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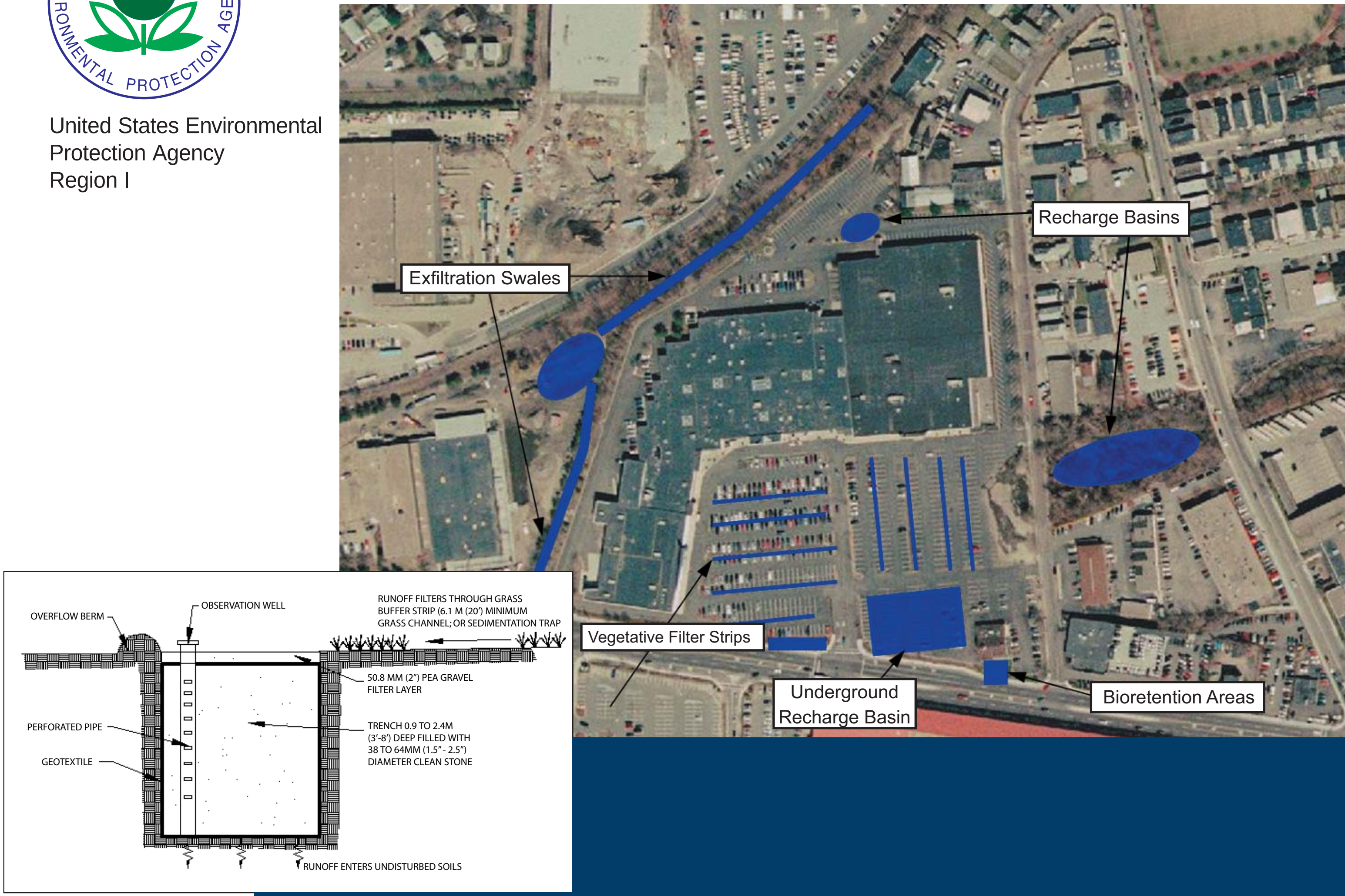

Stormwater TMDL Implementation Support Manual

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1.0 INTRODUCTION

After more than 30 years of the Clean Water Act, our rivers, lakes, and estuaries are generally cleaner than they have been since before the age of industrialization. We have successfully cleaned up most of the industrial and municipal sewage sources of water pollution, but our water bodies still suffer from diffuse sources of pollution which originate in the way we use land. In particular, stormwater runoff from urban and suburban land development with impervious (hard, non-absorptive) surfaces is currently the largest contributor to the impairment of water quality in New England, as well as in many other parts of the country.

Stormwater not only carries a mix of pollutants from roads, parking lots, roofs, and lawns into water bodies during and after rainfall, but by not soaking into the ground, and by running over hard, smooth surfaces directly into streams, it causes additional problems because of the resulting large and accelerated flow volumes. As the amount of impervious cover in watersheds increases, greater quantities of stormwater runoff wreak havoc with the physical structure and stability of streams and the habitat for aquatic life, while increased runoff of pollutants create water quality problems, and less base flow is available to aquatic life in streams during low flow periods.

EPA requires states to develop total maximum daily load (TMDL) targets for water bodies that are classified as impaired for uses they are supposed to, but are not, supporting (recreation, aquatic life, shellfishing, for example). TMDLs are calculations of the maximum amount of each pollutant that can be released into a polluted water body while still allowing it to meet its water quality standards (i.e., clean enough to meet the Clean Water Act's “fishable and swimmable” goals). TMDLs may be expressed through surrogate measures if the key pollutants causing the problem are difficult to determine.

In a previous document (ENSR 2005), we showed that by using the impervious cover method (ICM), it is possible to develop TMDL targets that are more meaningful in the selection, design, and implementation of stormwater best management practices (BMPs). BMPs are the primary control strategies for reducing the volume and speed of stormwater runoff into water bodies, the ultimate goal of which is to reduce adverse hydrologic effects and the complex mixture of pollutants and other stressors to a receiving stream.

The objective of this document is to provide support to stakeholders, who will be implementing the TMDLs, in identifying and taking actions to reduce, and ultimately fix, stormwater impairments in water bodies. In particular, this document is focused on achieving stormwater loading targets identified in TMDL reports developed using the impervious cover method (e.g., ME DEP 2005, ENSR 2005).

Stormwater TMDLs using the impervious cover method provide estimates of the existing percent impervious cover (%IC) and identify target %IC values for an impaired water body, which if met, should result in the removal of water quality impairments and in water quality standards being achieved. Research has demonstrated a correlation between the amount of impervious cover and level of impairments in water bodies. IC serves as a surrogate measure of impairment, connected to stream habitat disturbance, pollutant loading, biological diversity, and stream health. Stormwater TMDLs are implemented by a variety of means which use BMPs to disrupt or disconnect the direct, uninterrupted pathway that impervious surfaces usually provide for water flowing between the source of runoff and a receiving water body. Some BMPs can make the impacts of stormwater runoff from highly developed areas resemble the impacts of runoff from areas with less impervious cover.

We believe that for most water bodies, this initial focus on controlling flow will fix most of the stormwater runoff problem. It is also important to remember that since small storms occur more frequently than large storms, they generate a larger volume of stormwater. Therefore, even modest initial efforts which reduce or eliminate direct runoff can have significant benefits.

Other implementation efforts to enhance instream and riparian habitat are also encouraged because restoration of the stream's physical habitat will enable more rapid and complete recovery of the aquatic biological community as % IC approaches the TMDL target. This document also acknowledges but does not focus on other essential stormwater BMPs that eliminate or minimize waste input from illicit discharges, lawn/landscaping runoff, pet and waterfowl waste runoff, and reduce the temperature of water discharges from stormwater detention structures. We refer readers to a list of websites for further information on these and other techniques and practices.

The process of implementing stormwater TMDLs may be represented as the following steps, and is sometimes referred to as adaptive management, for its focus on repeating the steps until water quality standards are met:

1. <u>Investigate</u>: Investigate existing conditions in terms of impervious cover and its connectivity to receiving streams;
2. <u>Prioritize</u>: Identify and prioritize "hot-spot" areas for stormwater mitigation actions;
3. <u>Mitigate:</u> Evaluate prioritized sites and take action to fix the problems (e.g., install BMPs);
4. <u>Monitor</u>: Monitor ambient stream water quality to ascertain the effectiveness of those corrective actions in reducing or removing the impairment(s); and
5. <u>Assess and Repeat</u>: Repeat this process iteratively until stormwater impairments are removed from the receiving stream, water quality standards are met, and aquatic life uses are protected.

Each of the 5 steps outlined above are described in detail throughout this document. An overview of stormwater impairments and a description of using the impervious cover method to support stormwater TMDL calculation and implementation are provided in Section 1 below.

1.1 An Overview of Stormwater Impairments

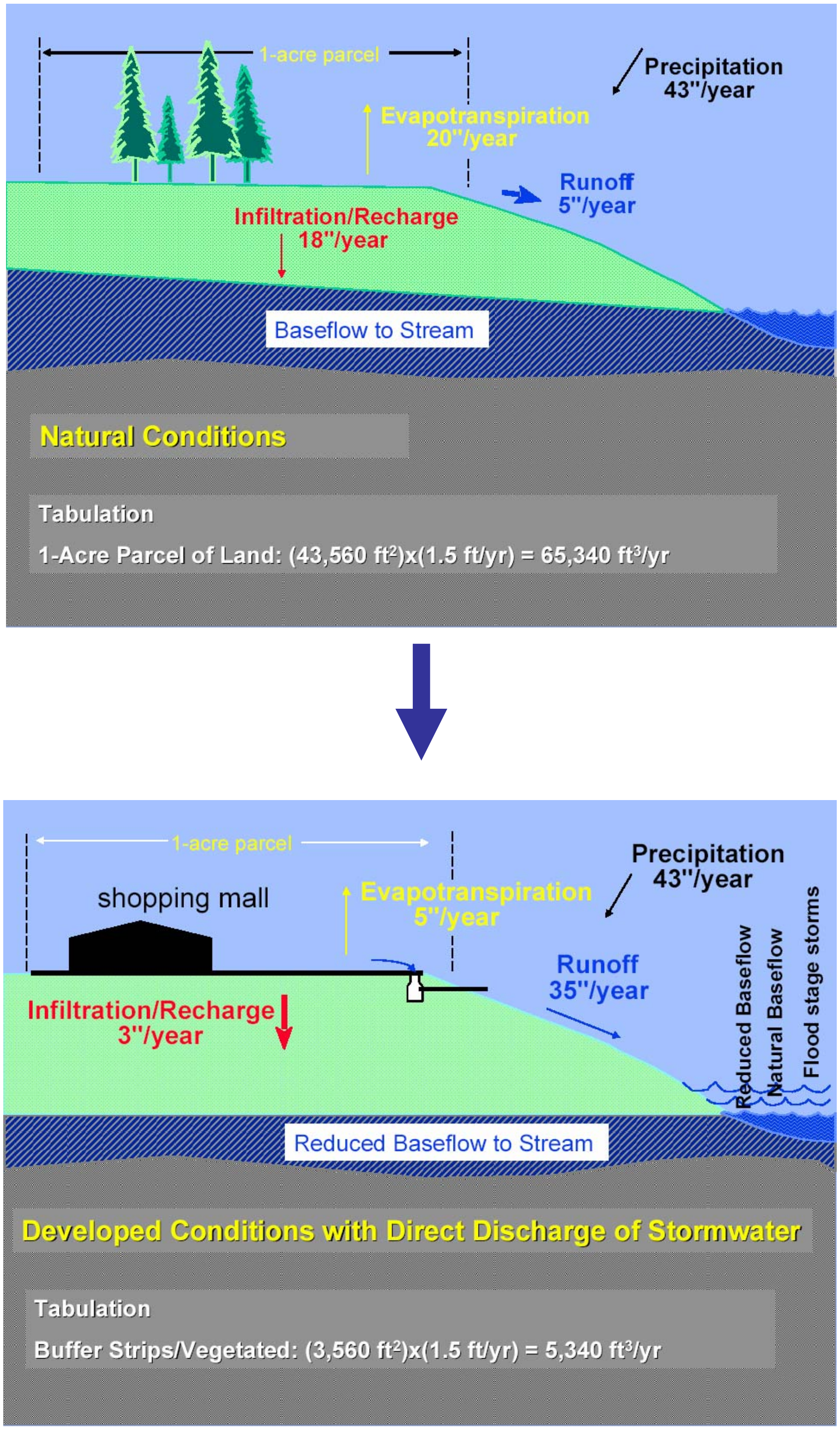
Water quality impairments related to stormwater in watersheds are typically due to a pattern of causes and effects, as follows. Historically, development activity (i.e., urbanization) takes place in a watershed and leads to changes in land cover; usually, forest and grasslands areas are converted to urban and suburban use, with less soil and vegetated surfaces and more hard, paved or roofed surfaces. These changes in land-uses result in changes to the hydrologic cycle of adjacent tributaries and rivers, primarily through reductions in infiltration and increases in surface runoff. Both the quantity and quality of water resources are affected by these hydrologic disruptions.

Figure 1-1 illustrates a hypothetical water budget for a parcel of land with both pre- and post-development conditions. In the post-development scenario, infiltration and resulting baseflow (through the ground) decrease dramatically with increases in hard, unabsorptive, impervious surfaces (roofs, pavement). Simultaneously, runoff (over the ground) increases significantly, especially during larger storms, causing bankfull flow conditions and stream bed scouring to occur more frequently. Consequently, with more impervious cover, the stream experiences lower low flows due to reduced baseflow, and higher high flows due to increased stormwater runoff volumes. Furthermore, instead of being slowed and filtered as it moves through or over the soil, water picks up speed and pollutants as it flows over paved or hard surfaces.

These changes have important effects. As water flows more quickly over the ground, it enters water bodies in large volumes suddenly upon rain events, and at much higher velocities, causing physical damage with its power. Streams are scoured, their physical structures and aquatic habitats are disrupted, sediment is deposited on fish spawning beds, and aquatic life is carried away by the force of the large volumes of water that enter a water body at high speed. Stormwater systems exacerbate the problem by collecting the diffuse runoff in stormwater pipes and transmitting it at high velocity to water bodies in a concentrated and more powerful form. Consequently, impervious surfaces are not only a source of pollution, but are a source of stream erosion, and stability and hydrology problems.

Increased impervious cover leads to increased loads of sediments, both from surface runoff and from in-stream disruption, and to increased loads of associated pollutants that are either applied to or are on the ground. Instream levels of a wide range of pollutants, including various types of bacteria, salt, heavy metals, other toxic materials, and nutrients and fertilizers that stimulate the growth of algae and cause fish kills have been observed to increase with increased IC.

Figure 1-1 Schematic Water Balance: Natural Conditions and Developed Conditions



Tabulation

1-Acre Parcel of Land: $(43{,}560\ ft^2) \times (1.5\ ft/yr) = 65{,}340\ ft^3/yr$

Tabulation

Buffer Strips/Vegetated: $(3{,}560\ ft^2) \times (1.5\ ft/yr) = 5{,}340\ ft^3/yr$

Stormwater management planning and stormwater permitting guidance documents (e.g., US EPA 2000) recognize this fundamental pattern of causes and effects in systems impaired by stormwater.

The typical pattern of effects caused by stormwater includes some or all of the following factors:

- modified land use with increased impervious cover (paved surfaces and roofs);
- modified stream hydrology, typically flashier streams with higher peaks and lower low flows;
- modified physical stream conditions, including channelization and stream bed scouring;
- increased sediment loading via surface runoff and stream bank erosion;
- increased pollutant loading via surface runoff;
- degraded ambient water quality conditions; and
- degraded ambient biological conditions.

Land cover and stream hydrology modifications are the causes, and reduced water quality and aquatic habitat, and biological modification are the results in this process. The impervious cover method, selected and applied to conduct stormwater TMDL assessments, provides a clear and straightforward link between causes and results. TMDL calculation and implementation using the ICM is described below.

1.2 The Impervious Cover Model for Stormwater Impact Evaluation

The impervious cover model (ICM) relates an aquatic system's health (i.e., state of impairment) to the percentage of impervious cover in its contributing watershed. The ICM is based on the scientific relationship between the portion of impervious cover in a watershed and its stream quality. The model is based on the work of the Center for Watershed Protection which has compiled and evaluated extensive data (from 1000s of streams) relating a watershed's impervious cover to hydrologic, physical, water quality, and biological conditions (Schueler 2003). The conclusions described in this section are based on the Watershed Protection Research Monograph No. 1 *Impacts of Impervious Cover on Aquatic Systems* (2003) produced by the Center for Watershed Protection.

Figure 1-2 provides a representation of the relationship between stream quality and watershed impervious cover, based on the ICM. This research indicates that a decline in stream quality occurs when impervious cover (IC) for a watershed exceeds 10% and that severe impairment can be expected when the IC exceeds 25%. The correlation of stream quality to impervious cover was established by compiling and analyzing large sets of data (representing 1000s of streams) on physical, hydrologic, water quality, and biological stream characteristics verses %IC.

