i.e. if the landscaping is being watered, the Filterra® should be, as well.

7.5.3 Sizing Guidelines

Appropriate sizing, location and installation of the Filterra® are essential to the performance of the stormwater treatment system. The Filterra® system is specifically designed to treat runoff flows from small watersheds (or "microsheds"). As such, it is intended to be used as a distributed, upstream control, per the design principles of Low Impact Development (LID) stormwater management. The Filterra® Bioretention System shall be sized in accordance with the manufacturer's standard New England sizing guidelines outlined in the following table to treat at least 90% of the annual runoff volume.

Filterra® Model Number	Area in Acres
4x6 or 6x4	0.32
4x8 or 8x4	0.42
6x6	0.47
6x8 or 8x6	0.64
6x10 or 10x6	0.79
6x12 or 12x6	0.95
7x13 or 13x7	1.20

This sizing table can also be found as Table 1. Filterra® Quick Sizing Table, located in the Filterra® Design Assistance Kit (DAKit) on the Filterra® website. The entire contributing drainage area to the Filterra® should be considered and the minimum allowable C factors noted. The maximum contributing drainage area will vary with site conditions.

Information on the pollutant removal efficiency of the Filterra® system is based on more than three-years of lab and field studies performed by the Civil Engineering Department at the University of Virginia, as well as field studies performed under the Washington TAPE protocol. Pollutant removal efficiencies for the Filterra® system are as follows:

Total Suspended Solids: 85%
Total Phosphorus: 60% - 70%
Total Nitrogen: 43%
Dissolved Zinc: 58%
Dissolved Copper: 46%
TPH: >93%

7.5.4 Maintenance Criteria

Routine clearing of accumulated trash and debris is required to prevent clogging of the inlet opening (just as with any catch basin, inlet or other in-curb unit). Americast includes a one-year maintenance plan with each Filterra® system to ensure the systems are operating per specifications. In addition, the owner will provide an executed 5 year inspection and maintenance contract prior to final DEP approval. Said contract will be with a professional with knowledge of erosion and stormwater control, including a detailed working knowledge of the proposed BMP's.

The company recommends that long-term maintenance be performed on at least a semiannual basis (generally spring and fall servicing) to help preserve Filterra® flow-through rates and treatment performance also found in the Filterra® IOM. Each maintenance session should include, at a minimum, the following:

• Inspection of the system structure and media;
• Removal of trash and silt from the filter surface;
• Replacement of the surface mulch layer. Complete replacement of the soil media is generally required only as part of a spill clean-up.
• Pruning of vegetation. If the vegetation is in dead or in poor health, it will require replacement; and
• Appropriate disposal of all refused items.

Americast offers extended maintenance services or training to facilitate on-going maintenance. A more detailed description of the maintenance procedures is presented in the Filterra® IOM.

Section 7.6
Roof Dripline Filtration BMP

7.6.1 Description

The runoff from a peaked roof without gutters may be detained at the drip line, be filtered through the foundation backfill and be discharged via a foundation underdrain pipe or equivalent.

7.3.2 General Design Criteria

The roof dripline filtration BMP needs to be designed with storage or for infiltration with the following design criteria:

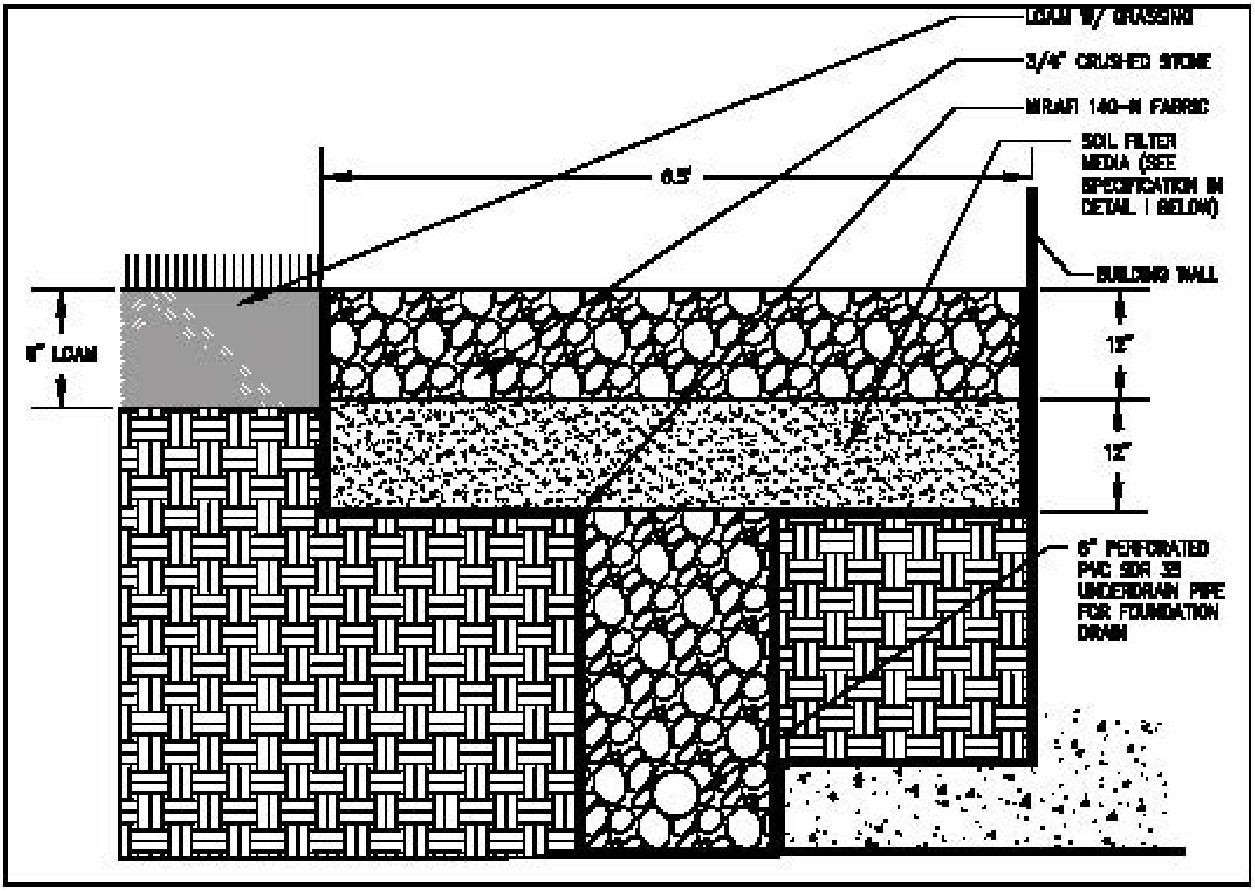
- All appropriate specifications from the Stormwater Management rules, Appendix E, and the Stormwater Management for Maine BMP Manual, Chapter 7, Filtration BMPs, apply to this design.
- To meet the General Standards requirements (treatment of 1 inch of runoff), a minimum storage capacity within a reservoir course is needed to allow for the treatment of one inch or more of runoff.
- To meet the Flooding Standards requirements, the reservoir needs to provide a minimum storage capacity for the direct entry of the rain precipitation from a 24-hour, 25-year storm (5 + inches) or an overflow may be needed or provided for.
- The filter bed may be part of the foundation backfill.
- An underdrain pipe system is needed to drain the infiltrated water and can have the dual purpose of underdraining the foundation also.
- Stored volume needs to fully drain within no less than 24 hours and no more than 48 hours. An orifice may be needed to regulate the outflow.

7.6.3 Specific Design Criteria

Drip line edge: The drip line trench needs to extend the length of the building or area of roof to be treated.
Treatment Storage; the reservoir bed at the drip line must consist of crushed rock with a porosity of 40%. Its width and depth is sized based on the runoff volume from the roof.(for example, a 30 foot wide roof panel will need a 4 foot wide by 1.5 foot deep rock storage bed.
Reservoir Course: The depth of the reservoir course shall be based on the desired storage volume and frost. The reservoir course should consist of clean washed ¾ to 1 inch aggregate that is free of debris.
Overflow: Unless an overflow system is provided for the runoff from larger storms, a deeper storage bed will need to be provided.
Treatment Filter: The backfill for the foundation may be used as the filter media as long as the material is a mineral soil with between 4 and 7% fines (passing #200 sieve) and is 4 inches thick at a minimum.
Impermeable Membrane: To prevent the penetration of water into a basement, the system may be lined with an impermeable membrane.
Underdrain Bed: An underdrained bed consisting of a minimum of 12 inches of underdrain gravel meeting the MDOT Specification 703.22, Type B should be a minimum of 12 inches to provide sufficient coverage for the underdrain piping. Crushed rock is an acceptable option and should be wrapped in filter fabric.

7.6.4 Maintenance Criteria

A dripline filter bed needs to be maintained like any other filter basin. The maintenance activities for filter BMPs listed in Chapter 7 of the BMP manual apply equally to this type of structure. Any debris must be removed from the reservoir course. The Maintenance plan needs to address that these structures are part of the stormwater management plan for the project, cannot be paved over or altered in anyway. No gutter may be installed on the roof line.



Section 7.7
Manmade Pervious Surfaces

7.7.1 Description

A porous surface consists of the use of a permeable surface material and mineral base and subbase materials which allow penetration of runoff and into the underlying soils.
The efficiency of pavement alternative systems will depend on whether the surface is designed to store and infiltrate most runoff with the remainder discharged to a storm drainage system or over-land flow. The effectiveness of pervious alternatives will also depend on their long term maintenance and serviceability.

7.7.2 General Design Criteria

A typical permeable pavement alternative consists of a top porous structure that is providing structural strength and will allow the infiltration of runoff, a filter course, a reservoir course (with drainage if needed), a geotextile fabric and existing soil or subbase material. The following surface alternatives are example of pervious surfaces:
Porous Asphalt and Concrete: Porous asphalt is similar to conventional asphalt except that it contains very few particles smaller than coarse sand (less than # 30 sieve). Without these finer particles, water is able to infiltrate and into the subsurface.
Block pavers: Block paves are interlocking concrete blocks that leave void spaces between which water can infiltrate. The void spaces can be filled with gravel or soil and grass.
Plastic grid Pavers: These are often constructed from recycled material and come in a honeycomb pattern. The voids are filled with gravel or may be grassed.
Artificial ball fields (turf ballfields): These are also considered pervious surfaces that require similar design considerations. The synthetic nature of the turf may be a concern for the infiltration of chemical into the subsurface; however, no restriction will be applied until more data is available on this subject.

Any manmade pervious surface shall be subject to the General Standards of Chapter 500, Stormwater Management Rules and the DEP licensing staff must be consulted for permitting requirements. However, the use of this technology will provide needed level of treatment to meet the General Standards if designed as below.

7.7.3 Specific Design Criteria

Traffic Volumes: Pavement alternatives are limited to areas with light to moderate traffic. They are not recommended for most roadways, and cannot withstand heavy vehicles.
Grading: The site should slope with less than 5% and preferably closer to 1%.
Sediment loading: Pavement should not be used in areas expected to receive high levels of sediments as they are highly susceptible to clogging. Also alternative measures such as salt should be implemented over these areas in the winter.
Reservoir Course: The reservoir course should consist of clean washed 11/2-inch to 3-inch aggregate that is free of debris. The depth of the reservoir course shall be based on the desired storage volume and frost penetration.

7.7.3 Design Criteria for Infiltration

- All specifications from SW rules, Appendix D, Section 2 apply.

- At a minimum, one foot separation is needed below the road subbase and above the groundwater table. The depth of the water table elevation needs to be considered in designing the road for sufficient frost protection depth.
- A filter layer providing pretreatment before infiltration to groundwater needs to be included in the road design and can be part of the subbase and base. The media must be a mineral soil with between 4 and 7% fines (passing #200 sieve) and should be a minimum of 8 inches thick.
- To meet the General Standards requirements (1 inch infiltration), a minimum storage capacity within the filter layer or subbase and base is needed to allow the direct entry of one inch or more.
- To meet the Flooding Standards requirements, the road design needs to provide a minimum storage capacity for the direct entry of the rain precipitation from a 24-hour, 25-year storm (5 + inches).
- Infiltration rate should be confirmed with a double ring infiltrometer test to determine the soils ability to accept water. The test needs to be on native subgrade even if there is fill above it, and not on the fill itself. Recommended infiltration should be less than 2.41 inches per hour but great enough that the inch of stored precipitation infiltrates in 24 hours (i.e. >0.04 inches per hour).
- The stored volume needs to fully infiltrate within 24-48 hours
- Provide appropriate drainage and discharge of flows from larger storms where is needed.

7.7.4 Design Criteria for Storage and Filtration

- Appropriate specifications from SW rules, Appendix E and BMP design standards for an underdrained filter bed apply
- To meet the General Standards requirements (treatment of 1 inch of runoff), a minimum storage capacity within the filter layer or subbase and base is needed to allow the treatment of one inch or more.
- To meet the Flooding Standards requirements, the road design needs to provide a minimum storage capacity for the direct entry of the rain precipitation from a 24-hour, 25-year storm (5 + inches).
- The filter bed may be part of the road base and subbase horizon. The filter media must be a mineral soil with between 4 and 7% fines (passing #200 sieve) and must be a minimum of 4 inches thick. .
- An underdrained bed consisting of a minimum of 12 inches of underdrain gravel meeting the MDOT Specification 703.22, Type B should be a minimum of 12 inches to provide sufficient coverage for the underdrain piping.
- An underdrain pipe network is needed to drain adequately the underdrain bed. Pipes should be placed perpendicular to the slope and should be spaced no further apart than 20 feet. An orifice may be needed to control the outflow.
- Stored volume needs to fully drain within 24-48 hours.
- Provide appropriate drainage and discharge of flows from larger storms where is needed.

7.7.5 Maintenance Criteria

Pervious surfaces and pavement, whether asphalt, concrete or paving stones, have the potential to become impervious if not properly maintained. The following need to be planned for and be met:

- Design pervious pavement structures to prevent erosion from surrounding areas from reaching the pavement and sediment deposition.
- Restrain vehicles with muddy wheels from accessing pervious pavement areas.
- Limit salt use for deicing and do not use sand.
- Remove leaves and organic debris in the fall.
- Sweep, vacuum and/or pressure wash pavement **twice** annually at a minimum.

Section 7.8
THE STORMFILTER®

7.8.1 General Description

The Stormwater Management StormFilter® (StormFilter) cleans stormwater through a patented passive filtration system, effectively removing pollutants to meet stringent regulatory requirements. Highly reliable, easy to install and maintain, and proven performance over time, the StormFilter system is recognized as a versatile BMP for removing a variety of pollutants, such as sediments, oil and grease, metals, organics, and nutrients. The StormFilter comes in variable configurations to match local conditions and is designed with prolonged maintenance periods to ensure long-term performance and reduce operating costs.

The StormFilter is typically comprised of a precast vault or manhole that houses rechargeable, media-filled cartridges. The Volume StormFilter configuration utilizes upstream detention to contain the water quality volume (WQv) which is fed to the StormFilter at low flow rates. This configuration is considered an approved alternative to the General Standard BMPs, provided all applicable design criteria are met.

Volume StormFilter Operation

Runoff first enters the upstream detention structure where it is temporarily detained and ultimately treated by the filtration components over a 24 to 72 hour drain down period. The slow release rate allows a substantial fraction of the suspended solids and attached pollutants to settle upstream of the filtration components, which extends the life of the filtration media and reduces maintenance frequency. Flow entering the StormFilter from the detention system is distributed to the cartridge bay by an energy dissipater/flow spreader. As the water level in the filtration bay begins to rise, stormwater enters the StormFilter cartridges and percolates horizontally through the filter media before passing into the cartridge's center tube. Inside each center tube, a calibrated float initially limits the flow rate into the underdrain manifold at the bottom of the cartridge. This causes the water elevation in the filtration bay to rise to the top of the filtration cartridges. Once the water elevation reaches the top of the filtration cartridges there is sufficient buoyant force to lift the float to the open position. The cartridge then begins operating at the design treatment rate which is regulated by a calibrated restrictor disc (orifice) at the base of each cartridge.

The combination of the float, cartridge hood and flow control orifice ensure that all available media surface area is utilized and the cartridge operates at its design operating rate. Once the float is lifted to the open position a siphon forms and the hood ensures each cartridge will maintaining a hanging water column during operation until the water surface elevation in the filtration bay drops to the elevation of the scrubbing regulators near the bottom of the cartridge hood. At this point, the siphon begins to break and air is quickly drawn beneath the hood through the scrubbing regulators, causing high energy turbulence between the inner surface of the hood and the outer surface of the filter media. This turbulence agitates the surface of the filter, releasing accumulated sediments on the surface, flushing them from beneath the hood, and allowing them to settle to the vault floor. This surface-cleaning mechanism maintains the permeability of the filter surface and enhances the overall performance and longevity of the system.

Standard Cartridge Heights
Three different cartridge heights are available at 12, 18, and 27 inches. Increasing the height of the cartridges increases the media surface area in a given footprint, but requires a greater hydraulic drop (head loss) across the system. Since each cartridge contains an individual orifice control, the calibrated restrictor disc, a consistent specific flow rate is sustained for all cartridge heights. Applications that have additional hydraulic drop available can opt for a taller cartridge and gain the benefit of a smaller number of required cartridges and therefore a smaller system footprint. Projects with limited available hydraulic drop can select the Low Drop StormFilter (12 inch effective cartridge height). However, more cartridges will be required to provide the required media surface area, which results in a larger system footprint.

Pollutant Removal
Solids and attached pollutants will settle in the upstream detention structure as well as within the StormFilter. The StormFilter cartridge is the central treatment device within the system. Physical straining through the media promotes solids removal by trapping solids within interstitial spaces throughout the filtration media. Dissolved pollutants such as metals and phosphorous are removed by both ion exchange and adsorption processes.

7.8.2 Site Suitability Criteria
The StormFilter is well suited to most stormwater treatment applications. The system is most commonly used on small and medium sized sites but can be scaled to accommodate larger applications. Sites without suitable hydraulic drop, excessive tailwater or atypical pollutant loads may warrant special consideration. CONTECH encourages anyone considering the StormFilter for a particular application to contact them prior to finalizing site plans to ensure the most appropriate design is specified.
Contact *Maine Office*: 207-885-9830 or *National Toll Free*: 800-338-1122

7.8.3 General Design
For standalone stormwater treatment applications in the State of Maine the StormFilter must be designed in a volume configuration and rely on a combination of fine zeolite and reactive alumina media. Sizing is based on the results of long term field monitoring that demonstrated the StormFilter is able to meet the Maine Department of Environmental Protection's (MEDEP) stormwater quality criteria. The volume StormFilter includes an upstream storage component sized to capture the water quality/channel protection volume and release it through the filtration components over a minimum of 24 hours. Each filtration cartridge contains an outer band of fine zeolite media and an inner band of reactive alumina media. Each filtration cartridge also includes a flow control orifice to restrict the maximum operating rate to 0.27gpm/ft^2 of media surface area.

7.8.4 Specific Design Criteria
Storage of the Water Quality Volume
Upstream storage must be provided for the water quality/channel protection volume (WQv) which consists of the first 1.0 inch of runoff from impervious surfaces and the first 0.4 inches of runoff from lawns and similar landscaped areas. The WQv should be hydraulically isolated from any additional storage provided onsite by weirs or other means so that only the WQv is routed through the StormFilter. Additionally, the WQv must be detained for a minimum of 24

hours (brimful emptying time) and a maximum of 72 hours.

Storage will typically be provided in an underground facility such as corrugated metal pipe (CMP), polypropylene chambers, concrete vaults or similar means. Since there is likely to be appreciable sediment accumulation in the storage facility a sump should be provided for sediment storage whenever feasible. In the case of CMP or similar facilities this can be accomplished by raising the outlet invert approximately 6 inches from the floor of the system. When chambers are utilized they should be configured such that sedimentation occurs primarily in a specific row of chambers. All storage systems must include sufficient access for maintenance personnel to remove accumulated sediment and debris. If desirable a pretreatment structure can be located upstream of storage to facilitate capture of coarse solids.

Filtration Media

StormFilter cartridges shall contain an outer band of fine zeolite media and an inner band of reactive alumina media. Each media shall represent 50% of the total media volume.

Cartridge Hydraulics

Each StormFilter cartridge shall include a flow restricting orifice that limits the filtration rate to a maximum surface area specific operating rate of 0.27gpm/ft^2 of media surface area. Relevant per cartridge operating rates for standard StormFilter cartridge heights are shown in Table 1.

Table 1. StormFilter Cartridge Treatment Flows

StormFilter Cartridge Height (in)	12"	18"	27"
Media Surface Area (ft^2)	5	7.5	11.25
Allowable Flow per Cartridge (gpm)	1.35	2.0	3.0
Surface Area Specific Operating Rate (gpm/ft^2)	0.27	0.27	0.27

Required Number of Filter Cartridges

To simplify the design of the StormFilter in the State of Maine a relationship has been established between the WQv and the amount of filtration surface area that is required. This relationship was derived based on the mass of pollutants expected to be delivered to the StormFilter during a typical rainfall year and the amount of mass that is generally captured by the StormFilter before maintenance is required. Ultimately the goal in establishing this relationship was to ensure the StormFilter was capable of operating for at least a year before media replacement is required. StormFilters sized for use in Maine must provide a minimum of 1 square foot of media surface area for every 301.73 gallon (40.34cf) of water that must be treated. Table 2 provides the Water Quality Volume that may be treated by standard StormFilter cartridges.

Table 2. Treatable Volume for Standard StormFilter Cartridges

StormFilter Cartridge Height (in)	12"	18"	27"
Media Surface Area (ft^2)	5	7.5	11.25
Allowable WQv Per Cartridge (Gal)	1509	2263	3394
Allowable WQv Per Cartridge (cf)	202	303	454

To determine the appropriate number of StormFilter cartridges for an application, the WQv should first be calculated. Next, a cartridge height should be chosen based on the constraints of the site. Cartridge height is typically governed by the amount of drop available onsite. Taller cartridges result in a smaller system footprint but require more hydraulic drop across the system. Shorter cartridges occupy a larger footprint (larger vault), but require less hydraulic drop. If uncertain about the best cartridge height for a project, CONTECH's design engineers are available to assist. Once the WQv has been calculated for the site and the cartridge size has been selected the WQv can simply be divided by the allowable WQv per cartridge (Table 2) to determine the appropriate number of cartridges. Any decimals should be rounded up to the nearest whole number of cartridges.

7.8.5 Construction Criteria

Typically the StormFilter will arrive onsite from the precaster with the internal components already installed. Note that the StormFilter should be kept offline during construction to avoid loading the cartridges excessive sediment. CONTECH will provide applicable drawings and installation instructions prior to installation of the system. The contractor is typically responsible for preparing the excavation for the system, setting the vault or manhole in place, confirming internal components are properly installed, making any necessary pipe connections and installing the risers and covers needed to bring the system to grade. Detailed installation instructions are available at:
http://www.conteches.com/Products/Stormwater-Management/Treatment/Stormwater-Management-StormFilter.aspx

Installation of upstream detention structures will vary based on the type of detention structure specified for a particular project. CONTECH provides drawings and installation instructions for each of the detention systems it provides.

Should any questions arise regarding installation contact CONTECH at: *Maine Office*: 207-885-9830 or *National Toll Free*: 800-338-1122

7.8.6 Maintenance Criteria

The MEDEP approved configuration of the StormFilter is expected to have an operational longevity of at least one year. To ensure long term performance the media cartridges must be replaced annually. Additionally, upstream storage facilities should be inspected to determine the volume of sediment accumulation. Sediment and other debris should be removed from storage facilities once devoted sediment storage areas have been consumed. Regular inspections provide the best means of establishing maintenance frequency since pollutant loads will vary at each installation.

StormFilter Maintenance Basics

StormFilter maintenance is typically performed using a vactor truck.
1) Media is vacuumed directly from the cartridges or a place within the structure is used as a staging area to empty cartridges.
2) Empty cartridge baskets and components are removed from the structure.
3) The structure is inspected for structural conditions and any accumulated sediment and debris is removed from the structure
4) New or clean/refilled cartridges are inserted into place.
5) Collected sediment and spent media are disposed of off-site, typically at a landfill.

StormFilter Maintenance Indicators

1) Scum line in relation to height on vault wall. If the scum line is above the outlet overflow elevation, then the system has been loaded to the point where overflow has occurred.
2) Accumulated sediment on the floor of 4 inches or greater typically warrants full maintenance.
3) If the cartridges are in standing water during dry weather and it has not rained in the previous 72 hours, this is direct evidence that the cartridges are occluded. However, the inspector needs to ensure that the cartridges are not submerged due to backwater conditions caused by high ground water, plugged pipes or high hydraulic grade lines. Completely plugged cartridges also can be associated with heavy O&G loading from animal and vegetable fats or petroleum hydrocarbons. If this is the case source control measures are warranted.

A detailed StormFilter maintenance manual is available at:
http://www.conteches.com/Products/Stormwater-Management/Treatment/Stormwater-Management-StormFilter.aspx

CONTECH is also available to answer maintenance questions or suggest local maintenance providers.
Phone: 410-740-8490 or 800-338-1122

Contact for more Information
CONTECH® Engineered Solutions LLC
Maine Office: 207-885-9830 or National Toll Free: 800-338-1122
www.conteches.com

Section 8.0 CONVEYANCE AND DISTRIBUTION STRUCTURES

Many of the water quality BMPs discussed in this manual rely on conveyance and distribution systems to adequately transport the water to the BMP. This chapter discusses some of the more common conveyance and distribution systems including:

- Vegetated Swales
- Flow Splitters
- Level Spreaders
- Permeable Road Bases

Chapter Contents:

Section 8.1
VEGETATED SWALES

September 2010

Vegetated swales are broad shallow earthen channels with a dense stand of vegetation. The combination of low velocities and vegetative cover promotes settlement of particulates and some degree of treatment by infiltration. The judicious use of low velocity swales can also help attenuate the volume and peak rate of runoff.

The use of check dams and wide depressions in swales increase runoff storage and promote greater settling of pollutants. Check dams create small infiltration pools along the length of the swale, which are used to retard and temporarily impound runoff to induce infiltration and promote filtering and settling of nutrients and other pollutants. Because of their limited ability to remove dissolved pollutants, vegetated swales should generally be viewed as pre-treatment systems. Grass filter systems are generally most effective when used in combination with other BMPs. Designers should seriously consider integrating redundant pollutant removal enhancement features such as stilling basins, stone infiltration or low-flow trenches, and check dams into swale systems (Galli, 1993). A typical vegetated swale with check dams is shown in Figure 8-1.

8.1.1 Site Suitability Criteria

1. Applicability: Vegetated swales are most applicable in residential or institutional areas where the percentage of impervious cover is relatively small. While swales are generally located along rear or side property lines of residential lots, they are also used along roadways instead of curbs and gutters. Roadside

IMPORTANT
Design Tips

- Provide increased swale widths and flatter cross-sections if the swale must be crossed or maintained with large equipment.
- Provide 15 foot easements on either side of the swale to allow access by heavy equipment.
- A flow velocity of 1 foot per second (fps) will provide the greatest water quality benefit. Higher velocities are permissible for channel stability, but could result in resuspension of settled particulates. The maximum allowable Q_{10} velocity should be less than 3 fps.
- Provide a minimum of 2 feet of soil between the bottom of the swale and the top of an underdrain pipe, if used.
- Provide scour protection downstream of checkdams.
- Design check dams should be designed to infiltrate ponded water behind them within 12 hours.

swales become less feasible as the number of driveways requiring culverts for swale crossings increases.

2. Slopes: Areas with steep slopes may limit the use of swales. In such areas, swales should parallel the contour, in effect becoming diversions. If the slopes are too steep, the construction of low velocity swale cross sections may involve excessive disturbance of existing grades to provide stable backslopes.

3. Flow Volume/Velocity: Vegetated swales are most effective when the flow depth is shallow and the velocities are low.

4. Using Natural Swales: Existing channels should only be used when they are shown to conform with the same design requirements that apply to new facilities. Existing ditches should be checked to ensure that they have adequate capacity and that their channels are stable. Gullied, natural channels should be avoided where they are impractical to stabilize.

8.1.2 Design and Construction Criteria

1. Soils: Soils should be suitable or be amended to establish a vigorous stand of vegetation. If dense vegetation cannot be maintained in the swale, its effectiveness will be severely reduced. Sites on A or B hydrologic group soils will be more effective for infiltration, although swales on other soils will still provide some treatment through sedimentation.

2. Flow Duration: To be effective in removing stormwater pollutants, swales must not be subjected to low flows of long duration and not kept wet for long pollutant removal as constant wetness will keep the soil saturated and may kill the vegetation reducing pollutant removal. The success of a swale system is enhanced by good stormwater management throughout its watershed. Good management practices reduce the peak rate of runoff and the volume of water to be carried, infiltrated, or filtered by the waterway. Effective erosion control practices will limit the pollutant loading to the waterway.

3. Equipment Access and Crossings: If the swale or waterway must be crossed or maintained with large equipment, the width should be increased and flatter cross-section incorporated into the design. Large mowing equipment may require a significant increase in width over that needed for hydraulic capacity and freeboard. This problem deserves careful study in each project area so that the proper modifications are made in swale width and side slopes to meet the needs of equipment common to the locality. Easements of sufficient width to allow access by equipment (typically 15 feet minimum) must be provided on either side of the swale.

4. Wildlife Habitat: In order to increase the wildlife habitat potential of these systems, it is recommended that an additional, minimum 10-12 foot wide, no-mow buffer strip be incorporated into their design. This buffer strip should be located between the swale and developed areas, and could be planted with a variety of food-producing grasses/small shrubs and/or native wildflowers. This buffer can also serve as a physical separation from other lawn areas in order to discourage equivalent levels of mowing.

5. Flow Velocity: The channel should be designed for low velocity flow. A velocity of 1 fps is the maximum design storm flow velocity recommended when vegetated swales are being designed as a BMP. Higher velocities might be permissible for channel stability, but could result in resuspension of settled particulates. The maximum allowable Q10 velocity should be less than 3 fps.

6. Flow Depth: Flow depths in the swales should be minimized to increase the amount of vegetative filtering and settling. A maximum design flow depth of 1 foot is suggested. This will generally result in wide, shallow channel designs.

7. Minimum Channel Dimensions: The minimum width of the flat bottom of a trapezoidal channel shall be at least 3 times the channel depth. Non-trapezoidal channels should have similar depth to width relationships. Channel side slopes shall not exceed 3 (horizontal):1 (vertical) for seeded or sodded slopes, or 2:1 for riprap slopes, although the channels may be parabolic or trapezoidal (Maryland, 1984). A V-shaped swale is not recommended.