1.3 Development of Stormwater TMDL Assessments using the ICM

Stormwater TMDL assessments have recently been developed using the impervious cover method (e.g., ME DEP 2005, ENSR 2005: please see web links in Section 9). The ICM method was selected based on a variety of factors including that it provides a straightforward link between the causes and effects of stormwater impairments, and that it is relatively efficient to apply. The process of applying the ICM to support stormwater TMDL assessments may be described by the following steps:

1. Delineate Watershed: Delineate each sub-watershed in an area of interest and develop a geographic information system (GIS) data-layer;

2. Map Impervious Cover: Develop watershed coverages for land cover and impervious cover within a GIS data-layer;

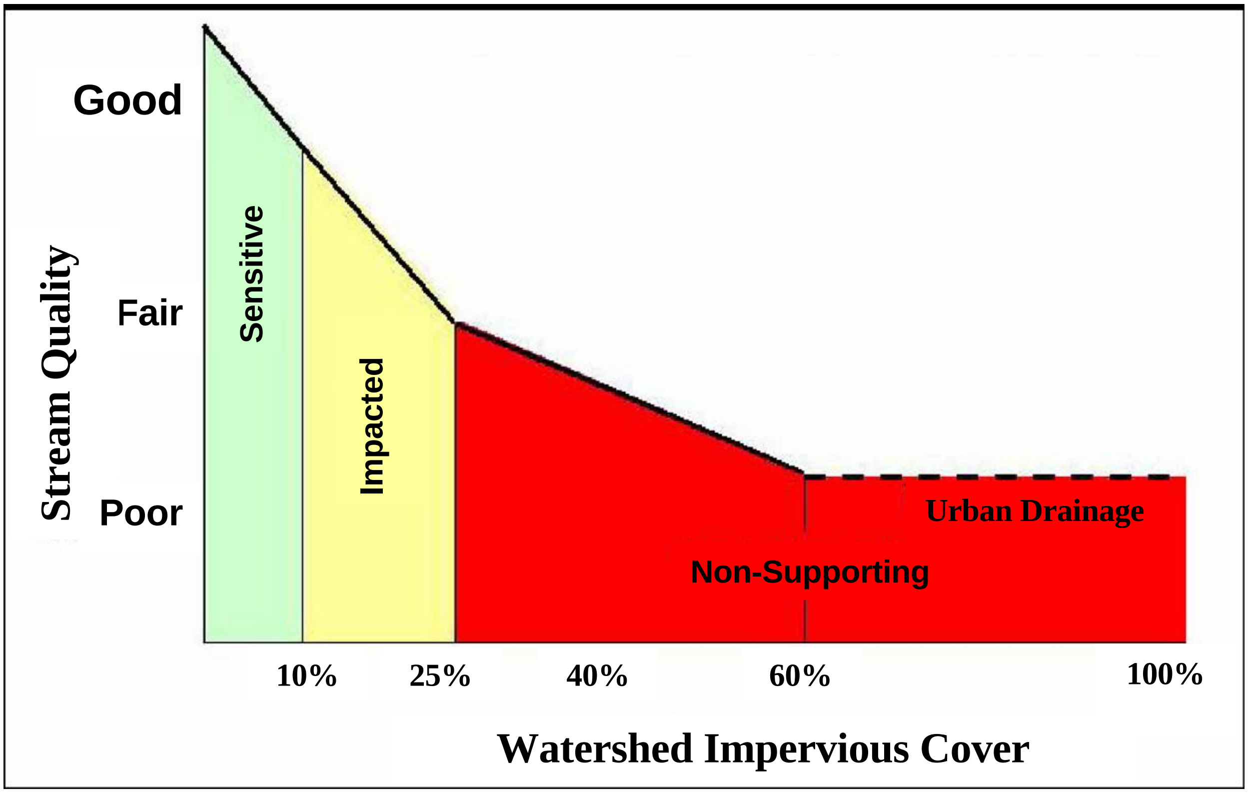
3. Determine Impervious Cover: Calculate overall watershed and sub-watershed impervious cover magnitude and percentage of watershed area; and

4. Identify Impairment: Determine which sub-watersheds are impaired based on impervious cover using the target %IC as a guide.

A complete description of the TMDL assessment process using the ICM is provided in the EPA Region 1 and Maine DEP documents (ENSR 2005, ME DEP 2005).

For the New England pilot TMDLs using the ICM (ENSR 2005), a target of 9%IC was selected as a TMDL metric. The 9%IC target was selected because at 9%IC stormwater impairments will likely be removed, based on extensive data and analysis conducted by the Center for Watershed Protection (Schueler 2003) and others. Alternative %IC targets may be appropriate depending on statewide or site-specific data and assessments. The TMDL process also requires monitoring to validate removal of impairment.

Figure 1-2 Impervious Cover Model: Stream Quality vs. Watershed Impervious Cover



1.4 An Overview of Stormwater TMDL Implementation Steps

TMDL implementation focuses on removing water body impairments by moving from existing conditions to target conditions so as to meet water quality standards. TMDL implementation is a process of identifying and taking management actions to iteratively move toward attaining target conditions and fixing water quality impairments for the water body in question. The ICM method provides direct guidance towards evaluating management scenarios to remove stormwater impairments because it deals directly with the causes of the problem such as land cover modification. The ICM is applicable to support evaluation of sub-watersheds and identification of problem areas (i.e., hot spots).

The recommended approach to implementing stormwater TMDLs is to begin with the IC information provided by the TMDL calculation and to take a closer look at the watershed to determine locations of greatest adverse stormwater impact. A set of specific tasks to support the process of homing in on watershed “hot spot” problem areas is provided below. Once watershed areas have been evaluated in greater detail, appropriate management actions may be identified. Areas with high %IC are likely associated with stormwater impairment and will likely require mitigation actions, such as BMP installation. Areas with lower %IC may not require mitigation, but may need to adopt specific standards for stormwater management to ensure that %IC does not increase significantly, which could lead to future stormwater impairments.

A phased TMDL implementation approach featuring adaptive management techniques will likely be required to ultimately fix stormwater impairments. An iterative, adaptive approach is appropriate due to the numerous and diffuse sources of stormwater problems and the expense of stormwater mitigation activities. Recommended steps for developing and applying phased TMDL implementation are listed below (each step is described in the sections referenced).

1. ***Investigate** (Section 2)*
    - Review available watershed data and reports, including the TMDL report and watershed assessment documents;
    - Review any available reports from USGS and the Corps of Engineers for information on and the history of stream properties and potential impacts;
    - Use local knowledge (e.g., from local Department of Public Works, Boards of Health, and watershed groups) and draw on other ongoing programs (e.g., NPDES Phase 2 Municipal Separate Storm Sewer System (MS4) stormwater discharge inventories and illicit discharge inspection programs);
    - Review infrastructure maps (e.g., storm sewer, sanitary sewer, and combined sewer overflow (CSO) maps) to identify potentially critical areas;

- Review aerial orthophotos to validate %IC estimates (Section 3);
- Compile data into GIS data layers featuring watershed delineations, land use areas, and %IC by watershed, sub-watershed, and by local areas of interest;
- Interpret ambient water quality data and reports to determine the spatial relationship between water quality problems and impervious cover areas; and
- Analyze data to support evaluation of connectedness of impervious cover and other prioritization tasks outlined below.

2. ***Prioritize*** *(Sections 3 and 4)*
    - Rank and prioritize sub-watershed and specific areas based on extent of adverse stormwater impact;
    - Review aerial orthophotos of the watershed to support characterization of the spatial relationship between IC areas and the receiving stream(s);
    - Conduct on-the-ground reconnaissance surveys to identify and map potential hot spots and characterize impervious area connectivity;
    - Areas with high %IC (and connectedness) should be prioritized for mitigation actions. Prioritization should take into consideration several factors including IC areas extent, proximity, and connectedness to the receiving stream(s); and
    - Areas with lower %IC should be prioritized for implementation of specific stormwater management standards and other development planning programs to reduce the potential for future stormwater impairment.

3. ***Mitigate*** *(Sections 4, 5, and 6)*
    - Beginning with top priority area(s), identify specific management techniques to take corrective actions;
    - Develop detailed site-specific designs and programs for each local management practice;
    - Obtain funding to remediate, starting with the highest priority areas; and
    - Implement management practices to mitigate adverse stormwater impact.

4. ***Monitor*** *(Section 8)*
    - Conduct routine stream monitor surveys to support characterization of in-stream conditions before the implementation program begins and continuing until stormwater impairments are removed and/or water quality standards are achieved.

5. ***Assess and Repeat***
    - Assess the results of monitoring surveys and return to the list of priorities to identify and implement the next set of corrective actions. Repeat the process until stormwater impairments are removed and or water quality standards are achieved.

Each of these steps is described in detail with project examples in the following sections.

2.0 STORMWATER DATA COLLECTION AND REVIEW

Stormwater data collection and review tasks are conducted to support characterization of existing conditions in terms of the spatial distribution of impervious cover, its connectedness to the receiving stream, and any other factors (i.e., flooding, erosion) associated with stormwater impacts throughout the watershed. Collection and review of available data provides a foundation of understanding to support evaluation and specification of various management actions to mitigate stormwater impairments.

2.1 Review Stormwater TMDL Allocations using the ICM

Results from ICM-based TMDL allocations provide useful information to support TMDL implementation. Stormwater TMDL allocations using the ICM contain watershed delineations, compilations of land uses by sub-watershed, and specification of %IC by sub-watershed. TMDL allocation documents often reference additional sources of data such as watershed assessment reports and orthophotographic coverages of the impaired watershed. Specification of %IC by sub-watershed is particularly useful information because it may be readily used to support identification of stormwater impact problem areas.

2.2 Gather Available Data, Reports, and Local Knowledge

Data should be collected and reviewed to support characterization of stormwater transport to streams, particularly in urbanized areas that are likely the cause of impairment (i.e., areas with high %IC). Thus, information that specifies the connection between impervious surfaces and the receiving water body, such as storm drainage system maps and local experts with knowledge of storm sewer systems, is of greatest value. Available reports and data may include (but are not limited to):

- TMDL Allocation reports;
- Watershed assessment reports;
- National Pollution Discharge Elimination System (NPDES) Phase 2 Municipal Separate Storm Sewer System (MS4) stormwater discharge inventories;
- Stormwater drainage system maps;
- CSO system maps;
- Roadway and bridge storm sewer system maps;
- Site storm sewer maps;

- BMP design reports and documents;
- Illicit discharge reports;
- Site development plans;
- Water quality data; and
- Aerial photographs and orthophotographs;

This information can be collected from a large array of sources. Data, reports, and local expertise may be found in many and varied sources including (but not limited to):

- Departments of Public Works and Highway Departments;
- Planning Boards;
- Regional Planning Authorities;
- Local Conservation/Wetland Commissions;
- Boards of Health;
- Local and regional watershed associations;
- State Departments of Environmental Protection and Management;
- State and local GIS websites and data bases;
- State Highway Authorities;
- US Army Corps of Engineers;
- US Environmental Protection Agency; and
- US Geological Survey.

In some cases, sufficient data and information may not be readily available. Review of aerial photography (below) and on-the-ground reconnaissance surveys (Section 4.3) are effective means of obtaining additional supporting information.

2.3 Review Watershed Aerial Photographic Coverages

Aerial photographic coverages of New England’s watersheds have improved in quality and have become more widely available in recent years. In some cases, aerial orthophotographic coverages of entire states are available to the public via websites. Orthophotographs are images that have been corrected for displacement and distortion. Orthophotographic coverages provide exact ground positions and may be utilized within GIS-based analysis systems. Aerial orthophotographs can provide an efficient means of validating %IC estimates and evaluating the nature and extent of IC and its proximity to receiving streams. In some cases, these images can support evaluation of the preliminary identification of high IC problem areas and potential locations for BMPs.

Compiling data in a GIS system is useful. Tools are available to assist in developing the %IC, such as the Impervious Surface Analysis Tool (ISAT) which can be used to calculate the percentage of impervious surface area of user-selected geographic areas (e.g., watersheds, municipalities, subdivisions). The National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center and the University of Connecticut Nonpoint Education for Municipal Officials (NEMO) Program developed this tool for coastal and natural resource managers (see http://www.csc.noaa.gov/crs/cwq/isat.html).

2.4 Summary

Stormwater data collection and review provides information required to support identification and prioritization of appropriate stormwater BMPs to fix stormwater problems. The review process results in a set of watershed maps that identify areas of problematic levels of impervious cover. Infrastructure maps and reports can provide local information regarding the connectivity of impervious cover to the stream. Stream hydrologic, water quality, and biological data and reports provide a characterization of the nature, extent, and locations of water body problems.

3.0 PRIORITIZING SUB-WATERSHEDS FOR STORMWATER MITIGATION

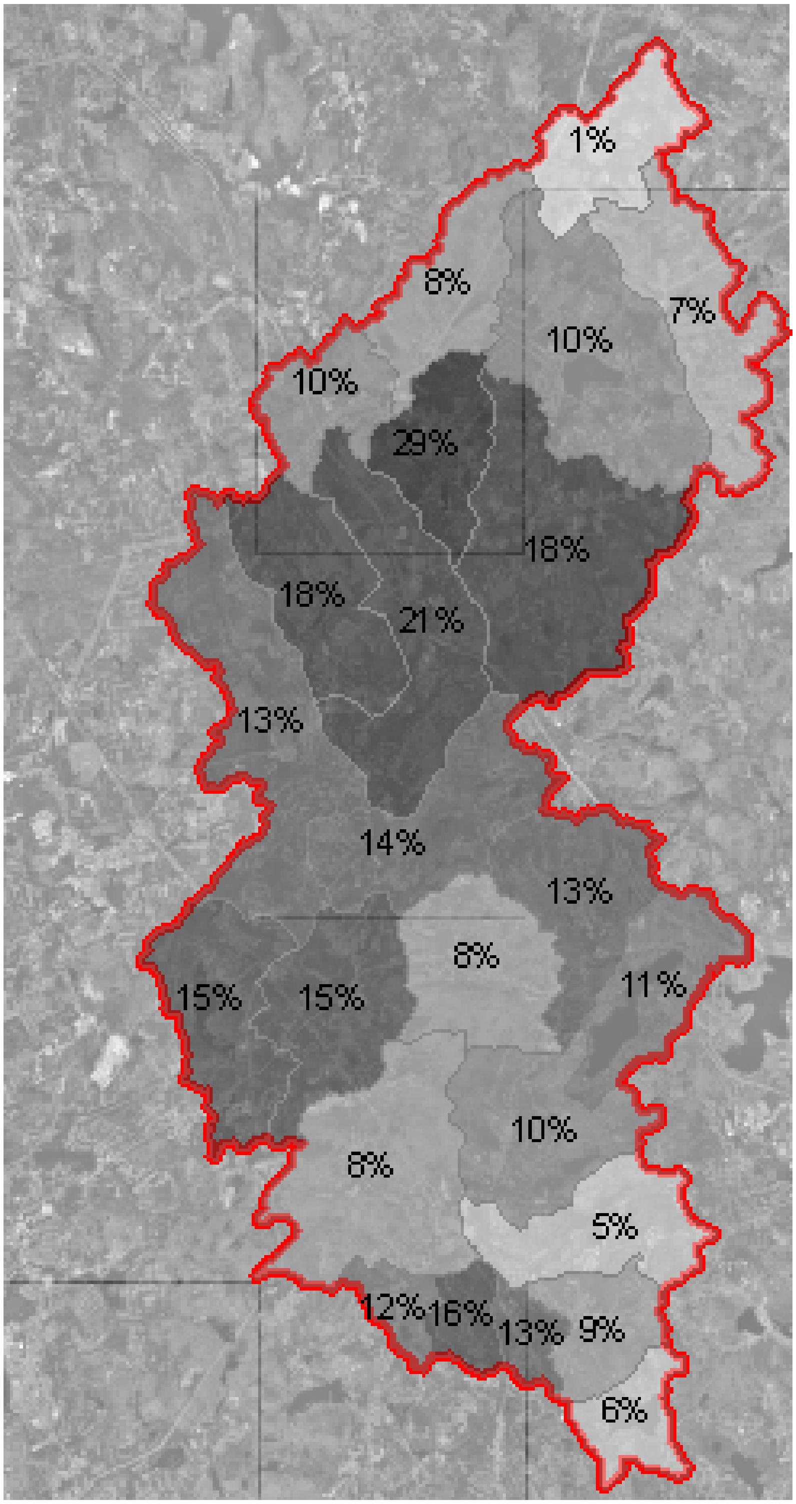
Identifying and prioritizing specific locations for stormwater mitigation may be conducted in two steps; on a sub-watershed level and then on a site-specific level. This process is conceptually similar to applying increasingly strong magnifying glasses to the impaired watershed. Initially, the entire watershed is evaluated and problematic sub-watersheds are identified and prioritized. Next, beginning with the most stormwater-impacted sub-watersheds, specific sites are identified, investigated, and prioritized. The process of prioritizing sub-watersheds is described below. The process of identifying and prioritizing specific mitigation sites requires an understanding of the goals and techniques of stormwater mitigation (Sections 4.1 and 4.2) and is described in Section 4.3.

Available %IC coverage data and orthophotographs should be used to support sub-watershed review and prioritization. Results from an ICM-based TMDL assessment provide a logical starting point for the sub-watershed investigation. The sub-watershed review and prioritization process will be described using an example watershed. A stormwater TMDL assessment was developed for the Beaver Brook (NH) watershed using the ICM (ENSR 2005). Figure 3-1 provides a map of the Beaver Brook watershed with %IC in each sub-basin indicated. This map of %IC in the watershed will be used to support prioritizing sub-watersheds for stormwater mitigation.

In the Beaver Brook watershed, 15 of 24 sub-watersheds were estimated to have IC greater than the TMDL target of 9%IC. Each of these 15 sub-watersheds will likely require stormwater mitigation actions to remove impairments and are selected for further assessment. In the remaining 9 sub-watersheds with IC less than 9%, mitigation is likely not required, but programs featuring specific stormwater management standards should be encouraged to ensure that %IC is not significantly increased. Sub-watersheds with 9%IC may be classified as sensitive and may be selected for further assessment. In addition, upstream watersheds with elevated levels of %IC can still impact downstream sub-watersheds' water quality even though the downstream sub-watershed could have a low %IC.