8. Vegetation: Vegetation for swale linings should be selected based on soils and hydrologic conditions at the site, in accordance with applicable Erosion and Sediment Control BMPs described in the Maine Erosion and Sediment Control BMPs, (2003). Recommended grasses include Ky-31 tall fescue, reed canary grass, redtop, rough stalked blue grass, and mixtures thereof (Galli, 1993).

9. Construction Considerations: Construct and stabilize the waterway in advance of any other channels or facilities that will discharge into it. Divert all flow from the waterway during the establishment period.

10. Use with Check Dams: The use of swales with check dams can enhance the pollutant removal efficiency. The following criteria should be followed when incorporating check dams into swales:

a. Separation from Seasonal High Water Table & Bedrock: The recommended depth to seasonal high groundwater or bedrock for a swale using check dams is a minimum of 3 feet.

b. Use with infiltration trenches: The use of swales with check dams can enhance the effectiveness of infiltration trenches when constructed above the trenches. The pool created by each check dam increases the volume of runoff infiltrated into the trench, while the vegetated swale helps to filter out suspended solids and other runoff pollutants. Refer to Chapter 6 Infiltration BMPs.

c. Alternative to curb and gutter design: Swales with check dams are excellent alternatives to conventional curb and gutter design for roadways and are generally less expensive to install, where road gradients and availability of land within or adjacent to the right-of-way allow.

d. Check Dam Design: The check dam should be constructed of durable rock or rock-lined material so that it will not erode. The area just downstream of the check dam should be protected from scour with properly designed rock riprap or protective channel lining. The check dam may have a solid level surface integrated into it for added durability. Check dam heights are generally 6 to 12 inches, depending on channel slope and desired storage capacity. The check dams should be notched or ported to allow the flows in excess of their infiltrative capacity to be bypassed. Check dams should be designed so that the water ponded behind them will infiltrate in 12 hours or less (Galli, 1993).

8.1.3 Maintenance

1. Mowing: Grass should not be trimmed extremely short, as this will reduce the filtering effect of the swale (MPCA, 1989). The cut vegetation should be removed to prevent the decaying organic litter from adding pollutants to the discharge from the swale. The mowed height of the grass should be 2-4 inches taller than the maximum flow depth of the design water quality storm. A minimum mow height of 6 inches is generally recommended (Galli, 1993).

2. Routine Maintenance and Inspection: The area should be inspected for failures following heavy rainfall and repaired as necessary for newly formed channels or gullies, reseeding/sodding of bare spots, removal of trash, leaves and/or accumulated sediments, the control of woody or other undesirable vegetation and to check the condition and integrity of the check dams.

3. Aeration: The buffer strip may require periodic mechanical aeration to restore infiltration capacity. This aeration must be done during a time when the area can be reseeded and mulched prior to any significant rainfall.

4. Erosion: It is important to install erosion and sediment control measures to stabilize this area as soon as possible and to retain any organic matter in the bottom of the trench.

5. Fertilization: Routine fertilization and/or use of pesticides is strongly discouraged. If complete re-seeding is necessary, half the original recommended rate of fertilizer should be applied with a full rate of seed.

6. Sediment Removal: The level of sediment deposition in the channel should be monitored regularly, and removed from grassed channels before permanent damage is done to the grassed vegetation, or if infiltration times are longer than 12 hours. Sediment should be removed from riprap channels when it reduces the capacity of the channel.

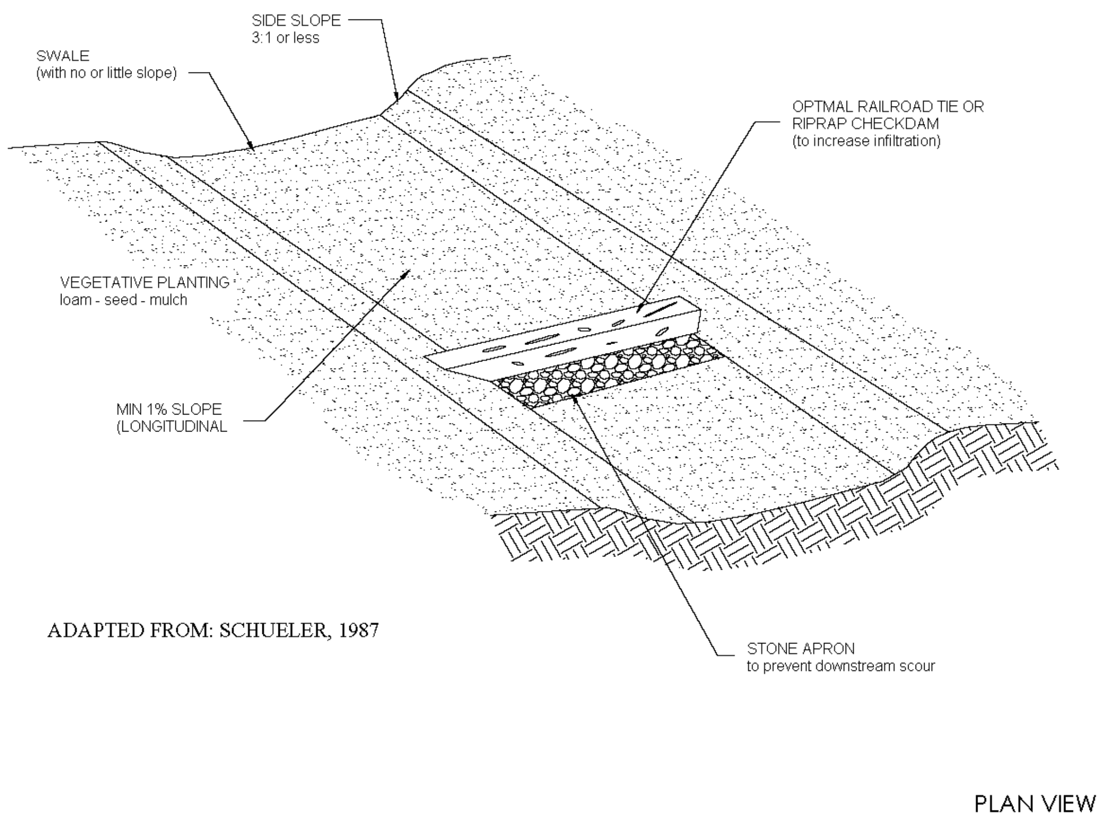


FIGURE 8-1. TYPICAL SWALE WITH CHECKDAMS

Section 8.2
FLOW SPLITTERS AND BY-PASS

September 2010

A flow splitter is an engineered structure used to divide flow into two or more directions. Its design uses specifically sized catch basins, pipes, orifices, and weirs set at specific elevations to control the direction of flow. Generally, a flow splitter will consist of a small storage area having one inlet and two outlets set at different elevations. The lower outlet is sized to convey low flows, such as the flow during a small storm or the flow at the beginning of a large storm. The higher outlet is sized to convey high flows that occur later in a larger storm. In this way, low flows can be conveyed to one area and high flows to another area. The flow splitter has one primary purpose for stormwater management, which is to break up flows from a given storm for water quantity or water quality control.

IMPORTANT

Flow splitters are used to divide flow into two or more parts; they do not provide any water quality treatment or quantity control. Flow splitters must be designed by someone familiar with hydraulics.

Water Quantity Control - A flow splitter can be used to split runoff volume to alleviate downstream flooding due to development or it can also be used to prevent a BMP, such as a wet pond, from overtopping and eroding due to excessive runoff during large storms. This can reduce the needed storage capacity, reducing the cost of building the BMP.

Water Quality Treatment - A flow splitter can be used to separate the first flush volume from runoff later in the storm. By doing so, it keeps the first flush volume, which can contain most of the runoff pollutants, from being diluted by later runoff. This also allows a longer treatment time within wet ponds; extended detention wet ponds, and created wetlands. These BMPs depend on plug flow and long retention times to have efficient pollutant removal. Without a flow splitter, runoff later in the storm would push the first flush out the outlet before the pollutants are removed. A basic example of a flow splitter is shown in Figure 8-2.

8.2.1 Design Criteria

Flow splitter design, to be effective, must be done by someone familiar with hydraulics. A badly-designed splitter can severely impede the function of the rest of the drainage system. The specific requirements for each design have to be done on a case by case basis. Only basic criteria are given below.

1. Head Loss: The flow splitter should be designed to minimize head loss by avoiding abrupt transitions in flows. Flow deflectors provide a gradual transition for flow and should be included in most designs

2. Outlets: The splitter must outlet to stable areas.

3. Construction Considerations: The functioning of a flow splitter depends on its construction as much as its design. Precise setting of elevations and grades are crucial to its performance. The splitter should be set using accurate leveling techniques by a licensed surveyor. "Eyeing-in" a splitter is not acceptable.

4. Erosion Control: Flow splitters built within drainage ditches may need additional armoring to withstand turbulent flows. The area where the flow will split should be well-protected with riprap or concrete.

5. Access: Because flow splitters involve a transition from larger pipes and channels to smaller pipes and channels, blockage is a problem. Debris that flows freely into the splitter may block the splitter's outlets. Thus, access to the splitter for routine removal of debris is a necessity.

8.2.2 Maintenance

A flow splitter should be checked regularly and after every large storm to remove debris within the splitter.

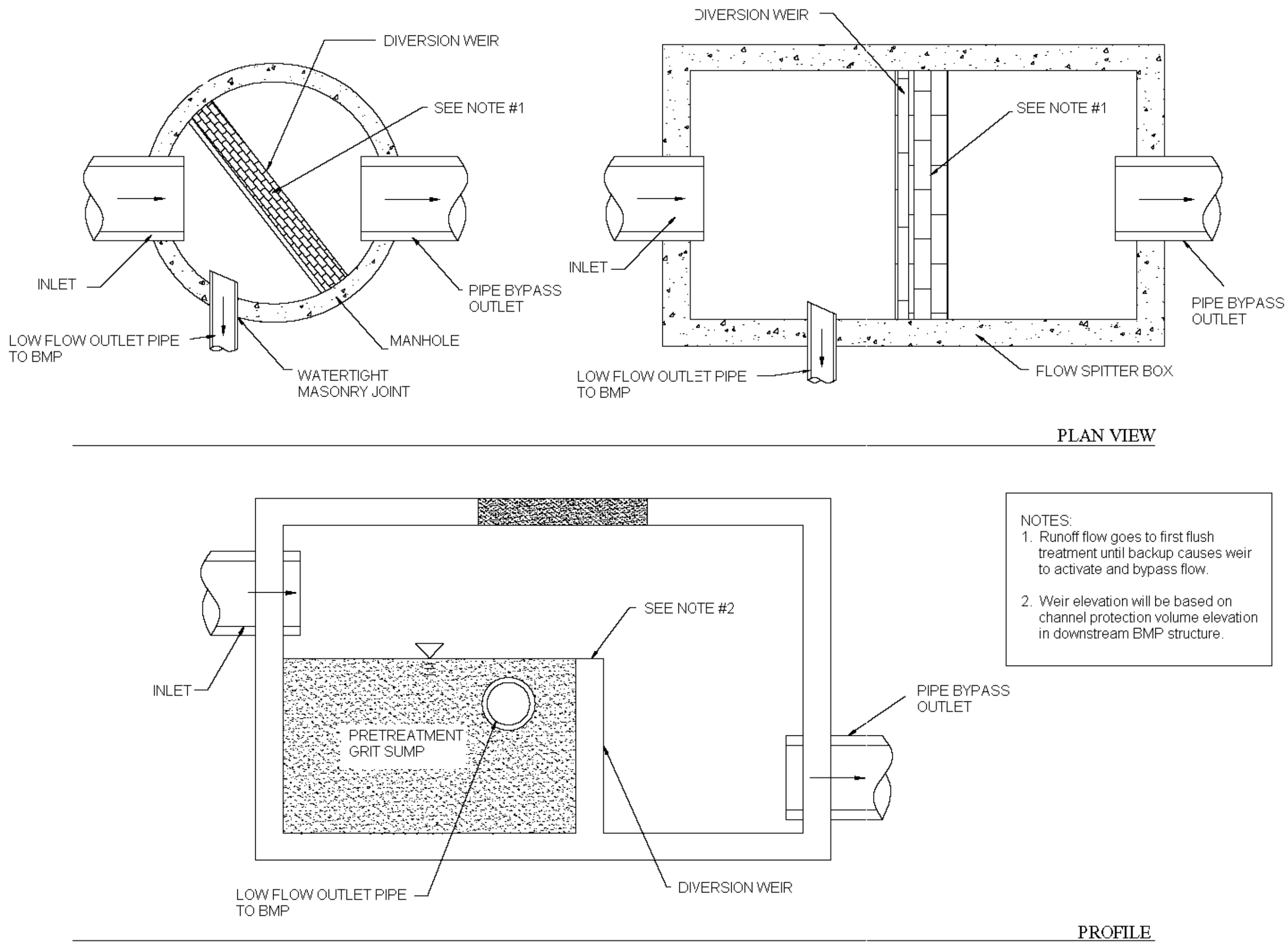


FIGURE 8-2. FLOW SPLITTER

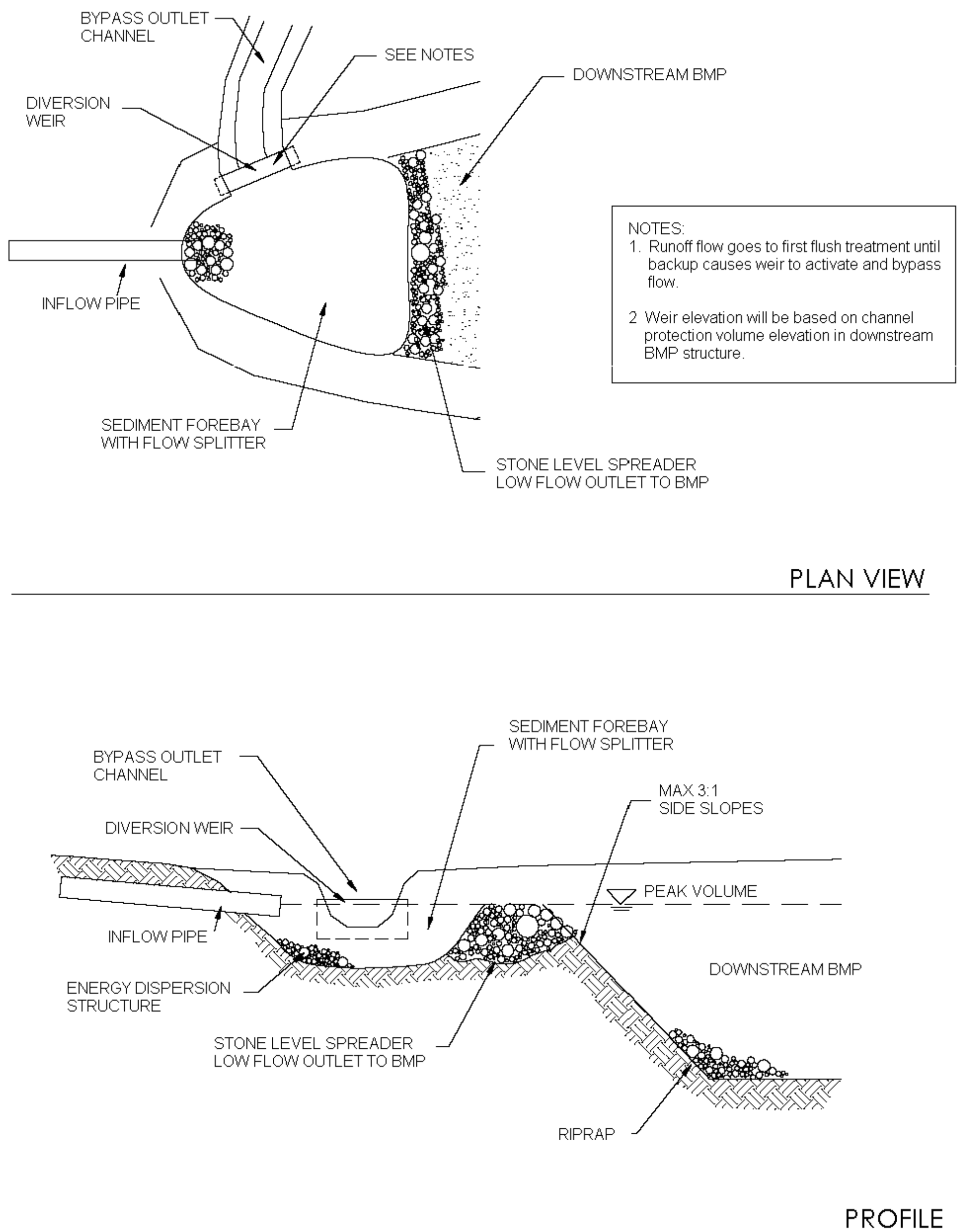


FIGURE 8-3. TYPICAL SURFACE FLOW SPLITTER IN FOREBAY

Section 8.3
LEVEL SPREADER

September 2 010

A level spreader is a vegetated or mechanical structure used to disperse or "spread" concentrated flow thinly over a receiving area. Level spreaders reduce erosion and movement of sediment and also assist to filter sediment, soluble pollutants, and sediment-attached pollutants. They are generally used where concentrated flows are discharged to the ground and serve to convert the concentrated flow to sheet flow to prevent erosion of the downstream receiving area. They are generally used to disperse flows over a relatively flat receiving area such as a buffer or swale to ensure uniform distribution of flow and minimize the channelization of water. Level spreaders are not designed to remove pollutants from stormwater; however, some suspended sediment and associated phosphorus, nitrogen, metals and hydrocarbons will settle out of the runoff by settlement filtration, infiltration, absorption, decomposition and volatilization.

8.3.1 Site Suitability Criteria

1. Drainage area: The maximum drainage area to the spreader may not exceed 0.10 acre per foot length of level spreader lip if the level spreader is not discharging directly to a buffer and is only used to dissipate flow volume and velocity. The drainage area served by the spreader discharging directly cannot be more than half the size of the receiving buffer area.

2. Slope: The maximum slope of the receiving area below a level spreader should be no more than 30%. If the slope is greater than 30%, the discharge will need to be brought by a conduit and velocity dissipator to an area that is suitable.

IMPORTANT

This section discusses the design of a level spreader to convert concentrated flow to sheet flow to prevent erosion of downstream receiving areas and to lengthen time of concentration to reduce peak flows. The use of level spreaders with buffers for water quality purposes must follow the design criteria in Chapter 5 Buffers.

8.3.2 Design and Construction Criteria

These standards are not applicable for level spreaders discharging runoff to buffers used to meet the Department's General BMP Standards. Requirements for these level spreaders can be found in Chapter 5 for buffers.

1. Discharge to a Level Spreader: The peak stormwater flow rate to a level spreader due to runoff from a 10-year, 24-hour storm must be less than 0.25

cubic feet per second (0.25 cfs) per foot length of level spreader lip.

2. Length of Level Spreader: The level spreader length may not be more than 25 feet unless approved by the department.

3. Sitting of Level Spreader: The level spreader must be sited so that flow from the level spreader will remain in sheet flow until entering a natural or man-made receiving channel.

4. Capacity: The capacity of each level spreader shall be based on the allowable velocity of the receiving soil. The flow area upstream of the level spreader shall be sufficient to ensure low approach velocities to the level "lip". The minimum flow area shall be equal to the flow area of the delivery channel.

5. Buffer: Each level spreader shall have a vegetated receiving area with the capacity to pass the flow without erosion. The receiving area shall be stable prior to the construction of the level spreader. The receiving area shall have topography regular enough to prevent undue flow concentration before entering a stable watercourse but it shall have a slope that is less than 30%. If the receiving area is not presently stable, then the receiving area shall be stabilized prior to construction of the level spreader. This will limit construction to the growing season.

6. Berm: The berm of the level lip should consist of crushed rock with a three-quarter to three inches in diameter size gradation that will allow flows to slowly seep through the berm, a minimum of 18 inch high and 3 feet wide. The berm should have a 6 to 12 inch deep header channel with a 3-foot bottom width to trap sediments and reduce lateral flow velocities behind the berm. The bottom and back of the spreader channel should be lined with erosion control matting.

7. Installation: A level spreader must be installed correctly with 0% grade on the spreader base and lip to ensure a uniform distribution of flow; otherwise the structure may fail and become a source of erosion.

8. Upstream Velocity: The flow area upstream of the level spreader shall be controlled to ensure low approach velocities to the level "lip." The minimum flow area of level spreader shall be equal to the flow area of the delivery channel. The base and lip shall be installed at a 0% grade (level).

9. Receiving Area: Level spreaders shall blend smoothly into the downstream receiving area without any sharp drops or irregularities to avoid channelization, turbulence and hydraulic jumps. The receiving area below the level spreader shall be protected from harm during construction. Sodding and/or netting in combination with vegetative measures shall stabilize disturbed areas. The receiving area shall not be used by the level spreader until stabilization has been accomplished. A temporary diversion may be necessary in this case.

10. Undisturbed Soils: Level spreaders shall be constructed on undisturbed soil where possible.

11. Entrance Drainage Channel Design: The entrance channel to the level spreader is constructed across the slope and consists of a combination of stone and existing natural vegetation used to disperse, filter and lower the runoff velocity into the level spreader. The entrance channel shall blend smoothly into the downstream receiving area without any sharp drops or irregularities, so to avoid turbulence and hydraulic jumps.

a. Shape: The entrance channel is typically trapezoidal in cross section, but may be parabolic as long as the soil bed design width is equivalent to the design bottom width for a trapezoidal section and is no more than 2 feet deep. Trenches shall be constructed along the existing contour and shall be 15-20 feet long and at least 7 feet wide across the top.

b. Bottom Width: Bottom width for a trapezoidal cross section of the entrance channel should be a minimum of two feet.

c. Side Slopes: Side slopes of the entrance channel shall be 2:1 or flatter to provide pretreatment of runoff entering the level spreader.

d. Longitudinal Slope: The longitudinal slope of the entrance channel should be 1% grade or less in order to avoid excessive velocity and deep water at the downstream end when ponding. If topography dictates a steeper net channel slope, the swale can be broken into relatively flat sections by check dams placed at no closer than 50 feet intervals.

e. Depth and Capacity: The swale should be designed to safely convey the 2 year storm with design velocities less than 4.0 to 5.0 feet per second. The swale should have sufficient total depth to convey the 10-year storm with 6 inches of freeboard.

8.3.3 Maintenance

Long term maintenance of the level spreader is essential to ensure its continued effectiveness. The following provisions should be followed. In the first year the level spreader should be inspected semi annually and following major storm events for any signs of channelization and should be immediately repaired. After the first year, annual inspection should be sufficient. Vegetated level spreaders may require periodic mowing. Spreaders constructed of wood, asphalt, stone or concrete curbing also require periodic inspection to check for damage and to be repaired as needed.

1. **Inspections:** At least once a year, the level spreader pool should be inspected for sand accumulation and debris that may reduce its capacity.

2. **Maintenance Access:** Level spreaders should be sited to provide easy access for removal of accumulated sediment and rehabilitation of the berm.

3. **Sediment Removal:** Sediment build-up within the swale should be removed when it has accumulated to approximately 25% of design volume or channel capacity. Dispose of the sediments appropriately.

4. **Debris:** As needed remove debris such as leaf litter, branches and tree growth from the spreader.

5. **Mowing:** Vegetated spreaders may require mowing.

6. Snow Storage: Do not store snow removed from the street and parking lot within the area of the level spreader.

7. Level Spreader Replacement: The reconstruction of the level spreader may be necessary when sheet flow from the spreader becomes channeled into the buffer.

Section 8.4 PERMEABLE ROAD BASE

September 2010

When surface water or groundwater is intercepted by a linear project such as a road, subsurface drainage techniques are required to drain the area and provide a solid base. Whenever possible, the roadgrade line should be placed above the watertable and well graded granular materials should be used for fill to prevent water from being drawn up into the fill by capillary action. Although the cost of installing such a drainage system is more than a normal road system, the long-term costs for maintenance will be reduced.

A good understanding of the seasonal groundwater fluctuation and any variation in lateral and vertical permeability is critical. But field investigations should be carried out during the wet season if possible to assess the groundwater table along the proposed route. Other necessary information is the soil's structure, the slope of the area and the native vegetation. However, because the initial investigation may not always identify all subdrainage problems for the road, it is critical that if discovered during construction, the road design must be altered at that time to incorporate a system that will allow unimpeded drainage.

The permeable road base (other common names are the French mattress or the rock sandwich) is a specialized road base consisting of coarse rocks that will allow water to freely pass and be discharge as sheet flow on the downgradient side of the road. It is designed to be used in wetlands to pass surface water and in road cuts and fills where the cut extends below the seasonal groundwater table in soils which groundwater seeps seasonally. It may be as narrow as a few feet or over several hundred feet. A permeable road base, unlike a culvert, does not concentrate water to a single entry and exit point but spread the water out over a distance equal to the with of the wetland crossing or intercepted groundwater thereby reconnecting the natural hydrology. Groundwater has enough latent heat to prevent the drainage layer from freezing. It is not designed to be used in concentrated flow areas or to handle just runoff water. It can be used in conjunction with a culvert if the wetland has concentrated flow channels or if the road cut is below seeping groundwater from the embankment, a surface water discharge in a low swampy area or the groundwater table.

The benefits of a permeable road base are as follow:

- They reconnect intercepted hydrology in a much more natural manner than culverts.
- When dispersed to a vegetated buffer, they assist in the treatment of road runoff by non-structural

methods avoiding the need for costly and time consuming installation of structured systems.
- They require little maintenance compared to cross-culverts.
- They have a wide discharge area that does not concentrate flows which can scour soil similar to the discharge from a culvert.
- They significantly strengthen the road base on soft soils.
- They prevent groundwater from wicking up into the road fill material; thus minimizing the potential for frost action and potholing.
- They provide an indefinite service life compared to a cross-culvert.

The following linear types of subdrainage systems are acceptable if a discharge point is established on a narrow spacing and if the discharge is a stable area that will allow the dispersion of flow via a level spreader.

1. **Pipe underdrain.** This system consists of perforated pipe placed at the bottom of a narrow trench and backfilled with a filter material such as coarse sand. It is generally used along the toes of cut or fill slopes. The trench should be below the groundwater surface and dug into a lower, more impervious soil layer to intercept groundwater. The drains may be made of metal, concrete, clay, asbestos-cement, or bituminous fiber and should be 6 inches in diameter or larger.

2. **French drains.** This system consists of trenches backfilled with porous material, such as very coarse sand or gravel. This type of drain is apt to become clogged with fines and is not recommended.

8.4.1 Site Suitability

The primary function of a permeable road base is to allow intercepted surface and/or groundwater to pass from one side of the road to the other over the entire width in which it is intercepted. Sites where the structure is most useful are for wetland crossings and for sections of road where cuts are made below the seasonal groundwater table where there is a large contributing watershed and the soils are medium to coarse textured so that there is a significant amount of groundwater passing through them. Commonly, the groundwater in these soils is oxygenated so they are not considered wetlands even though they have a high seasonal groundwater table.

8.4.2 General Design Criteria

The road base consists of 3” – 6” stone “sandwiched” between layers of permeable filter fabric through which water can freely pass from one side of the road to the other as sheet flow. Both ends of the layer must be exposed so that water can enter and pass through it unimpeded. A permeable road base structure should be used in areas of:

1. Non-concentrated flows: areas where concentrated flows from a pipe may be undesirable, impractical, or regulated.

2. Road impoundment: In areas where a road is acting as an impoundment or dam to the natural water flow by isolating subsurface water on one side of the road from the other.

3. Shallow bedrock depth: Areas where placement of a pipe at the depth necessary to provide structural cover would lower the natural water table of the area and require long term maintenance.

4. Wetland crossing: Low-lying areas near streams or wetlands where maintaining sheet flow would be difficult.

5. Road load bearing: A filter fabric and rock layer in the lower portion of a road provides bearing strength. The water collects in the voids provided by the larger rock and moves away by gravity rather than softening the subbase soils.

8.4.3 Specific Design Criteria

1. Site Preparation: To minimize the alteration of wetlands, do not stump and grub wetland surfaces under the road footprint. Cut trees close the ground, leaving the stumps in place which will provide added structural support to the additional weight. This woody debris will not decompose as it will be anaerobic. The intact soil surface is less of a threat to move and plug up the drainage layer. In cut and fill roads, minimize ground disturbance and avoid excavating ditches!

2. Bottom geotextile: After the site has been prepared, place a permeable woven/non-woven filter fabric over the length of roadway. Filter fabric "joints" should overlap by at least 18".

3. Material: the core material of the drainage layer is a minimum of 12" thick layer of clean 3"-6" diameter stone on the fabric for the full width of the roadway.

4. Top geotextile: Place permeable, non-woven filter fabric on top of the entire length of rock layer. Do not cover the upgradient and downgradient sides (lateral sides of the road) of the rock layer with filter fabric or soil. Leave these areas exposed so that surface water from the upslope part of the wetland can pass unimpeded to the downslope part of the wetland.

5. Upgradient soil disturbance: If inadvertent soil disturbance has occurred on the upslope side of the permeable road base layer, place stone on the disturbed soil so that it will not migrate and plug the drainage layer.

6. Road fill and road base: Place additional road fill as designed and the driving surface material over the top filter fabric according to specifications and procedures (minimum of 6" recommended after compaction). However, when more than 2-3 feet of fill is needed to bring the road grade up to the desired elevation, a third layer of filter fabric should be added to provide structure to the fill and prevent the fines in the subbase from moving through the fill and to the permeable drainage layer.

7. Upgradient of cut slopes: Place a layer of 3"-6" stone on cut face up to the height of seeps. This allows for seepage to reach the permeable drainage layer in the roadbed while holding the soil in place.

8. Downgradient of fill slopes: Do not cover the downslope edge of the permeable road base layer with geotextile so that water can freely be diffused back into sheet flow and that the slope is protected.

9. Culverts in a permeable road base structure: If the crossing has a stream, a defined drainage way or larger concentrated flows are anticipated, a culvert should be installed according to appropriate design standards. The culvert should be installed where its invert is at least 3” above the elevation of the bottom of the drainage layer to assure that base flows can sheet flow through it rather than at the culvert which should activate only during high runoff flows.

8.4.3 Maintenance

Check upslope face of stone layer to prevent clogging by eroded soil, road sand, debris and leaf litter.

Chapter 9
Separator BMPs

A number of devices, structures and systems are available for providing varying levels of pretreatment of stormwater before it enters a BMP. These range from the relatively simple modified catch basin (catch basin with a sump and oil trap) to the sophisticated (and expensive) coalescing plate oil separator. The devices discussed in this Chapter include:

- Water Quality Inlet
- Oil/Grit and Oil/Water Separator
- Proprietary Systems

9.1 Water Quality Inlet

9.1.1 Description

IMPORTANT

Water quality inlets are generally deep sump catch basins with the outlet fitted with a hood. They are used to remove coarse sediments and hydrocarbons from stormwater runoff. They are most appropriate as pretreatment structures for other types of water quality BMPs.

The water quality inlet is a conventional stormwater drainage structure (catch basin) provided with a sump and a hood. The sump is intended to trap coarse sediment and non-floating debris. The hood is intended to prevent floating debris and floating hydrocarbons from exiting the catch basin. Figure 9-1 shows a typical water quality inlet with hood.

High flow events can result in mixing within the basin and resuspension of accumulated sediment, so the contributing watershed should be kept relatively small. Also, size limits on commercially available hood castings limit the allowable size of the outlet pipe from the catch basin.

Catch basins are useful in limiting the volume of debris and coarse sediment that may be conveyed to another stormwater management facility and should be considered as a component of an overall

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piped drainage system, as a relatively low cost device for intercepting coarse sediment and debris that would otherwise consume available capacity or clog the pipe network or downstream management facilities. Existing catch basins may be readily modified, in some instances, to retrofit an existing system to intercept coarse sediment and floating debris.

9.1.2 Design Criteria

The following design criteria should be followed at a minimum:

1. **Sump:** A water quality inlet should be provided with a four foot (minimum) sump to collect sediments. Larger sumps should be provided in areas to receive heavy sanding or where a heavy sediment load is anticipated.

2. **Hood:** Hood dimensions are generally determined by pipe size, and are commercially available through a number of vendors as stock items. They typically use a cover, an elbow or tee with the inlet of the fitting pointed toward the floor of the basin. However, it must be properly vented to allow the basin to drain. A vent must extend to above the anticipated high water level within the basin, so that floating material does not overflow the fitting and exit the basin. A threaded cap should also be placed in-line with the pipe for cleaning access.

9.1.3 Maintenance

Regular maintenance is imperative to remove the sediment from the sump and any floating debris and products for the continuity of the effectiveness of the structure. When sediments are visible at the bottom of the outlet pipe, the sump is full and needs cleaning.

1. **Inspection:** Water quality inlets should be inspected three to four times annually, depending on their performance.

2. **Sediment Removal:** Sediment should be removed when it accumulates within 6 inches of the bottom of the hood, but not less than twice a year.

Selected References

Schueler, T.R. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs.* Metropolitan Washington Council of Governments, Washington DC.

Schueler, T.R, P.A. Kumble, and M.A. Heraty. 1992b. *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* Metropolitan Washington Council of Governments, Washington, D.C.

9.2 Oil/Grit and Oil/Water Separators

9.2.1 Description

IMPORTANT

Oil/grit and oil/water separators are used to remove coarse sediments and hydrocarbons from stormwater runoff. They are most appropriate as pretreatment structures for other types of water quality BMPs.

Oil/grit separators are chambers designed to remove sediment and hydrocarbons from urban runoff and are also effective for removing floating trash from runoff. They are normally used close to the source before pollutants are conveyed to storm sewers or as pretreatment for other BMPs such as infiltration trenches. Oil/grit separators are typically used in areas with heavy traffic or high potential for petroleum spills such as parking lots, gas stations, roads, and loading areas.

Runoff is only detained briefly in conventional oil/grit separators, so only moderate removal of coarse sediments, oil, and grease can be expected. Even more limited removal is likely for fine-grained sediment and pollutants attached to the sediment, such as trace metals and nutrients. Soluble pollutants will most likely pass through oil/grit separators.

The use of an oil/grit separator to pre-treat flows of stormwater runoff ahead of structural BMPs, i.e. as a "forebay", can provide economic and environmental benefits. The structures are easily accessible and can be located underground, minimizing valuable space. However, the structures have limited pollutant removal capability and require frequent cleanout.

9.2.2 Design Criteria

A typical oil/grit or oil/water separator (Figure 9-2) has two chambers. Runoff enters the first chamber, which contains a permanent pool of water. Coarse sediment is trapped in this chamber by settling. The first chamber can also trap floating trash and debris, such as leaves.

Runoff then passes through an orifice to the second chamber which also contains a permanent pool of water. An inverted pipe elbow which draws water from the lower part of the pool discharges to the storm drainage system. By drawing water from below the surface, floating oil and grease are trapped. Some hydrocarbons may become adsorbed to sediment particles which settle out.

The following provides some guidance on oil/grit or oil/water separator design:

1. **Pool Storage:** In order for the structure to provide even moderate pollutant removal benefits, at least 400 cubic feet of permanent pool storage should be provided per acre of drainage area (MPCA). Also, the pool should be at least 4 feet deep.

2. **Access:** Manhole access should be provided to each chamber to allow for cleaning.

There are several proprietary oil/grit and oil/water separator devices available and the designer is encouraged to investigate alternative designs that may be applicable to the treatment or pre-treatment of stormwater. For selection and design of proprietary oil/grit separator devices, refer to the product literature for these structures.

9.2.3 Maintenance

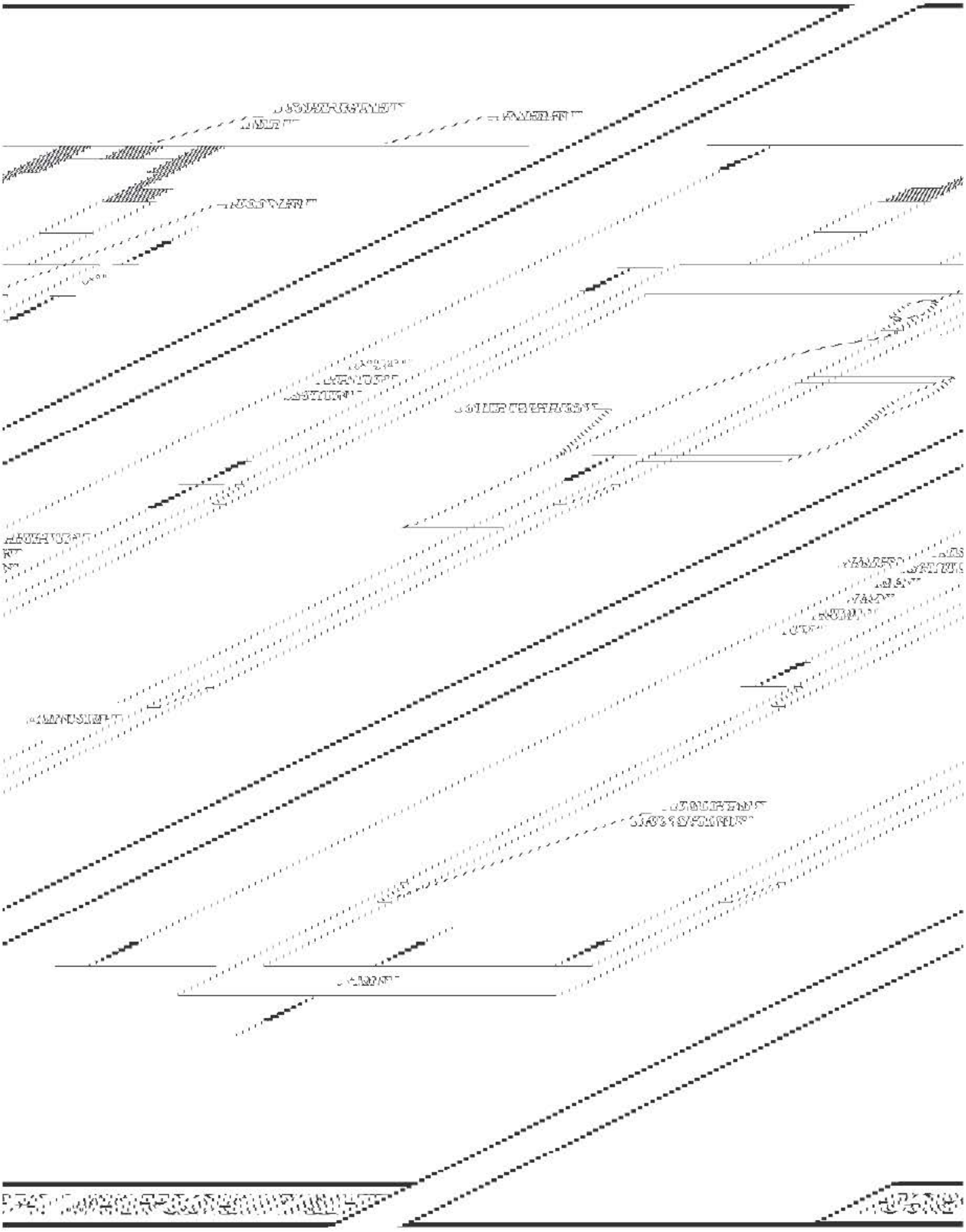
In order to have any effectiveness for pollutant removal, oil/grit separators are very dependent on the regular and frequent clean-out of trapped sediments. Oil/grit separators should be cleaned out at least twice a year in order to maintain their pollutant removal capabilities. Failure to clean them out on a regular basis can result in mixing of floating hydrocarbons into the water column and resuspension and loss of previously trapped material. The designer should consult the Maine DEP Bureau of Hazardous Materials and Solid Waste Control to determine options for disposal of the oil-contaminated water sediment and slurry that will be removed during cleaning prior to the installation of these devices at a site.

Selected References

Schueler, T.R. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs.* Metropolitan Washington Council of Governments, Washington DC.

Schueler, T.R, P.A. Kumble, and M.A. Heraty. 1992b. *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* Metropolitan Washington Council of Governments, Washington, D.C.

9.3 Proprietary Systems



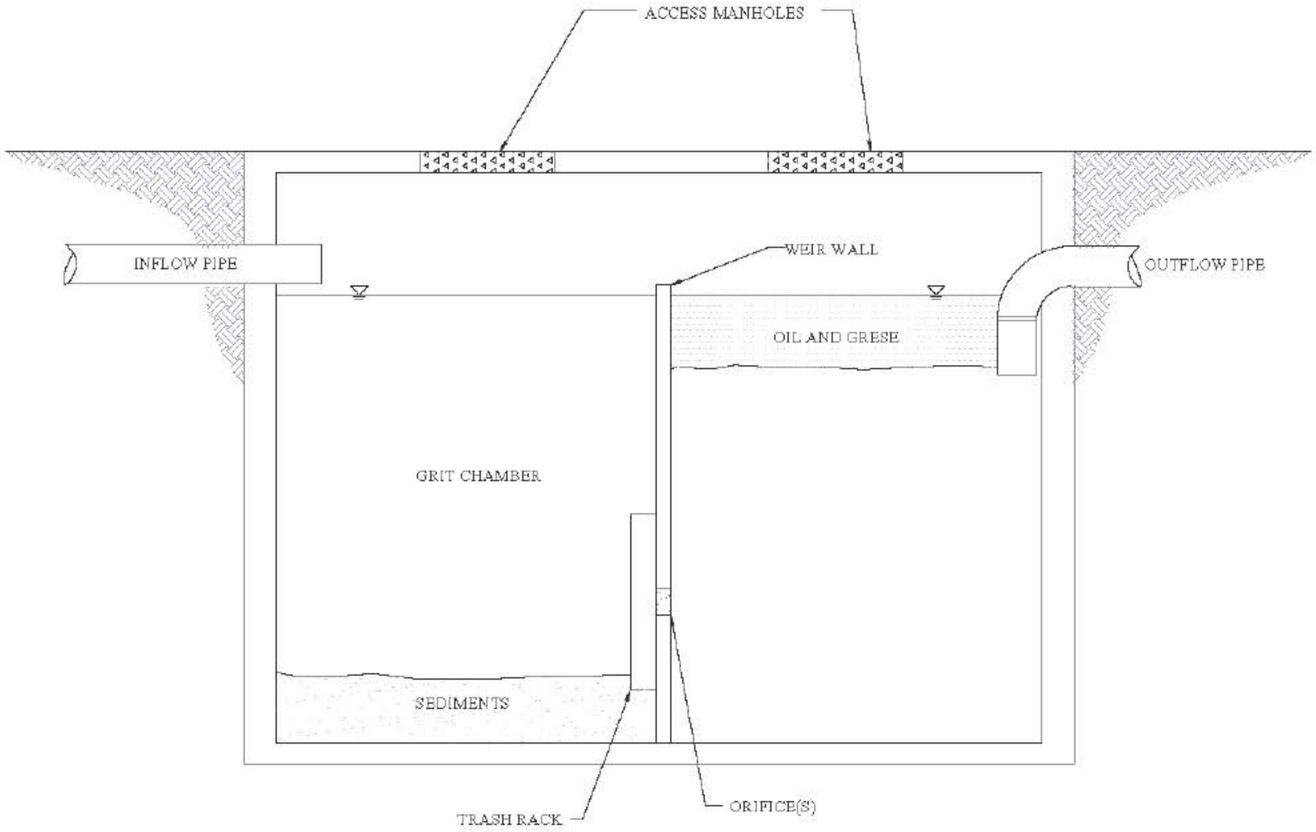


FIGURE 9-2. TYPICAL OIL/GRIT SEPARATOR

Chapter 10
LID Design Practices and Techniques

IMPORTANT

ME DEP strongly encourages the use of LID measures. LID helps reduce stormwater impacts by minimizing developed and impervious areas on a site and through the incorporation of runoff storage measures dispersed throughout a site.

Description

Low impact development (LID) is a process of developing land to mimic the natural hydrologic regime. It incorporates land planning and design practices and technologies to achieve this objective. LID begins at the design phase of a new development, incorporating planning techniques to minimize site clearing and impervious surfaces. This first step helps to reduce stormwater runoff generated from the site. By reducing the volume of water leaving a site, the pollutant loading is also reduced - less runoff equals fewer pollutants. Other low impact development techniques are then incorporated into the design and used throughout the site to keep the runoff that is generated from the site on the site. When incorporated and designed properly, LID reduces both the volume and peak flow rates of runoff generated from a development. LID is an effective tool to protect stream flows, minimize stream channel erosion, reduce pollutant loadings and reduce thermal impacts.

The use of LID practices has benefits to the developer, the municipality in which it is being used, and the environment. These include:

Chapter Contents:

Benefits to the Developer
- Reduces land clearing and grading costs
- Reduces infrastructure costs
- Reduces stormwater control costs
- Increased house lot value - more income

Benefits to the Municipality
- Protects open space
- Protects drinking water quantity
- Keeps drinking water pure
- Promotes water conservation
- Reduces maintenance costs associated with infrastructure

Benefits to the Environment
- Preserves the hydrologic cycle
- Protects streamflows
- Fish and wildlife benefits
- Reduces flooding and property damage from peak flows
- Protects streambanks from erosion

Site Suitability Criteria

LID is a concept that can be incorporated into any site development. It is not a rigid set of standards or a one size fits all approach. It is up to the design engineer to develop creative ways to prevent, retain, detain, use and treat runoff with features unique to that site. The planning components of LID can fit any site with any soil type. The key is to creatively design a site that minimizes site disturbance and the total amount of impervious surface created. The structural techniques generally involve infiltration, but can be adapted for retention by including underdrain filters for tight soils. The design criteria for infiltration and underdrain filters should be followed in these cases.

10.1 Planning for LID

Planning is the first step in incorporating LID into a new development. The developer should plan on investing more time and money in the initial planning phase, which can later be recouped through the reduced infrastructure and higher house lot sales. LID goals and objectives should be incorporated into the site planning process as early as possible. When incorporated at the early stages, LID site planning can allow for full development of the property, while maintaining natural hydrologic functions. The following steps serve as a guideline to use in the planning stage. Refer to the selected references for more information on planning and designing for LID.

1. Identify and preserve sensitive areas that affect the hydrology. Features that should be protected include floodplains, streams, wetlands, buffers, woodland conservation zones, steep slopes, and high-permeability soils.

IMPORTANT
Design Tips

It is critical to incorporate LID measures in the planning phase of a development. This will help to minimize stormwater runoff, which can reduce the size and cost of structural measures needed for ultimate treatment. The following planning components should be considered:

- Minimize site clearing
- Minimize impervious areas
- Minimize connected impervious areas
- Maintain time of concentration
- Manage stormwater at the site

2. Layout alternative development schemes to minimize site disturbance and impervious

area, while achieving full development of the site. This should incorporate the minimization of site clearing.

3. Once a layout is selected, minimize the impervious surfaces directly connected to drainage conveyance systems.

4. Incorporate LID techniques to control stormwater at the source. Think small and break the site into several smaller drainage areas that can be handled through simplistic LID practices.

Some of these key planning features are discussed further below.

10.1.1 Minimize Site Clearing

Development typically involves the creation of impervious surfaces such as roads and buildings, as well as disturbed pervious areas such as lawns and landscaped areas. Removal of topsoil and trees results in increased runoff, higher potential for erosion, decreased infiltration capacities, and decreased habitat. Removal of trees and topsoil also degrades the quality of the planting environment, resulting in landscapes that require high water usage and the application of fertilizers and pesticides, which results in greater environmental impacts and higher costs to the homeowner. Minimizing site clearing and directing development to areas that are less sensitive to disturbance reduces runoff and promotes groundwater recharge. For example, developing on lightly vegetated, tight clay soils will have less impact on stormwater runoff than clearing and developing on forested, sandy soils. Sensitive areas initially identified in the planning phase should not be developed.

The following standards should be followed to minimize site clearing.

- Identify and clearly show sensitive areas (i.e., floodplains, streams, wetlands, buffers, woodland conservation zones, steep slopes, and high-permeability soils), clearing and grading limit lines, stockpile areas, and proposed development when planning a new development. These should be included on the plans submitted for review and approval, along with the existing vegetation to be preserved.

- Place areas of development outside of sensitive areas.

- Avoid developing high-permeable soils.

- The amount of topsoil left for lawn and landscaped areas and any other disturbed pervious areas should follow the landscape design standards in Appendix B in Volume I. If topsoil is to be exported from the site, the cubic yards removed and the remaining depth of soil left for lawn/landscaped areas shall be noted for approval by the Department. The percent organic content of topsoil remaining in lawn areas should also be noted.

- Prior to commencement of construction activity, clearing and grading limit lines shall be staked in the field and checked by the Department.

10.1.2 Minimize Impervious Areas

Once the sensitive areas have been identified, the road and lot layouts should be developed. The traffic distribution network (roadways, sidewalks, driveways, and parking areas) is generally the greatest source of site imperviousness and these should be the focus for reducing impervious area. Impervious areas contribute significantly to the volume and rate of runoff from a development and their reduction will aid to reduce these impacts. Methods that can be used to reduce imperviousness are presented below:

- **Alternative Roadway Layout:** The layout of a subdivision and its roads contributes significantly to the amount of imperviousness. Alternative road layouts can be used to reduce total pavement, while allowing for the same number of lots. The use of cluster designs as opposed to the traditional grid design is one example of how changing road layout can considerably decrease imperviousness. This is illustrated in Figure 10-1. (grab figure 2-9 from Low-Impact Development Design Strategies, An integrated Design Approach, June 1999)

- **Narrow Road Sections:** Roadways often include paving of the primary driving surface as well as the shoulder and in many cases include a curb and gutter layout. The width of pavement can be reduced to include the primary driving surface only, providing pervious pavers for the shoulder and ditch drainage swale in place of the curb and gutter. This will reduce the total amount of site imperviousness, as well as minimize clearing and grading impacts, which results in lower construction costs. However, cities and towns must allow for the narrower roads in order for this option to be used.

- **Reduced Application of Sidewalks to One Side of Primary Roads:** Paved sidewalks add a significant amount of impervious area to a development. Where necessary, sidewalks should be reduced to one side of the road only. In other areas, such as on smaller secondary roads, sidewalks may be eliminated altogether.

- **Reduced On-Street Parking:** On street parking significantly increases the width of a road, and therefore total site imperviousness. Reduction to one side or elimination of on-street parking can potentially reduce overall site imperviousness by 25 to 30 percent (Sykes, 1989).

- **Rooftops:** Rooftops are also a source of imperviousness. The number and size of buildings will dictate the impervious area associated with rooftops. For example, larger one-story homes will result in more impervious surface than the same size homes built with two stories. Vertical construction is preferred over horizontal construction for this reason. In addition to reduction in total roof area, greenroofs are another option to reduce impervious surfaces. Greenroofs act to reduce the amount of runoff generated from the rooftop.

- **Driveways:** Minimizing paved driveway area can also reduce imperviousness. This can be accomplished through narrower driveways (maximum 9 feet wide) or minimizing setbacks from road to reduce length. The use of shared driveways will also help to reduce imperviousness. In addition to these options for reducing the size of the driveway, alternative materials may be used such as porous pavers or gravel to minimize the runoff from driveways. Alternative materials are discussed in more detail in section 10.2.6.

10.1.3 Minimize Connected Impervious Areas

No matter how much pre-planning is performed, there will be some impervious surfaces that will generate runoff. The impacts from these impervious surfaces can be minimized by disconnecting these areas from piped drainage networks and instead treating these at the sources. For example:

- Roof drains should be directed to vegetated areas rather than impervious surfaces and piped drainage networks.

- Paved driveways and roads should be directed to stabilized vegetated areas.

- Flows from large paved surfaces should be broken up and for on-site treatment of smaller flows. Breaking flows up allows the flows to be directed to vegetation as sheet flow.

- LID techniques should be used to treat flows from impervious surfaces. These should be dispersed throughout the development, such as at individual house lots to obtain the most benefit. They can be incorporated into the landscaping of the property to provide a natural treatment system.

10.1.4 Maintain Time of Concentration

Time of concentration (Tc) is the time it takes for stormwater runoff to flow from the furthest point in the watershed to the point of interest. It is based on the flow path and length, ground cover, slope and channel shape. When development occurs, the Tc is often shortened due to the impervious area, causing greater flows to occur over a shorter period of time. LID practices can be used to help maintain the pre-development Tc. These include:

- Increasing the flow length
- Increasing the surface roughness of the flow path
- Detaining flows on site
- Minimizing land disturbance
- Creating flatter slopes
- Disconnecting impervious areas, which will decrease their travel rates

10.1.5 Manage Stormwater at the Source

Once the development has been designed and the LID practices above have been incorporated, the remainder runoff from the site can be handled through various LID techniques, which are discussed further below. The key is to try to mimic natural hydrologic functions and the best way to do this is to mitigate impacts at the source. This allows for more even distribution of flows, rather than trying to control it at the end of the pipe. For example, using drywells to infiltrate roof runoff is a great method to prevent more street runoff that will become contaminated and add to the volume requiring treatment. It also helps in reestablishing a more natural hydrologic cycle.

Smaller treatment sites such as rain gardens and swales that only handle a small area use the soil matrix for treatment and are quite effective. These smaller sites have not been found to create groundwater pollution but instead the microorganisms in the soil rapidly break down pollutants and produce clean groundwater. Since so many areas have declining groundwater due to imperviousness (by prevention of recharge), this can help reestablish the natural hydrologic cycle and produce clean baseflow for stream discharge. The designs in Section 10.2 of this chapter give guidance on structural techniques that can be used to minimize runoff from development in northern climates. Using a combination of alternative designs will result in a more effective stormwater management design and may also provide more flexibility in site design by allowing a wider variety for locations of devices.

The cost benefits of this approach can be substantial. Typically, the most economical and simplistic stormwater management strategies are achieved by controlling runoff at the source.

Selected References

Comprehensive Environmental Inc. November 2003. *Design Guidelines and Criteria for Stormwater Management*. Milford, MA.

Prince George's County. June 1999. *Low-Impact Development Design Strategies: An Integrated Design Approach*. Largo, MD.

Sykes, R.D. 1989. Chapter 3.1 - Site Planning. University of Minnesota.

10.2 LID Techniques

Many of the LID techniques presented in this manual rely on infiltration, retention and evapotranspiration to minimize stormwater runoff. There are many sites in Maine where infiltration may not be a possibility. In these cases, the initial planning techniques described above should be the primary focus, followed by underdrained techniques that rely on soils and vegetation to retain and transpire stormwater runoff. When infiltration and/or underdrain filters are combined with the following LID techniques, the design criteria provided in respective Chapters 6.0 and 7.0 must also be followed.

10.2.1 Bioretention Areas and Raingardens

Bioretention areas or raingardens consist of a specific soil filter media, usually containing some percentage of organic material, planted with vegetation that can handle wet and dry conditions. These systems are built with a slight depression to allow shallow ponding of stormwater runoff as it infiltrates through the soil media and into the groundwater or an underdrained filter. The soil media and vegetation help reduce the volume of runoff through absorption and evapotranspiration. They are best used to treat small areas of runoff. Refer to Chapter 7.0 for further information on the performance and design of bioretention practices.

10.2.2 Infiltration

Infiltration involves the discharge of stormwater to the ground. It reduces the total runoff from a site and removes pollutants by filtration through the soils. Infiltration serves to mimic the natural hydrologic cycle by directing water into the ground, where it normally goes before development takes place. It is best to use smaller, dispersed infiltration techniques throughout a site to most effectively mimic the natural hydrologic cycle and to best fit it into the natural landscape. The most common forms of infiltration are infiltration basins, trenches and drywells, but with a little creativity, it can be incorporated into multiple forms of attractive BMPs that can be used in parking areas and landscaped settings. Refer to Chapter 6.0 for further information on the performance and design of infiltration practices. The design information in Chapter 6.0 should be followed for any infiltration practice.

10.2.3 Filter Strips/Vegetated Buffers

Vegetated filter or buffer strips use soils and vegetation to remove pollutants from storm water. Filter strips are typically used as pretreatment devices for bioretention cells and other infiltration practices, as the vegetation promotes sediment deposition from sheetflow. Buffers can be used as a stormwater BMP for small scale developments functioning to remove sediments and other pollutants and minimizing the amount of runoff generated. Refer to Chapter 5.0 for detailed information on the performance and design of vegetated buffers.

10.2.4 Vegetated Swales

Vegetated swales are typically used to convey flows to areas for treatment. They can replace conventional curb and gutter and piped systems, slowing stormwater velocities and increasing the time of concentration of flows, which in turn reduces peak flows. They also help to filter pollutants such as sediment from stormwater, and can be used as pretreatment to the ultimate treatment system. Refer to Chapter 8.0 for further information on the performance and design of vegetated swales.

10.2.5 Level Spreader

Level spreaders are typically used to convert concentrated flows into overland sheet flow. This allows for even distribution of runoff over land to minimize erosion that would normally occur with channelized flow. Refer to Chapter 8.0 for further information on the performance and design of level spreaders.

10.2.6 Porous Pavement

Porous pavement consists of the use of a permeable surface, base, and subbase materials which allow penetration of runoff through the surface and into the underlying soils. Pavement alternatives vary in load bearing capacities but are generally appropriate for low traffic areas such as sidewalks, parking lots, overflow parking and residential roads. It is important to choose a material appropriate for the desired use (light, moderate or heavy use). Maintenance is essential for long term use and effectiveness.

Porous pavement is essentially a means of infiltration, thus, pollutant removal will be similar to other infiltration practices. The efficiency of pavement alternative systems will depend on whether the pavement is designed to store and infiltrate most runoff, or only limited volumes of runoff (e.g., "first-flush") with the remainder discharged to a storm drainage system or overland flow. The effectiveness of pavement alternatives will also depend on the long term serviceability. Pretreatment of any off-site runoff that may be directed to the system is required to prevent clogging of the pavement structure and underlying soils.

This manual describes three different permeable pavement alternatives, each of which is appropriate for specific situations. These types include:

- Porous asphalt
- Block pavers
- Plastic grid pavers

Examples of these porous pavement alternatives are shown in Figure 10-2.

Types of Porous Pavement

A typical permeable pavement alternative consists of a top porous asphalt, block paver or plastic grid paver course, a filter course, a reservoir course, a geotextile filter fabric and existing soil or subbase material. Brief descriptions of three types of porous pavements are provided below. A comparison of the three alternatives is provided in Table 10-1, with general design and maintenance criteria provided further in this section.

<u>*Porous Asphalt*</u>

Porous asphalt is very similar to conventional asphalt except that it is mixed without particles smaller than coarse sand (less than 600 μm or No. 30 sieve). Without these smaller size particles water is able to pass through the surface and into a crushed stone storage area which allows the water to slowly infiltrate into the ground.

The lack of fine particles in the material limits the load capacity of the asphalt compared to conventional asphalt thus it should not be used for areas of high traffic. However, porous asphalt needs less stormwater conveyance systems and less other additional BMPs.

<u>*Block Pavers*</u>

Block pavers consist of a set of interlocking, normally concrete pavers that connect in a way to leave open or void spaces between them to allow water to infiltrate into the underlying gravel reservoir. Typical installation consists of a soil subgrade, a gravel subbase, a layer of bedding sand, and the grid pavers. The infiltration capacity is based on the thickness of the gravel subbase and the material in the void space. Void spaces can be filled with gravel or soil and grass.

<u>*Plastic Grid Pavers*</u>

Plastic grid pavers are often constructed from recycled material. They generally come in a honeycomb pattern and the voids are filled with either gravel or soil and grass depending on use. The grid pavers give added stability to and allow minimal compacting of soils in voids. They are flexible and can be used in areas with uneven terrain.

Table 10-1
Comparison of Porous Pavement

	Porous Asphalt	Block Pavers	Plastic Grid Pavers
Application	•Parking areas •Pedestrian walkways •Overflow & event parking •Roadways with light traffic •Tennis and basketball courts •Bike paths	•Parking areas •Pedestrian walkways •Overflow & event parking •Roadways with light traffic •Driveways •Medians •Fire lanes	•Parking areas •Pedestrian walkways •Driveways •Fire lanes •Emergency access roads •Golf cart paths •Bike paths
Design Strength	Slightly less than porous concrete, which is between 259,200 and 345,600 lbs/ft^2	About 1,150,000 lbs/ft^2	24,000-820,000 lbs/ft^2 depending on the type chosen
Life Span (assuming proper maintenance)	15-20 years	Most have lifetime guarantee	Varies by manufacturer
Subbase	Geotextile fabric topped with 18-36" of washed crushed stoned topped with 1" of chocker course	Geotextile fabric topped with minimum 6" of gravel topped with 1" sand bedding layer. Residential use can omit gravel base. Fill voids with gravel or soil and grass.	Varies depending on manufacturer. Some grids lay directly on existing grass. Others require gravel subbase or planting base. Voids typically filled with gravel or soil and grass.
Maintenance	•Annual inspection for deterioration •Periodic vacuum sweeping •Fill small potholes and cracks with patching mix unless >10% of surface •Drill 0.5" holes every few feet to address spot clogging •No sanding •No salt near groundwater drinking supplies •Raise plow blade 1" above surface	•Refill voids •Replace damaged blocks •Mow, water and seed grass as needed •Use salt and sand sparingly •No salt near groundwater drinking supplies •Plowing allowed	•Refill voids •Replace damaged sections as needed •Mow, water and seed grass as needed •Use salt and sand sparingly •No salt near groundwater drinking supplies •Raise plow blade slightly or outfit with flexible rubber bottom piece

Adapted from University of Rhode Island Cooperative Extension. 2005

General Site Suitability Criteria

- **Soils:** Soils with field-verified permeability rates less than 0.50 inches per hour or with a clay content greater than 30%, are not suitable for pavement alternatives. Soil borings must be taken two to four feet below the level of the base of the pavement system or the bottom filter course, whichever is deeper, to identify any restrictive layers (Schueler et al., 1992)

  - o Frost-susceptible soils are not good candidates for pavement alternatives.