The four Beaver Brook sub-watersheds with the highest %IC are clustered in toward the northern portion of the watershed and have estimated values of 29%, 21%, and two with 18%IC. These four sub-watersheds are likely to be impaired and would likely be identified as top priorities for stormwater mitigation. The next highest %IC sub-watersheds are 16%, 15%, and 15%IC and are situated in the southwestern portion of the watershed. In some watersheds, sub-watershed %IC delineation may not be available and obtaining additional %IC coverages may be required to support sub-watershed prioritization.

Figure 3-1 Beaver Brook (NH) Watershed with %IC by Sub-Watershed



The location of the sub-watershed within the total watershed influences the impact that area has on the receiving water. Sub-watersheds in the headwaters of the watershed influence the entire downstream portion of the water body whereas sub-watersheds near the mouth may have less impact depending on use and water quality standards. Therefore, sub-watersheds further up in the watershed should be a higher priority.

Prioritizing sub-watersheds using the Impervious Cover Method requires evaluation of numerous factors including:

- Total %IC;
- Preliminary assessment of the proximity of IC to receiving streams and connectedness of IC (using the data obtained from the data collection and review described in Section 2 and described further in Section 4);
- Preliminary assessment of impairment of stream segments with high %IC;
- Water body impairment and location of the stream within the watershed to determine those segments and sub-watersheds with the greatest impacts; and
- Preliminary assessment of feasibility and cost of conducting mitigation actions (discussed further in Section 4 and 5, and in references).

The prioritization process is similar to the process of identifying potential mitigation sites (Section 4.3.1), but on a more macro-scale. Some of the same steps are involved in both. The tools used include reviewing the data collected in Section 2, such as aerial orthophotos and other map-based data, and potentially some on-the-ground field reconnaissance surveys. Reviewing orthophotos helps assess the proximity of IC areas to receiving streams. Often, areas with large amounts of impervious cover will be readily observable.

Other mapping tools such as GIS data layers and USGS quadrangle maps may be able to show important site features such as contours (for slope), mapped land features such as wetlands, land marks, land-use classifications, and soil types. Information gathered from site development plans, BMP design reports and documents, local and regional watershed associations, planning and zoning boards and other municipal authorities, and many of the other sources described in Section 2, will help identify directly connected imperious cover, the existence of stormwater systems, and other site-specific data. However, it still may be necessary to gather some additional data from reconnaissance surveys in the field to identify some of these details in order to prioritize sub-watersheds.

Sub-watersheds should be prioritized with those having the highest %IC (that is directly connected as associated with water body impairments) given the highest priority, and investigators should conduct site-specific investigations in highest priority sub-watersheds with the understanding that the sub-watershed prioritization process will be conducted iteratively.

4.0 IDENTIFYING MITIGATION SITES AND TECHNIQUES

Selection of specific mitigation sites and management practices follows sub-watershed prioritization. Several factors will be involved in choosing the location and type of stormwater mitigation. Physical, economic and social constraints specific to each site and mitigation measures must be considered. This section provides a description of the philosophy behind choosing BMP sites and techniques, and step-by-step procedures for choosing mitigation sites, types of BMPs, and sizing of BMPs. Illustrative examples of stormwater mitigation are provided throughout this section. Detailed descriptions of specific BMPs designs are provided in Section 5.

4.1 Stormwater Mitigation Philosophy

Since the primary mechanism of impervious cover impacts are hydrologic changes, an effective way to reverse those impacts is to restore the natural hydrology of the area of concern. Impervious cover causes higher runoff volume than natural conditions during all events. This runoff can destabilize streams and carry pollutants, compromising the water quality of the receiving stream. In addition, hydrologic changes induced by impervious cover lead to higher storm event flows and lower base flows, which in turn lead to water body and habitat impairments from an array of impacts (see Section 1.0). Returning a site to its pre-existing hydrologic condition involves either eliminating (or reducing) impervious cover, or mitigating the hydrologic effects of impervious cover (higher runoff, less infiltration) through the use of site design strategies and BMPs. These practices should be chosen to counter the effects of impervious cover by increasing infiltration and retention, increasing times of concentration (time it takes stormwater to reach a water body from the most distance point in the watershed), and matching runoff volumes to pre-development conditions for smaller storms.

Directly connected impervious areas are areas that are connected hydrologically (water flows in an uninterrupted manner over hard, non-absorptive surfaces) to a receiving water body, such as parking lots that drain directly to storm drains that then empty into streams. Directly connected impervious areas (DCIA) contribute to hydrologic impairment more significantly than areas that are not directly connected, such as parking lots that drain to retention or infiltration basins, or other places where flow is broken up by absorptive surfaces. DCIAs contribute runoff to receiving waters in all but the smallest storm events with little or no opportunity for attenuation of flow rates or volumes. Runoff from impervious areas that drains to vegetated/pervious surfaces (i.e., non-DCIAs) has a chance to be trapped in micro-topography and to percolate into the ground before entering receiving waters. This results in full attenuation of small storms and reduced flow rates and volumes for larger storms. In essence, DCIAs amplify a watershed’s response to rainfall events, making the receiving water impacted as if it were a much larger storm. This effect is particularly pronounced for smaller storm events. Therefore, DCIA areas should be given the highest priority for implementing of mitigation activities (i.e., disconnection, BMPs).

The following categories of BMPs may be employed to mitigate for the hydrologic impact of impervious cover:

- Recharge/exfiltration BMPs;
- Low impact development strategies;,and
- Extended detention BMPs.

Each of these BMP categories is described below.

4.2 Categories of Stormwater BMPs

The subsequent sections address how the types of practices identified above could be employed to reduce the effective impervious cover in critical sub-watersheds.

4.2.1 Recharge/Exfiltration BMPs

Recharge BMPs are designed to exfiltrate collected stormwater from the BMP into the ground. These BMPs mitigate impervious cover impacts by allowing runoff to infiltrate to the groundwater slowly. This mitigates higher runoff volumes caused by impervious cover by keeping the water in the watershed and recharging the groundwater instead of contributing to the receiving water during storm events. This also helps to mitigate low post-storm base flows in receiving waters because replenished groundwater ultimately feeds stream baseflows. Infiltration also provides pollutant removal via filtration and microbial action through the soil column. Because of these qualities, recharge/exfiltration BMPs are the most preferred type of BMP to mitigate for impervious cover and reach the goal of returning the watershed to pre-existing hydrologic conditions. There are many designs for this type of BMP and they can be retrofitted into an array of locations in a developed area as discussed in Section 4.6 and Section 5.

Recharge BMPs include surface systems, such as retention basins, and underground systems, such as infiltration galleries and leaching catch basins. These systems are typically installed at the end of a stormwater collection system and operate by temporarily storing stormwater and allowing it to percolate into the ground. The siting of recharge BMPs is primarily dependent on two factors: soil hydraulic conductivity and groundwater elevations. Effective recharge systems must be located in soils with sufficient permeability to allow groundwater to recharge between storm events. Generally a soil hydraulic conductivity of 0.5 inches/hour or greater is desired for recharge BMPs. Effective recharge systems must also be located with sufficient vertical separation from the groundwater table.

Recommended site characteristics for recharge/exfiltration practices include the following:

- Surface slope less than 10%;
- Permeable (sandy) soils;
- Water table greater than 2 to 4 feet below recharge bed; and
- Significant contributing area.

A minimum separation of 2 feet between the bottom of the recharge BMP and the seasonal high groundwater table is recommended. However a greater separation is desirable to prevent a groundwater mound that intersects the bottom of the recharge system, since once this occurs, recharge rates are significantly reduced. In addition to reducing stormwater runoff volume, recharge systems remove pollutants by filtration through the soil matrix. This process is more effective in non-saturated aerobic soils. Therefore, maximum separation between the recharge BMP and the water table is desired to provide maximum treatment before contributing to the groundwater.

From an operational viewpoint, recharge BMPs are very susceptible to obstruction (i.e., clogging) of the exfiltration interface (bottom of the recharge basin) by suspended sediment, which is typically abundant in urban runoff. Therefore, pretreatment of runoff is essential for an effective recharge BMP. This factor also makes surface recharge BMPs preferable to underground systems. Surface BMPs can be accessed more readily than underground BMPs for maintenance in the event that the infiltration interface becomes obstructed. Vegetated surface recharge BMPs are also somewhat self-healing in this respect. Root growth and the action of earthworms tend to keep the infiltration interface open by creating macro-pores.

To avoid compromising the integrity of the receiving groundwater, recharge/exfiltration BMPs should not be used alone for mitigating runoff from high-pollutant areas, but should be used in conjunction with pretreatment BMPs. For example, parking lot runoff with high salt and auto-related contaminants should be pretreated before exfiltrated or be mitigated with other BMP measures. Low Impact Development Strategies (LIDS) are appropriate for these areas because they spread the mitigation over a larger portion of the watershed and would not concentrate pollution in one area. Examples of recharge/exfiltration BMP applications are provided in Sections 4.6 and 5.0.

4.2.2 Low Impact Development Strategies (LIDS)

LIDS are methods of controlling stormwater runoff in a way that simulates natural hydrologic conditions. The central idea of LIDS is to limit the effect of development and encourage groundwater infiltration. LIDS are defined in *Low Impact Development, A Literature Review, EPA-841-B-00-005*, dated October 2000, published by the United States Environmental Protection Agency, Low Impact Development Center as follows:

> *LID is a site design strategy with a goal of maintaining or replicating the pre-development hydrologic regime through the use of design techniques to create a functionally equivalent hydrologic landscape. Hydrologic functions of storage, infiltration, and ground water recharge, as well as the volume and frequency of discharges are maintained through the use of integrated and distributed micro-scale stormwater retention and detention areas, reduction of impervious surfaces, and the lengthening of flow paths and runoff time (Coffman, 2000). Other strategies include the preservation/protection of environmentally sensitive site features such as riparian buffers, wetlands, steep slopes, valuable (mature) trees, flood plains, woodlands and highly permeable soils.*
>
> *LID principles are based on controlling stormwater at the source by the use of micro-scale controls that are distributed throughout the site. This is unlike conventional approaches that typically convey and manage runoff in large facilities located at the base of drainage areas. These multifunctional site designs incorporate alternative stormwater management practices such as functional landscape that act as stormwater facilities, flatter grades, depression storage and open drainage swales. This system of controls can reduce or eliminate the need for a centralized best management practice (BMP) facility for the control of stormwater runoff. Although traditional stormwater control measures have been documented to effectively remove pollutants, the natural hydrology is still negatively affected (inadequate base flow, thermal fluxes or flashy hydrology), which can have detrimental effects on ecosystems, even when water quality is not compromised (Coffman, 2000). LID practices offer an additional benefit in that they can be integrated into the infrastructure and are more cost effective and aesthetically pleasing than traditional, structural stormwater conveyance systems.*

Although LIDS are primarily focused on new development, many of the principles are applicable for redevelopment and retrofits. As described in their definition, LIDS mitigate for impervious cover, by “*maintaining or replicating the pre-development hydrologic regime*”. Not only do LID methods provide mitigation of stormwater impacts by simulating natural hydrologic functions, but their main feature is to control stormwater at the source by the use of micro-scale controls that are distributed throughout the site. Because the IC TMDL addresses water body impacts in areas that are already developed, it is often necessary to adapt multiple small BMPs that are distributed throughout the affected area to mitigate impacts to receiving water bodies. Because LID strategies have been created with this goal in mind, they will increase infiltration, reduce runoff volumes and maintain base flows, and ultimately mitigate for the impervious cover. Typical LIDS include detention (rain barrels, green roofs), infiltration (bioretention, soil amendment), and other practices. Examples of LIDS applications are provided in Sections 4.6 and 5.0.

4.2.3 Extended Detention BMPs

Extended detention BMPs are designed to store stormwater flows for an extended period following storm events and discharge them at a controlled rate over an extended period. Extended detention BMPs are not the preferred choice for impervious cover mitigation because they only address the timing of the runoff instead of addressing runoff volume and infiltration. However, while recharge/exfiltration type BMPs may be preferable from a groundwater recharge/runoff volume reduction standpoint, extended detention BMPs may be more suited to soil and groundwater conditions found at a given site.

Although extended detention BMPs do not actually reduce a watershed's runoff volume, if the detention time is long enough (days versus the typical hours), then the watershed's effective impervious cover can be reduced. The long detention times can mimic the time water would spend traveling through a watershed under pre-existing conditions. The total volume of stormwater discharged will not be reduced for these BMPs as with retention systems, but if the flows are spread out over a sufficiently long period, then some similar benefits can be achieved. For example, vegetated wetlands are nature's extended detention BMPs. These types of BMPs are generally better suited for long-term viability than recharge-type BMPs which are subject to obstruction over time. An effective extended detention BMP could include created wetland/extended detention basins.

One potential concern with extended detention BMPs is thermal impact to the receiving waters due to increases in water temperature via solar radiation during the detention period. This potential adverse impact should be a considered when evaluating an extended detention BMP, and discussed with the state, particularly if the receiving water is sensitive to temperature.

Generally, favorable site characteristics for extended detention practices include:

- Surface slope less than 10%;
- Located in an upland (non-wetland) area; and
- Significant contributing area.

4.2.4 Other BMPs

Other BMPs that do not mitigate for hydrologic impacts of impervious cover, but that are designed to specifically mitigate for water quality or another target may be employed to increase the effectiveness of the BMPs described above. For example, deep-sump hooded catch basins, water quality inlets, or sand filters may be used as “pretreatment” devices to remove entrained sediment and oils from runoff before it is routed to an exfiltration BMP. Other BMPs, not fully described in this section include planting trees, rehabilitation of compacted soils, streamside buffers, and roof top gardens. These are also measures that can reduce run off and contribute to improved water quality while at the same time adding attractive features to a developed area.

4.3 Identifying and Prioritizing Stormwater Mitigation Sites

Within highest priority sub-watersheds, detailed investigations should be conducted to support characterization of existing conditions in terms of the spatial distribution of impervious cover, its connectedness to the receiving stream, and any other factors associated with stormwater impacts. The primary goal of the detailed investigation is to obtain sufficient information to support prioritization of specific areas in which to implement stormwater mitigation actions. A secondary goal of the watershed investigation is to support identification of areas where specific stormwater management standards and other programs including low impact development strategies should be adopted to reduce the potential for future stormwater impairments.

The sub-watershed prioritization task described in Section 3 results in identification of highest priority sub-watersheds and should be conducted prior to beginning the site-specific mitigation investigation described herein. The following set of steps may be followed to support stormwater mitigation site identification and specific BMP selection:

Step 1. Identify potential mitigation sites;

Step 2. Identify constraints and limitations of each site; and

Step 3. Rank, categorize, and select the sites and further investigate selected sites.

Each site must be considered specifically to determine what category(s) of BMPs are applicable. Often multiple BMPs types and sites will be required to achieve the TMDL goals within the constraints of the sub-watershed. Each of the steps is described below.

4.3.1 Identifying Potential Mitigation Sites

Identifying potential mitigation sites requires use of a variety of tools and typically results in a set of sites for further evaluation. Iteratively returning to the data gathered as described in Sections 2 and 3, the tools for identifying mitigation sites include review of aerial orthophotos, other map-based data, and on-the-ground field reconnaissance surveys. Additional data collection and analysis may also be required to support identification of potential mitigation sites. Review of orthophotographic coverages begun in Section 3, can be further refined to identify the proximity of IC areas to receiving streams and open spaces where BMPs could potentially be located. Also, areas with large amounts of impervious cover that are good targets for mitigation should have been identified in the process described in Section 3, from aerial orthophotos and other mapping tools such as GIS data layers and USGS quadrangle maps used to identify important site features such as contours (for slope), mapped land features such as wetlands, land marks, land-use classifications, and soil types. Information gathered during reconnaissance surveys that identified directly connected imperious cover, the existence of stormwater systems and other site-specific data should be refined with BMP identification in mind.