  - o Pavement alternatives should not be used on an unstable subgrade of fill soils (especially when wet), or if prone to slope failure. (Sites without suitable natural soils for infiltration may possibly be used for pavement alternatives, but would require extensive excavation and replacement with suitable sub-base material and provision of subsurface drainage, with an outlet to discharge the partially treated percolate from the system).

- **Traffic Volumes:** Pavement alternatives are limited to areas with light to moderate traffic. They are not generally recommended for most roadways, and cannot withstand use by heavy trucks (Schueler et al., 1992). Typically, they are used for lightly used satellite or seasonal parking areas and access drives.

General Design Criteria

- **Site Slope:** The slope of the site should be less than 5% (Schueler et al., 1992b) and preferably closer to 1%.

- **Separation from Seasonal High Water Table & Bedrock:** Three feet of minimum clearance is required between the bottom of the system and bedrock or seasonal high water table, whichever is shallower (Ibid.)

- **Sediment Loading:** Pavement alternatives should not be used in areas expected to receive high levels of sediment loading from upland areas. Also, if used during the winter, these areas should not be sanded. The pavement surface and sub-structure are highly susceptible to clogging, and should be protected against sediment input.

- **Subgrade/Natural Soils:** The subgrade soils shall have a field-verified permeability of at least 0.50 inches per hour (Schueler et al., 1992)

- **Porous Asphalt Course:** The top porous asphalt course should be 2-4 inches thick, depending on load and traffic application. A typical porous asphalt mix is provided below. The porous asphalt mix and thickness shall be designed based on site specific conditions such as the use of the paved area, the required load bearing capacity, climate, etc.

Typical Porous Asphalt Gradation	
Sieve Size	**Percent Passing**
1/2”	100
3/8”	95
#4	35
#8	15
#16	10
#30	2
Percent bituminous 5.75-6.0% by weight	

Adams, 2003

- **Filter Course:** A filter course shall be provided between the top porous asphalt or paver course and the reservoir course. This provides a level surface to construct the top porous asphalt or paver course. The filter course is typically a 1 to 2 inch thick layer and should meet the following gradation requirements:

Typical Filter Course Gradation	
Sieve Size	**Percent Passing**
1/2”	100
3/8”	0-5

- **Reservoir Course:** The reservoir course shall be clean, washed, 1½ -inch to 3-inch aggregate, free of debris. The depth of the reservoir course shall be based on the desired storage volume and frost penetration. Stone gradation should meet the following:

Typical Reservoir Course Gradation	
Sieve Size	**Percent Passing**
2 1/2”	100
2”	90-100
1 1/2”	35-70
1”	0-15
1/2”	0-5
#30	2

- **Geotextile Fabric:** A geotextile fabric with suitable characteristics must be placed between any stone layer and adjacent soil. The fabric will prevent the surrounding soil from migrating into the system and reducing its storage capacity. Use an appropriate geotextile design manual to choose a fabric that is compatible with the surrounding soil for the purposes stated above. The filter fabric should be free of tears, punctures, and other damage. Overlap seams a minimum of 12 inches.

- **Cold Climates:** Demonstration projects have shown successful applications of pavement alternatives in regions with freeze/thaw conditions, such as in Rochester, NY (Field, 1982), Philadelphia (Glourek and Urban, 1980), and Concord, MA. However, winter maintenance procedures may be problematic (e.g., scraping by plows, clogging by sand, clogging by or inability to treat de-icing chemicals). The University of Rhode Island and the University of New Hampshire are currently in the process of testing various porous pavement alternatives in winter climates.

General Maintenance Criteria

- **Inspection Frequency:** Inspection several times during the first few months following construction, followed by annual inspections. Inspections should be made after significant storm events to check for surface ponding that could indicate failure due to clogging.

- **Snow Removal:** Snow removal and deicing activities should be done carefully to avoid disturbance to the pavement structure and stripping of any vegetation. The plow blade should be raised 1" above the surface or outfitted with a flexible rubber bottom piece.

- **Rehabilitation:** Non-routine maintenance may require reconstruction of the surface treatment, and possibly the filter and reservoir layers, to relieve major clogging. Measures should be taken to ensure that an area designed to be porous does not receive a future overlay of conventional non-porous paving.

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10.2.7 Rain Barrels and Cisterns

Rain barrels are inexpensive, effective, and easily maintainable devices that are designed to capture roof runoff. They are most commonly used in residential applications to capture roof runoff for later watering of lawns and gardens. Rain barrels include a hole at the top to allow for flow from a downspout, a sealed lid, an overflow pipe and a spigot at or near the bottom of the barrel. A screen is often included to control mosquitoes and other insects. Rain barrels can be connected in series to provide larger storage volumes.

Cisterns are distinguishable from rain barrels only by their larger sizes and different shapes. They can be located either above or below ground, and in out of the way places that can easily be incorporated into a site design. Commercially available systems are typically constructed of high-density plastics and can include pumps and filtration devices. Cisterns can have up to a 10,000 gallon capacity.

Design Criteria

- **Sizing:** The required capacity of a rain barrel or cistern is a function of the rooftop surface area that drains to it, the inches of rainfall required to fill the barrel, and water losses, due mainly to evaporation. A general rule of thumb to utilize in the sizing of rain barrels is that 1 inch of rainfall on a 1000 square foot roof will yield approximately 600 gallons. Actual barrel is recommended to be at least 55 gallons.

- **Cistern Sizing Addendum:** Cisterns designed for more than just supplemental use (i.e., for full time domestic use) should be sized based upon a minimum of 30 gallons per day per person when considering all potential domestic water uses

- **Covers and Screens:** Provide removable, child-resistant covers and mosquito screening on water entry holes.

- **Drain Spigot:** Equip rain barrel with drain spigot with garden hose threading.

- **Safety:** Consider a sealed yet removable child resistant top.

- **Material:** Rain barrels are traditionally made of plastic. Cisterns can be mad out of redwood, polyethylene, fiberglass, metal, concrete, plaster (on walls), ferro-cement and impervious rock such as slate and granite.

Maintenance Criteria

- o Maintenance requirements for rain barrels and cisterns involve inspection at least twice a year and the repairing or replacement of appropriate components. Inspections and repairs should be done during dry parts of the year such as in summer but it is helpful to have the option of completely draining the system for maintenance.

- **General Inspections:**
  - o Roof catchments, to ensure that no particulate matter or other parts of the roof are entering the gutter and downspout to the rain barrel.
  - o Gutters and downspouts, to ensure that no leaks or obstructions are occurring.

- **Rain barrel Inspections:**
  - o Rain barrel, to check for potential leaks, including barrel top and seal.
  - o Runoff /overflow pipe, to check that overflow is draining in non-erosive manner.
  - o Spigot, to ensure that it is functioning correctly.

- **Cistern Inspections:**
  - o Roof washer and cleanout plug, inspection and replacement if needed.
  - o Cistern screen, cover and overflow pipe, inspection and replacement if needed.

Selected References

Low Impact Development Center. http://www.lid-stormwater.net/raincist/raincist_home.htm

10.2.8 Rooftop Greening

Rooftop greenery involves the establishment of vegetation on the rooftops of both new and existing buildings. This is a long-standing practice conducted throughout Europe. It provides three primary benefits: attenuation of stormwater runoff and peak flows, reductions in the heat island effects with significant improvements in building insulation, and the substantial increase in the life expectancy of the base roof material. The obvious stormwater benefit is that green roofs act to absorb the smaller, more common storm events, minimizing peak runoff and the net volume of stormwater runoff typically produced by roofs. Green roofs are not specifically intended to reduce atmospheric pollutant loadings because of the relative porous nature of the growth media.

In the world of green roofs, there are two primary types: extensive and intensive. The term "extensive" simply represents the practice of covering the entire roof area in a vegetative mat. These systems are designed to provide only a few inches of growth media and are relatively lightweight in structure. Because of the focus of minimizing weight/growing media, the vegetation is typically limited to various species of sedums or other similar arid plants. Due to the shallow media, the roofs have little organic substrate to retain potential pollutant loads.

The term "intensive" represents additions to the roof intended for general access and reuse of the rooftop resembling that of open space such as parkland, where direct access and use by the building inhabitants is encouraged. Intensive roof landscaping runs the gamut from small city parks to commercial enterprises representing sidewalk cafes, etc. This type of green roof typically requires more growth media and significant additional weight loading to the roof structure which would need to be accounted for. The deeper media provide for more nutrient uptake and greater flow attenuation.

One point of consideration is that data for thin media green roofs has shown that the runoff water quality can be impacted by the organic media it flows through. As such, the initial flow from rainwater will typically contain elevated levels of organic constituents such as nitrogen and phosphorus, depending on the growth media used, including the depth and the absorptive capacity of the media. To address this issue, typical green roof designs include residual stormwater detention tanks with a pump back system. The recirculating system allows for watering of the media during dry periods, providing for additional uptake of first flush pollutants and summertime evaporative cooling and reduction in the heat island effect experienced in most cities.

Design and Construction Criteria

Green roofs represent a technology onto themselves for which numerous technical and reference manuals are available. In summary, typical green roofs include the planting media underlying highly permeable growth media, a protective geotextile liner, and a root barrier membrane that consists of an impermeable membrane consistent with typical roof construction practices within the region. As stated, the inclusion of a containment structure for the first flush significantly improves stormwater water quality and enhances the overall effectiveness of the green roof technology. Planning and designing for a green roof requires that all characteristics of the building related to structural and vegetation-technical aspects be evaluated. The following design criteria are provided as guidelines. A structural engineer should be consulted to ensure the building can support the added weight from the planting media and vegetation.

1. **Suitability for Use:**. Access to vegetated areas should be restricted to people who care for and maintain the site.
2. **Roof Slope:** Roof slope has to be taken into account along with structural and vegetation requirements. A minimum slope of 2% is considered normal for extensive and simple intensive greening. In extensive greening, controlled drainage will meet the basic needs of the vegetation. Roofs with less than 2% slope will require special measures. Extensive greening on roofs with less than 2% slope require a drainage course to avoid water logging in the vegetation support course.
3. **Roof Design Suitability for Greening:** Green roof design requires consideration of a variety of conditions, involving both the way in which the site is constructed and the physical conditions on-site. The physical characteristics of roof structures must be checked.
4. **Design Loads:** The design load of the building is the critical factor in deciding what type of greening to use and how to cultivate the site. All the courses must be considered, at maximum water capacity and including the surface load generated by the vegetation, as a component in the surface load. The load generated by any water stored in an integral reservoir will also need to be added into the figures. Spot loadings generated by large-scale bushes, trees and structural components, such as pergolas, water pools and peripheral items, will need to be calculated separately.
5. **Protection Against Falls:** Protection devices preventing falls during execution, care and maintenance activities on buildings (e.g., barriers, options for securing workers with ropes) must be incorporated into design.
6. **Draining:** Drainage must be available through the layered superstructure and off the surface. Excess water may be drained within the vegetation area, outside the vegetation area, or through separate drainage facilities for areas which have undergone greening and those which have no vegetation. Regardless of the size of the roof surface, roofs with drainage facilities located

within the vegetation area must have at least one run-off facility and at least one emergency overflow.

7. **Watering:** The number of mains pipes and junction points required for watering, along with the sizes used, will depend upon local conditions and on the structure involved.

8. **Compatibility of Materials:** All materials used for the roof and vegetation layered superstructure must have mutual chemical compatibility.

9. **Environmental Compatibility:** The materials used must not be allowed to generate atmospheric pollution due to processes such as leaching or the release of gaseous substances.

10. **Plant Compatibility:** Materials must not contain any components which are harmful to plant life and which are capable, over a given period, of finding their way out into the environment.

11. **Protection Against Root Penetration:** Both intensive and extensive green-roof sites must have suitable and lasting protection against root ingress or penetration which would damage the damp-proof lining. Protection against root penetration may be provided by means of protective sheeting or full surface treatment/liquid coating. Floors made of non water-permeable concrete and welded metal vats are resistant to rood penetration. Settlement joints in floors made of non water-permeable concrete have to be equipped with a special treatment against root penetration.

12. **Protection Against Mechanical Damage:** Damp-proof linings and root-penetration barriers on roofs can be protected against mechanical damage by:

- Protective non-woven fabrics
- Protective boards
- Protective sheeting
- Full surface treatment, or
- Drainage courses

13. **Drainage Facilities:** Drainage facilities must be capable of collecting both overflow from the drainage course and surface water from the vegetation support course and of conveying it away. Water from adjoining facades has to be drained off in such a manner that the functions of the vegetation course and structure are not impeded. Materials consist of::

- Roof outlets
- Interior guttering
- Guttering
- Downpipes, and
- Emergency overflows

14. **Joints and Borders:** Joints and borders include joints with facades and other vertical structural components, joints where the roof is penetrated, and borders at roof edges. Damp-proof lining/root-penetration barriers on roofs must be brought up to the following heights:

- 15 cm high for a roof slope of up to 5°
- 10 cm high for a roof slope of over 5°

The minimum height for borders is:

- 10 cm high for a roof slope of up to 5°
- 5 cm high for a roof slope of over 5°

As a rule, a strip made up of slabs or gravel must be provided to separate vegetation areas from the structural component in question.

15. **Protection Against Emissions:** Areas affected by ventilation and/or air-conditioning should be evaluated to determine their suitability for planting, and the best types of vegetations suited to them. The generation of warm and cold air and currents can cause frost and drought damage to plants.

16. **Wind Loads:** Wind can generate positive and negative pressure forces, as well as friction, which act on structures. The strength of these forces is a direct function of wind strength and direction and of the shape and height of the building in question.

17. **Protection Against Slipping and Shearing:** Where a roof slopes at an angle in excess of 200 (36% gradient), structural anti-shear protection will normally be needed. Care must be taken to ensure that the action taken to prevent shearing does not create tension at the point of contact with the damp-proof lining and the root-penetration barrier.

18. **Vegetation Support Course:** The vegetation support course should be capable of accommodating a dense root stock, having all the requisite basic physical, chemical and biological properties needed for plant growth. The type of greening and form of cultivation will be factors in selecting a vegetation support course. Available materials include

- Soil mixtures - improved top and underlying soil
- Aggregate mixtures - mineral aggregate mixtures with high or low organic content or with an open-pore granular structure with no organic content
- Substrate boards -boards made from modified foam materials or mineral fibres
- Vegetation matting - matting with mineral/organic aggregate mixtures

The organic content of the vegetation support course should be as shown below:

Type of Greening	Substrate Density	Organic Content
Intensive Greening	≤ 0.8 > 0.8	≤ 12% by mass ≤ 6% by mas
Extensive Greening		
Multiple-Course Construction	≤ 0.8 > 0.8	≤ 8% by mass ≤ 6% by mass
Single-Course Construction	N/A	≤ 4% by mass

Reference: The Landscaping and Landscape Development Research Society E.V. - FLL

19. **Filter Course:** The filter course should be designed to prevent fine soil and substrate components from being washed out of the vegetation support course into the drainage course in a slurry. Nonwoven geotextile fabrics are typically used as filter courses.

20. **Drainage Course:** The drainage course must contain sufficient spaces to take up any excess water. The drainage course may be constructed of:

- Aggregate-type materials - gravel and fine chippings, lava and pumic, or expanded clay and slate
- Recycling aggregate-type materials - brick hardcore, slag, or foamed glass
- Drainage matting - textured nonwoven matting, studded plastic matting, fibre-type woven matting, or flock-type foam matting
- Drainage boards - boards made from foam pellets, studded rubber boards, shaped rigid plastic boards, shaped plastic foam boards
- Drainage and substrate boards - boards made from modified foam

Course materials and dimensions will depend on construction requirements and objectives for vegetation.

21. **Protective Layer:** The protective layer provides additional protection for the damp-proof lining/root penetration barrier on the roof.

22. **Roof-penetration Barrier:** The root-penetration barrier must provide constant protection for the damp-proof lining on the roof by preventing plant roots from growing into or through it.

23. **Water Retention:** Percent annual water retention on green roof sites as a function of course depth is provided in the table below.

24. **Water Storage:** Water can be stored in the individual courses as follows:

    - Storage in the vegetation support course through the use of substances which retain water for vegetation substrates or prefabricated substrate boards

    - Storage in the vegetation support course and, additionally, in the drainage course, through the use either of open-pore type aggregate materials in graded granular sizes or of prefabricated draining substrate boards

    - Storage in the vegetation support course and, additionally, in the drainage course, by allowing a water supply to build up in the aggregate over the entire area or by using pre-formed drainage boards with partial retention characteristics

    Water may be stored simultaneously in the vegetation support and drainage courses, whatever type of greening is used.

25. **Additional Watering:** Green-roof sites are designed to depend chiefly on precipitation for their water supply, this being readily available without cost. Additional watering may be provided through the use of a spray or dip type hose, hose and sprinkler, an overhead irrigation system, or automated water systems where there is a built-in reservoir. Where sprinklers, spray-type watering by a hose or drip-type water is used, the system can either be operated manually or controlled by means of a timer.

Maintenance Criteria

Green roof technologies follow the same startup and maintenance criteria as would be applied to any facility landscape feature. The more complicated and intensive the green roof, the more maintenance associated with caring for the vegetation, whereas an extensive roof planted in sedums can represent little or no maintenance other than a periodic feeding during the first year of operation.

Type of Greening	Course Depth (cm)	Form of Vegetation	% Water Retention - Annual Average
Extensive Greening	2-4	Moss-sedum greening	40
	>4-6	Sedum-moss greening	45
	>6-10	Sedum-moss-herbaceous plants	50
	>10-15	Sedum-herbaceous-grass plants	55
	>15-20	Grass-herbaceous plants	60
Intensive Greening	15-25	Lawn, shrubs, coppices	60
	>25-50	Lawn, shrubs, coppices	70
	>50	Lawn, shrubs, coppices, trees	>90

Reference: The Landscaping and Landscape Development Research Society E.V. - FLL

Selected References

Dunnet, Nigel and Kingsbury, Noel, 2004. *Planting Green Roofs and Living Walls.* Timber Press, Inc., Portland, Oregon.

Green Roofs for Healthy Cities and the Cardinal Group Inc., 2004. *Green Roof Design 101 Introductory Course.*

Guideline for the Planning, Execution and Upkeep of Green-Roof Sites. January 2002. Bonn, Germany. The Landscaping and Landscape Development Research Society E.V. - FLL.

10.2.9 Other Techniques

As previously stated, LID is about creativity. There are multiple practices that can be implemented and fit into various sites and situations. For example, infiltration can be incorporated into parking lot layouts without losing any parking spaces. Several examples are included in Appendix F. These examples generally use infiltration to treat stormwater and minimize runoff, but could easily be modified to incorporate an underdrain soil filter for tighter soils.

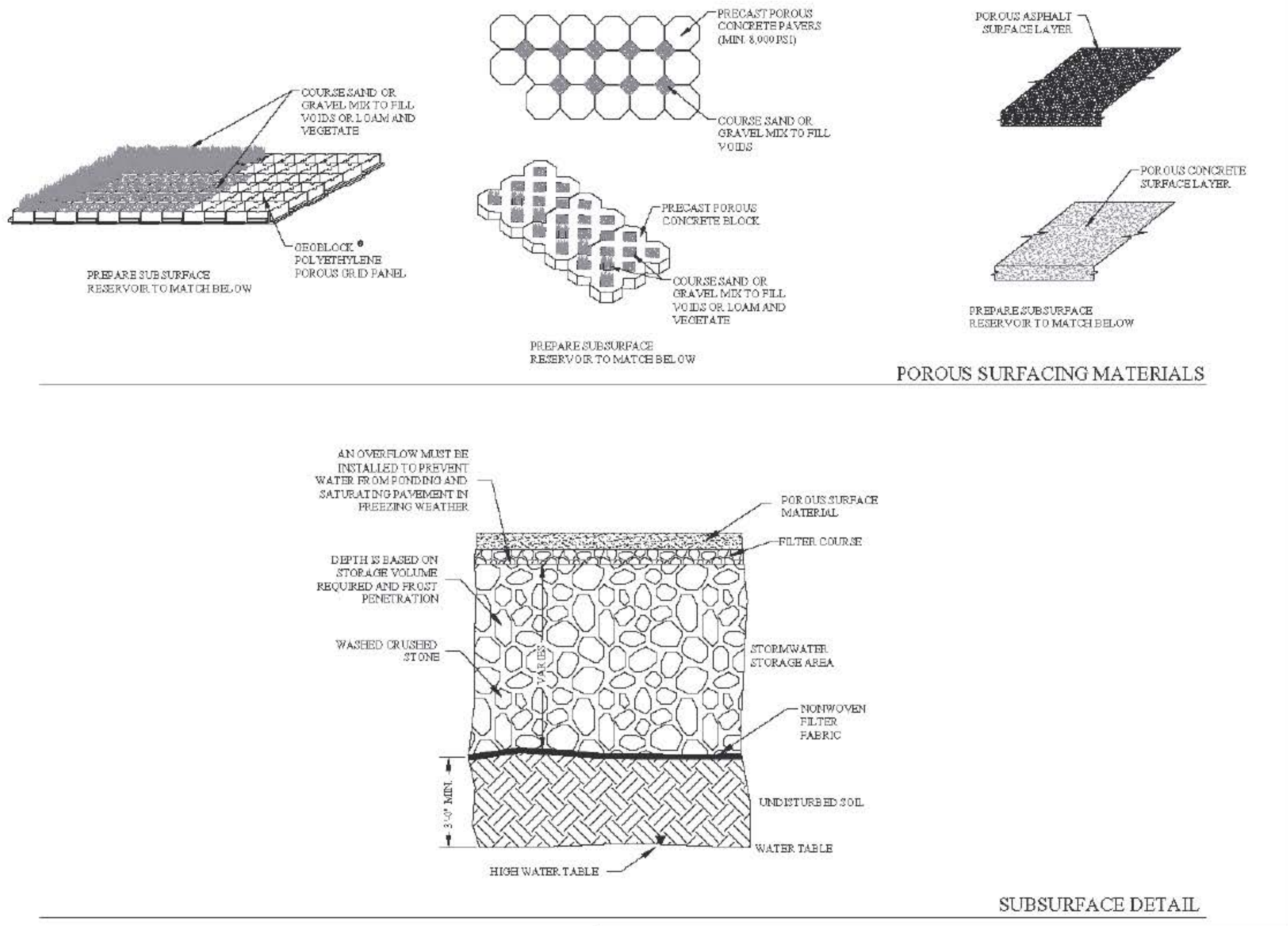

FIGURE 10-1. TYPICAL POROUS PAVEMENTS

Chapter 11
Designing for Operation & Maintenance

11.1 Description

The operation and maintenance of a BMP is as critical to its performance as the design. Thus, it is crucial that maintenance issues be given serious consideration and thought during the design process to set up realistic maintenance expectations. Without proper maintenance, BMPs are likely to fail, providing little or no treatment of stormwater. Both the maintenance schedules and access provide challenges to BMP owners. Common maintenance issues that are encountered with existing designs include:

- A single family residential lot draining to buffer;
- Too frequent maintenance;
- Proposed maintenance burden on owner too great;
- Difficult access for equipment;
- Difficult to clean without complete renovation;
- Lack of maintenance 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.

IMPORTANT

Pretreatment devices must be provided for all BMPs and should be sized to hold a minimum of one-year's worth of sediment.

Proper operation and maintenance ensures that the BMP will remain effective at removing pollutants as designed. It will:

- Increase volume of stormwater treated over the long term;
- Reduce BMP failure, therefore improving water quality;
- Decrease risk of resuspending sediment; and
- Increase pollutant removal efficiency.

Chapter Contents:

Designs need to consider reasonable, cost-effective maintenance frequencies, as well as provide access for ease of maintenance.

11.2 Design and Construction Criteria

1. **Provide Pre-Treatment:** Pre-treatment devices must be provided for each BMP.

2. **Sediment Removal Schedule:** All pre-treatment devices must be designed to accommodate a minimum of one year's worth of sediment. The estimated annual sediment accumulation must be provided as part of the design calculations.

3. **Size for Anticipated Sediment Loading:** Sediment loadings from both pervious and impervious areas must be considered and units should be sized to hold a year's worth of sediment.

   - *Pervious Areas:* The Universal Soil Loss Equation (USLE) should be used to calculate sediment deposits that would occur from pervious areas adjacent to the BMP.

   - *Roadways and Parking Areas:* Sand deposits from winter storm applications should be accounted for when designing a pre-treatment system. The design should be capable of holding a minimum of one-year's worth of sediment. Sediment loads should be calculated using a sand application rate of 500 lbs/acre for sanding of parking areas and access drives, a sand density of 90 lbs per cubic foot and assuming a minimum frequency of ten sandings per year.

   Sanding rates and numbers of storms may need to be adjusted based on specific application rates in a community.

4. **Make Maintenance Needs Apparent:** BMPs must be designed to alert the owner when it is failing and maintenance is required. Bypasses should not be used unless there is risk to public health or safety.

5. **Design for Anticipated Pollutants:** Pre-treatment devices must be designed to capture anticipated pollutants, such as oil and grease.

6. **Accessibility:** All devices must be designed and located to be easily accessible for inspection and for the appropriate equipment needed for maintenance. Formal access must be provided.

7. **Easements:** Permanent maintenance easements must be provided to the entity responsible for maintenance when that entity does not own the property.

8. **Operation and Maintenance Plan:** The proper operation and maintenance of a device must be laid out in an operation and maintenance plan that clearly identifies required inspection activities, the maintenance schedule and provides a method for determining when maintenance is necessary. The operations and maintenance plan must also outline manpower and budget needs to perform maintenance. Specific maintenance needs for each type of BMP are provided in their respective sections. A summary table of the inspection and maintenance needs of each BMP type is included in Table 11-1.

To obtain an annual sediment volume, perform the following calculation:

$$\text{Area to be sanded (acres)} \times 500\ \frac{\text{pounds}}{\text{acre-storm}} \div 90\ \frac{\text{pounds}}{\text{ft}^3} \times 10\ \frac{\text{storms}}{\text{year}} = \text{cubic feet of sediment/yr}$$

9. **Sediment Marker:** A sediment marker should be provided to enable the inspectors to get an accurate and consistent depth of sediment under the current conditions.

Selected References

Comprehensive Environmental Inc., November 2003. *Design Guidelines and Criteria for Stormwater Management*. Milford, MA.

Table 11-1
Long-Term Inspection & Maintenance Plan

	Spring	Fall or Yearly	After a Major Storm	Every 2-5 Years
Vegetated Areas				
Inspect all slopes and embankments	X		X	
Replant bare areas or areas with sparse growth	X		X	
Armor areas with rill erosion with an appropriate lining or divert the erosive flows to on-site areas able to withstand concentrated flows. See Appendix A(5) of Rule.	X		X	
Stormwater Channels				
Inspect ditches, swales and other open stormwater channels	X	X	X	
Remove any obstructions and accumulated sediments or debris	X	X		
Control vegetated growth and woody vegetation		X		
Repair any erosion of the ditch lining		X		
Mow vegetated ditches		X		
Remove woody vegetation growing through riprap		X		
Repair any slumping side slopes		X		
Replace riprap where underlying filter fabric or underdrain gravel is showing or where stones have dislodge		X		
Culverts				
Remove accumulated sediments and debris at the inlet, at the outlet, and within the conduit	X	X	X	
Repair any erosion damage at the culvert's inlet and outlet	X	X	X	
Catch Basin Systems				
Remove and legally dispose of accumulated sediments and debris from the bottom of the basin, inlet grates, inflow channels to the basin, and pipes between basins.	X	X		
Remove floating debris and floating oils (using oil absorptive pads) from any trap designed for such	X	X		
Roadways and Parking Surfaces				
Clear accumulated winter sand in parking lots and along roadways	X			
Sweep pavement to remove sediment	X			
Grade road shoulders and remove excess sand either manually or by a front-end loader	X			
Grade gravel roads and gravel shoulders	X			
Clean-out the sediment within water bars or open-top culverts	X			
Ensure that stormwater is not impeded by accumulations of material or false ditches in the shoulder	X			

Table 11-1
Long-Term Inspection & Maintenance Plan

	Spring	Fall or Yearly	After a Major Storm	Every 2-5 Years
Buffers				
Inspect treatment buffers for evidence of erosion, concentrated flow, or encroachment by development		X		
Manage the buffer's vegetation with the requirements in any deed restrictions		X		
Mow vegetation in non-wooded buffers no shorter than six inches and less than three times per year		X		
Repair any sign of erosion within a buffer		X		
Inspect and repair down-slope of all spreaders and turn-outs for erosion		X		
Install more level spreaders, or ditch turn-outs if needed for a better distribution of flow		X		
Clean-out any accumulation of sediment within the spreader bays or turn-out pools		X		
Stormwater Detention and Retention Facilities				
Inspect the embankments for settlement, slope erosion, internal piping, and downstream swamping. A professional engineer must review these immediately.		X	X	
Mow the embankment to control woody vegetation		X		
Inspect the outlet control structure for broken seals, obstructed orifices, and plugged trash racks		X	X	
Remove and dispose of sediments and debris within the control structure		X		
Repair any damage to trash racks or debris guards		X		
Mow vegetated spillways to control woody vegetation and replace any dislodged stone in riprap spillways		X		
Remove and dispose of accumulated sediments within the impoundment and forebay				X
Runoff Infiltration Facilities				
Inspect and clean-out any pre-treatment measures that collect sediment and hydrocarbons entering an infiltration measure	X	X		
Provide for the removal and disposal of accumulated sediments within the infiltration area				X
Renew the infiltration measure if it fails to drain within 72 hours after a rainfall of one-half inch or more				X
Till and replant the soil of vegetated infiltration basins				X
Reconstruct rock-lined basins or stone-filled trenches by removing the stones, replacing new underlying filter fabric, and tilling or removing the underlying soil				X
Proprietary Treatment Devices				
Contract with a third-party for the removal of accumulated sediments, oils, and debris within the device and replacement of any absorptive filters	The frequency of maintenance is established by the unit's storage capacity, the pollutant load and the manufacturer recommendations			
Other Practices and Measures				
Contact the department for appropriate inspection and maintenance requirements for other drainage control and runoff treatment measures.				