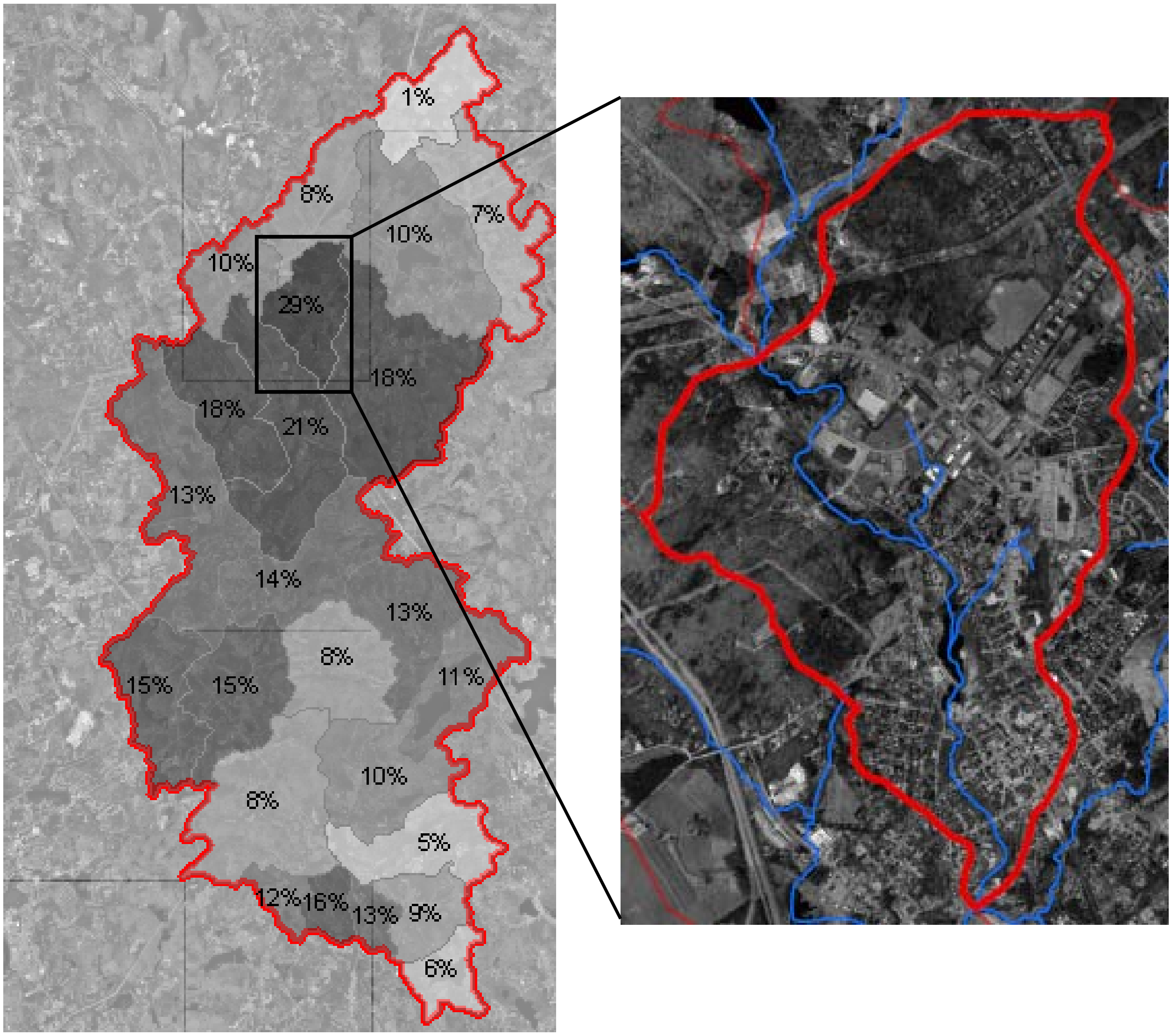
When identifying specific sites for potential BMP retrofits, areas that are adjacent and down slope of impervious area, especially directly connected areas, are prime candidates for mitigation. Publicly owned land should also be identified as potential mitigation sites. In addition, some sites may already contain BMPs but could benefit from enhancements geared at mitigating for impervious cover.

Orthophotographic coverage is available for the Beaver Brook (NH) watershed example and is provided to illustrate the process of identifying potential mitigation sites. Figure 4-1 provides a map of the Beaver Brook watershed with %IC in each sub-basin indicated. The highest %IC sub-watershed was identified as top priority through the sub-watershed prioritization process described in Section 3. In Figure 4-1, an orthophoto of the selected sub-watershed is provided. The stream and adjacent areas of IC are readily observable in the image and may be used to support identification of potential mitigation sites.

<u>Field Reconnaissance Surveys</u>

Once potential mitigation sites have been identified through review of orthophotos and other mapped data, field reconnaissance and surveying should be conducted. Field reconnaissance surveys consist of walking around specific areas and recording observations such as the location of key structures and conveyances and result in creation of maps of actual stormwater flow pathways. Since field reconnaissance is labor intensive, it is recommended that some initial prioritization be conducted before conducting reconnaissance activities.

Figure 4-1 Beaver Brook (NH) Watershed with %IC by Sub-Watershed and Orthophotograph of Top Priority Area



To conduct on-the-ground reconnaissance, a field team is assembled and equipped with appropriate equipment such as a field notebook, a hand-held Global Positioning System (GPS), and a field measuring tape. Field teams should also use any available maps including street maps, storm drain maps, and orthophotos of the survey area.

In general, the focus of the survey will be to map stormwater flow pathways between impervious cover areas and the receiving water body. Surveyors may opt to work from the IC area toward the water body or vice versa depending on the nature and extent of stormwater-related features (e.g., intermittent creek beds, concrete conveyances, pipes) that are visible. In each area surveyed, the following information should be noted:

- drainage area boundaries;
- the type of land cover present;
- the extent, location, size and ownership of each land cover type;
- the distance from key drainage areas to the receiving stream;
- the type and condition of conveyance present between the IC areas and the stream, and the ownership of the conveyance;
- the width of any vegetated buffer areas between development and the stream;
- locations, dimensions, condition, and inlet/outlet characterization of any existing BMPs; and
- locations and specifications of any stormwater outfalls.

Ideally, a reconnaissance survey will result in a detailed map of the survey area containing the information outlined above. The reconnaissance survey map when combined with other existing data would clearly delineate the extent of IC and its proximity and connectedness to the receiving water body.

4.3.2 Identifying Constraints and Limitation of Each Site

Once a set of potential mitigation sites has been identified, an evaluation of site constraints and limitations should be conducted to support selection of the best site(s) for mitigation. This step involves identifying the physical factors that limit site selection by causing BMP methods to be technically infeasible or prohibitively expensive. Physical factors such as surface slope, wetland conditions, soil conditions, water table depth, land use/land cover and contributing watershed area all affect BMP site selection. These characteristics of a watershed can be identified using GIS or other mapping tools as available. If GIS information is available, several characteristics can be examined simultaneously to isolate the best mitigation sites. Table 4-1 shows how these requirements relate to general BMPs and exfiltration BMPs.

Table 4-1 Physical Site Requirements

Characteristic	Exfiltration BMP	General BMP
Surface Slope	<10 %	<10 %
Wetland Conditions	Upland	Upland
Soil Conditions	Sandy Soils	All
Water Table Depth	>2 – 4 ft	Any
Landuse / Land Cover	Open	Open
Contributing Area	Impervious area	Impervious area

Surface Slope

Steep surface slopes generally make the construction of stormwater BMPs more difficult. Because these devices must be constructed level, steep slopes would require excessive cut and fill leaving little room for larger BMPs. Flat slopes are needed for infiltration measures to allow time for infiltration to occur, however, trenches and swales can sometimes be constructed along contour lines to retain or treat stormwater flows. In addition, BMPs that include overland or channel flow require mild slopes to maintain low velocities, prevent erosion, and retain channel vegetation.

Wetland Conditions

Stormwater BMPs should not be constructed in existing wetlands. Only upland areas should be considered suitable for construction of a BMP although wetland enhancement could be an option.

Soil Conditions and Water Table Depth

Soil conditions and water table depth affect exfiltration BMPs. Effective exfiltration BMPs should drain between storm events and this is possible only with soils with moderate to high hydraulic conductivity, such as sandy soils. In addition, the depth of the water table must be great enough to provide separation between the recharge system and water table during all conditions. Without adequate separation, infiltration rates are significantly reduced and pollutant removal that would normally occur as the water filters through the soil matrix is lessened.

Land Use / Land Cover

Land use/land cover will affect site selection on a case-by-case basis. A site might be unavailable for stormwater management because of its classification (e.g., wetlands) or due to existing development. Space limitations can narrow site selection regardless of these other factors. Publicly owned land should be examined as potential BMP sites in addition to cropland, forest, and open areas. Developed land should be evaluated to identify areas that might be retrofitted with BMPs on existing development with the possibility that multiple, smaller BMPs could be installed that would have the effect of a single, larger BMP (see examples of small- and large-size retrofits shown in Figure 4-7.)

Contributing Area

The area that drains to a site affects its viability for siting a BMP. A site needs to be downstream of the impervious cover area of interest otherwise it cannot mitigate the runoff. Also, if a site has only a small contributing area it may not be cost-effective to construct a BMP because of its limited mitigation potential. Multiple, smaller BMPs can be cost effective, particularly if a site is undergoing upgrades or re-development.

Other Issues

Assuming limited funds for mitigation efforts, total and relative cost, and corrective benefit values are another set of prioritization factors. A cost/benefit analysis can be performed for the sites and mitigation may be prioritized and may assist in the selection of BMPs or other mitigation management actions.

The public and stakeholders involved in the watershed should be considered when prioritizing potential BMP sites. Some areas may have more importance in the community or cause more disruption than others and therefore make implementation efforts more difficult.

4.3.3 Ranking, Selecting and Further Investigating Top Priority Sites

Potential mitigation sites should be ranked based on a variety of factors including mitigation benefits and identified limitations and constraints. Ranking will result in selecting the most viable sites and conducting further investigation in preparation of BMP design. Potential mitigation sites should be grouped and ranked as follows:

- Top Priority - Sites able to support recharge/exfiltration with a large contributing impervious area;

- Lower Priority - Sites able to mitigate through extended detention; and
- Eliminated From Consideration - Site with little contributing watershed area or extreme physical limitations.

BMP installations may be required at several sites to mitigate the impervious cover required to meet the target for the sub-watershed. The chosen sites should be further investigated including field visits to locate exact areas, examine slopes and perform soil tests. In some cases, an insufficient number of mitigation sites may be available and alternative locations, such as privately owned land, may need to be considered. In general, land acquisition or agreements with private landowners should be arranged before siting a BMP. Also, sites should be surveyed for exact locations of utilities and other landmarks in addition to surface topology.

4.4 Designing Stormwater BMPs for Mitigation Sites

The goal of selecting and installing management practices (e.g. recharge basins and disconnecting impervious areas) is to restore areas and mimic the sub-watershed natural or pre-development hydrology. Each BMP installed should eliminate the effective impervious cover of its contributing watershed (i.e. reduce effective impervious cover to 0%) as part of the effort to reduce the overall effects of impervious cover. Through the site selection process, site conditions that dictate the most appropriate type of BMPs are identified. Knowing the category of BMP (recharge/exfiltration, LIDS, extended detention) appropriate to a site will narrow the BMP selection process.

4.4.1 Choosing BMPs

Table 4-2 lists BMPs and their applicability to the common situations of high impervious cover. This table serves as a quick reference and starting point for BMP selection based on the land use and mitigation desired. Types of impairment are listed across the top in order of their influence on stormwater impairment: watershed hydrology parameters, channel modifications, and specific pollutants. BMP selection will depend heavily on the available sites. As mentioned in the previous section, land use and physical factors restrict the sites available and therefore restrict the BMPs selection process. In addition, financial limitations will constrain and guide the selection of BMPs.

4.4.2 Calculating the Size of BMPs

This section discusses recommended BMP design criteria for mitigating the impact of impervious cover. To accomplish this goal, BMPs must be designed to produce a rainfall-runoff flow response (i.e. flow duration curve) similar to that which occurred under pre-development

Table 4-2 Best Management Practices Selection Matrix

Management Practice	Ability to Mitigate																Applicability						
	Runoff Volume (↑)	Peak Flow Rates (↑)	Bankfull Flow (↑)	Baseflow (↓)	Mod. Sed. Transport	Channel Morph. Changes[1]	In-Stream Temp. (↑)	Sediment conc. (↑)	Nutrient conc. (↑)	Metal Conc. (↑)	Hydrocarbon Conc. (↑)	Bacteria/Pathogens (↑)	Organic carbon Conc. (↑)	MTBE Conc. (↑)	Pesticide conc. (↑)	Deicer conc. (↑)	New Development	Existing Dev. (Retrofit)	Urban	Sub-Urban	Residential Sub-Division	Commercial/Industrial	Roads and Highways
Recharge / Exfiltration Practices[2]																							
Exfiltration Trench/Galley	●	●	●	●	●	●	●	●	●	●	●	●	●	◐	●	◐	●	●	●	●	●	●	●
Exfiltration Swale	●	●	●	●	●	●	●	●	●	●	●	●	●	◐	●	◐	●	◐	◐	●	●	●	●
Retention/Exfiltration Basin	●	●	●	●	●	●	●	●	●	●	●	●	●	◐	●	◐	●	◐	◐	●	●	●	●
Low Impact Development Practices																							
Minimize Disturbance Area[4]	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	○	●	●	●	●	●
Minimize Site Imperviousness[5]	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	○	●	●	●	●	●
Porous Pavement	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	○
Green Roof	●	●	●	○	●	●	●	●	●	●	●	●	●	●	●	●	●	◐	●	●	◐	●	○
Bioretention	●	◐	◐	◐	◐	◐	●	●	●	●	●	●	●	◐	●	◐	●	●	●	●	●	●	●
Rain Garden	●	◐	◐	◐	◐	◐	●	●	●	●	●	●	●	◐	●	◐	●	●	●	●	●	●	◐
Preserve Infiltratable Soils[4]	●	◐	◐	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	●	○	●	●	●	●	●
Rain Barrels/Cisterns	●	◐	◐	◐	◐	◐	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	●	●	●	●	●	●	○
Disconnecting Impervious Area	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	○	●	●	◐	●	●	●	●
Vegetated Filter Strip	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	○	○	○	●	●	◐	●	●	●	●
Flow Path Practices[3]	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	●	○	●	●	●	●	◐
Preserve Natural Depression Areas[4]	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	●	○	●	●	●	●	◐
Soil Amendment[4]	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	●	●	◐	●	●	◐	◐
Vegetation Preservation[4]	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	●	○	●	●	●	●	●
Extended Detention Practices																							
Extended Detention Pond	○	●	◐	○	◐	◐	☒	◐	◐	◐	●	◐	◐	○	◐	○	●	◐	◐	●	●	●	●
Wet Detention	○	●	◐	○	◐	◐	☒	◐	◐	◐	●	☒	◐	○	◐	○	●	◐	◐	●	●	●	●
Created Wetland/Biofilter Detention	◐	●	◐	○	◐	◐	☒	◐	◐	◐	◐	○	◐	◐	◐	◐	●	◐	◐	●	●	●	●
Other Best Management Practices																							
Swale[7]	◐	●	◐	○	◐	◐	○	◐	◐	◐	●	◐	◐	○	◐	○	●	◐	◐	●	●	●	●
Deep Sump Catch Basins[6]	○	○	○	○	○	○	○	◐	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●
Sand/Organic Filter	○	○	○	○	○	○	○	◐	◐	◐	◐	◐	◐	◐	◐	○	●	●	●	●	●	●	●
Water Quality Inlet[6,8]	○	○	○	○	○	○	○	◐	○	○	◐	○	○	○	○	○	●	●	●	●	●	●	●

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[1] *Impacts include channel enlargement/incision/embededness, changes in pool/riffle structure, and reduced channel sinousity.*

[2] *Recharge and exfiltration measures require permeable soils. Pre-treatment is recommended. See specific BMP descriptions for more information.*

[3] *Includes increasing roughness, sheet flow, flow path length, and flattening slopes.*

[4] *Use as a component of LID site design.*

[5] *Includes imiting use of sidewalks, and reducing road/driveway length/width.*

[6] *Pre-treatment prior to exfiltration BMPs*

[7] *Dry swale with some exfiltration.*

[8] *Includes proprietary hydrodynamic devices.*

Key

Ability to Mitigate
- ● **Good Mitigation**
- ◐ **Moderate Mitigation**
- ○ **Minimal Mitigation**
- ☒ **Adverse Impact**

Applicability
- ● **Well Suited**
- ◐ **Moderately Suited**
- ○ **Not Applicable**

conditions. Mimicking pre-development hydrology increases the proportion of rainfall recharging into the ground and reduces the portion running off to surface waters, which benefits receiving waters in multiple ways including increasing baseflow, reducing post-storm flow rates and volumes, reducing pollutant masses and decreasing in-stream temperatures. Another benefit is to help replicate channel forming flows associated with past stable stream bed form and increase chances of achieving stable stream habitat that will be maintained by the stream over time. For more information on channel forming flows, please see the Center for Watershed Protection's Stormwater Manager's Resource Center, at http://www.stormwatercenter.net/. (At the site look under "Manual" and then click on "Channel Protection Sizing.")

A primary BMP design question that must be answered is: how much volume must the BMP hold? One method to determine this is to conduct iterative long term hydrologic/hydraulic simulations of hypothetical BMP designs. While appropriate, this method can be expensive. An efficient alternative method is to use one or more single event “design storms” for sizing BMPs that are selected to represent multiple hydrologic conditions. To replicate existing hydrologic conditions, two factors should be considered in selecting a representative design storm:

- Runoff volumes must approximate natural conditions for most storms; and
- The threshold rainfall value, under pre-development conditions, below which no runoff occurs (also known as the “initial abstraction”) should be used as a design target for BMPs.

Evaluation of precipitation records for the northeast reveals that 99 percent of rainfall events are two inches or smaller. Therefore, a two-inch storm would be logical for evaluating BMPs relative to runoff volume reduction. This ensures the effectiveness of the BMPs for the most frequent rainfall events. In an attempt to refine BMP design criteria for local conditions, some states in the Northeast recommend controlling for the one-*year* storm instead of the two-*inch* storm, and set different flow thresholds throughout the state. The one-*year* storm and two-*inch* storm happen to be generally the same in New England as a whole, but can vary throughout the region depending on location. Flood control benefits would be derived for sizing BMPs for peak runoff rate control for larger storms (e.g., 10- and 100-year storms) as well. Most states and local jurisdictions now require this sort of control for new development.

When sizing recharge/exfiltration BMPs, the pre-existing initial abstraction should also be considered. The initial abstraction of a site is the volume of water that is stored on site before runoff occurs. Equivalently, it is the rainfall depth for which runoff just begins to occur. DCIAs produce runoff in all but the smallest storm events and therefore have virtually zero initial abstraction. BMPs may be employed to artificially increase the initial abstraction for impervious areas to mimic natural conditions. Therefore, the initial abstraction calculated for natural conditions can be used as a design target for recharge/exfiltration BMPs to mimic natural abstraction. Detention BMPs by design will not abstract any volume of runoff but instead only affect the timing of discharge off site. Therefore, to be effective, detention-type BMPs would need to release stored runoff volumes very slowly.

Recommended steps for sizing BMPs are presented below followed by detailed description and a BMP sizing example using this method.

Step 1. Evaluation of existing conditions

- Calculate overall site curve number as discussed below;
- Calculate site impervious cover percentage; and
- Estimate directly connected impervious area (DCIA).

Step 2. Determining existing and pre-existing conditions runoff (two-inch storm) and initial abstraction depth

Step 3. Set target mitigation volume based on pre-existing conditions (two-inch storm)

Step 4. Size BMP based on type of BMP

- Recharge/exfiltration – consider initial abstraction and pre-existing runoff;
- Extended detention – consider pre-existing runoff with storage factor; and
- Consider reducing impervious cover and/or DCIA.

Step 1. Evaluation of Existing Conditions

The characteristics of the site draining to the BMP under existing conditions determine how much runoff the site produces. The runoff Curve Number (CN) should be calculated for the site as the first step in this evaluation. CN is a parameter frequently used by hydrologists to determine how much rainfall will become runoff. Runoff CN values typically vary from 30 to 98 with higher values corresponding with greater proportions of rainfall becoming runoff. Runoff CNs are determined based on land cover (higher CN for more impervious surfaces) and soil properties. For more information on CNs see the NRCS publication TR-55, Urban Hydrology for Small Watersheds. (located at http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-tr55.html - click on "TR-55 documentation")

A composite CN of the site should be calculated using an area-weighted average of the curve numbers for the impervious cover and pervious portions of the site. The site reviews performed as described in the previous sections of this manual should provide the estimated percentages of the drainage area with each type of soil group and cover (vegetated, bare soil, impervious cover, etc.). The Curve Number used for impervious areas is generally 98; for representative curve numbers associated with other cover types and soil conditions, see TR-55 website provided above. The percentage of each type of cover including both the impervious cover and directly connected impervious cover should be calculated or estimated for use in runoff calculations.

Step 2. Determine Runoff Volumes and Initial Abstraction Depths

Calculate the existing and pre-existing 2-inch (or 1-year) storm runoff volume separately for the DCIA and remainder of the watershed (pervious and disconnected impervious areas). Impervious areas that are not directly connected to receiving waters may be grouped with the pervious areas because runoff from disconnected impervious cover has the opportunity to be partially mitigated by flowing over pervious areas, whereas directly connected impervious cover contributes directly to runoff.

Figure 4-2 shows the runoff depth (in inches) produced by a two-inch storm for a range of curve numbers and percentages of DCIA using this method. The curve numbers in Figure 4-2 are composite curve numbers (including directly connected and non-directly connected impervious area) of the entire contributing area. The figure can be used as follows:

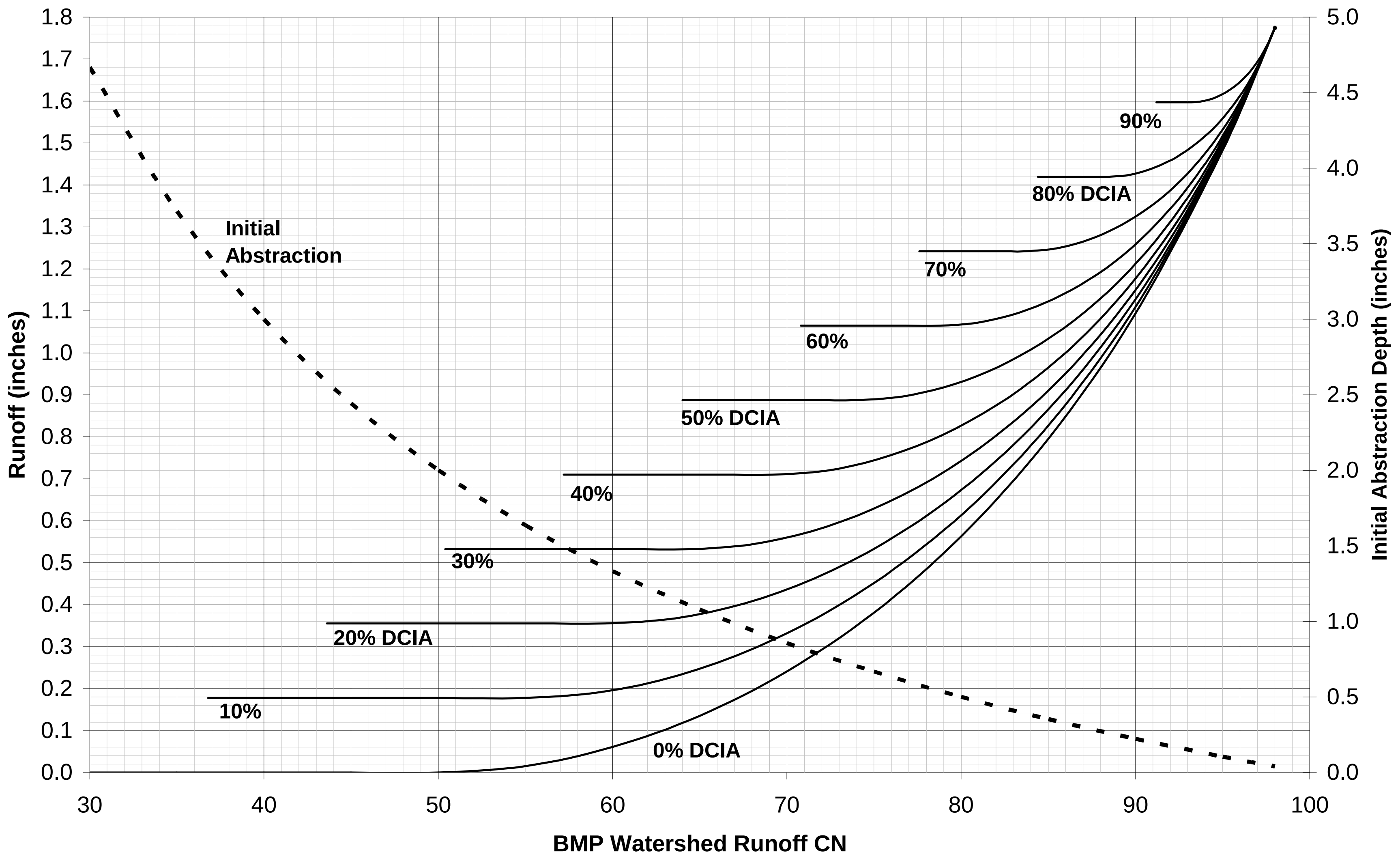
- Locate the curve number of interest;
- Follow up the graph to the DCIA of interest; and
- Follow over to the associated runoff depth.

If runoff volumes are desired for a rainfall depth other than 2-inches, the following procedure should be used:

- Calculate composite curve number for site, but excluding DCIA (i.e., pervious areas and non-directly connected impervious area);
- Calculate runoff volume for the pervious/non-DCIA portion of the site using the following formula:

  V = R * A/12 , where
    V = Runoff volume (acre-feet)
    A = Area (acres)

Figure 4-2 Two-Inch Storm Runoff Volume and Initial Abstractions Depths



R = Runoff Depth (inches) = $(P - 0.2 * S)^2 / (P + 0.8 * S)$, where

P = Precipitation depth (inches)

S = Soil Storage (inches) = 1000/CN -10;

- Calculate runoff volume from DCIA-area of site (typically based on a CN of 98) using the same formula as for the pervious/non-DCIA portion of the site; and
- Sum calculated runoff volumes for pervious/non-DCIA and DCIA portions of site.

Calculate the runoff volume for natural conditions using the DCIA and composite site CN as discussed above with the storm of interest (i.e., two-inch for the northeast) or by using Figure 4-2. The curve number for natural conditions is based on an estimate of pre-existing conditions generally assuming open space or forest cover with soils typical of the area. For natural conditions, the DCIA should be 0%.

Calculate the initial abstraction rainfall depth for natural conditions. Figure 4-2 also plots the initial abstraction for the full range of curve numbers.

Step 3. Determine Target Mitigation Volume

Calculate the target mitigation volume as the difference in runoff volume between pre-existing and existing conditions. If this volume is mitigated, the area is considered having an effective impervious cover of 0%. The sub-watershed's effective impervious cover can then be re-calculated including 0% effective impervious cover from this site (if the BMP was able to be designed for full mitigation). It may not be feasible or desired to mitigate the entire runoff difference, in which case a smaller target value can be used.

Step 4. Size BMP

The BMP sizing criteria depends on the category of BMP that can be located at the site (recharge/exfiltration, LIDS, extended detention). In all cases, a hydrologic routing model along with the 2-inch design storm using the appropriate SCS storm distribution should be used as part of a detailed BMP design.

Recharge/Exfiltration: Recharge/exfiltration BMPs should be sized to ensure that no runoff occurs during the initial abstraction storm. This volume is calculated as the pre-existing initial abstraction depth multiplied by the directly connected impervious area, as this is the area that contributes to runoff. The volume can be possibly less than this value depending on the recharge rate of the underlying soils. The design volume should then be checked against the two-inch storm runoff volume and storm distribution. Again, the soil recharge rate will affect the ability of the BMP to mitigate the storm volume.

Extended Detention: Extended detention BMPs do not exfiltrate runoff but instead slowly release stored runoff to adjacent surface waters over a period of time (days). Detention BMPs should be sized to store the full difference between existing and pre-existing 2-inch storm runoff volume. The detention BMP outlet should be designed to draw the full mitigation volume down over a period of 7 to 10 days and to draw down the initial abstraction mitigation volume over a period of 3 to 4 days. These extended drawdown periods are intended to maximize attenuation of flows while allowing for recovery of storage volume for future events. When designing such flow storage systems, it is important to consider the impacts of storage on the temperature of water released to the stream, especially if coldwater fisheries need to be protected, as the extended period of detention can cause significant warming of the stored water. The rate at which stored stormwater is released back to the stream should be designed to mimic natural flow conditions, and should be determined in consultation with the state.

LIDS: Some structural low impact development strategies can be categorized as either recharge/exfiltration (e.g., bioretention) or detention (e.g., rain barrels) type BMPs. In these cases, the same methods described above apply to LIDS. In addition, several LIDS aid in disconnecting impervious cover and do not have to be specifically sized, but contribute to the mitigation effort. LIDS are usually more effective mitigating small areas and used together on a site to accomplish the target runoff.

Disconnecting Impervious Areas: The potential for disconnecting impervious area should be evaluated. As will be shown in the following example, disconnecting impervious area reduces the existing runoff volume considerably and therefore can reduce the required structural BMP design size.

4.5 BMP Sizing Example

This section provides a hypothetical example to demonstrate how the methodology described above can be used when sizing a BMP for reversing impervious cover impacts. This example assumes a hypothetical sub-watershed with the following characteristics:

- Total area of 10 acres; and
- 29% impervious cover.

A BMP site has been chosen with the following characteristics:

- Contributing area of 2 acres;

- 30% is impervious, all of it directly connected to the receiving water;
- 70% with good soils and a curve number of 61.

Step 1: Evaluate Existing Conditions: The total watershed area curve number can be calculated from a weighted average of the impervious area (curve number 98) and pervious area (curve number 61). This results in an overall curve number of 72.

Step 2: Determine Runoff and Initial Abstraction: Given a curve number of 72 and 30% directly impervious area, the runoff depth for a two-inch storm is 0.58 inches (Figure 4-3, shown as a green dashed line). The runoff for pre-existing conditions based on an estimated natural-state curve number of 61 and 0% DCIA from Figure 4-3 (in red) is 0.08 inches. Figure 4-3 shows these results.

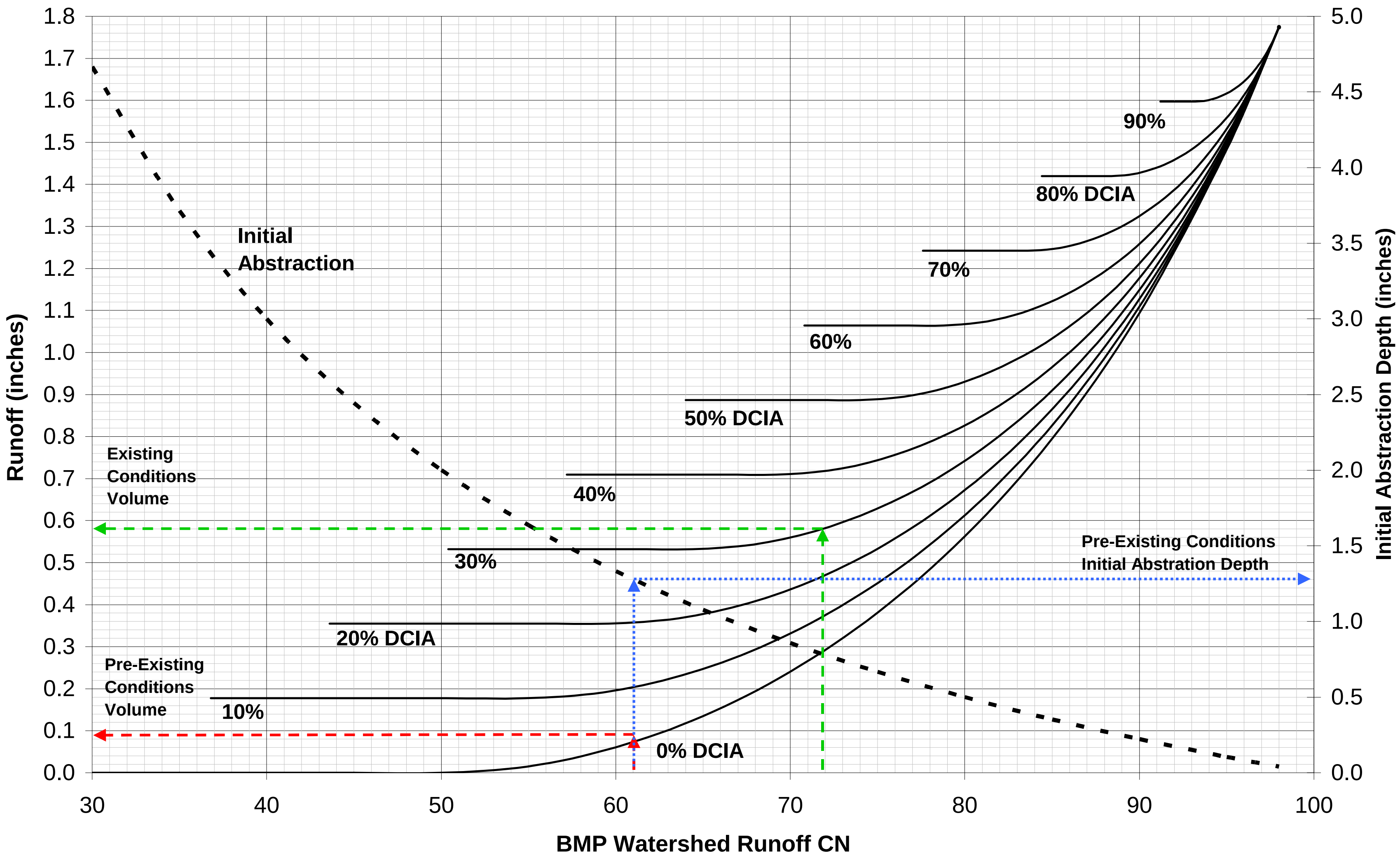
The initial abstraction depth from Figure 4-3 (in blue) for pre-existing conditions (curve number of 61) is approximately 1.25 inches. This indicates that to mimic pre-existing conditions, no runoff should leave the site for storms smaller than 1.25 inches.

Step 3: Determine Target Runoff: Calculate the target mitigation volume by comparing the existing condition runoff and pre-existing runoff volumes. The difference between the existing runoff (0.58 inches) and the pre-existing runoff (0.08 inches) is the amount of water the BMP must mitigate (0.50 inches). This volume equals 3,600 cubic feet based on the contributing watershed area. Table 4-3 shows the results for this example.

Table 4-3 BMP Sizing Example Summary

	Pre-Existing Conditions (sandy soils)	**Existing Conditions**	**Existing Conditions w/Disconnected Impervious Area**
Effective Impervious Area (%)	0	30	0
Curve Number	61	72	72
Initial Abstraction	1.25	0	0.80
Runoff Volume (in)	0.08	0.58	0.30
Storage Required - Recharge/Exfiltration* (cf)	-	2,700 - 3,600	980 – 1,600
Storage Required - Extended Detention (cf)	-	3,600	1,600
*Storage volume for recharge/exfiltration BMPs can be smaller based on soil properties /recharge rate and basin configuration.			

Figure 4-3 BMP Sizing Example



Step 4: Size BMP:

For recharge/exfiltration systems: The initial guidelines for sizing are based on the runoff volumes. The maximum size required for a recharge/exfiltration BMP is equal to the differential runoff volume between pre-existing and existing condition. In this example, the maximum size is 3,600 cubic feet. The minimum size of the BMP should accommodate the pre-existing initial abstraction volume that instead runs off due to impervious cover under existing conditions. The runoff associated with this initial abstraction is based on the impervious areas. In this case, the associated runoff volume is 1.25 inches times the impervious area, or 2,700 cubic feet. The exact storage volume needed for a recharge BMP will depend on the underlying soils, the speed of exfiltration, and configuration of the BMP.