The maintenance needs for most vegetative and stabilization measures may be found in the Maine Erosion and Sediment Control BMPs manual as published in 2003.

Appendix A
Hydrologic Data for Maine

Contents

The material presented in this appendix has been compiled based on a review of selected literature, and is for general information only. This information should not be used without first securing competent advice with respect to its suitability for any general or specific application.

The contents of this appendix are not intended to be and should not be construed to be a standard of the Maine Department of Environmental Protection (MDEP) and are not intended for use as a reference in purchase specifications, contracts, regulations, statutes, or any other legal document.

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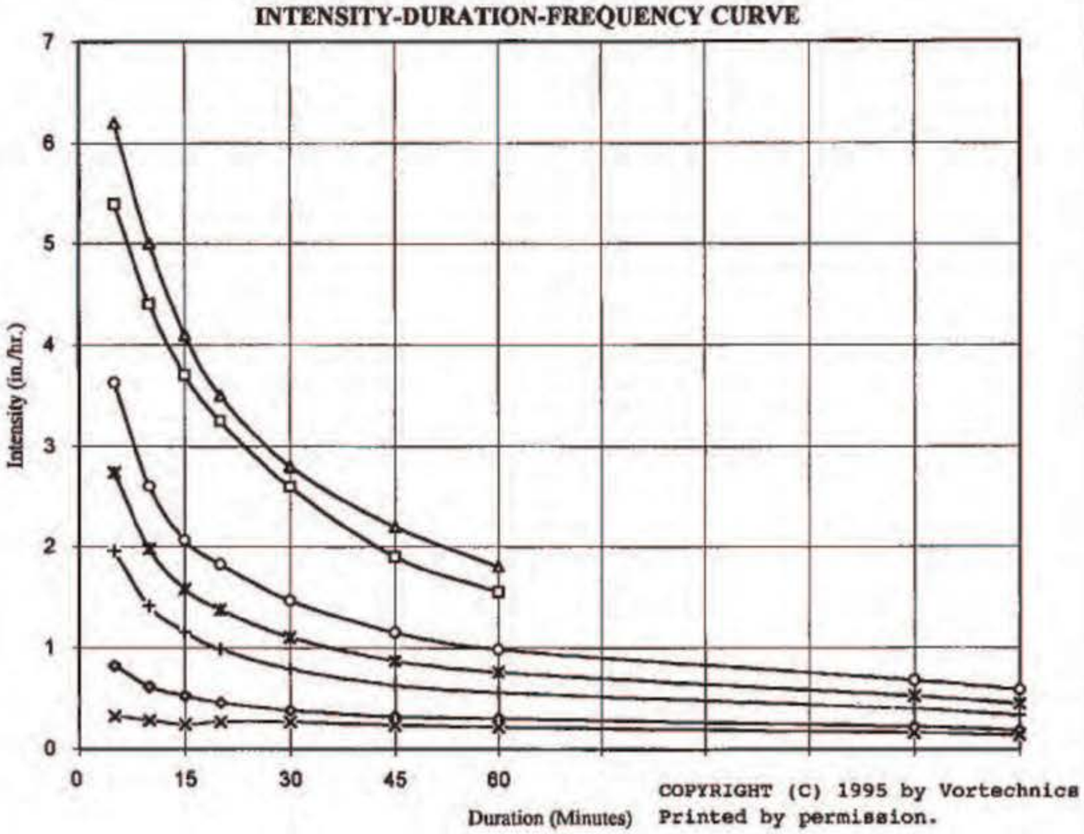
Appendix A-1: Intensity-Duration Curves (Vortechnics)



- 25 YEAR STORM
- 10 YEAR STORM
- 24 MONTH STORM
- 12 MONTH STORM
- 6 MONTH STORM
- 2 MONTH STORM - Represents a storm with a 1 in 2, (50%), chance of being equalled or exceeded in a given month.
- 1.01 MONTH STORM - has a 99% chance of being equalled or exceeded in a given month.

NOTE: the 1-month storm would have a 100% chance of being equalled or exceeded in a given month; in other words, the 1-month rainfall intensity is zero inches per hour for all durations.

SOURCES:

Curves expressed in monthly recurrence intervals calculated by Tom Adams, P.E. from short term monthly maximum precipitation data from the Portland, Maine Jetport published by the U.S. Department of Commerce, National Climatic Data Center, Ashville, NC.

Sample Size = 144 months.

Statistical Method = Pearson Type III.

Curves expressed in yearly recurrence intervals compiled from the Stormwater Management Manual by the Greater Portland Council of Governments.

Appendix A-2: Portland & Cumberland County Precipitation Intensity/Duration (COG)

Portland & Cumberland County

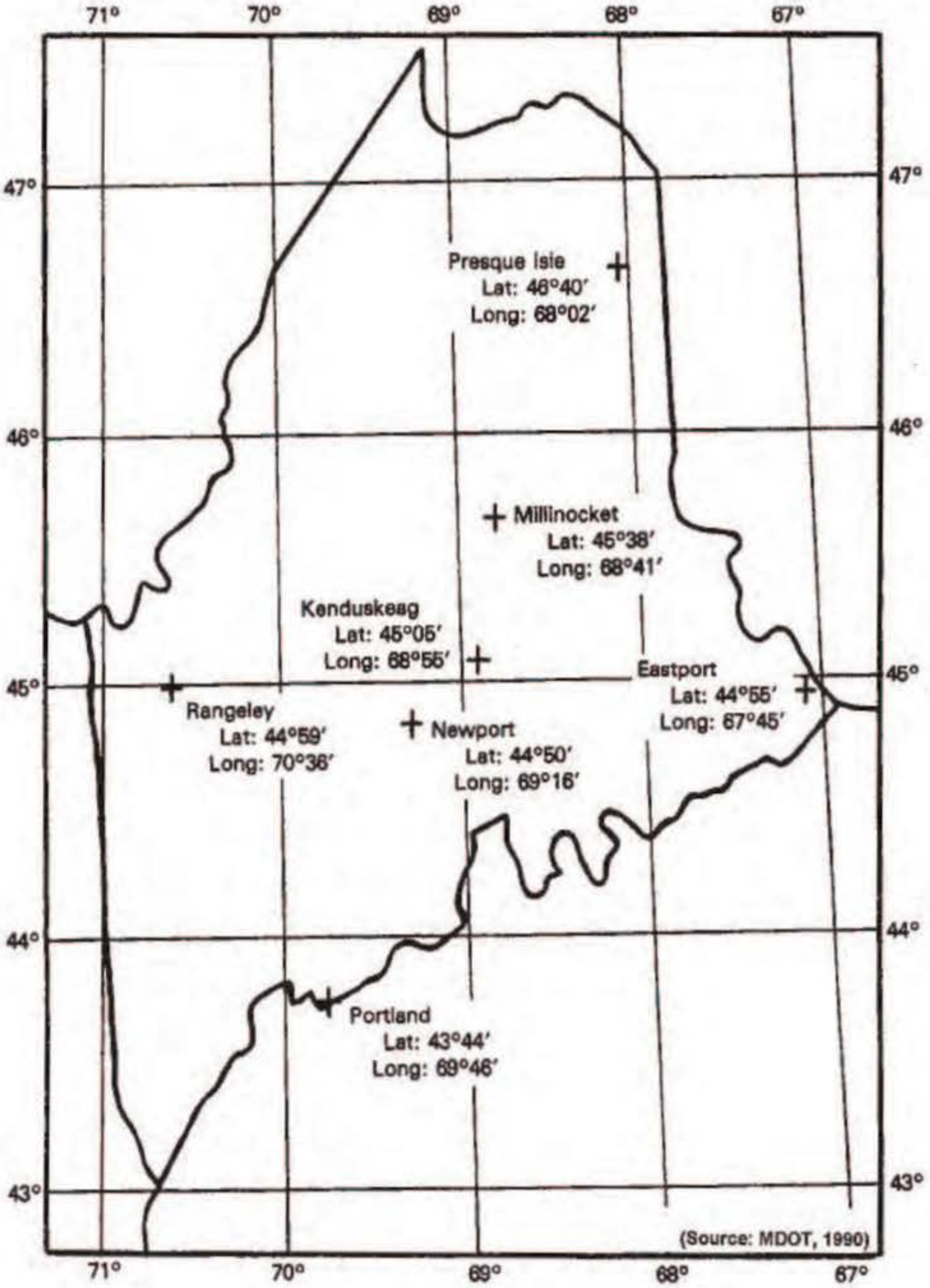
Precipitation Intensity/Duration

	2 years		5 years		10 years		25 years		50 years		100 years	
	Cumb. Co. (NOAA 35)	Portland (COG '81)	Cumb. Co. (NOAA 35)	Portland (COG '81)	Cumb. Co. (NOAA 35)	Portland (COG '81)	Cumb. Co. (NOAA 35)	Portland (COG '81)	Cumb. Co. (NOAA 35)	Port. (COG '81)	Cumb. Co. (NOAA35)	Portland (COG '81)
5 minute	0.34	0.312	0.40	0.368	0.45	0.410	0.52	0.471	0.58	0.520	0.63	0.568
10 minute	0.51	0.480	0.63	0.573	0.72	0.641	0.84	0.739	0.93	0.818	1.03	0.896
15 minute	0.63	0.579	0.79	0.699	0.90	0.786	1.05	0.912	1.18	1.01	1.30	1.11
30 minute	0.83	0.758	1.07	0.948	1.23	1.08	1.46	1.27	1.64	1.42	1.82	1.57
1 hour	1.04	1.00	1.36	1.24	1.58	1.40	1.89	1.65	2.13	1.83	2.37	2.02
	(TP 40)		(TP 40)		(TP 40)		(TP 40)		(TP 40)		(TP 40)	
2 hours	1.4	1.30	1.8	1.46	2.2	1.59	2.45	1.78	2.7	1.94	3.1	2.09
3 hours	1.6		2.1		2.45		2.7		3.1		3.5	
6 hours	2.1		2.65		3.1		3.4		4.0		4.4	
12 hours	2.5		3.4		3.9		4.8		5.0		5.7	
24 hours	3.0	3.18	4.0	3.87	4.7	4.37	5.5	5.08	5.8	5.65	6.7	6.21

TP 40 = "Rainfall Frequency Atlas", Government Printing Office, 1961
NOAA 35 = "Five to 60 Minute Precipitation Frequency for the Eastern and Central U.S.", National Weather Service 1977.
COG '81 = Hand calculations by Joan Feely (GPCOG intern), from "Rainfall Intensity-Frequency Analysis" - Form 612-47, Environmental Science Services Admin., Weather Bureau, adjusted for partial-duration series as in NOAA 35.

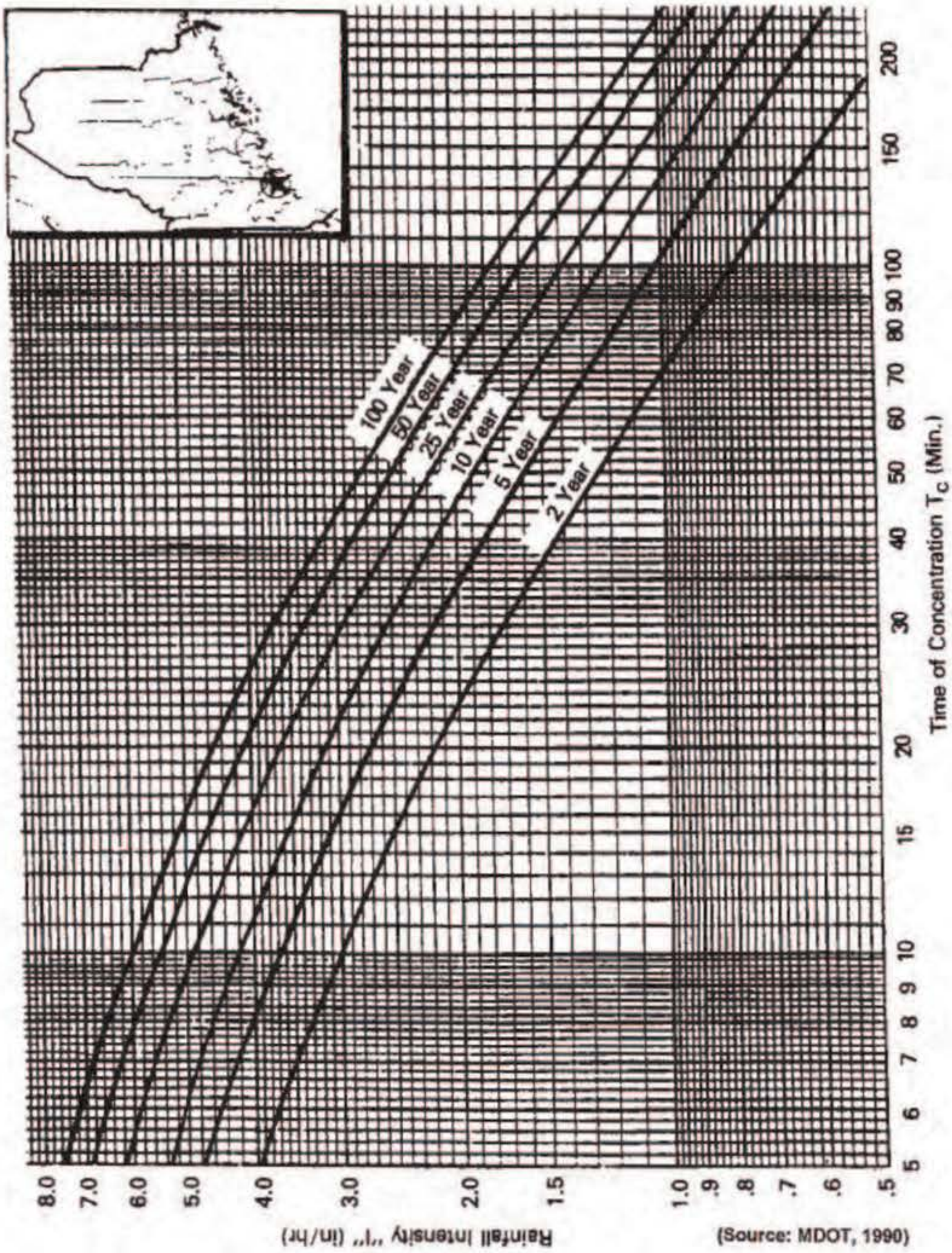
(Source: GPCOG, 1981)

Appendix A-3: IDF Reference Sites in Maine (MDOT)



IDF REFERENCE SITES IN MAINE
(Rational Method)

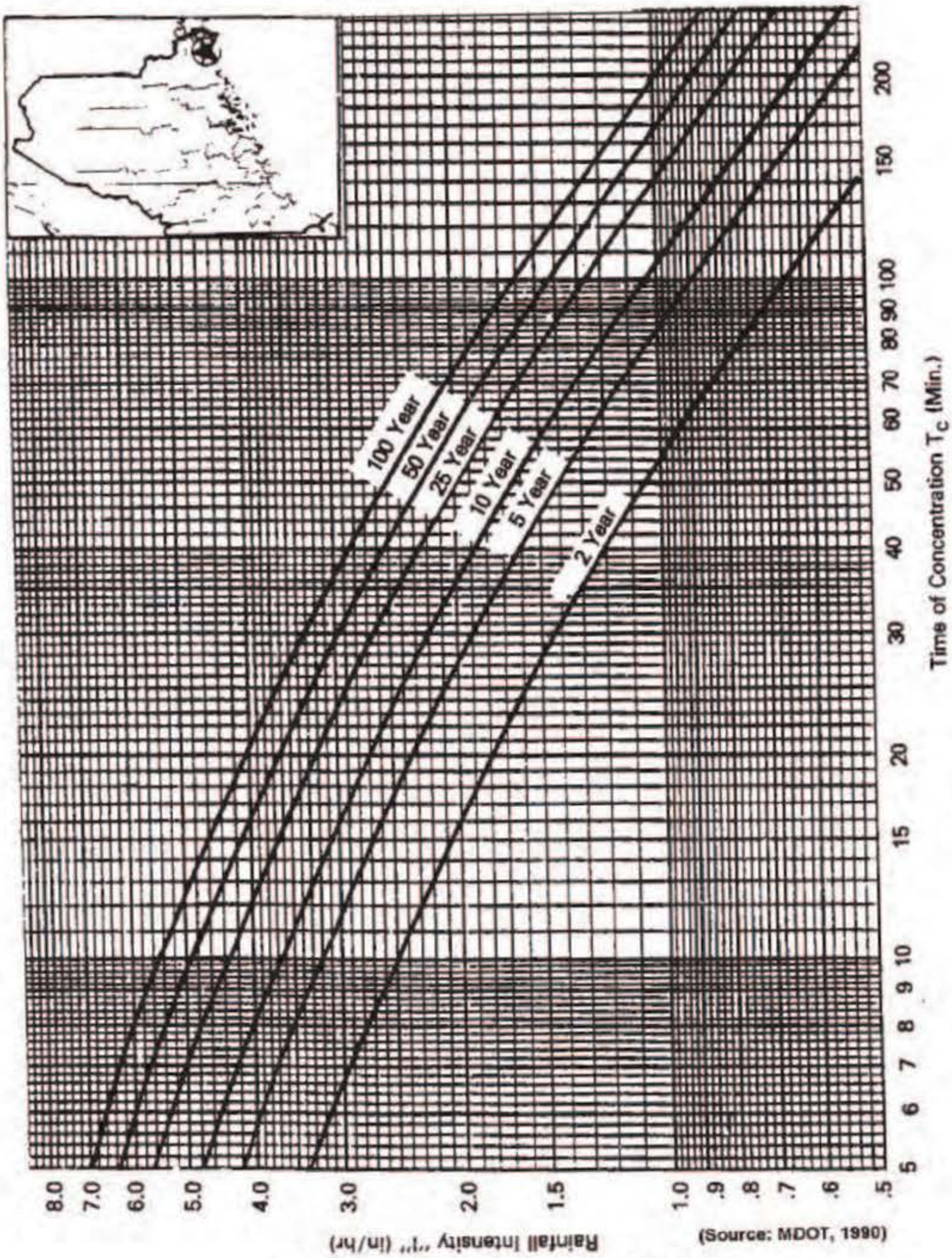
Appendix A-4: IDF Curve for City of Portland



IDF CURVE FOR CITY OF PORTLAND
(Rational Method)

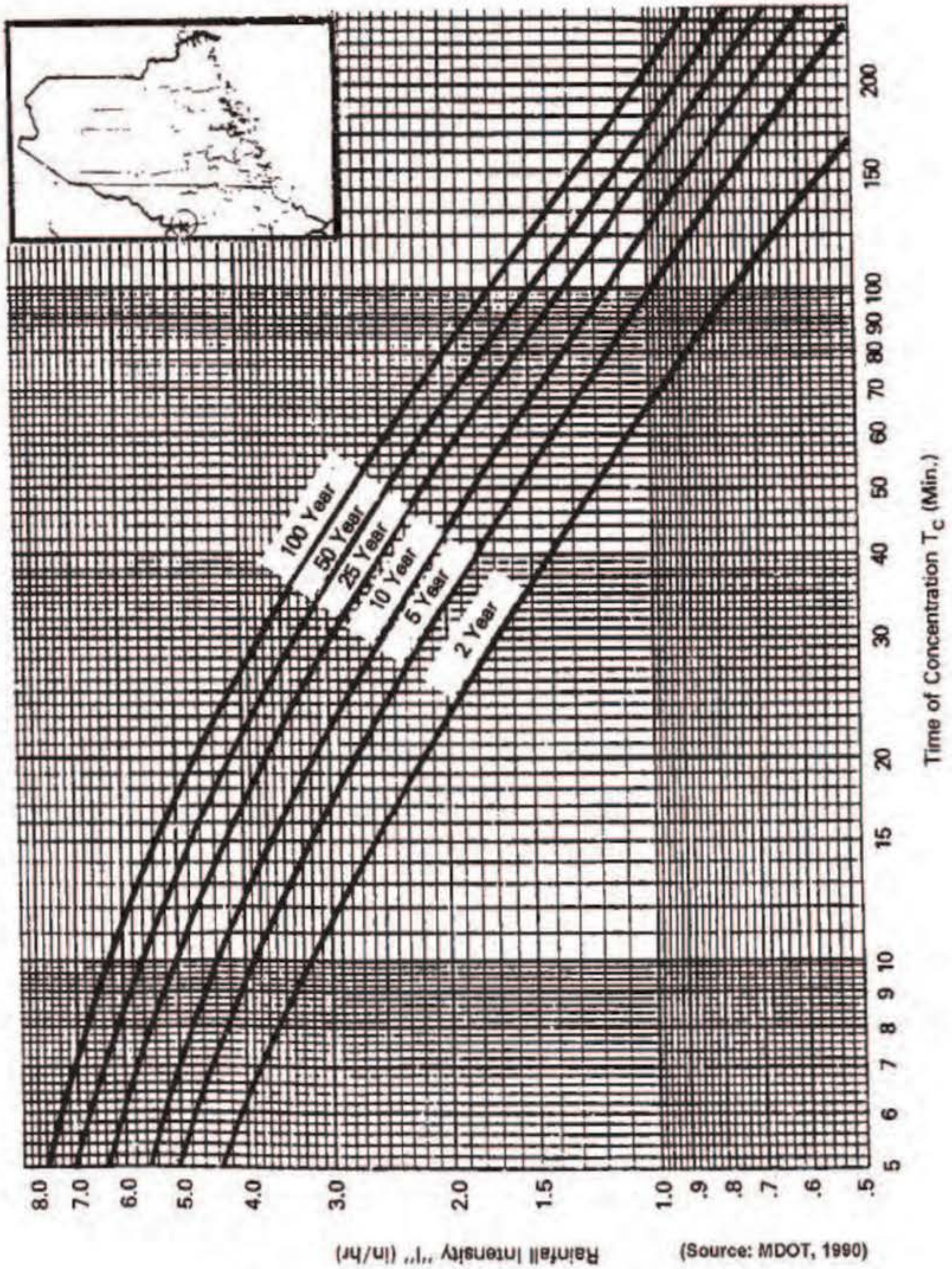
3

Appendix A-5: IDF Curve for City of Eastport



IDF CURVE FOR CITY OF EASTPORT
(Rational Method)

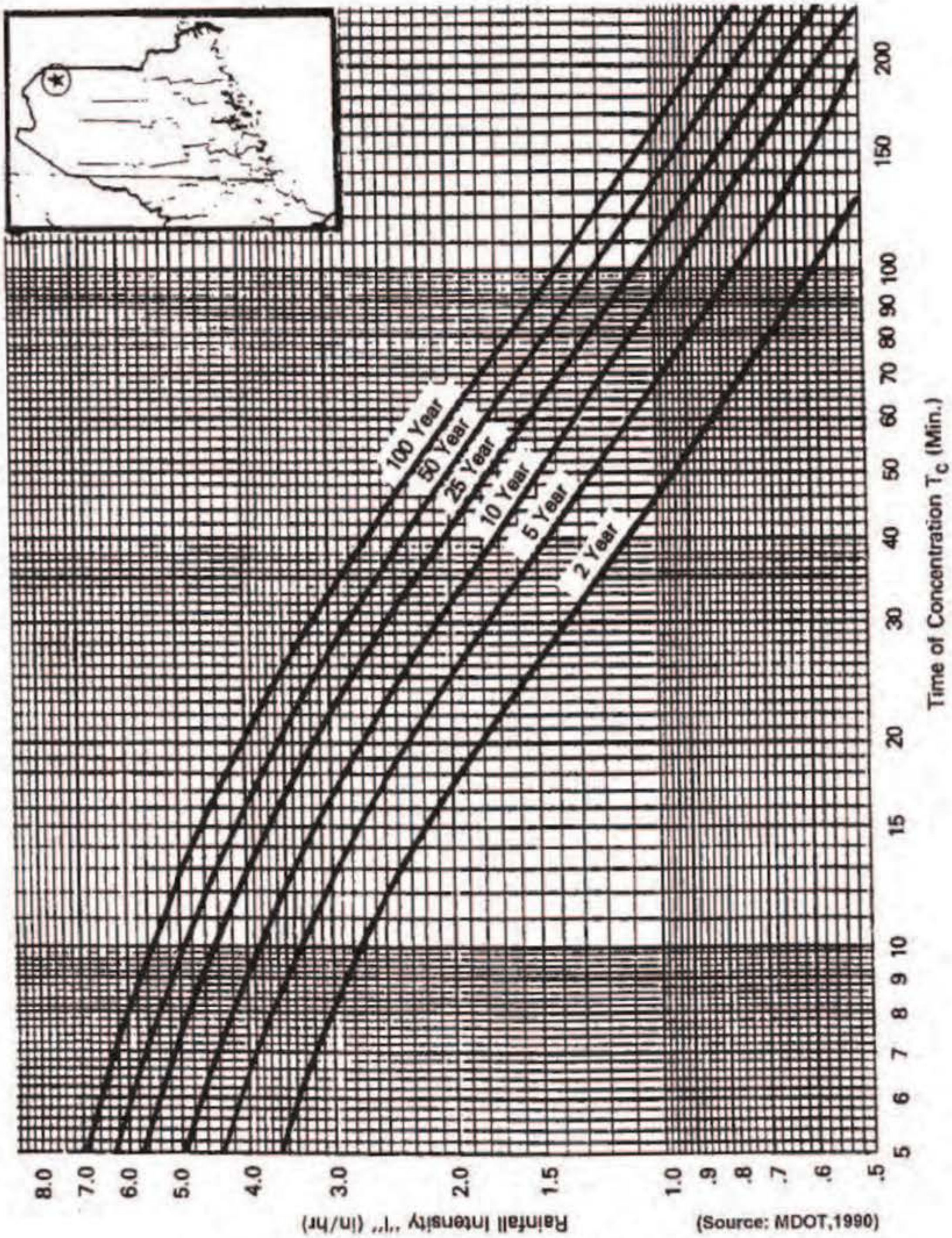
Appendix A-6: IDF Curve for Town of Rangeley



(Source: MDOT, 1990)

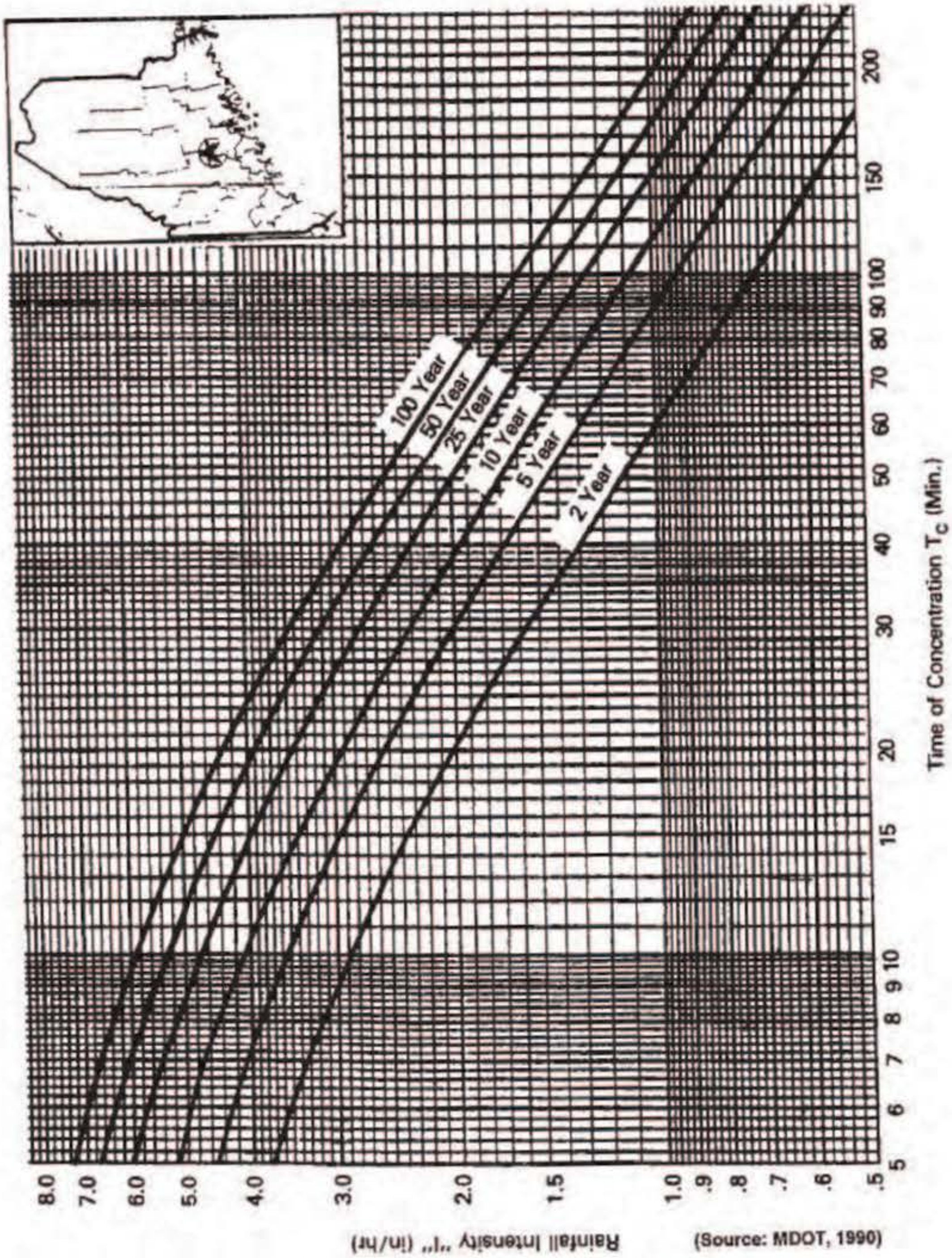
IDF CURVE FOR TOWN OF RANGELEY
(Rational Method)

Appendix A-7: IDF Curve for City of Presque Isle



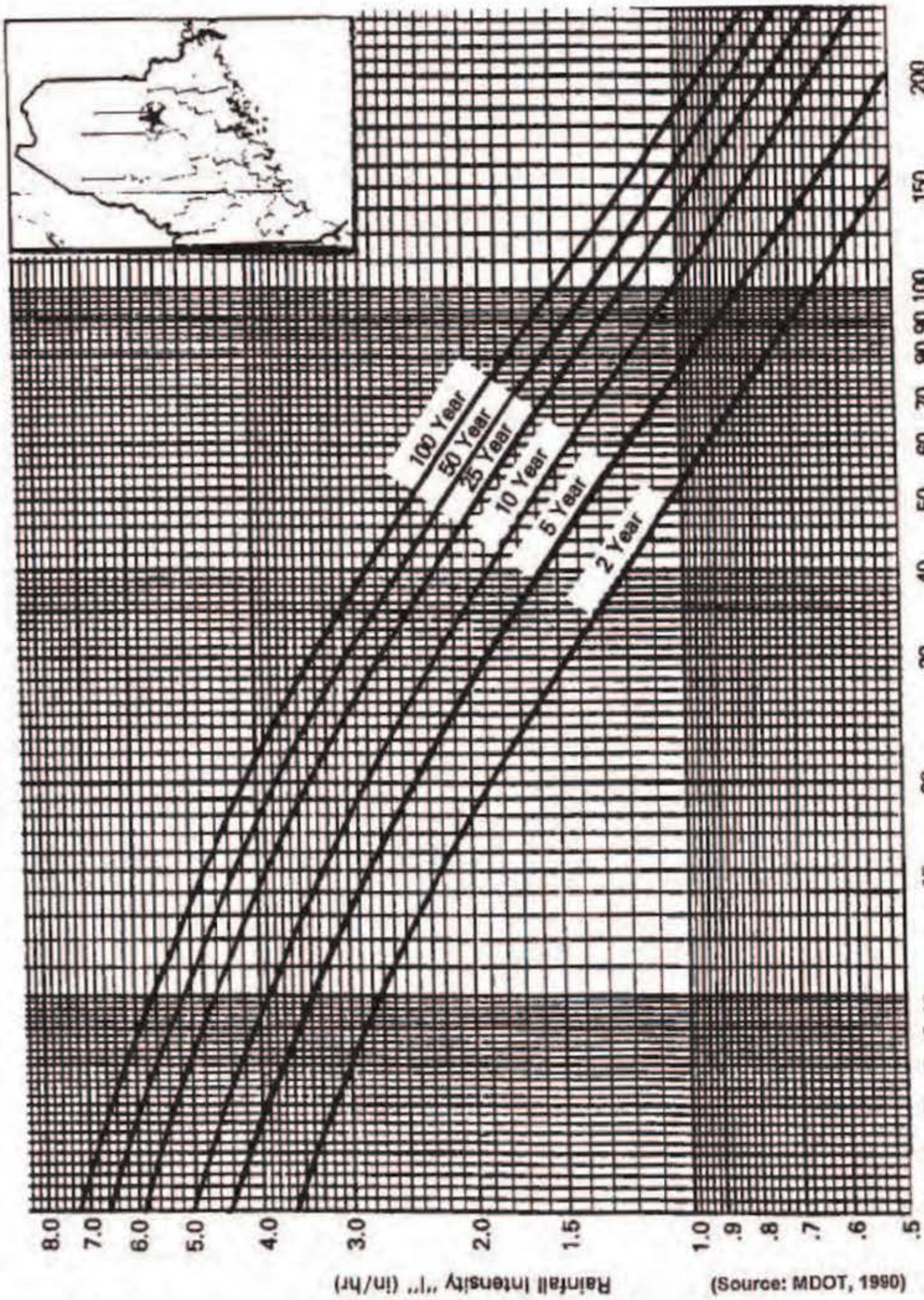
IDF CURVE FOR CITY OF PRESQUE ISLE
(Rational Method)

Appendix A-8: IDF Curve for Town of Newport



IDF CURVE FOR TOWN OF NEWPORT
(Rational Method)

Appendix A-9: IDF Curve for Town of Millinocket



IDF CURVE FOR TOWN OF MILLINOCKET
(Rational Method)

Appendix A-10: Runoff Coefficients for the Rational Formula

Typical Composite Runoff Coefficients by Land Use.

Description of Area	C-value
Business:	
Downtown areas	0.70-0.95
Neighborhood areas	0.50-0.70
Residential:	
Single-family areas	0.30-0.50
Multi units, detached	0.40-0.60
Multi units, attached	0.60-0.75
Suburban	0.25-0.40
Apartment	0.50-0.70
Industrial:	
Light areas	0.50-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.20-0.35
Railroad yard areas	0.20-0.35
Unimproved areas	0.10-0.30

Normal Range of Runoff Coefficients.

Character of Surface	C-value
Lawns:	
Sandy soil, flat (2%)	0.05-0.10
Sandy soil, ave. (2-7%)	0.10-0.15
Sandy soil, steep (7%)	0.15-0.20
Heavy soil , flat (2%)	0.13-0.17
Heavy soil, ave. (2-7%)	0.18-0.22
Heavy soil, steep (7%)	0.25-0.35
Agricultural land:	
Bare packed soil	
Smooth	0.30-0.60
Rough	0.20-0.50
Cultivated rows	
Heavy soils, no crop	0.30-0.60
Heavy soils with crop	0.20-0.50
Sandy soil no crop	0.20-0.40
Sandy soil with crop	0.10-0.25
Pasture	
Heavy soil	0.15-0.45
Sandy soil	0.05-0.25
Woodlands	0.05-0.25
Pavement	
Asphalt and Concrete	0.70-0.95
Brick	0.70-0.85
Roofs	0.75-0.95

NOTE: The designer must use judgment to select the appropriate "C" value within the range for the appropriate land use. Generally, larger areas with permeable soils, flat slopes, and dense vegetation should have lowest "C" values. Smaller areas with slowly permeable soils, steep slopes, and sparse vegetation should be assigned highest "C" values. The range of "C" values presented are typical for return periods of 2-10 years. Higher values are appropriate for larger design storms. (ASCE 1992 and others)

Appendix A-11: Runoff Coefficients for the Rational Formula by Hydrologic Soil Group and Slope

Runoff Coefficients for the Rational Formula by Hydrologic Soil Group and Slope Range *

	A			B			C			D		
Land use	0–2%	2–6%	6%+	0–2%	2–6%	6%+	0–2%	2–6%	6%+	0–2%	2–6%	6%+
Cultivated land	0.08	0.13	0.16	0.11	0.15	0.21	0.14	0.19	0.26	0.18	0.23	0.31
	0.14	0.18	0.22	0.16	0.21	0.28	0.20	0.25	0.34	0.24	0.29	0.41
Pasture	0.12	0.20	0.30	0.18	0.28	0.37	0.24	0.34	0.44	0.30	0.40	0.50
	0.15	0.25	0.37	0.23	0.34	0.45	0.30	0.42	0.52	0.37	0.50	0.62
Meadow	0.10	0.16	0.25	0.14	0.22	0.30	0.20	0.28	0.36	0.24	0.30	0.40
	0.14	0.22	0.30	0.20	0.28	0.37	0.26	0.35	0.44	0.30	0.40	0.50
Forest	0.05	0.08	0.11	0.08	0.11	0.14	0.10	0.13	0.16	0.12	0.16	0.20
	0.08	0.11	0.14	0.10	0.14	0.18	0.12	0.16	0.20	0.15	0.20	0.25
Residential												
Lot size $\frac{1}{8}$ acre	0.25	0.28	0.31	0.27	0.30	0.35	0.30	0.33	0.38	0.33	0.36	0.42
(0.05 ha)	0.33	0.37	0.40	0.35	0.39	0.44	0.38	0.42	0.49	0.41	0.45	0.54
Lot size $\frac{1}{4}$ acre	0.22	0.26	0.29	0.24	0.29	0.33	0.27	0.31	0.36	0.30	0.34	0.40
(0.10 ha)	0.30	0.34	0.37	0.33	0.37	0.42	0.36	0.40	0.47	0.38	0.42	0.52
Lot size $\frac{1}{3}$ acre	0.19	0.23	0.26	0.22	0.26	0.30	0.25	0.29	0.34	0.28	0.32	0.39
(0.13 ha)	0.28	0.32	0.35	0.30	0.35	0.39	0.33	0.38	0.45	0.36	0.40	0.50
Lot size $\frac{1}{2}$ acre	0.16	0.20	0.24	0.19	0.23	0.28	0.22	0.27	0.32	0.26	0.30	0.37
(0.2 ha)	0.25	0.29	0.32	0.28	0.32	0.36	0.31	0.35	0.42	0.34	0.38	0.48
Lot size 1 acre	0.14	0.19	0.22	0.17	0.21	0.26	0.20	0.25	0.31	0.24	0.29	0.35
(0.4 ha)	0.22	0.26	0.29	0.24	0.28	0.34	0.28	0.32	0.40	0.31	0.35	0.46
Industrial	0.67	0.68	0.68	0.68	0.68	0.69	0.68	0.69	0.69	0.69	0.69	0.70
	0.85	0.85	0.86	0.85	0.86	0.86	0.86	0.86	0.87	0.86	0.86	0.88
Commercial	0.71	0.71	0.72	0.71	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
	0.88	0.88	0.89	0.89	0.89	0.89	0.89	0.89	0.90	0.89	0.89	0.90
Streets	0.70	0.71	0.72	0.71	0.72	0.74	0.72	0.73	0.76	0.73	0.75	0.78
	0.76	0.77	0.79	0.80	0.82	0.84	0.84	0.85	0.89	0.89	0.91	0.95
Open space	0.05	0.10	0.14	0.08	0.13	0.19	0.12	0.17	0.24	0.16	0.21	0.28
	0.11	0.16	0.20	0.14	0.19	0.26	0.18	0.23	0.32	0.22	0.27	0.39
Parking	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87
	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97

*First row of each entry gives runoff coefficients for storm recurrence intervals less than 25 years; second row gives runoff coefficients for storm recurrence intervals of 25 years or more.

(Source: Rawls et.al., 1981)

(Source: Rawls et al., 1981, and Browne, 1990)

Appendix A-12: Runoff Curve Numbers for use in TR-55 and TR-20

	Hydrologic Soil Group			
Land Use/Cover type and hydrologic condition	A	B	C	D
Cultivated Land				
without conservation	72	81	88	91
with conservation	62	71	78	81
Pasture land				
poor condition: heavily grazed, no mulch	68	79	86	89
fair condition: 50 to 75% ground cover	49	69	79	84
good condition: lightly grazed, > 75% ground cover	39	61	74	80
Meadow (protected from grazing)	30	58	71	78
Wood or forest land				
Thin stand - poor cover, no mulch, burned over	45	66	77	83
Good stand - good cover, litter and brush cover soil	25	55	70	77
Wood yard (log storage)	72	82	87	89
Open space, lawns, parks, golf courses, cemeteries, etc.				
Good condition: grass cover on 75% or more of the area	39	61	74	80
Fair condition: grass cover on 50 to 75 % of the area	49	69	79	84
Commercial and business areas (85% impervious)	89	92	94	95
Industrial districts (72% impervious)	81	88	91	93
Residential: Development completed, vegetation established, house and driveway drains toward road				
Average lot size — Average % impervious				
1/8 acre or less (town houses) — 65	77	85	90	92
1/4 acre — 38	61	75	83	87
1/3 acre — 30	57	72	81	86
1/2 acre — 25	54	70	80	85
1 acre — 20	51	68	79	84
2 acre — 15	46	65	77	82
Paved parking lots, roofs, driveways, etc.(excluding R-O-W)	98	98	98	98
Streets and roads				
Paved with curb and storm sewers (excluding R-O-W)	98	98	98	98
Paved with ditches (including R-O-W)	83	89	92	93
Gravel (including R-O-W)	76	85	89	91
Dirt (including R-O-W)	72	82	87	89
Newly graded area (denuded)	77	86	91	94

Note: Average runoff condition and $I_a = 0.2S$

Source: SCS, 1986 and DEP staff.

Appendix A-13: Curve Number Adjustments Based on Differing AMCs

Curve Numbers and Constants for the case Ia = 0.2S									
CN for AMC II	CN for AMC I	CN for AMC III	S* value (in.)	I_a	CN for AMC II	CN for AMC I	CN for AMC III	S* value (in.)	I_a
100	100	100	0	0	60	40	78	6.67	1.33
99	97	100	0.101	0.02	59	39	77	6.95	1.39
98	94	99	0.204	0.04	58	38	76	7.24	1.45
97	91	99	0.309	0.06	57	37	75	7.54	1.51
96	89	99	0.417	0.08	56	36	75	7.86	1.57
95	87	98	0.526	0.11	55	35	74	8.18	1.64
94	85	98	0.638	0.13	54	34	73	8.52	1.70
93	83	98	0.753	.015	53	33	72	8.87	1.77
92	81	97	0.870	.017	52	32	71	9.23	1.85
91	80	97	0.989	0.20	51	31	70	9.61	1.92
90	78	96	1.11	0.22	50	31	70	10.0	2.00
89	76	96	1.24	0.25	49	30	69	10.4	2.08
88	75	95	1.36	0.27	48	29	68	10.8	2.16
87	73	95	1.49	0.30	47	28	67	11.3	2.26
86	72	94	1.63	0.33	46	27	66	11.7	2.34
85	70	94	1.76	0.35	45	26	65	12.2	2.44
84	68	93	1.90	0.38	44	25	64	12.7	2.54
83	67	93	2.05	0.41	43	25	63	13.2	2.64
82	66	92	2.20	0.44	42	24	62	13.8	2.76
81	64	92	2.34	0.47	41	23	61	14.4	2.88
80	63	91	2.50	0.50	40	22	60	15.0	3.00
79	62	91	2.66	0.53	39	21	59	15.6	3.12
78	60	90	2.82	0.56	38	21	58	16.3	3.26
77	59	89	2.99	0.60	37	20	57	17.0	3.40
76	58	89	3.16	0.63	36	19	56	17.8	3.56
75	57	88	3.33	0.67	35	18	55	18.6	3.72
74	55	88	3.51	0.70	34	18	54	19.4	3.88
73	54	87	3.70	0.74	33	17	53	20.3	4.06
72	53	86	3.89	0.78	32	16	52	21.2	4.24
71	52	86	4.08	0.82	31	16	51	22.2	4.44
70	51	85	4.28	0.86	30	15	50	23.3	4.66
69	50	84	4.49	0.90					
68	48	84	4.70	0.94	25	12	43	30.0	6.00
67	47	83	4.92	0.98	20	9	37	40.0	8.00
66	46	82	5.15	1.03	15	6	30	56.7	11.34
65	45	82	5.38	1.08	10	4	22	90.0	18.00
64	44	81	5.62	1.12	5	2	13	190.0	38.00
63	43	80	5.87	1.17	0	0	0	∞	∞
62	42	79	6.13	1.23					
61	41	78	6.39	1.28					

Source: Browne, 1990; SCS 1972

*For CN listed for AMC Condition II: S=((1000/CN)-10), I_a=0.2S

Appendix B
Runoff Estimation & Hydrologic Models

Contents

The material presented in this appendix has been compiled based on a review of selected literature, and is for general information only. This information should not be used without first securing competent advice with respect to its suitability for any general or specific application.

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Appendix B-1 Storm Hydrograph & Runoff Volume Calculations

B-1.1 SCS TR-20

B-1.1.1 Primary Reference

Soil Conservation Service, 1983

B-1.1.2 Applicability

Applicable for drainage areas up to 20 square miles. The TR-20 hydrologic model or an equivalent must be used for watershed analysis where any of the following conditions are applicable.

1. Sub-areas are significantly different in size (5:1), land use (cover), or hydrologic soil groups.

2. An outflow hydrograph from a detention pond is needed.

3. A detention basin has multiple sub-areas in its drainage area, requiring an accurate peak discharge value and a composite runoff volumes.

4. Multiple detention structures are used either in parallel or in series.

5. Conveyance channel storage is large.

6. Calibration of the model using actual rainfall amounts and distribution is needed.

7. Flow (splitting) diversions are required

B-1.1.3 Description of Method

SCS TR-20 Hydrologic Model is a watershed computer model which uses the SCS Synthetic Unit Hydrograph to calculate runoff from any specified precipitation event. SCS TR-20 performs reservoir routing using the storage-indication method and channel routing using the Modified Att-Kin method. Time of concentration, travel time and antecedent moisture conditions are taken into account. The program provides hydrographs at any desired location allowing the evaluation of the effects of urbanization or other varied conditions within a watershed. The program allows for the analysis of nine different rainstorm distributions over a watershed and can utilize varied combinations of land treatment, floodwater retarding structures, diversions and channel configurations. Up to 200 reaches and 99 structures may be analyzed. The model can be used in design or watershed simulation. It is normally calibrated to actual events for large projects.

B-1.1.4 Assumptions

Refer to primary reference material.

B-1.1.5 Limitations

Refer to primary reference material.

B-1.2 SCS TR-55 Tabular Method

B-1.2.1 Primary Reference

Soil Conservation Service, 1986

B-1.2.2 Applicability:

Drainage areas up to 2,000 acres and where the requirements of TR-20 (See B.1.1) listed in applicability section are not needed.

B-1.2.3 Description of Method

The Tabular Method approximates TR-20 which is a more detailed hydrograph procedure; TR-55 is in fact derived from a simplification of the TR-20 model. The Tabular Method can develop composite flood hydrographs at any point in a watershed by dividing the watershed into homogeneous subareas. In this manner, the method can estimate runoff from non-homogeneous watersheds. The method is especially applicable for estimating the effects of land use change in a portion of a watershed. It can also be used to estimate the effects of proposed structures. Refer to TR-55 for a detailed description of the use of the method.

B-1.2.4 Assumptions

See TR-55, TR-20 and NEH-4 reference material.

B-1.2.5 Limitations

1. Refer to applicable chapters of TR-55 for specific limitations, including those pertaining to the derivation of Curve Number (CN) and Time of Concentration (Tc).

2. TR-55 is based on open and unconfined flow over land or in channels. For large events during which flow is divided between piped or channelized and overland flow, more information about hydraulics is needed to determine Tc. After flow enters a closed system, the discharge can be assumed constant until another flow is encountered at a junction or another inlet.

3. The Tabular Hydrograph method is derived from TR-20 output. The use of Tc permits it to be used for any size watershed within the scope of the curves or tables. The Tabular Method can be used for a heterogeneous watershed that is divided into a number of homogeneous sub-watersheds. Hydrographs for the sub-watersheds can be routed and added.

4. The Tabular Method is used to determine peak flows and hydrographs within a watershed. However, its accuracy decreases as the complexity of the watershed increases. To compare present and developed conditions of a watershed, use the same procedure for estimating Tc for both conditions.

5. Use the TR-20 computer program instead of the Tabular Method if any of the following conditions applies:

   - T_t is greater than 3 hours

   - T_c is greater than 2 hours

   - Drainage areas of individual subareas differ by a factor of 5 or more.

- The entire composite flood hydrograph or entire runoff volume is required for detailed flood routings. The hydrograph based on extrapolation is only an approximation of the entire hydrograph.

- The time of peak discharge must be more accurate than that obtained through the Tabular Method.

- CN is less than 30.

6. The composite flood hydrograph should be compared with actual stream gage data where possible. The instantaneous peak flow value from the composite flood hydrograph can be compared with data from USGS curves of peak flow versus drainage area.

B-1.3 Corps of Engineers: HEC-1

B-1.3.1 Primary Reference

Hydrologic Engineering Center, 1990

B-1.3.2 Applicability

Same as TR-20, (See B.1.1) but in addition considers snowmelt behavior. It can be used in reverse to determine a unit hydrograph given watershed parameters and an actual rainfall and hydrograph event.

B-1.3.3 Description of Method

HEC-1 is a computer model for rainfall-runoff analysis developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers. This program develops discharge hydrographs for either historical or hypothetical events for one or more locations in a basin. The basin can be subdivided into many subbasins. Reservoirs and diversions can also be accommodated.

The available program options include the following: calibration of unit hydrograph and loss-rate parameters, calibration of routing parameters, generation of hypothetical storm data, simulation of snow pack processes and snow melt runoff, dam safety applications, multiplan/multiflood analysis, flood damage analysis, and optimization of flood control system components (DeVries 1993).

B-1.3.4 Assumptions

Refer to primary reference material.

B-1.3.5 Limitations

Refer to primary reference material.

B-1.3.6 Availability

HEC-1 is available from program vendors who supply the compiled program or source code and also provide various degrees of program support. Some vendors provide modified versions of the program as well as their own data editors and plotting utilities. HEC-1 is available from the Hydrologic Engineering Center only to U.S. government agencies. A List of program vendors is available from the Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616 (DeVries 1993).B-2.1.1

Appendix B-2: Runoff Peak and Volume Calculations

B-2.1 SCS TR-55 Graphical Method

B-2.1.1 Primary Reference

Soil Conservation Service, 1986

B-2.1.2 APPLICABILITY

Determines peak runoff, the runoff volume, and the time to peak for a single homogeneous sub-area or watershed only. Applicable for drainage areas up to 2000 acres.

B-2.1.3 DESCRIPTION OF METHOD

The Graphical Method was developed from hydrograph analyses using TR-20. It provides a simplified approach to estimating peak runoff and total runoff volumes while accounting for slope, soils, and watershed shape. Refer to TR-55 for a detailed description of the use of the method.

B-2.1.4 ASSUMPTIONS

See TR-55 and TR-20 reference material.

B-2.1.5 LIMITATIONS

1. Refer to applicable chapters of TR-55 for specific limitations, including those pertaining to the derivation of Curve Number (CN) and Time of Concentration (Tc).

2. TR-55 is based on open and unconfined flow over land or in channels. For large events during which flow is divided between sewer and overland flow, more information about hydraulics is needed to determine Tc. After flow enters a closed system, the discharge can be assumed constant until another flow is encountered at a junction or another inlet.

3. The Graphical Peak Discharge method is derived from TR-20 (SCS 1983) output. The use of Tc permits it to be used for any size watershed within the scope of the curves or tables. The Graphical method is used only for hydrologically **homogeneous** watersheds because the procedure is **limited** to a **single** watershed subarea.

4. The Graphical method provides a determination of peak discharge only. If a hydrograph is needed or watershed subdivision is required, use the Tabular Hydrograph method. Use TR-20 if the watershed is very complex or a higher degree of accuracy is required.

5. The watershed must be hydrologically homogeneous, that is, describable by one CN. Land use, soils, and cover are distributed uniformly throughout the watershed.

6. The watershed may have only one main stream or, if more than one, the branches must have nearly equal Tc's.

7. The method cannot perform valley or reservoir routing.

8. The ponding factor can be applied only for ponds or swamps that are not in the Tc flow path.

9. Accuracy of peak discharge estimated by this method will be reduced if Ia/P values are used that are outside the range given in the TR-55 reference. The limiting Ia/P values are recommended for use.

10. This method should be used only if the weighted CN is greater than 40.

11. When this method is used to develop estimates of peak discharge for both present and developed conditions of a watershed, use the same procedure for estimating Tc.

12. Tc values with this method may range from 0.1 to 10 hours.

Appendix B-3: Runoff Peak Discharge Calculations

B-3.1 Rational Method

B-3.1.1 Primary Reference

ASCE, 1992 and Rossmiller, 1980

B-3.1.2 Applicability

Required output = peak discharge only
Drainage area < 20 acres

B-3.1.3 Description of Method

The Rational Method is used for determining peak discharges from small drainage areas. This method is traditionally used to size storm sewers, channels and other stormwater structures which handle runoff from drainage areas less than 20 acres.

The Rational Formula is expressed as Q = CiA [Eq B-1]

where:

Q=Peak rate of runoff in cubic feet per second

C=Runoff coefficient, an empirical coefficient representing a relationship between rainfall and runoff.

i =Average intensity of rainfall in inches per hour for the time of concentration (Tc) for a selected frequency of occurrence or return period.

Tc =The rainfall intensity averaging time in minutes, usually referred to as the time of concentration, equal to the time required for water to flow from the hydraulically most distant point in the watershed to the point of design.

A =The watershed area in acres

The general procedure for determining peak discharge with the Rational Formula is:

Step 1 Determine the drainage area.

Step 2 Determine the runoff coefficient, C, for the type of soil/cover in the drainage area. If land use and soil cover are homogeneous over the drainage area, a C value can be determined directly from referenced sources. If there are multiple soil cover conditions, a weighted average must be performed. See hydrologic charts included in Appendix A.

Step 3 Determine the rainfall intensity averaging time, Tc, in minutes for the drainage area (time required for water to flow from the hydraulically most distant point of that tributary watershed which produces the greatest discharge to the point of design).

Step 4 Determine the Rainfall Intensity Factor, i, for the selected design storm. This is done by using the Rainfall Intensity - Frequency - Duration charts (available through local National Weather Bureau Offices). Select the chart for the locality closest to your project site. Enter the "Duration" axis of the chart with the calculated time of concentration, Tc. Move vertically until you intersect the curve of the appropriate design storm, then move horizontally to read the Rainfall Intensity Factor, i, in inches per hour. See the Maine Department of Transportation Highway Design Guide hydrologic charts included in Appendix A of this volume.

Step 5 Determine the peak discharge (Q - in cubic feet per second) from equation B-1.

B-3.1.4 Assumptions (Adapted from Rossmiller, 1980)

1. The peak rate of runoff at any point is a direct function of the tributary drainage area and the average rainfall intensity during the time of concentration to that point.

   This is the rational formula stated in words and forms the basic assumption for Kuichling's 1889 paper. Neither sufficient rainfall nor runoff records are available to test this hypothesis.

2. The return period of the peak discharge rate is the same as the return period of the average rainfall intensity or rainfall event.

   While watershed-related variations such as antecedent moisture conditions may cause this relationship to break down, this assumption is widely used in methodologies for estimating peak flows or hydrographs.

3. The rainfall is uniformly distributed over the watershed.

   Whether this assumption is true depends upon the size of the watershed and the rainfall event.

4. The rainfall intensity remains constant during the time period equal to Tc.

   Based on rainfall records, this assumption is true for short periods of time (a few minutes), but becomes less true as time increases. In turn, this assumption has led to a common misconception that the duration of the storm is equal to Tc. This is theoretically possible but it is much more common for the total storm duration to be considerably longer than Tc.

   Of equal importance is the concept that Tc (the rainfall intensity averaging time) can occur during any segment of the total storm duration; at the beginning, before, during or after the middle portion; or near the end . This concept has important implications for the runoff coefficient C and how well the Rational Formula mirrors the hydrologic cycle. If an intensity for a duration equal to or slightly greater than Tc occurs at the beginning of the storm, then the antecedent moisture conditions become important. If Tc occurs near the end of a long storm, then the ground may be saturated and depression storage already filled when Tc begins.

5. The relationship between rainfall and runoff is linear.

   If rainfall is doubled then runoff is doubled. This is not accurate because of all the variables which interact and determine runoff. In fact, one of the major misconceptions on the use of the formula is that each of the variables (C, i, A) is independent and estimated separately. In reality, there is some interdependency among variables; however, the aids used in estimating the variables do not recognize such a relationship.

6. The runoff coefficient, C, is constant for storms of any duration or frequency on the watershed.

   This is a major misconception of many who use the Rational Formula. C is a variable and during the design of a stormwater system, especially a storm sewer, it should take on several different values for the various segments even though the land use remains the same.

B-3.1.5 Limitations

1. The Rational Formula only produces one point on the runoff hydrograph, the peak discharge rate. Where a hydrograph is required, other methods must be used.

2. When basins become complex, and where sub-basins combine, the Rational Formula will tend to overestimate the actual flow. The overestimation will result in the oversizing of stormwater management systems.

   For this reason, the formula should not be used for larger developments as a basis for establishing predevelopment flow rates, which are used to define the restrictions needed for peak rate control. The artificially high estimates could result in release rates higher than existing conditions, resulting in adverse effects downstream.

3. The method assumes that the rainfall intensity is uniform over the entire watershed. This assumption is true only for small watersheds and time periods, thus limiting the use of the formula to small watersheds.

4. The results of using the formula are frequently not replicable from user to user. There are considerable variations in interpretation and methodology in the use of the formula. The simplistic approach of the formula permits, and in fact, requires, a wide latitude of subjective judgment in its application.

5. The average rainfall intensities used in the method bear no time sequence relation to the actual rainfall pattern during a storm. The intensity-duration-frequency curves prepared by the Weather Bureau are not time sequence curves of precipitation. The maxima of the several durations as used in the method are not necessarily in their original sequential order; and the resulting tabulations of maxima ordered by size or duration may bear little resemblance to the original storm pattern. In many, if not most, cases, the intensities on the same frequency curve for various durations are not from the same storm.

B-3.2 USGS Regression Equations (for Maine)

B-3.2.1 Primary Reference

USGS, 1975

B-3.2.2 Applicability

Drainage areas from 200 acres and up.

B-3.2.3 Description of Methods

The method gives peak discharges for unregulated watersheds in Maine. It does not give runoff volumes or hydrographs. This method may be used for structures needing only a peak discharge for design. It can also be used to calibrate or "ground truth" the TR-20 model.

The gage network of data analyzed did not include urban (developed) watersheds with a high percent of imperviousness.

- The USGS method requires the following data as inputs:
- Drainage area (square miles)
- Channel length (miles)
- Mean sea level (MSL) elevation at 85% of the length at the upper end.
- MSL elevation at the 10% of length at lower end.
- Pond and lake area in watershed (sq miles).

It gives the 2, 5, 10, 25, 50, 100 and 500 year peak discharge values.

B-3.2.4 Assumptions

The watershed being studied must be unregulated (no dams, etc.), not heavily urbanized, and of a configuration common to watersheds in the database used.

B-3.2.5 Limitations

Before and after comparisons are not possible. The method's records include changing land use patterns, and records do not exist for long enough to do separate analysis of past and present land use and peak values.

Appendix B-4: Other Methods and Models

B-4.1 Soil Conservation Service NEH-4

B-4.1.1 Primary Reference

Soil Conservation Service, 1972.

B-4.1.2 Description

National Engineering Handbook Section 4 provides watershed analysis using the SCS Unit Hydrograph Method. Runoff hydrographs are calculated for a preselected rainfall distribution or duration, either natural or synthetic. Either peak discharge or a composite runoff hydrograph can be developed for watersheds of any size. This reference, primarily intended for SCS engineers and technicians, also contains methods and examples for studying the hydrology of watersheds and for solving hydrologic problems.

Appendix B-5: Small Storm Hydrology Models

B-5.1 Source Loading and Management Model (SLAMM)

B-5.1.1 Primary Reference

Pitt, 1992

B-5.1.2 Applicability

This model is designed for calculating urban runoff water quality, and does not contain the many assumptions that affect runoff predictions for small storm events which other drainage design models require. The model enables close examination of individual source areas and their resulting impact on overall pollutant load if they are controlled or removed from the total study area.