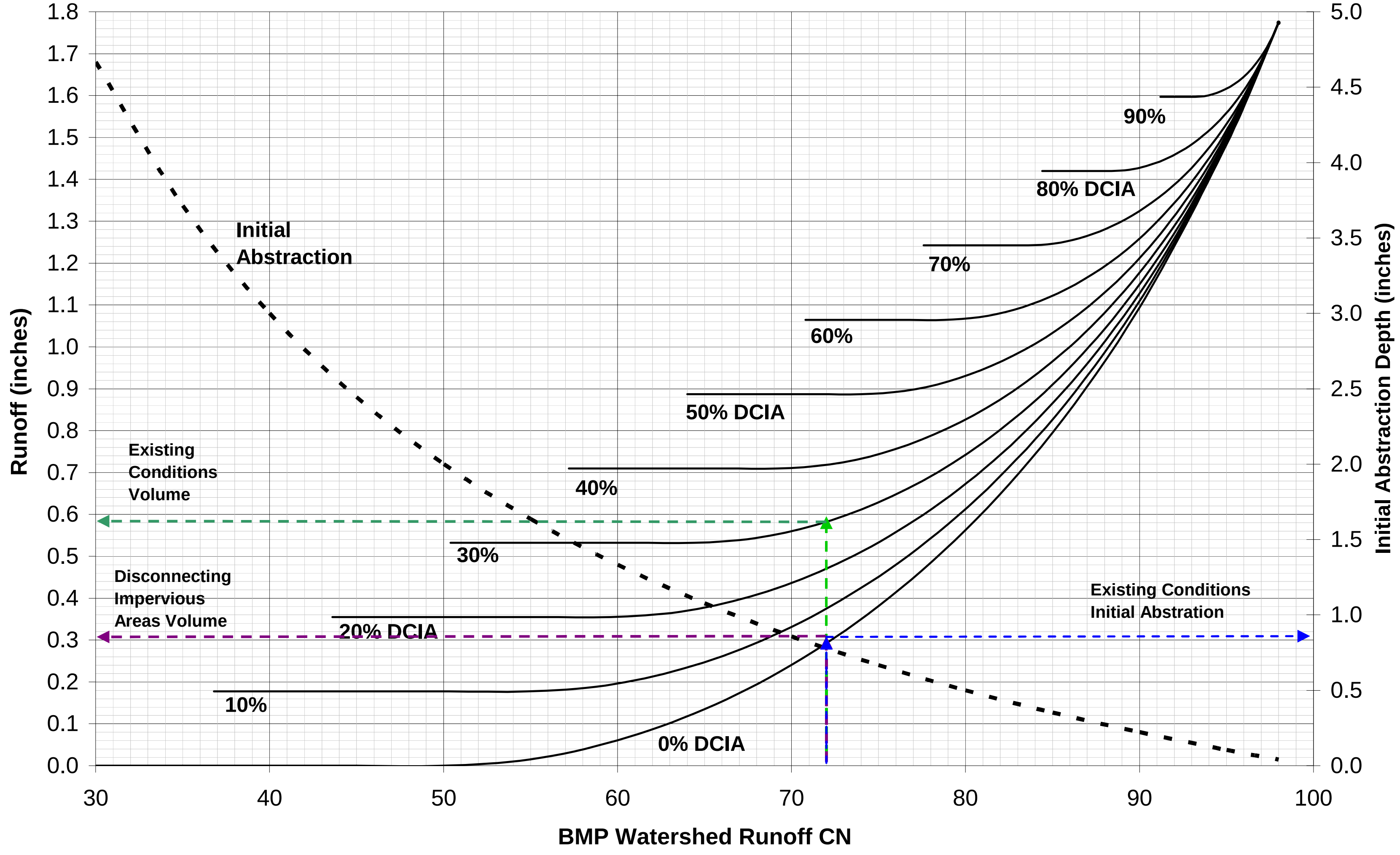
For extended detention systems: Extended detention BMPs do not exfiltrate runoff but instead slowly release stored runoff to surface waters over long periods of time (days). Because of this design, the detention BMPs must be sized to accommodate the full difference between existing and pre-existing runoff volume. The outlet sizing should ensure that the draw-down period for the initial abstraction volume is approximately three to four days and the draw-down for the two-inch storm volume is approximately seven to ten days.

Disconnecting Impervious Cover

Another way to mitigate runoff from impervious cover is to disconnect the impervious cover that is directly connected to the receiving water body, where site conditions allow for it. Disconnecting impervious areas reduces runoff from a watershed in smaller storm events and increases initial abstraction and therefore should be evaluated before sizing a BMP. The maximum size of the BMP should accommodate difference in pre-existing and existing runoff volumes. By disconnecting the impervious area, the curve number of the contributing area does not change, but the runoff is reduced to 0.30 inches for 0% DCIA (see Figure 4-4). Re-calculation of the size of the BMP results in 0.22 inches (0.30 inches minus 0.08 inches at pre-existing conditions) times the area of the watershed or 1,600 cubic feet of storage required, as summarized in the third column of Table 4-3. Disconnecting the impervious areas results in a reduction of 2,000 cubic feet of required storage or a reduction in required storage of 55%. This reduction is even greater for watersheds with larger DCIA.

The minimum size required should accommodate the difference of initial abstraction between the pre-existing conditions (1.25 inches) and the initial abstraction for the existing conditions with no directly connected impervious cover (0.80 inches from Figure 4-4). Therefore a minimum of 0.45 inches times the impervious area or 980 cubic feet would need mitigation to return the pre-existing initial abstraction.

Figure 4-4 Disconnected Impervious Area BMP Sizing Example



Recalculating Sub-watershed Impervious Cover

Once a BMP has been installed and has converted an area that was 30% impervious cover to an area with 0% effective impervious cover (assuming full mitigation was possible), the sub-watershed impervious cover may be reassessed. The two acres (of 10 acres total in the example) that previous contributed to the impervious cover have been mitigated to 0%IC. Since 20% of the total area has been mitigated (2 of 10 acres), a reduction to 24%IC from 30%IC is realized in the sub-watershed. This example shows that watershed impervious cover will most likely not be mitigated with one BMP alone. Combinations of BMPs implemented in a phased approach will allow for reassessment of the watershed and evaluation of the installed BMP performance. When assessing BMPs, flow paths (further described in Section 5.2) should also be evaluated to achieve the maximum benefit from the mitigation approach chosen, particularly when disconnecting impervious areas as part of the mitigation.

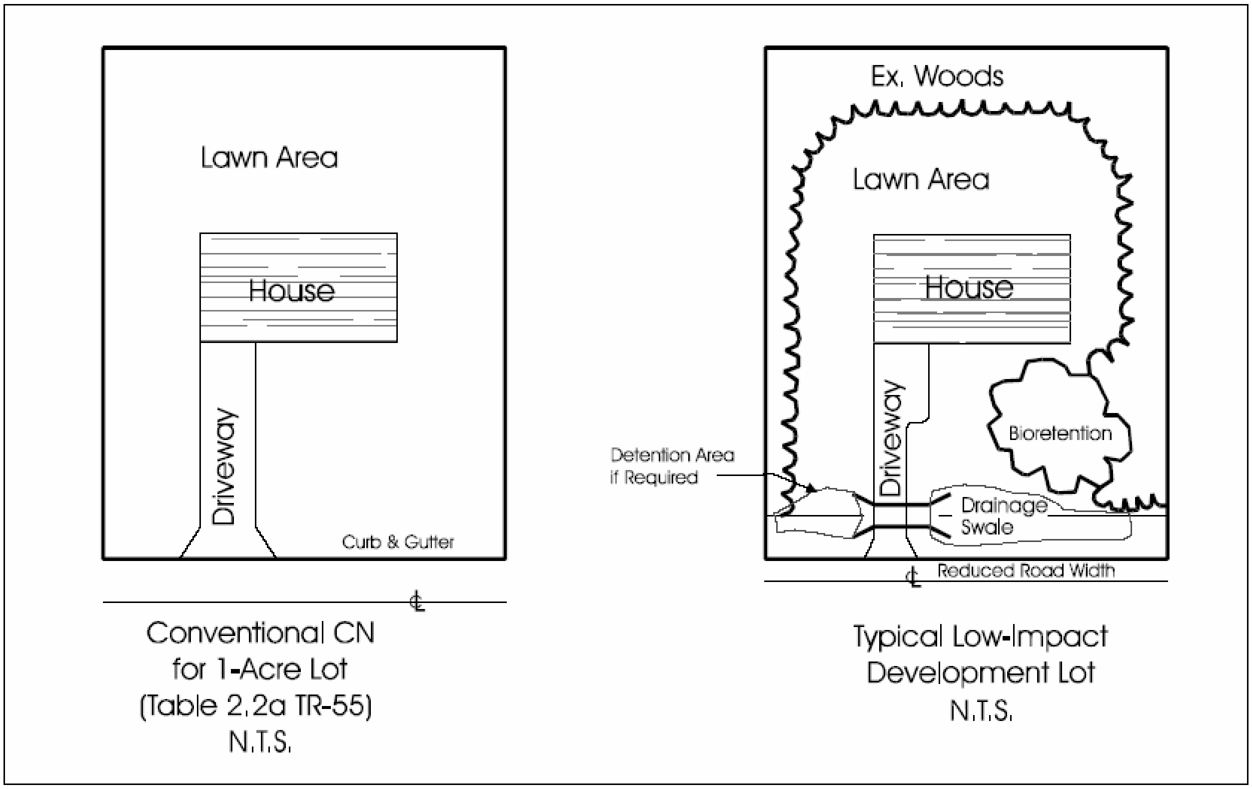
4.6 BMP Layout Examples

Several examples of BMP layouts are provided below. Firstly, a simple example of how one category of BMPs, LIDS, can be incorporated into an average residential site is shown in Figure 4-5. In this example, several LIDS and BMPs are incorporated into one residential site. Vegetation has been preserved and impervious cover (driveway and road width) has been limited. Also, the open drainage and bioretention included encourages infiltration and lowers runoff volumes.

A site more typical of an urban watershed with high impervious cover is shown in Figure 4-6. Ideally, recharge/exfiltration BMPs would be chosen for this site, if feasible based on soils, slopes, groundwater table and other considerations. The site includes some limited space around the main building and parking areas where BMPs could be located to intercept and retain runoff instead of contributing to a centralized drainage system. Figure 4-7 shows a possible layout of BMPs to mitigate for the large building and parking lot.

As can be seen in Figure 4-7, there are many opportunities to mitigate stormwater runoff from the site. The larger open spaces can be used to site retention basins (or extended detention basins if soils have low permeability). Exfiltration swales can collect roadway runoff and convey runoff to the recharge basin. Vegetative filter strips can be located in the parking lot to disconnect the large impervious area. In smaller areas, bioretention cells can contribute to the mitigation. If there is a need to mitigate more runoff after these options have been exhausted, an underground recharge gallery could be located under the parking lot. Roof drains routed to cisterns might mitigate runoff from the large expanse of the building. The combination of these BMP efforts would remove effective impervious cover from the watershed while many of these BMPs can also add value to the landscaping and attractiveness of the site.

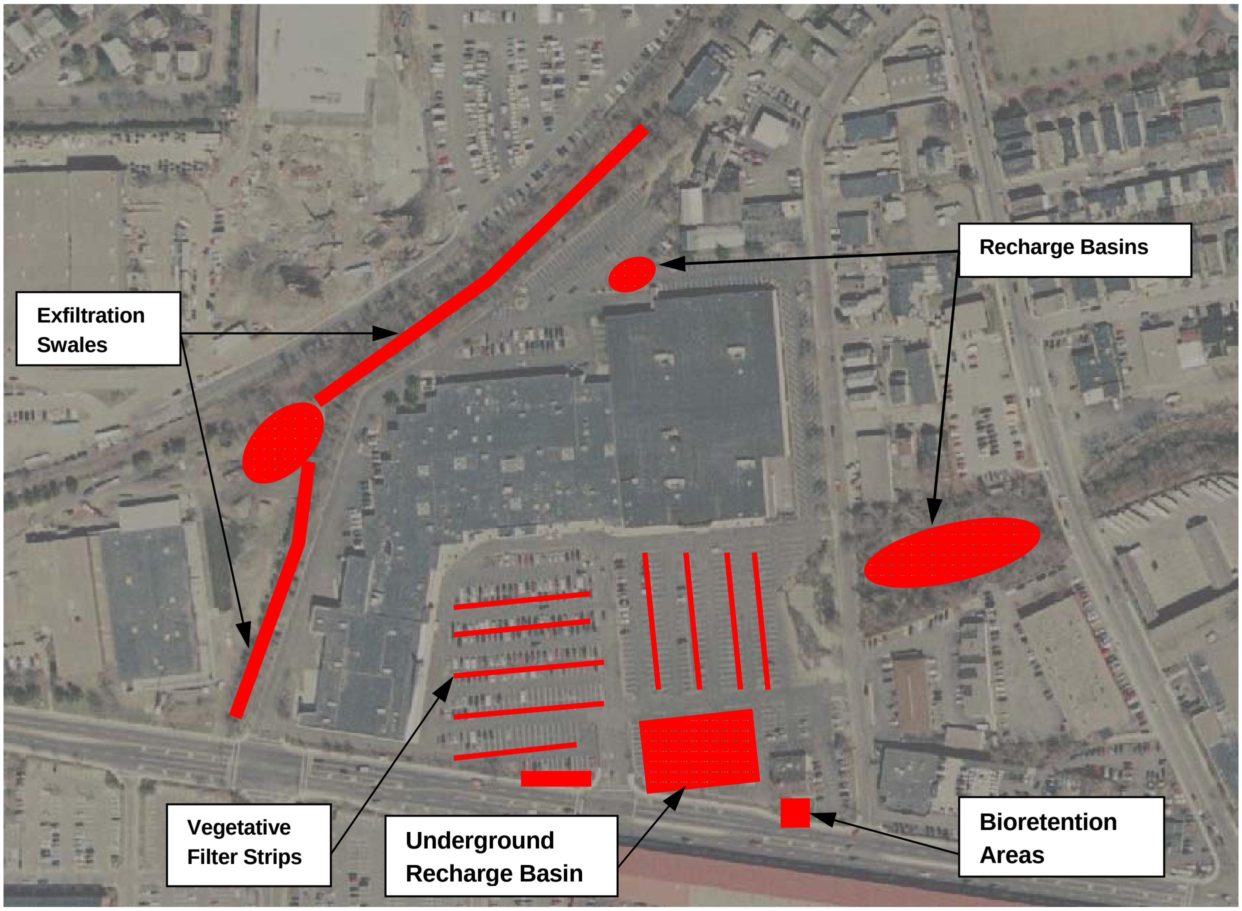
Figure 4-5 Low Impact Development Residential Layout



Source: Low-Impact Development Hydrologic Analysis, Prince George's County, Maryland Department of Environmental Resources, Programs and Planning Division, July 1999

Figure 4-6 Highly Impervious Site

Figure 4-7 BMP Layout Example



Low impact development that features cluster development which minimizes impervious cover and preserves undeveloped areas for receipt and infiltration of stormwater is useful. One extensively monitored development in Connecticut, Jordan Cove (http://www.canr.uconn.edu/jordancove) has demonstrated a high level of success maintaining pre-development runoff volumes through LID.

5.0 STORMWATER BMP DESCRIPTIONS

This section presents detailed descriptions and examples of each BMP listed in Table 4-2 including figures and information regarding the benefits and limitations for each.

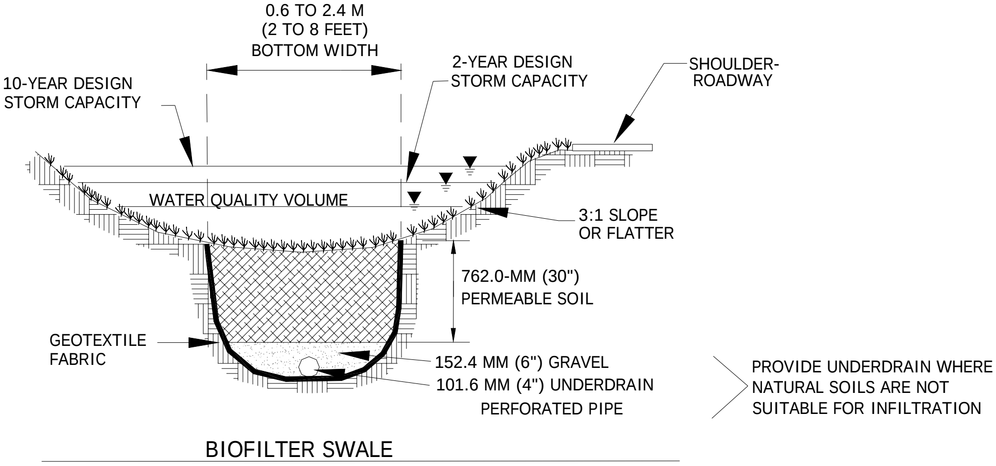
5.1 Stormwater Exfiltration/Retention Practices

Stormwater exfiltration and retention BMPs store runoff and allow it to gradually infiltrate to groundwater. Retention BMPs, also known as exfiltration systems, include infiltration basins, trenches, swales, and vegetated filter strips. These systems must be designed with sufficient storage capacity to hold runoff long enough to permit gradual exfiltration. Exfiltration systems remove pollutants by filtration through the soil matrix and reduce stormwater volume. Pretreatment of runoff is often required to prevent failure of infiltration systems due to sediment accumulation. Exfiltration systems historically have had significant failure rates and site constraints often limit their effectiveness (Schueler et al 1992). A set of specific exfiltration/retention practices is provided below.