B-5.1.3 Description

The Source Loading and Management Model (SLAMM) is a small storm hydrology model used to predict runoff volumes associated with different land uses and development practices. The basis for the model, developed by Robert Pitt, is the fact that the majority of rainfall is contained in small rains (less than one inch) where other models, such as TR-55, do not correlate well with actual precipitation and runoff data for these smaller storms. SLAMM predicts runoff volumes associated with a variety of land uses and stormwater controls, and than calculates runoff pollutant yield (or reduction) estimates for the watershed.

B-5.1.4 Assumptions

Refer to primary reference material.

B-5.1.5 Limitations

SLAMM only calculates runoff volume which is needed for water quality studies. It does not calculate peak flow rate and time of concentration as typically needed for flooding and drainage studies.

Appendix C
Proprietary Hydrology and Hydraulics Computer Programs

Contents

The material presented in this appendix has been compiled based on a review of selected literature, and is for general information only. This information should not be used without first securing competent advice with respect to its suitability for any general or specific application.

The contents of this appendix are not intended to be and should not be construed to be a standard of the Maine Department of Environmental Protection (MDEP) and are not intended for use as a reference in purchase specifications, contracts, regulations, statutes, or any other legal document.

No reference made in this appendix to any specific method, product, process, or service constitutes or implies an endorsement, recommendation, or warranty thereof by the MDEP or the contributing authors of this appendix.

The MDEP and the contributing authors of this appendix make no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this appendix, and assume no liability therefor.

Anyone utilizing this information assumes all liability arising from such use, including but not limited to infringement of any copyright or patent.

Appendix C-1 HydroCAD

HydroCAD, developed by Applied Microcomputer Systems, is a computer aided design program, primarily incorporating a hydrograph generation and routing program. (Ref: HydroCAD Stormwater Modeling System, Applied Microcomputer Systems, Page Hill Road, Chocorua, New Hampshire 03817). HydroCAD accomplishes both reservoir and valley routing, providing SCS TR-20 accuracy and SCS TR-55 compatibility in a CAD type format. HydroCAD provides the user with several methodologies for determining; the time of concentration, runoff, and hydrograph generation. Time of Concentration methods include; the Curve Number Method, TR-55 Methods, and the Upland Method. Runoff can be determined by the Rational Method and SCS TR-20 methods. Additionally, HydroCAD performs reach routing, pond routing, and hydraulic control structure analysis, and allows for link calculations to import external hydrographs into the routing diagram. The routing diagram, a major feature of HydroCAD, provides a graphical representation of the watershed characteristics, or structures. HydroCAD generates tabular and graphical hydrographs.

Appendix C-2 Haestad Methods

Haestad Methods, Inc. has developed Pond Pack consisting of two integrated programs; Quick TR-55 and Pond-2. (Ref: Haestad Methods, Civil Engineering Software, 37 Brookside Road, Waterbury Connecticut 06708). These programs, designed to work together, incorporate identical interfaces. Their pull down menus and data entry screens are consistent. Quick TR-55 provides general site drainage and detention pond sizing and routing and is compatible with SCS TR-55. Additionally, Quick TR-55 can model hydrology utilizing the Rational and Modified Rational methods, the Santa Barbara Urban Hydrograph procedure, and pond sizing methods. Pond-2 provides detention pond design and analysis and can add and route hydrographs, estimate storage requirements, compute design volumes, develop rating curves for single and multi-stage outlet control structures and plot inflow and outflow hydrographs. Hydrographs can also be imported from HEC-1 and TR-20 programs or any spread sheet type format.

Single or multiple storm events can be routed through a pond and the outflow hydrographs used for other applications. Pond-2 utilizes the conical method to compute pond volumes from a grading plan allowing for the conversion from planimeter or CAD readings to volumes.

Appendix C-3 Dodson & Associates, Inc.

Dodson & Associates, Inc. Hydrologists and Civil Engineers has developed HYDROPRO, HYDROCALC, and ProStorm series computer modeling programs (Ref: Dodson & Associates, Inc. 5629 FM 1960 West, Suite 314, Houston, Texas, 77069).

HYDROPRO

HYDROPRO series programs contain ProHEC1 and ProHEC2 models which are enhanced versions of the Army Corps of Engineers watershed analysis and floodplain analysis programs. Both programs are driven by a master menu and include ProED, the Dodson Professional Editor. ProED functions as a spreadsheet program, similar to Lotus 1-2-3, for data input and editing.

ProHEC1, based on HEC-1, version 4.0, can be used to; compute hydrographs for simple and complex stream systems, design stormwater detention basins, analyze reservoirs and perform dam breach analysis, and compute urban runoff using the kinematic wave method.

ProHEC2 computes flood plain widths and water surface elevations along a river or stream channel. ProHEC2 also designs channel improvements and performs culvert and bridge hydraulic analysis. ProHEC2 is based on HEC-2, version 4.6.

HYDROCALC

HYDROCALC series programs contain HYDROCALC Hydraulics and HYDROCALC Hydrology models. Both programs are fully compatible with standard manual methods of computation and analysis and provide instant graphics capabilities.

HYDROCALC Hydraulics contains programs to analyze; trapezoidal channels, box culverts, circular channels, and pipe culverts. Program results provide water surface profile, critical depth and rating curve computations for channels. Culverts are analyzed using the Federal Highway Administration methods.

HYDROCALC Hydraulics contains programs to compute runoff and design detention basins in small, projects using; the Rational Method, the Triangular Hydrograph Detention Program, the Quick Hydrograph Program, or the Small Watershed Method Program. The Quick Hydrograph Method incorporates SCS methods and includes SCS storm distributions. Additionally this method computes Corps of Engineers storm distributions and includes Corps of Engineers hydrograph methods. Single sub-area results are consistent with HEC-1 results.

ProStorm

ProStorm, a recently developed program, contains menus similar to ProHEC1 and ProHEC2 and also contains ProED. ProStorm is modeled after the Army Corps of Engineers STORM program. ProStorm performs an analysis of runoff quantity and quality from urban or nonurban watersheds.

Runoff quantity can be computed by; the SCS Curve Number Technique, the coefficient method or a combination of both. The SCS method utilizes a rainfall-runoff technique based on antecedent moisture conditions for each rainfall event. The coefficient method specifies that a certain fraction of rainfall will runoff the site during each hour of the rainfall event. The combination option uses the SCS method for pervious areas and the coefficient method for impervious surfaces.

Runoff quality computes pollutant accumulation by the dust and dirt method and the daily accumulation method. The dust and dirt method assumes that all pollutants are associated with dust and dirt accumulated in streets, and that the pollutants are expressed as a fraction of the dust and dirt for each use. This method should not be used in areas where a significant portion of pollutants originate from sources other than streets or in cases where nonurban uses represent a major portion of the watershed. The daily accumulation method, used in areas where a significant portion of pollutants originate from areas other than streets, or in non-urban land uses, incorporates daily accumulation rates of each pollutant.

Appendix C-4: Engineering Data Systems Corporation

Engineering Data Systems Corporation has developed several hydrological programs; Watershed Modeling, Water Surface Profiling, Storm Sewer and Sanitary Sewer. (Ref: Engineering Data Systems Corporation, Clock Tower West, Suite G, Dubuque, Iowa 52003). All programs are menu driven and information can be transmitted between programs, or imported from one program to another. All programs include the use of Reference Library, a memory resident utility program providing online help and reference information. Reference Library is activated through a "Hot-key" which interrupts the hydrology program in use and displays the reference screens. These screens contain information pertaining to roughness coefficients, curve numbers, runoff coefficients and rainfall data.

Watershed Modeling

Watershed Modeling analyzes single runoff hydrographs, combines hydrographs, performs flood routing and designs ponds. Watershed analysis is accomplished, utilizing SCS or the Rational methods, by selecting the desired function from the menu, beginning at the uppermost reach of the watershed. The menu allows for channel routing or reservoir routing modeling.

Water Surface Profiling

Water Surface Profiling analyzes and computes water surface profiles through channels and stream networks. Hydraulic analysis is performed using the Modified Standard Step Method. Pressure and non pressure flows through channels, culverts or bridge sections, can be analyzed and the results plotted as cross-sections, plan views and hydraulic profiles. The program provides for sub and super critical flow regimes.

Storm Sewer

Storm Sewers is a computer model that designs and analyzes the hydraulic grade line for storm sewer systems utilizing the Standard Step Method. Hydraulic profiles and rainfall intensity curves are calculated and the hydraulic grade results plotted to the printer or screen. Capacities of existing sewer systems can also be analyzed.

Appendix D
Templates for Deed Restrictions & Conservation Easements

1. FORESTED BUFFER, LIMITED DISTURBANCE

DECLARATION OF RESTRICTIONS (Forested Buffer, Limited Disturbance)

THIS DECLARATION OF RESTRICTIONS is made this _______________day of ___________, 20___, by ____,
(name)
____, ___________________,
(street address) (city or town)
_____________________County, Maine, ________, (herein referred to as the "Declarant"),
(county) (zipcode)
pursuant to a permit received from the Maine Department of Environmental Protection under the Stormwater Management Law, to preserve a buffer area on a parcel of land near _________________________,____
(road name) (known feature and/or town)

WHEREAS, the Declarant holds title to certain real property situated in ___________________,
(town)
Maine described in a deed from________________________to _________________________
(name) (name of Declarant)
dated _______________, 20____, and recorded in Book ____ Page ____ at the _______________County Registry of Deeds, herein referred to as the "property"; and

WHEREAS, Declarant desires to place certain restrictions, under the terms and conditions herein, over a portion of said real property (hereinafter referred to as the "Restricted Buffer") described as follows: (Note: Insert description of restricted buffer area location here)

WHEREAS, pursuant to the Stormwater Management Law, 38 M.R.S.A. Section 420-D and Chapter 500 of rules promulgated by the Maine Board of Environmental Protection ("Stormwater Management Rules"), Declarant has agreed to impose certain restrictions on the Restricted Buffer Area as more particularly set forth herein and has agreed that these restrictions may be enforced by the Maine Department of Environmental Protection or any successor (hereinafter the "MDEP"),

NOW, THEREFORE, the Declarant hereby declares that the Restricted Buffer Area is and shall forever be held, transferred, sold, conveyed, occupied and maintained subject to the conditions and restrictions set forth herein. The Restrictions shall run with the Restricted Buffer Area and shall be binding on all parties having any right, title or interest in and to the Restricted Buffer Area, or any portion thereof, and their heirs, personal representatives, successors, and assigns. Any present or future owner or occupant of the Restricted Buffer Area or any portion thereof, by the acceptance of a deed of conveyance of all or part of the Covenant Area or an instrument conveying any interest therein, whether or not the deed or instrument shall so express, shall be deemed to have accepted the Restricted Buffer Area subject to the Restrictions and shall agree to be bound by, to comply with and to be subject to each and every one of the Restrictions hereinafter set forth.

1. Restrictions on Restricted Buffer Area. Unless the owner of the Restricted Buffer Area, or any successors or assigns, obtains the prior written approval of the MDEP, the Restricted Buffer Area must remain undeveloped in perpetuity. To maintain the ability of the Restricted Buffer Area to filter and absorb stormwater, and to maintain compliance with the Stormwater Management Law and the permit issued thereunder to the Declarant, the use of the Restricted Buffer Area is hereinafter limited as follows.

a. No soil, loam, peat, sand, gravel, concrete, rock or other mineral substance, refuse, trash, vehicle bodies or parts, rubbish, debris, junk waste, pollutants or other fill material may be placed, stored or dumped on the Restricted Buffer Area, nor may the topography of the area be altered or manipulated in any way;

b. Any removal of trees or other vegetation within the Restricted Buffer Area must be limited to the following:

(i) No purposefully cleared openings may be created and an evenly distributed stand of trees and other vegetation must be maintained. An "evenly distributed stand of trees " is defined as maintaining a minimum rating score of 24 points in any 25 foot by 50 foot square (2500 square feet) area, as determined by the following rating scheme:

Diameter of tree at 4 1/2 feet above ground level	Points
2-4 inches	1
4-8 inches	2
8-12 inches	4
>12 inches	8

Where existing trees and other vegetation result in a rating score less than 24 points, no trees may be cut or sprayed with biocides except for the normal maintenance of dead, windblown or damaged trees and for pruning of tree branches below a height of 12 feet provided two thirds of the tree's canopy is maintained;

(ii) No undergrowth, ground cover vegetation, leaf litter, organic duff layer or mineral soil may be disturbed except that one winding path, that is no wider than six feet and that does not provide a downhill channel for runoff, is allowed through the area;

c. No building or other temporary or permanent structure may be constructed, placed or permitted to remain on the Restricted Buffer Area, except for a sign, utility pole or fence;

d. No trucks, cars, dirt bikes, ATVs, bulldozers, backhoes, or other motorized vehicles or mechanical equipment may be permitted on the Restricted Buffer Area;

e. Any level lip spreader directing flow to the Restricted Buffer Area must be regularly inspected and adequately maintained to preserve the function of the level spreader.

Any activity on or use of the Restricted Buffer Area inconsistent with the purpose of these Restrictions is prohibited. Any future alterations or changes in use of the Restricted Buffer Area must receive prior approval in writing from the MDEP. The MDEP may approve such alterations and changes in use if such alterations and uses do not impede the stormwater control and treatment capability of the Restricted Buffer Area or if adequate and appropriate alternative means of stormwater control and treatment are provided.

2. Enforcement. The MDEP may enforce any of the Restrictions set forth in Section 1 above.

3. Binding Effect. The restrictions set forth herein shall be binding on any present or future owner of the Restricted Buffer Area. If the Restricted Buffer Area is at any time owned by more than one owner, each owner shall be bound by the foregoing restrictions to the extent that any of the Restricted Buffer Area is included within such owner's property.

4. Amendment. Any provision contained in this Declaration may be amended or revoked only by the recording of a written instrument or instruments specifying the amendment or the revocation signed by the owner or owners of the Restricted Buffer Area and by the MDEP.

5. Effective Provisions of Declaration. Each provision of this Declaration, and any agreement, promise, covenant and undertaking to comply with each provision of this Declaration, shall be deemed a land use restriction running with the land as a burden and upon the title to the Restricted Buffer Area.

6. Severability. Invalidity or unenforceability of any provision of this Declaration in whole or in part shall not affect the validity or enforceability of any other provision or any valid and enforceable part of a provision of this Declaration.

7. Governing Law. This Declaration shall be governed by and interpreted in accordance with the laws of the State of Maine.

(NAME)

____

STATE OF MAINE
_________________ County, ___________________, 20__.
(County) (date)

Personally appeared before me the above named ___________________________, who swore to the truth of the foregoing to the best of (his/her) knowledge, information and belief and acknowledged the foregoing instrument to be (his/her) free act and deed.

____
Notary Public
____

2. FORESTED BUFFER, NO DISTURBANCE

DECLARATION OF RESTRICTIONS (Forested Buffer, No Disturbance)

THIS DECLARATION OF RESTRICTIONS is made this __________day of ______________ , 20___, by _________________________, ____,
(name) (street address)
____________________, _________________County, Maine, ________ , (herein referred to as the
(city or town) (county) (zipcode)
"Declarant", pursuant to a permit received from the Maine Department of Environmental Protection under the Stormwater Management Law, to preserve a buffer area on a parcel of land near _______________________, ____ .
(road name) (known feature and/or town)

WHEREAS, the Declarant holds title to certain real property situated in ________________, Maine
(town)
described in a deed from _________________________to _____________________________,
(name) (name of Declarant)
dated _______________, 20____, and recorded in Book ____ Page ____ at the _______________County Registry of Deeds, herein referred to as the "property"; and

WHEREAS, Declarant desires to place certain restrictions, under the terms and conditions herein, over a portion of said real property (hereinafter referred to as the "Restricted Buffer") described as follows: (Note: Insert description of restricted buffer location here)

WHEREAS, pursuant to the Stormwater Management Law, 38 M.R.S.A. Section 420-D and Chapter 500 of rules promulgated by the Maine Board of Environmental Protection ("Stormwater Management Rules"), Declarant has agreed to impose certain restrictions on the Restricted Buffer Area as more particularly set forth herein and has agreed that these restrictions may be enforced by the Maine Department of Environmental Protection or any successor (hereinafter the "MDEP"),

NOW, THEREFORE, the Declarant hereby declares that the Restricted Buffer Area is and shall forever be held, transferred, sold, conveyed, occupied and maintained subject to the conditions and restrictions set forth herein. The Restrictions shall run with the Restricted Buffer Area and shall be binding on all parties having any right, title or interest in and to the Restricted Buffer Area, or any portion thereof, and their heirs, personal representatives, successors, and assigns. Any present or future owner or occupant of the Restricted Buffer Area or any portion thereof, by the acceptance of a deed of conveyance of all or part of the Covenant Area or an instrument conveying any interest therein, whether or not the deed or instrument shall so express, shall be deemed to have accepted the Restricted Buffer Area subject to the Restrictions and shall agree to be bound by, to comply with and to be subject to each and every one of the Restrictions hereinafter set forth.

1. Restrictions on Restricted Buffer Area. Unless the owner of the Restricted Buffer Area, or any successors or assigns, obtains the prior written approval of the MDEP, the Restricted Buffer Area must remain undeveloped in perpetuity. To maintain the ability of the Restricted Buffer Area to filter and absorb stormwater, and to maintain compliance with the Stormwater Management Law and the permit issued thereunder to the Declarant, the use of the Restricted Buffer Area is hereinafter limited as follows.

   a. No soil, loam, peat, sand, gravel, concrete, rock or other mineral substance, refuse, trash, vehicle bodies or parts, rubbish, debris, junk waste, pollutants or other fill material will be placed, stored or dumped on the Restricted Buffer Area, nor shall the topography of the area be altered or manipulated in any way;

   b. No trees may be cut or sprayed with biocides except for the normal maintenance of dead, windblown or damaged trees and for pruning of tree branches below a height of 12 feet provided two thirds of the tree's canopy is maintained;

   c. No undergrowth, ground cover vegetation, leaf litter, organic duff layer or mineral soil may be disturbed except that one winding path, that is no wider than six feet and that does not provide a downhill channel for runoff, is allowed through the area;

   d. No building or other temporary or permanent structure may be constructed, placed or permitted to remain on the Restricted Buffer Area, except for a sign, utility pole or fence;

   e. No trucks, cars, dirt bikes, ATVs, bulldozers, backhoes, or other motorized vehicles or mechanical equipment may be permitted on the Restricted Buffer Area;

   f. Any level lip spreader directing flow to the Restricted Buffer Area must be regularly inspected and adequately maintained to preserve the function of the level spreader.

Any activity on or use of the Restricted Buffer Area inconsistent with the purpose of these Restrictions is prohibited. Any future alterations or changes in use of the Restricted Buffer Area must receive prior approval in writing from the MDEP. The MDEP may approve such alterations and changes in use if such alterations and uses do not impede the stormwater control and treatment capability of the Restricted Buffer Area or if adequate and appropriate alternative means of stormwater control and treatment are provided.

2. Enforcement. The MDEP may enforce any of the Restrictions set forth in Section 1 above.

3. Binding Effect. The restrictions set forth herein shall be binding on any present or future owner of the Restricted Buffer Area. If the Restricted Buffer Area is at any time owned by more than one owner, each owner shall be bound by the foregoing restrictions to the extent that any of the Restricted Buffer Area is included within such owner's property.

4. Amendment. Any provision contained in this Declaration may be amended or revoked only by the recording of a written instrument or instruments specifying the amendment or the revocation signed by the owner or owners of the Restricted Buffer Area and by the MDEP.

5. Effective Provisions of Declaration. Each provision of this Declaration, and any agreement, promise, covenant and undertaking to comply with each provision of this Declaration, shall be

deemed a land use restriction running with the land as a burden and upon the title to the Restricted Buffer Area.

6. Severability. Invalidity or unenforceability of any provision of this Declaration in whole or in part shall not affect the validity or enforceability of any other provision or any valid and enforceable part of a provision of this Declaration.

7. Governing Law. This Declaration shall be governed by and interpreted in accordance with the laws of the State of Maine.

____
(NAME)

STATE OF MAINE, ____________________County, dated __________________, 20__.
(County)

Personally appeared before me the above named _________________________, who swore to the truth of the foregoing to the best of (his/her) knowledge, information and belief and acknowledged the foregoing instrument to be (his/her) free act and deed.

____
Notary Public

____

3 . MEADOW BUFFER

DECLARATION OF RESTRICTIONS (Non-Wooded Meadow Buffer)

THIS DECLARATION OF RESTRICTIONS is made this ________day of ____________, 20___, by

_____________________________________, ____
(name) (street address)

___________________, ________________County, Maine,________, (herein referred to as the
(city or town) (county) (zipcode)

"Declarant"), pursuant to a permit received from the Maine Department of Environmental Protection under the Stormwater Management Law, to preserve a buffer area on a parcel of land near __________________________, ____ .
(road name) (known feature and/or town)

WHEREAS, the Declarant holds title to certain real property situated in _________________,
(town)

Maine described in a deed from_________________________to ___________________________,
(name) (name of Declarant)

dated _______________, 20____, and recorded in Book ____ Page ____ at the _______________County Registry of Deeds, herein referred to as the "property"; and

WHEREAS, Declarant desires to place certain restrictions, under the terms and conditions herein, over a portion of said real property (hereinafter referred to as the "Restricted Buffer") described as follows: (Note: Insert description of restricted buffer location here)

WHEREAS, pursuant to the Stormwater Management Law, 38 M.R.S.A. Section 420-D and Chapter 500 of rules promulgated by the Maine Board of Environmental Protection ("Stormwater Management Rules"), Declarant has agreed to impose certain restrictions on the Restricted Buffer Area as more particularly set forth herein and has agreed that these restrictions may be enforced by the Maine Department of Environmental Protection or any successor (hereinafter the "MDEP"),

NOW, THEREFORE, the Declarant hereby declares that the Restricted Buffer Area is and shall forever be held, transferred, sold, conveyed, occupied and maintained subject to the conditions and restrictions set forth herein. The Restrictions shall run with the Restricted Buffer Area and shall be binding on all parties having any right, title or interest in and to the Restricted Buffer Area, or any portion thereof, and their heirs, personal representatives, successors, and assigns. Any present or future owner or occupant of the Restricted Buffer Area or any portion thereof, by the acceptance of a deed of conveyance of all or part of the Covenant Area or an instrument conveying any interest therein, whether or not the deed or instrument shall so express, shall be deemed to have accepted the Restricted Buffer Area subject to the Restrictions and shall agree to be bound by, to comply with and to be subject to each and every one of the Restrictions hereinafter set forth.

1. Restrictions on Restricted Buffer Area. Unless the owner of the Restricted Buffer Area, or any successors or assigns, obtains the prior written approval of the MDEP, the Restricted Buffer Area must remain undeveloped in perpetuity. To maintain the ability of the Restricted Buffer Area to filter and absorb stormwater, and to maintain compliance with the Stormwater Management Law and the permit issued thereunder to the Declarant, the use of the Restricted Buffer Area is hereinafter limited as follows.

a. No soil, loam, peat, sand, gravel, concrete, rock or other mineral substance, refuse, trash, vehicle bodies or parts, rubbish, debris, junk waste, pollutants or other fill material will be placed, stored or dumped on the Restricted Buffer Area, nor may the topography or the natural mineral soil of the area be altered or manipulated in any way;

b. A dense cover of grassy vegetation must be maintained over the Restricted Buffer Area, except that shrubs, trees and other woody vegetation may also be planted or allowed to grow in the area. The Restricted Buffer Area may not be maintained as a lawn or used as a pasture. If vegetation in the Restricted Buffer Area is mowed, it may be mown no more than two times per year.

c. No building or other temporary or permanent structure may be constructed, placed or permitted to remain on the Restricted Buffer Area, except for a sign, utility pole or fence;

d. No trucks, cars, dirt bikes, ATVs, bulldozers, backhoes, or other motorized vehicles or mechanical equipment may be permitted on the Restricted Buffer Area, except for vehicles used in mowing;

e. Any level lip spreader directing flow to the Restricted Buffer Area must be regularly inspected and adequately maintained to preserve the function of the level spreader.

Any activity on or use of the Restricted Buffer Area inconsistent with the purpose of these Restrictions is prohibited. Any future alterations or changes in use of the Restricted Buffer Area must receive prior approval in writing from the MDEP. The MDEP may approve such alterations and changes in use if such alterations and uses do not impede the stormwater control and treatment capability of the Restricted Buffer Area or if adequate and appropriate alternative means of stormwater control and treatment are provided.

2. Enforcement. The MDEP may enforce any of the Restrictions set forth in Section 1 above.

3. Binding Effect. The restrictions set forth herein shall be binding on any present or future owner of the Restricted Buffer Area. If the Restricted Buffer Area is at any time owned by more than one owner, each owner shall be bound by the foregoing restrictions to the extent that any of the Restricted Buffer Area is included within such owner's property.

4. Amendment. Any provision contained in this Declaration may be amended or revoked only by the recording of a written instrument or instruments specifying the amendment or the revocation signed by the owner or owners of the Restricted Buffer Area and by the MDEP.

5. Effective Provisions of Declaration. Each provision of this Declaration, and any agreement, promise, covenant and undertaking to comply with each provision of this Declaration, shall be deemed a land use restriction running with the land as a burden and upon the title to the Restricted Buffer Area.

6. Severability. Invalidity or unenforceability of any provision of this Declaration in whole or in part shall not affect the validity or enforceability of any other provision or any valid and enforceable part of a provision of this Declaration.

7. Governing Law. This Declaration shall be governed by and interpreted in accordance with the laws of the State of Maine.

____
(NAME)

STATE OF MAINE, ___________________, County, dated ___________________, 20__ .
(County)

Personally appeared before me the above named _______________________, who swore to the truth of the foregoing to the best of (his/her) knowledge, information and belief and acknowledged the foregoing instrument to be (his/her) free act and deed.

____
Notary Public

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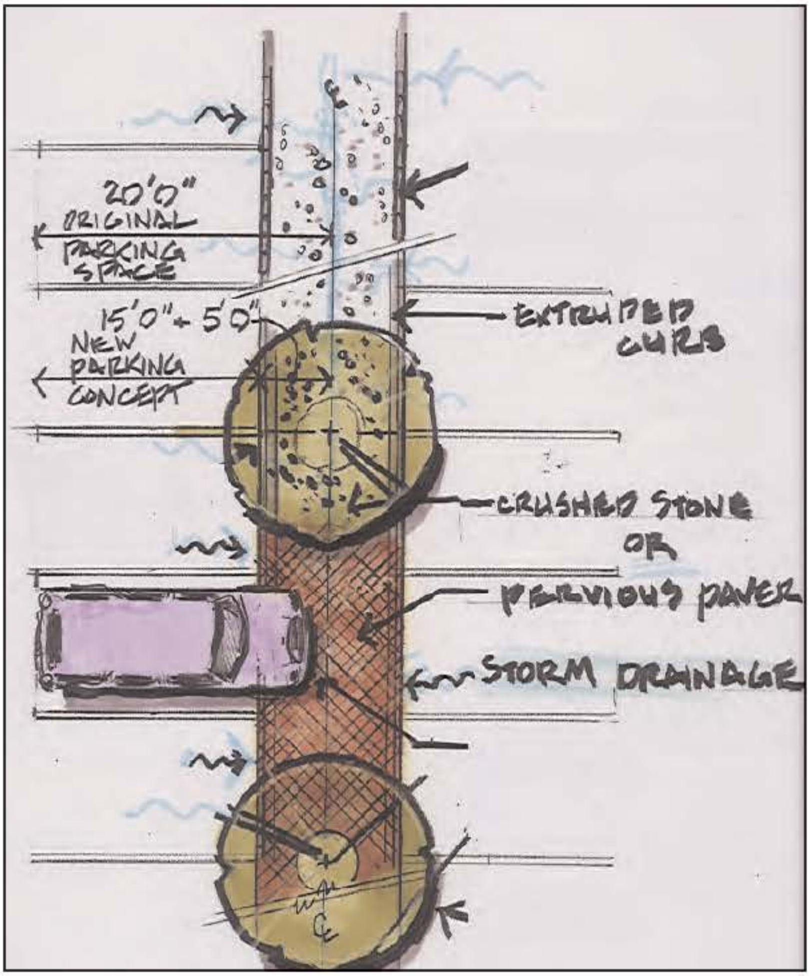
Appendix E
Example LID Measures

Contents

Appendix E-1: Infiltration Divider



Description

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

Application

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

Advantages

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

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

Disadvantages

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

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

Design Considerations

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

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

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

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

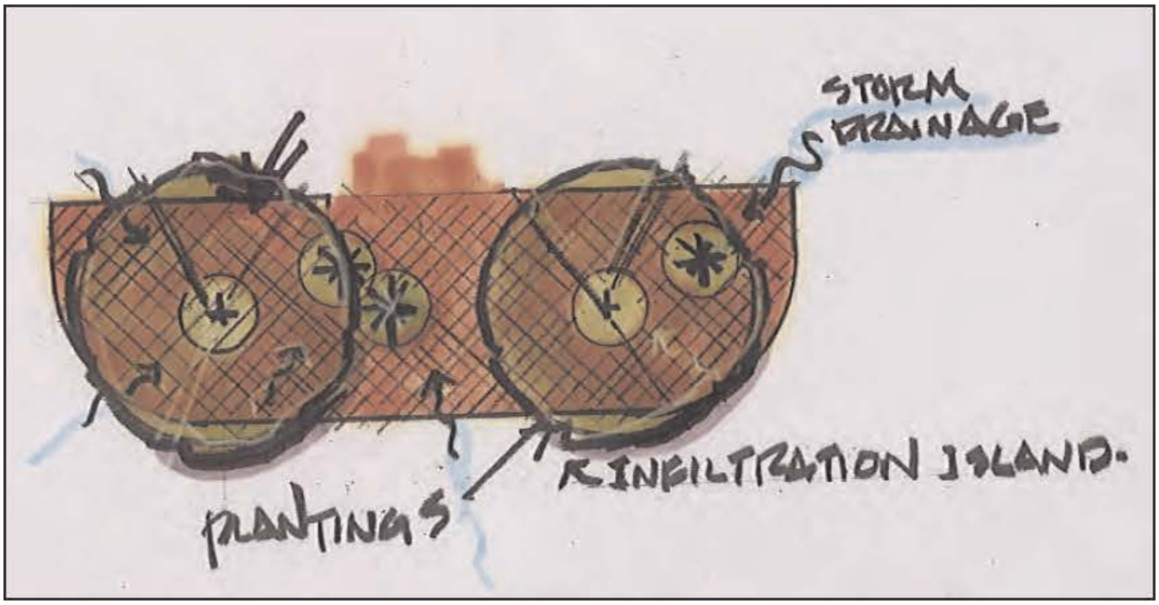
Treatment of stormwater in this device is accomplished by the stormwater passing first though the filter fabric and then through the native soil surrounding the main chamber. The main distinction of the Infiltration Divider is its ability to rapidly accept stormwater below grade. Organic material and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

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

Maintenance

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

Appendix E-2: Infiltration Islands



Description

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

Application

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

Advantages

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

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

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

Disadvantages

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

Pavers are more costly than a simple crushed stone surfacing.