Exfiltration/Biofilter Swales

Exfiltration swales (also referred to as biofilter swales) are channels designed to retain stormwater runoff until it infiltrates to the groundwater. Figure 5-1 is a schematic diagram of an exfiltration swale. To ensure adequate exfiltration they must either be built in areas with soils capable of supporting significant infiltration or must have an underdrain system (MassHighway 2004). In addition to reducing runoff, exfiltration swales can significantly reduce pollutant loading to a water body by eliminating the direct discharge of stormwater runoff to surface waters. Due to their linear nature, exfiltration swales are well suited for treating road runoff.

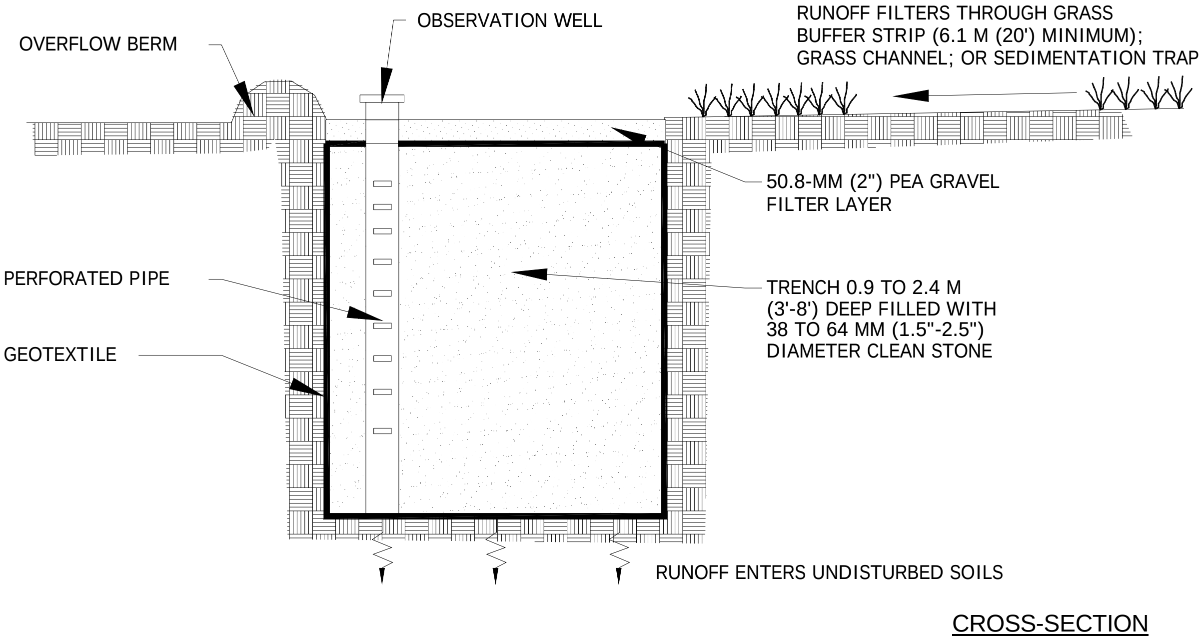
Figure 5-1 Exfiltration Swale (MassHighway, 2004)



Exfiltration Trenches

Exfiltration trenches are trenches backfilled with stones to create a reservoir to store runoff and allow it to infiltrate to the groundwater. Figure 5-2 is a schematic diagram of an exfiltration trench. It is important that soils at the site have sufficient permeability and the water table is deep enough to allow infiltration. Pretreatment is necessary for removing sediments to reduce clogging. Grass clippings, sediments, and leaves can accumulate on the surface of the trench and should be removed regularly. Exfiltration trenches tend to have a high failure rate due to insufficient maintenance. Investigators have found that slightly more than half of these systems totally or partially fail within five years of construction (Schueler et al. 1992). With proper maintenance, exfiltration trenches can successfully reduce runoff volume.

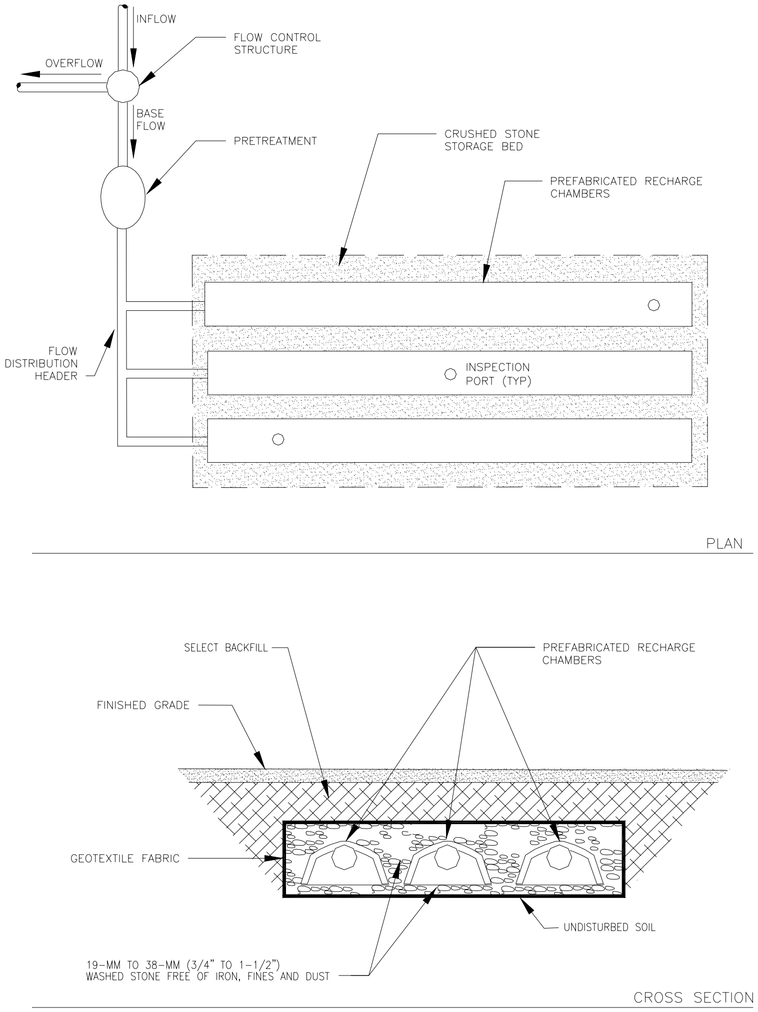
Figure 5-2 Exfiltration Trench (MassHighway, 2004)



Underground Exfiltration Galley

Underground exfiltration galleys are underground structures filled with stones to create a reservoir to store runoff and allow it to infiltrate to groundwater. Figure 5-3 is a schematic diagram of an exfiltration galley. Plastic or concrete chambers are used to increase storage volume over the void space alone. Centralized drainage systems can carry runoff to these structures instead of transporting runoff off site. These structures are advantageous to sites that have no usable area above ground although being located underground causes difficult access for maintenance. As with all exfiltration BMPs, it important that soils at the site have sufficient permeability and the water table is deep enough to allow infiltration. Pretreatment is necessary for removing sediments to reduce clogging.

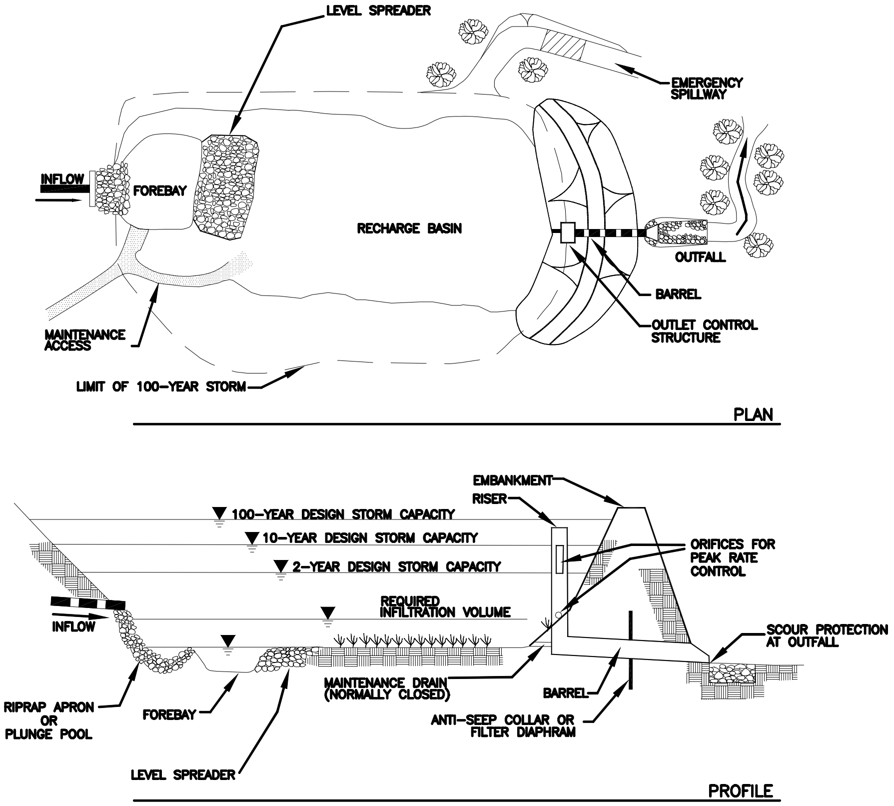
Figure 5-3 Exfiltration Galley (MassHighway, 2004)



Retention/Exfiltration Basin

Retention/exfiltration basins are stormwater impoundment structures designed to store runoff until it infiltrates to the groundwater through the floor of the basin. Failures will likely occur without proper maintenance and pretreatment. Therefore, regular maintenance and pretreatment of runoff to remove sediments is vital. Limiting storage depth to one to two feet will also prevent overloading the system. Figure 5-4 is a schematic diagram of an exfiltration basin showing side and top views. Exfiltration basins may be designed to allow a portion of the stormwater to run out during large storm events. Their use is limited to areas with permeable soils and deep groundwater tables. Pollutant removal is achieved by filtration through the soil matrix. These above-ground systems are preferable to underground systems due to their accessibility.

Figure 5-4 Retention / Exfiltration Basin (MassHIghway, 2004)



5.2 Low Impact Development Strategies

Low impact development strategies (LIDS) are a set of tools intended to restore or maintain the hydrology of the watershed by reducing runoff rates and volumes and by increasing groundwater recharge. LIDS are defined as follows (from USEPA 2000a):

Although LIDS are often intended primarily for new development, many of these practices can be applied as retrofits to existing sites with similar benefits. The following section focuses on the LIDS that are most likely to be applicable to existing developments.

A set of LIDS types are described below.

Bioretention

Bioretention uses a conditioned planting soil bed and planting materials to filter runoff stored within a shallow depression. The method combines physical filtering and adsorption with biological processes. These processes are likely to remove sediments and associated pollutants from the water. A bioretention system can include the following components: a pretreatment filter consisting of a grass channel inlet area, a shallow surface water ponding area, a bioretention planting area, a soil zone, an underdrain system, and an overflow outlet structure (MD DNR, 1999).

Disconnecting Impervious Areas

One of the most effective LIDS is “disconnecting” impervious areas. Impervious areas that drain directly to closed drainage systems or receiving waters produce runoff in all but the smallest rain events. If runoff from paved surfaces is allowed to flow over pervious or vegetated surfaces before entering a drainage collection system, some or all of the runoff from small rain events will be intercepted and percolated into the ground. The following steps can be taken to disconnect impervious areas:

- Remove curbs on roads and parking lots;
- Locate catch basins in pervious areas adjacent to parking lots, as opposed to in the paved portion of the lot;
- Disconnect roof drains and direct flows to vegetated areas;
- Direct flows from paved areas such as driveways to stabilized vegetated areas;
- Break up flow directions from large paved surfaces;
- Encourage sheet flow through vegetated areas; and
- Carefully locate impervious areas so that they drain to natural systems, vegetated buffers, natural resource areas, or other zones or soils in which infiltration can take place.

Flow Path Practices

Typical development practices significantly decrease a watershed’s time of concentration (Tc) by concentrating flows and efficiently conveying them to the outlet. The time of concentration, in conjunction with the hydrologic site conditions, determines the peak discharge rate for a storm event. Shorter Tcs result in higher peak discharge rates. Site and infrastructure components that affect the time of concentration include travel distance (flow path), slope of the ground surface and/or water surface, surface roughness, and channel shape, pattern, and material components. Several techniques may be employed to manage flow and conveyance systems within the development to mimic pre-development Tc, including:

- Maximize overland sheet flow;
- Increase and lengthen flow paths;
- Lengthen and flatten site and lot slopes;
- Maximize use of open swale systems; and
- Increase and augment site and lot vegetation.

An additional benefit of these flow path practices is an increased opportunity for infiltration of runoff, thereby reducing runoff volume in addition to runoff peak rates (MD DER, 1999).

Green Roofs

Green roofs, also known as vegetated roof covers, eco-roofs or nature roofs, are multi-beneficial structural components that help to mitigate the effects of urbanization on water quality by filtering, absorbing or detaining rainfall. They are constructed of a lightweight soil media, underlain by a drainage layer, and a high quality impermeable membrane that protects the building structure. The soil is planted with a specialized mix of plants that can thrive in the harsh, dry, high temperature conditions of the roof and tolerate short periods of inundation from storm events. Green roofs provide stormwater management benefits by:

- Utilizing the biological, physical, and chemical processes found in the plant and soil complex to prevent airborne pollutants from entering the storm drain system; and
- Reducing the runoff volume and peak discharge rate by holding back and slowing down the water that would otherwise flow quickly into the storm drain system.

Other benefits include energy savings and lengthened life of the roof, improved air quality, and cooler air temperatures (www.lowimpactdevelopment.org).

Minimizing Disturbance Area

Conserving natural drainages, trees and other vegetation, and soils is the first step in low impact development. Trees and natural forest cover are terrific “sponges” for storing and slowly releasing stormwater. Comprehensive land use planning, watershed or basin planning, habitat conservation plans, and stream and wetland buffers are good tools to identify and set aside natural areas within a community and on an individual site.

Once conservation areas are established for each site, the designer can then work within the developable area envelope and evaluate the effects of design options on these areas. A significant portion of trees and other vegetation should be left in a natural state and not developed (www.lowimpactdevelopment.org).

Minimizing Site Imperviousness

Reducing the amount of imperviousness on the site will have a significant impact on the amount of other storm water management practices required for mitigating development impacts. The following practices may be employed to help minimize site imperviousness (MD DER, 1999):

- Evaluate alternative roadway layouts to minimize total road length;
- Use reduced road width sections;
- Limit sidewalks to one side of primary roads;
- Use vertical construction to reduce rooftop footprints;
- Use shared driveways whenever possible;
- Limit driveway width to 9 feet;
- Minimize building setbacks to reduce driveway length; and
- Use pervious/porous pavement or pavers.

Porous Pavement

Porous pavement is a special type of pavement that allows rain and snowmelt to pass through it, thereby reducing the runoff from a site and surrounding areas. The two primary types of porous pavement include porous asphalt and pervious concrete. Porous asphalt pavement consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Pervious concrete consists of specially formulated mixtures of Portland cement, uniform, open-graded coarse aggregate, and water. Pervious concrete has enough void space to allow rapid percolation of liquids through the pavement.

The porous pavement surface is typically placed over a highly permeable layer of open-graded gravel and crushed stone. The void spaces in the aggregate layers act as a storage reservoir for runoff. Two common modifications made in designing porous pavement systems are (1) varying the amount of storage in the stone reservoir beneath the pavement and (2) adding perforated pipes near the top of the reservoir to discharge excess storm water after the reservoir has been filled. Porous pavement may substitute for conventional pavement on parking areas, areas with light traffic, and the shoulders of airport taxiways and runways, provided that the grades, sub-soils, drainage characteristics, and groundwater conditions are suitable. Slopes should be flat or very gentle. (EPA 1999)

Pervious Pavers

Pervious pavers are assemblies of rigid paving blocks which have open spaces at their corners, or in some other configuration, through which water can percolate into the ground. They are very effective at infiltration since there is actual open space in their design, which can be as much as 20% or more. Studies have shown large reductions in stormwater runoff volume and in pollutant loads from their use. Pavers need to be installed on road beds that have been appropriately prepared, but they have a variety of applications and can be a very attractive surface, visually.

Preservation of Infiltratable Soils

This practice includes site planning techniques such as minimizing disturbance of soils, particularly vegetated areas, with high infiltration rates (sandy and loamy soils), and placement of infrastructure and impervious areas, such as houses, roads, and buildings on more impermeable soils (silty and clayey soils) (MD DER, 1999).

Preservation of Natural Depression Areas

This practice involves preserving existing topographic depressions during the planning process. These areas can serve to naturally reduce runoff volume via percolation and evaporation.

Rain Barrels and Cisterns

Rain barrels are low-cost, effective, and easily maintained retention devices applicable to residential, commercial, and industrial sites. Rain barrels operate by retaining a predetermined volume of rooftop runoff. Rain barrels are typically used to store runoff for later reuse in lawn and garden watering. Stormwater cisterns are roof runoff management devices that provide retention storage volume in underground storage tanks for re-use for irrigation or other uses. On-lot storage with later reuse of stormwater also provides an opportunity for water conservation and the possibility of reducing water utility costs (MD DER, 1999).

Rain Gardens

A simple, yet effective method to control stormwater is through the use of rain gardens. Also known as bioretention areas, rain gardens are small vegetated depressions that collect, store, and infiltrate stormwater runoff. They contain various soil types from clays to sands and their size varies depending on area drained and available space. The design of a rain garden involves the hydrologic cycle, non-point pollutant treatment, resource conservation, habitat creation, nutrient cycles, soil chemistry, horticulture, landscape architecture, and ecology. Beyond its use for stormwater control, the rain garden provides aesthetically pleasing landscaping and a natural habitat for birds and butterflies. Finally, rain gardens promote sustainable design practices while encouraging environmental stewardship and community pride (www.lowimpactdevelopment.org).