Design Considerations

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

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

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

Maintenance

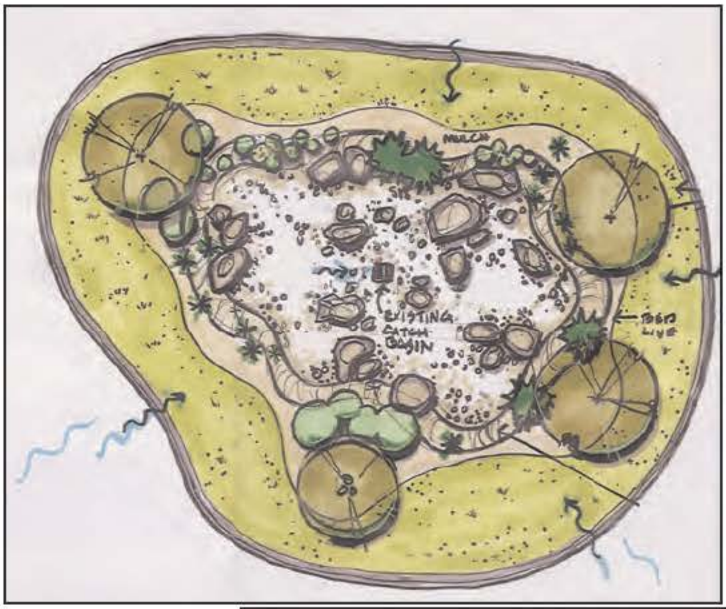
Paver surfaces located in traffic areas will require periodic inspection for deflection (raised or uneven surfaces) to ensure that they will not be pulled up during winter plowing activities. This is best inspected in the Fall, before snowfall. If deflection approaches half of the paver thickness, the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

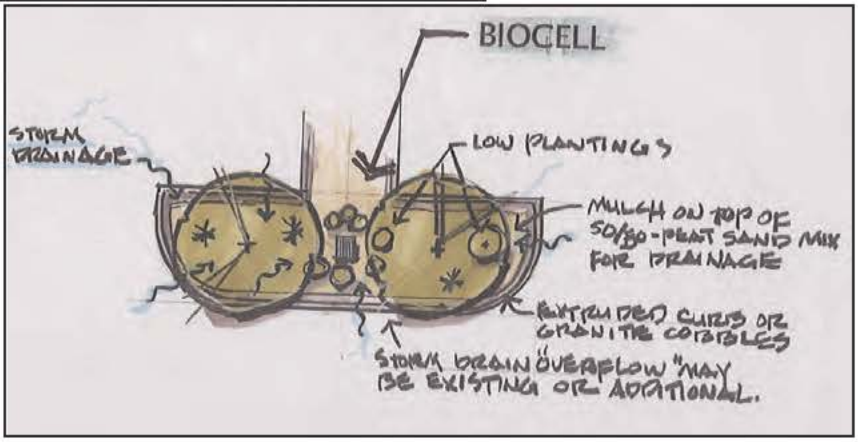
Sand deposits that have accumulated on the surface of the RPM will need to be removed periodically. A wet/dry vacuum is ideal for this and will prolong the life expectancy of the surface of the structure before the pavers, bedding material, and filter fabric must be completely removed and replaced and/or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

It is advisable to occasionally monitor the RPM during a rainstorm to determine if "preferential flow paths" have developed and/or if water seems to make its way to the overflow before using up the capacity of the reservoir/depression area. Forty-eight hours after the storm has stopped[1] the reservoir/depression area should have completely drained. Surface ponding conditions that exceed 48 hours are undesirable as nuisance conditions can develop soon thereafter. Prolonged surface ponding (over 48 hours) indicates that the surface area needs to be rehabilitated by removing and cleaning or replacing the surface material down to and including the first filter fabric barrier encountered. An observation well can be installed in the structure to determine whether the infiltration media below the filter fabric has clogged.

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

Appendix E-3: Bio-Islands & Bio-Cells





Description

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

Application

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

Advantages

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

Disadvantages

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

Design Considerations

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

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

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

Maintenance

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

Appendix E-4: Grassed Infiltration Strips

Description

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

Application

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

Advantages

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

Disadvantages

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

Design Considerations

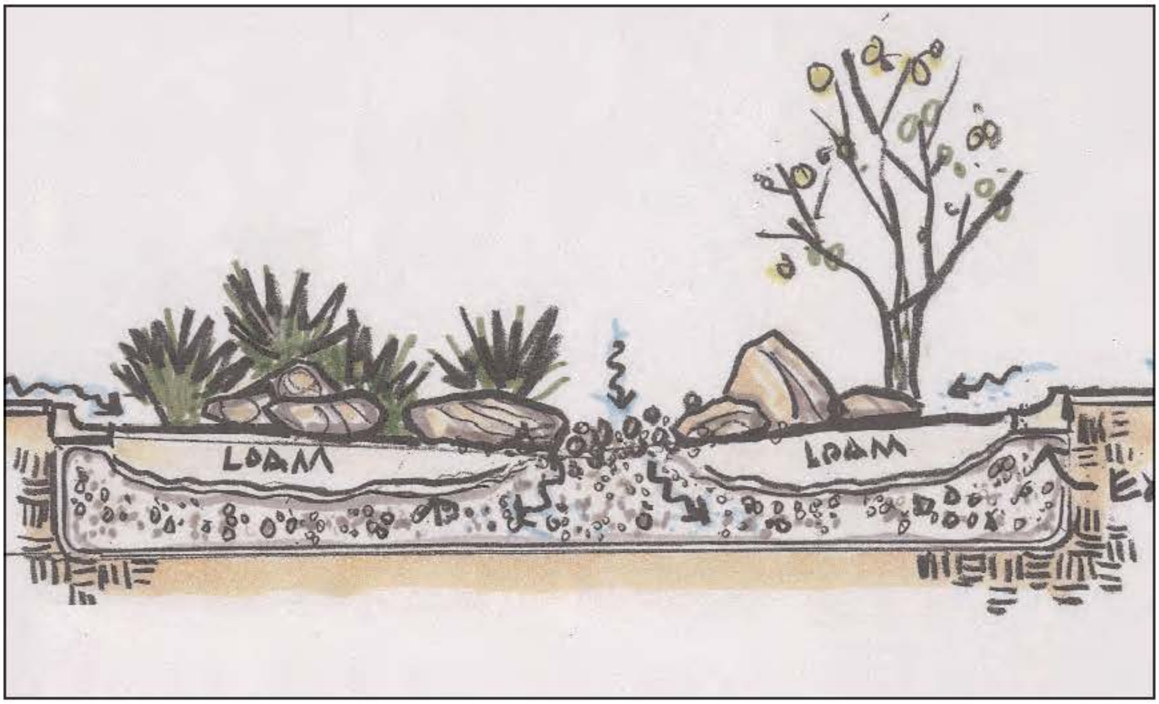
Parking lots and drives with perimeters sloping into them are not feasible for this device. Water must be able to flow across the device and away from the parking lot. Runoff flows with high concentrations of sediment will cause the depression to fill in. This will necessitate frequent maintenance for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

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

Maintenance

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

Appendix E-5: Dry Stream Infiltration Bed



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

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

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

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

Design Considerations

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

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

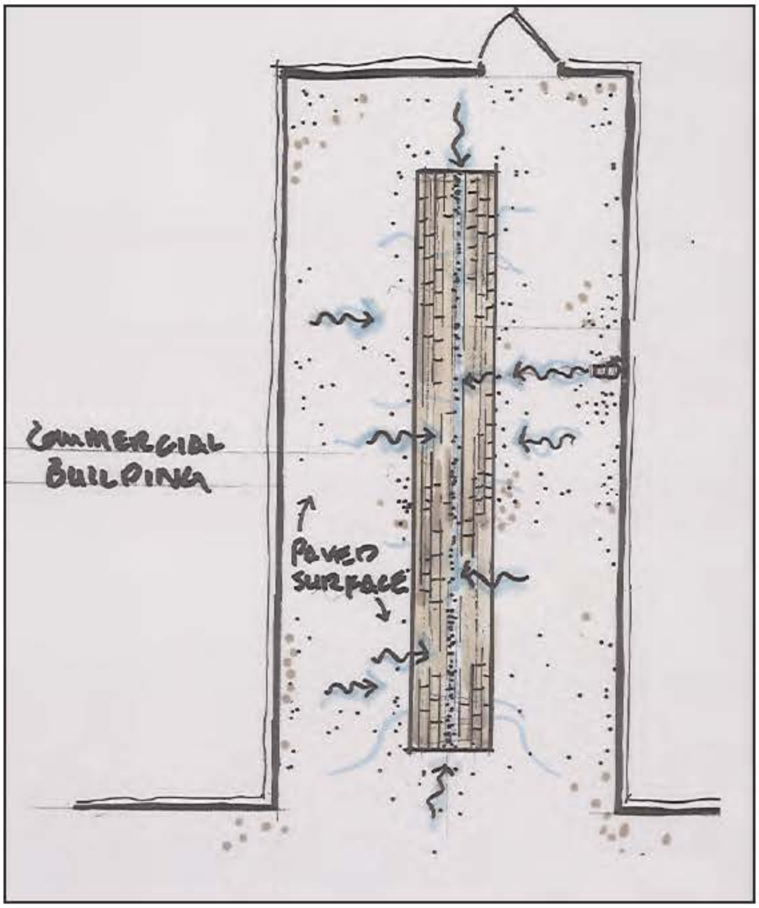
Because of its size, a significant slope throughout the length of the structure (when installed parallel to the slope) can cause ponding, and associated overflows at the downgradient end and underutilized storage volume at the upper end. Installing the structure perpendicular to the slope is the preferred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

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

Maintenance

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

Appendix E-6: Alley Infiltration



Description

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

Application

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

Advantages

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

Disadvantages

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

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

Design Considerations

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

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

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

Maintenance

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

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

Appendix E-7: Decorative Planters

Description

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

Application

The Planters are designed to capture and treat stormwater originating from rooftops, by intercepting water from roof leaders prior to it entering an existing underground piped drainage system.
Advantages
For sidewalks and other areas with constricted spaces, the planters can be designed to be narrow, and yet still perform well and look attractive.

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

Disadvantages

Planters are not designed to provide recharge to groundwater.

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

Design Considerations

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

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

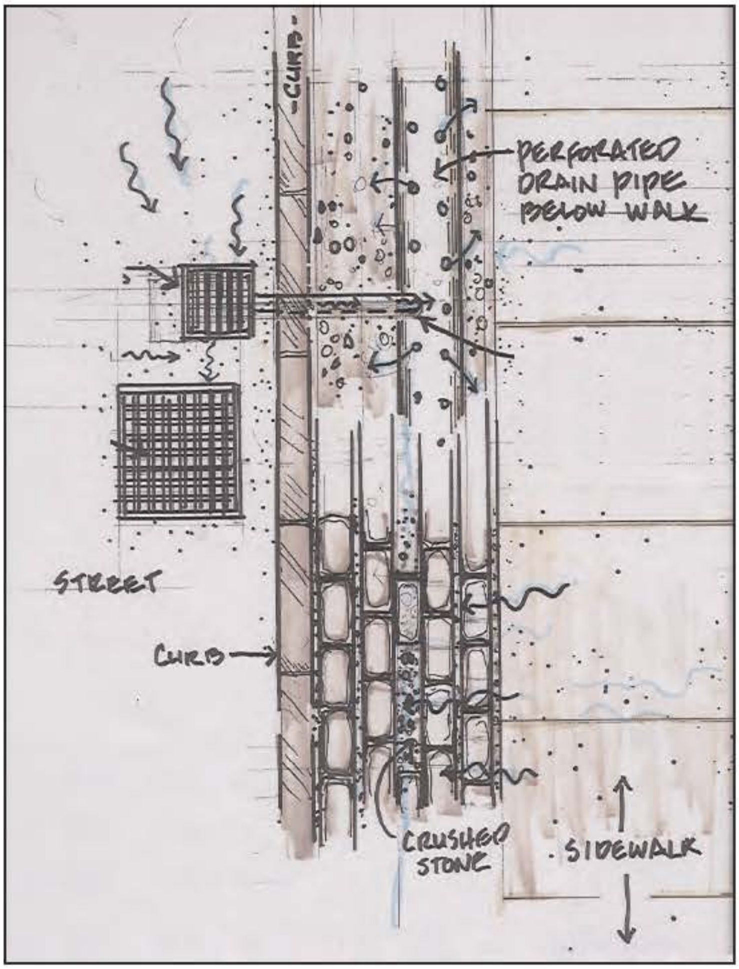
Weep holes should be provided at the lowest point in the structure to allow the system to drain between storms. The weeps could drain to the overflow pipe and thus back into an existing underground drainage system. This would be desirable if the planters are located on a sidewalk so that water does not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

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

Maintenance

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

Appendix E-8: Curbside Treatment



Description

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

Application

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

Advantages

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

Disadvantages

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

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

Design Considerations

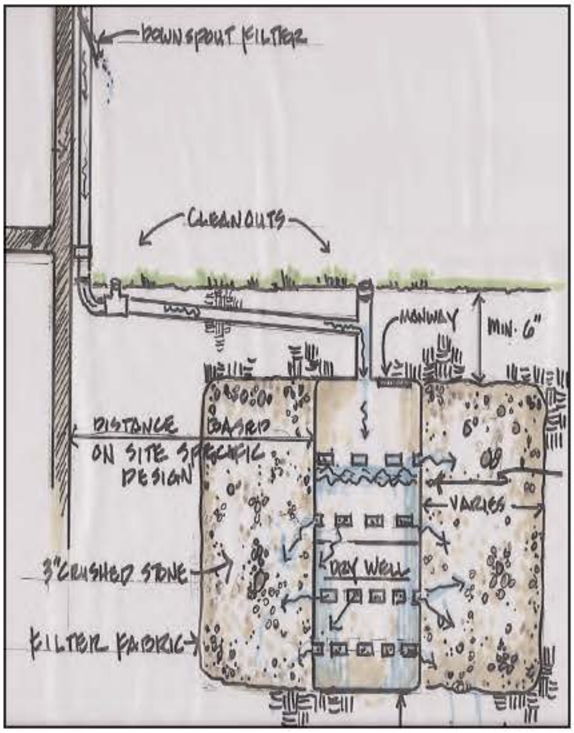
Pretreatment of the roadway runoff is provided in a new upstream catchbasin. To enhance the removal rate of particles, trash and floatables, a hooded outlet cover may be installed. The sump in the catchbasin should be as deep as is practical to further enhance settling.

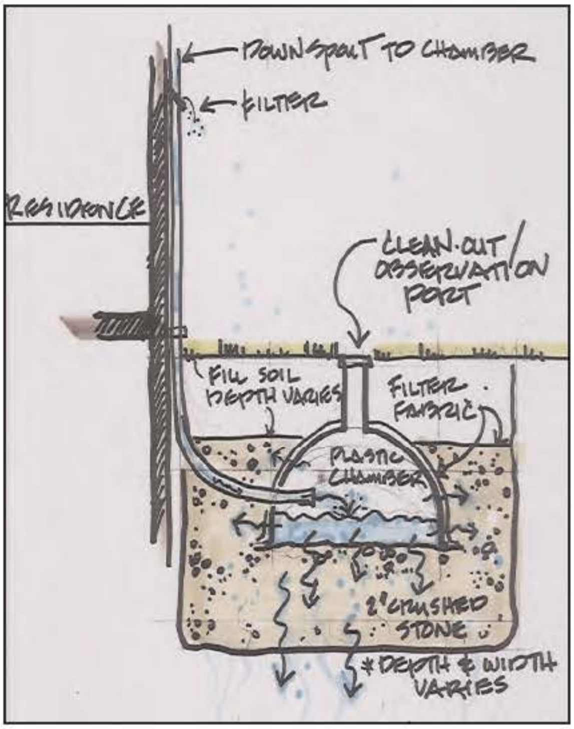
A variety of pervious surfacing choices exist for use in this design since the runoff from most sidewalks can be captured and infiltrated sufficiently even with a brick (ungrouted) sidewalk. In areas where sidewalks are plowed, designers should confer with local personnel on this matter and utilize surfacing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

Maintenance

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

Appendix E-9: Drywells





Description

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

Application

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

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

Advantages

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

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

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

Disadvantages

Installations near foundations can cause leaky basements.

Design Considerations

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

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

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

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

Maintenance

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

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

Appendix E-10: Pocket Raingarden

Description

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

Application

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

Advantages

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

Disadvantages

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

Design Considerations

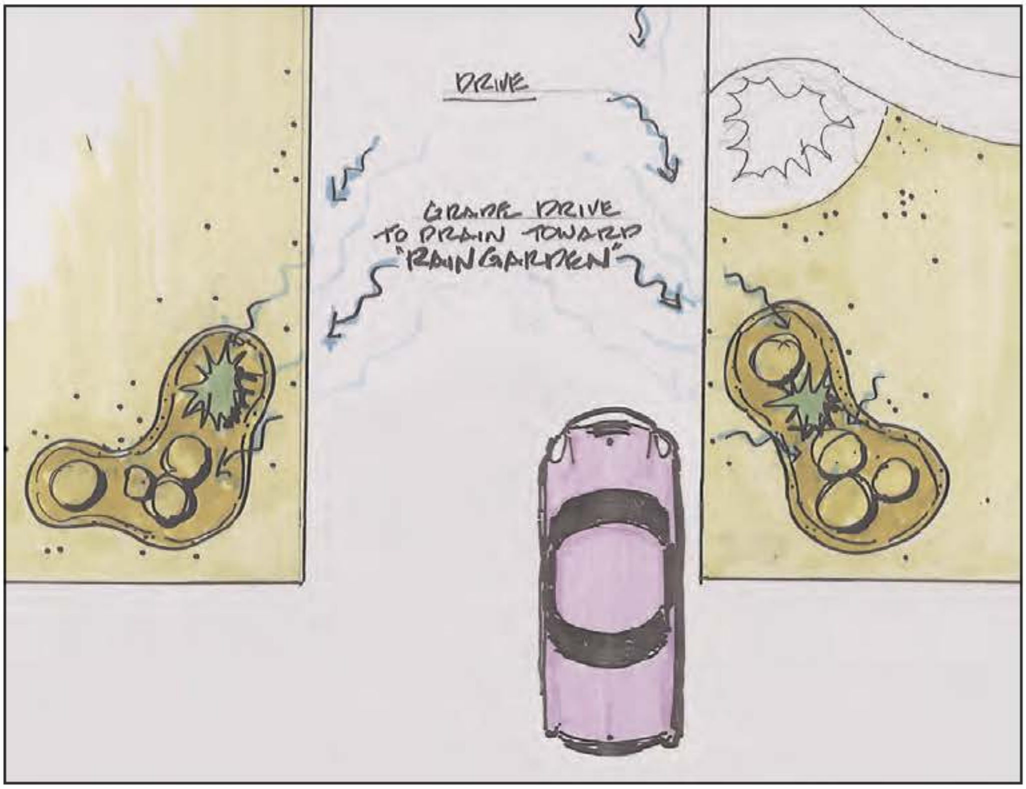
Designers and installers of Pocket Raingardens should be careful not to let the surface ponding depth exceed 8 inches, or let the water stay on the surface for more that 48 hours as nuisance conditions can develop in 3 to 4 days. The installation of an underdrain may be helpful in promoting shorter drain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

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

Maintenance

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

Appendix E-11: Raingarden Planter



Description

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

Application

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

Advantages

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

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

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

Disadvantages

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

Design Considerations

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

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

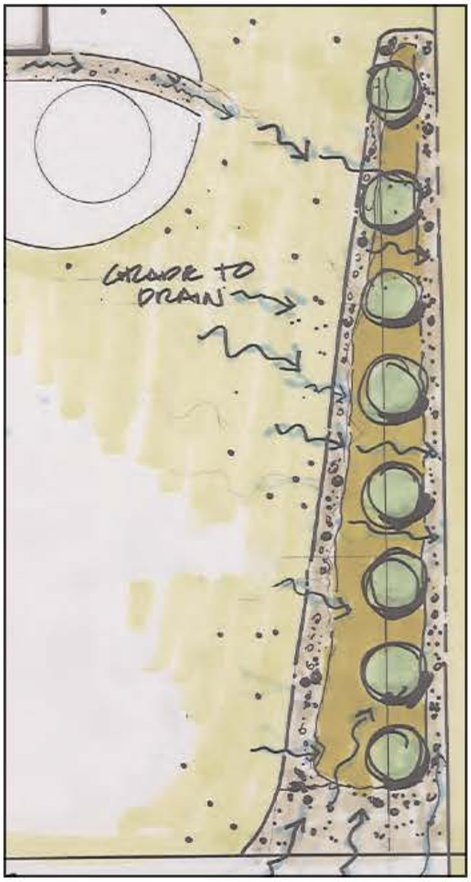
Maintenance

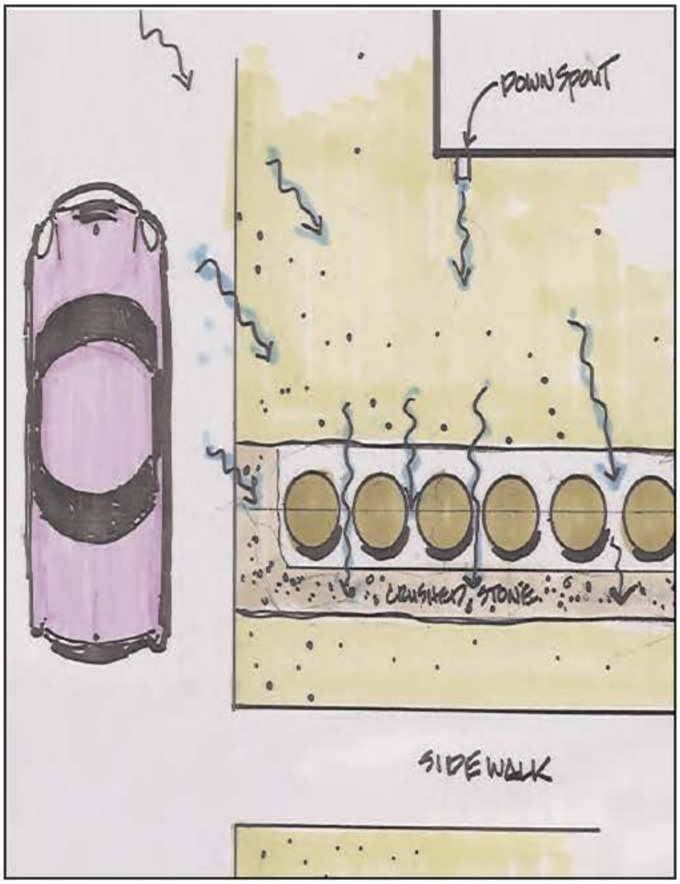
The Raingarden Planter is vulnerable to compaction and so homeowners need to be aware of this when performing the simple maintenance that this RPM requires. Maintenance will involve the periodic removal of sediments from the surface. The duration for the system to drain can be used as an indicator of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

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

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

Appendix E-12: Raingarden Strip





Description

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

Application

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

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

Advantages

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

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

Disadvantages

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

Design Considerations

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

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

Maintenance

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

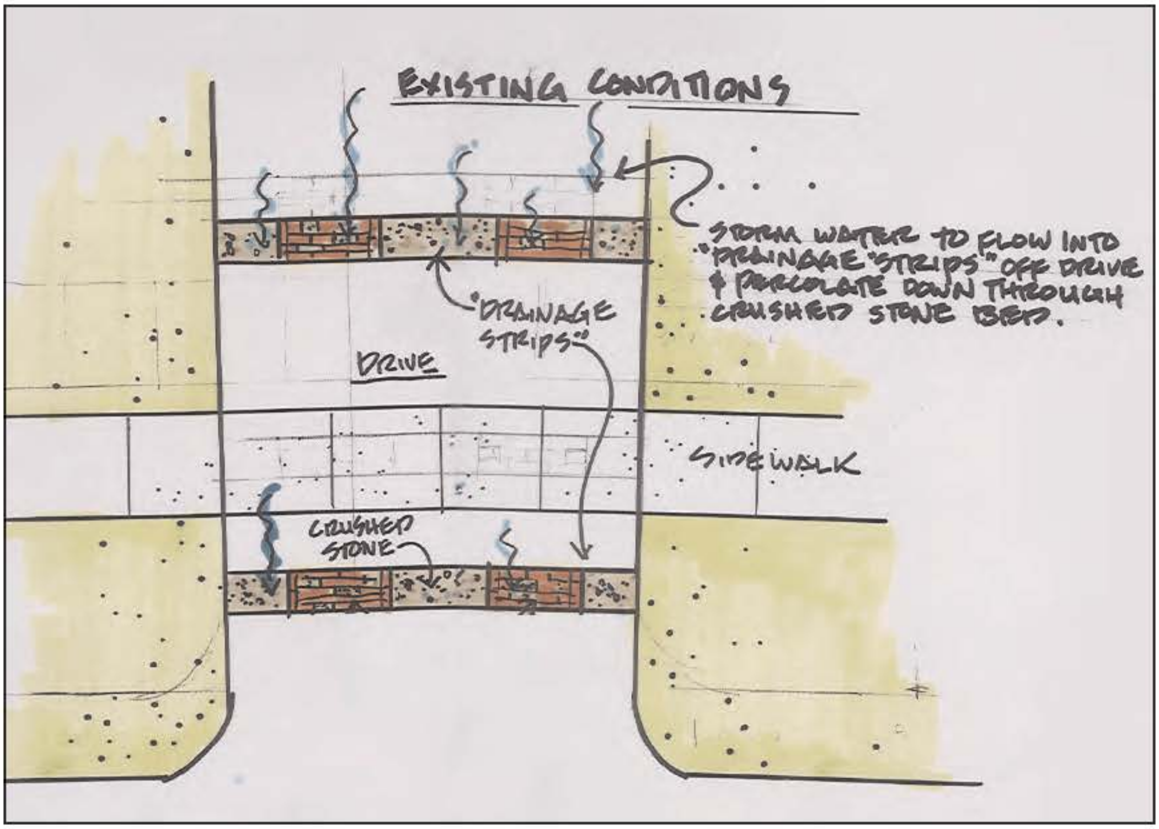
The bark mulch that covers the planting media should be replaced as needed.

If stormwater ponds on the surface of the structure for longer than 48 hours after the end of a storm[1], the filter fabric pre-filter may be clogged. In this case, the filter fabric and material covering the upper most layer of filter fabric should be removed. Owners may then either replace both the filter fabric and the cover material or, alternatively, clean the clogging material from them and reuse them. This material should not need to be disposed of at a landfill, however it should not be placed on an area that will be subject to runoff which might resuspend it.

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

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

Appendix E-13: Driveway Drainage Strip



Description

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

Application

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

Advantages

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

Disadvantages

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

Design Considerations

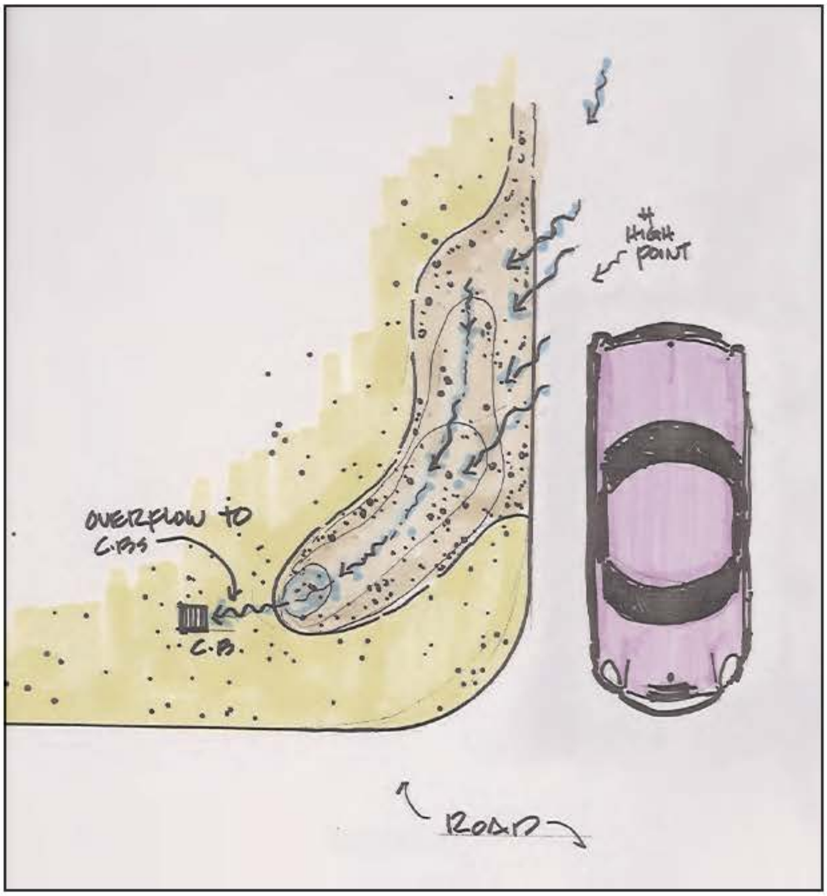
In driveways where there is a high degree of crown or cross-slope, a Driveway Drainage Strip may subject the adjacent pavement to abuse from plows. As with most plowing obstacles, prior scouting of the site (before it snows) by the plow operator and sufficient markings (reflectors or similar object)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

Maintenance

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

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

Appendix E-14: Containment Swale



Description

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

Application

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

Advantages

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

Disadvantages

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

Design Considerations

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

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

Maintenance

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

If stormwater ponds on the surface of the structure for longer than 48 hours after the end of a storm[1], the filter fabric pre-filter may be clogged. In this case, the filter fabric and material covering the upper most layer of filter fabric should be removed. Owners may then either replace both the filter fabric and the cover material or, alternatively, clean the clogging material from them. This material should not need to be disposed of at a landfill, however it should not be placed on an area that will be subject to runoff which might resuspend it.

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

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

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