Soil Amendment

The aeration and addition of compost amendments to disturbed soils is extremely effective at restoring the hydrologic functions of soils and reducing runoff. Soil amendments increase the spacing between soil particles so that the soil can absorb and hold more moisture. Compared to compacted, unamended soils, amended soils provide greater infiltration and subsurface storage and thereby help to reduce a site's overall runoff volume, helping to maintain the pre-development peak discharge rate and timing. Soil amendments help to provide water quality and quantity benefits, not only by increasing the infiltration capacity of the soil, but also by:

- Filtering and breaking down potential pollutants;
- Immobilizing and degrading pollutants by holding potential pollutants in place so that soil microbes can decompose them;
- Reducing the need for fertilizers, pesticides and irrigation by supplying more nutrients and a slow-release of them to plants;
- Holding more rainwater on-site, decreasing runoff, and providing increased soil moisture and infiltration capacity;
- Increasing soil stability, leading to less potential erosion;
- Providing added protection to groundwater resources, especially from heavy metal contamination;
- Reducing thermal pollution by maintaining runoff in the soil and on-site longer;

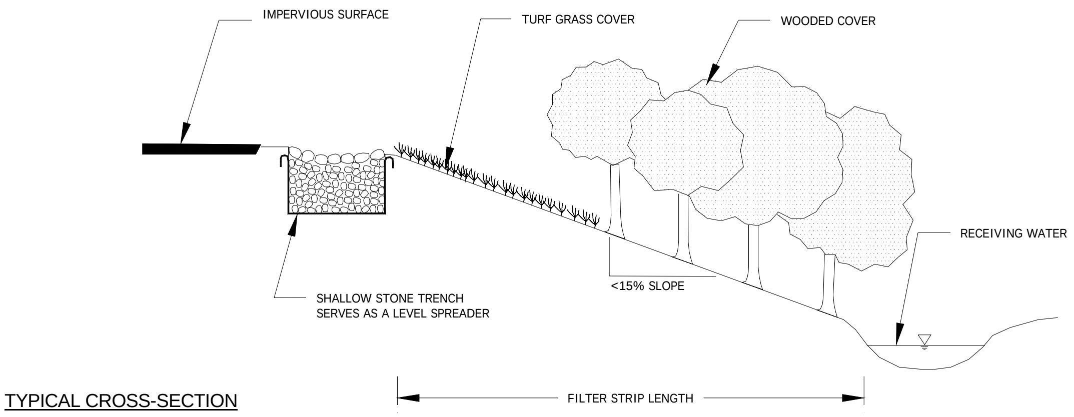
- Providing increased groundwater recharge through better infiltration and by maintaining the water on-site longer;
- Improving soil structure and stability, while increasing infiltration capacity and available storage within the soil; and
- Increasing soil stability, leading to less runoff and erosion through improved cover conditions.

(source: www.lowimpactdevelopment.org)

Vegetated Filter Strips

Vegetated filter strips are vegetated areas that are intended to treat sheet flow from adjacent impervious areas. Figure 5-5 is a schematic diagram of a vegetated filter strip. Filter strips function by slowing runoff velocities, filtering out sediment and other pollutants, and providing some infiltration into underlying soils. The reduction of flow and removal of sediments can also reduce the pollutant load to adjacent water bodies. Filter strips were originally used as an agricultural treatment practice, and have more recently evolved into an urban practice. One problem associated with filter strips is that maintaining sheet flow is difficult. Consequently, urban filter strips are often "short circuited" by concentrated flows, which results in little or no treatment of stormwater runoff. With proper design and maintenance, filter strips may provide relatively high pollutant removal in some circumstances. Filter strips are best suited to treating runoff from roads and highways, roof downspouts, and small parking lots. They are also ideal components of the "outer zone" of a stream buffer or as pretreatment for other stormwater treatment practices (Stormwater Manager's Resource Center, undated).

Figure 5-5 Vegetated Filter Strip (MassHighway, 2004)



Vegetation Preservation

Woods and other vegetated areas provide many opportunities for storage and infiltration of runoff. By maintaining the surface coverage to the greatest extent possible, the requirement for other stormwater management practices is reduced. Vegetated areas can also be used to provide surface roughness, thereby increasing the time of concentration. In addition, vegetated areas filter out and uptake pollutants.

Resources – Low Impact Development Strategies

The following websites provide additional information on LIDS.

- Low Impact Development Page. USEPA Website: http://www.epa.gov/owow/nps/lid/
- Low Impact Development Center. Website: http://www.lowimpactdevelopment.org/
- Low Impact Development Design Strategies. Prince George's County Maryland, Department of Environmental Resources 1999. Available at: http://www.epa.gov/owow/nps/lid/lidnatl.pdf
- Low Impact Development, a Literature Review. USEPA 2000a. EPA-841-B-00-005. Available at: http://www.epa.gov/owow/nps/lid/lid.pdf
- Bioretention Applications. USEPA 2000. EPA-841-B-00-005A. Available at: http://www.epa.gov/owow/nps/bioretention.pdf
- Field Evaluations of Permeable Pavements for Stormwater Management. USEPA 2000. EPA-841-B-00-005B. Available at: http://www.epa.gov/owow/nps/pavements.pdf
- Vegetated Roof Cover. USEPA 2000. EPA-841-B-00-005D Available at: http://www.epa.gov/owow/nps/roofcover.pdf
- Jordan Cove Watershed National Monitoring Project:

  http://www.canr.uconn.edu/jordancove

  http://dep.state.ct.us/wtr/nps/succstor/jordncve.pdf

  http://www.bae.ncsu.edu/programs/extension/wqg/319/319index_files/Ct-98.1.pdf

5.3 Stormwater Extended Detention Practices

Stormwater detention BMPs are structures that temporarily store runoff and slow its release to the watershed. These methods are primarily designed to reduce stormwater surges and the concentrations of sediments and nutrients in stormwater.

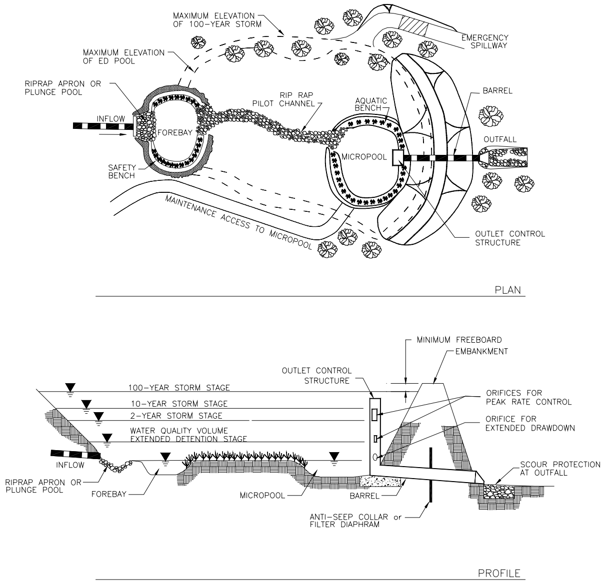
Created Wetlands

Created wetlands are shallow pools that create conditions suitable for the growth of marsh or wetland plants. These systems maximize pollutant removal through vegetative uptake, soil binding, bacterial decomposition, and enhanced settling while creating habitat for wildlife. Created wetlands may be combined with wet ponds or extended detention. These structures are suitable for on-line or off-line treatment (assuming adequate hydrology can be maintained with off-line systems).

Extended Detention Ponds

Extended detention ponds are designed, as the name suggests, to hold stormwater in the pond and slow its release to the watershed. Figure 5-6 is a schematic diagram showing an aerial and a cross sectional view of an extended detention pond. Extended detention ponds generally feature a low-flow orifice attached to the outlet of the pond.

Figure 5-6 Extended Detention Pond (MassHighway, 2004)



ADAPTED FROM MARYLAND, 1999

There are two types of extended detention ponds for mitigating stormwater impacts, wet and dry detention ponds. Wet extended detention ponds include a storage volume above a permanent pool. Dry ponds drain completely between precipitation events. Wet ponds may be enhanced with wetland features or combined with extended detention. In comparison to wet ponds, sediment re-suspension is more likely in dry detention ponds and they generally do not provide adequate soluble pollutant removal. Extended detention ponds are suitable for on-line or off-line treatment.

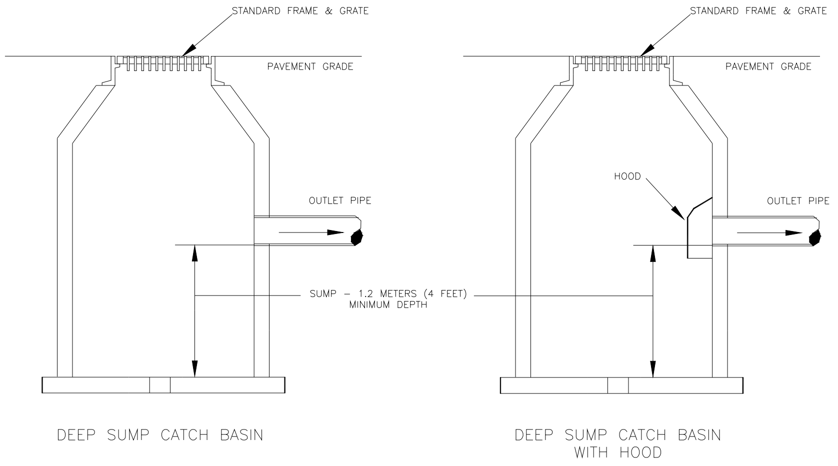
5.4 Other Best Management Practices

The other best management practices that do not fall into the category of retention/infiltration, LIDS, or detention can be used in conjunction with the BMPs listed above to pretreat runoff for particulates for recharge BMPs.

Deep Catch Basin w/ Sumps & Hood

Deep sump catch basins are inlet structures that provide some removal of sediments and floating contaminants. Therefore, catch basins may provide adequate pretreatment for other BMPs. Figure 5-7 is a schematic diagram of a deep sump catch basin. Deep sump catch basins function similarly to oil and grit chambers. Stormwater flows into the sump where coarse sediment is removed by settling. The outlet of the sump is below the waterline so oil and grease and other floating materials are retained in the catch basin. When regularly maintained, they may remove limited amounts of coarse sediments and oil and grease.

Figure 5-7 Deep Sump Catch Basin (MassHighway, 2004)

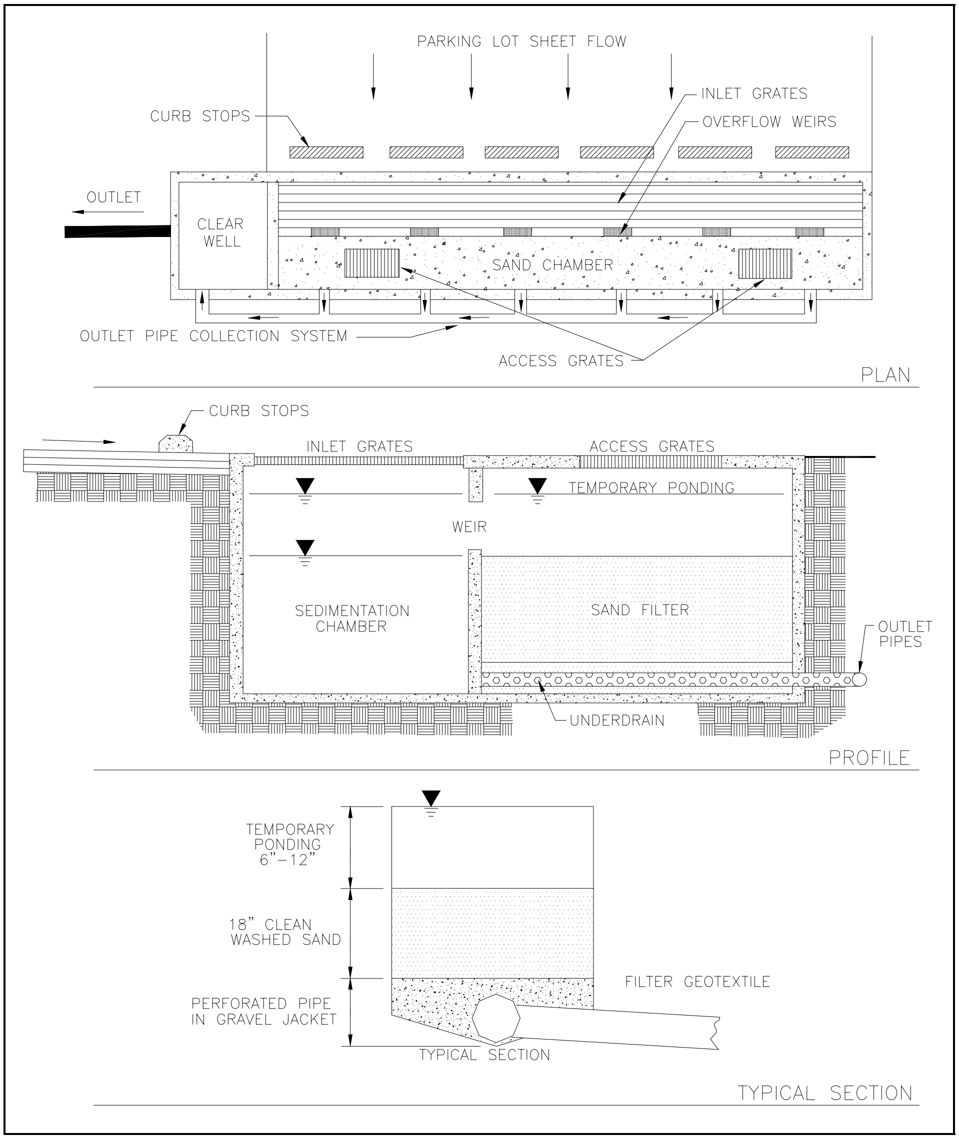


CATCHBASIN MATERIALS AND FABRICATION VARIES. SEE DRAWINGS
IN MASSHIGHWAY "CONSTRUCTION AND TRAFFIC STANDARD DETAILS"
(METRIC EDITION 1996).

Sand Filters/Filter Beds

Filter beds are designed to strain runoff through a sand filter to an underdrain system for discharge. Figure 5-8 is a schematic diagram showing top and side views of a sand filter. To date, extensive application of this technology has been limited to the mid-Atlantic and southwestern US. In addition, sand filters reduce sediment, nutrient, and trace metal concentrations. Frequent maintenance of the filter is required to remove accumulated sediments, trash, debris, and leaf litter (Schueler et al 1992). Sand filters should not generally be used as on-line systems.

Figure 5-8 Sand Filter (MassHighway, 2004)



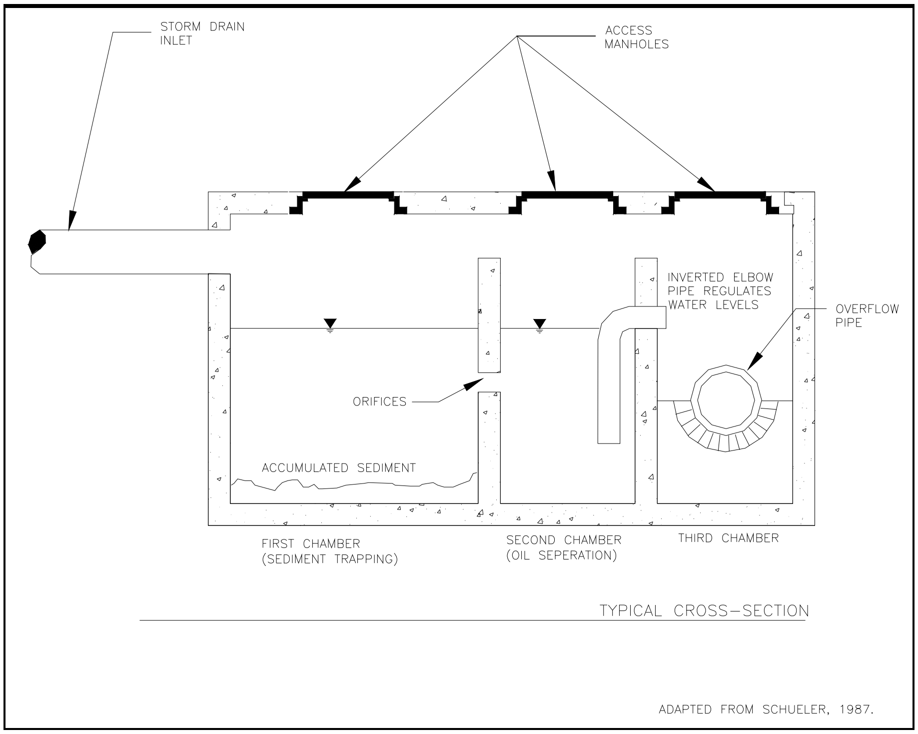
Swales

Grassed swales are vegetated earthen channels that convey and runoff. Depending on site conditions, infiltration may also occur. Pollutant removal primarily occurs via settling, filtration through the vegetation, and plant uptake. Use of check dams may enhance pollutant removal. Wet swales typically have water tolerant vegetation permanently growing in the retained body of water. These systems are often used on highway designs.

Water Quality Inlets-Oil/Grit Chambers

Figure 5-9 is a schematic diagram of an oil and grit chamber. There are a number of oil/grit chamber designs currently on the market. These self-contained units include a small permanent pool below the inlet to permit the settling of coarse sediments and typically have hooded outlet structures to remove oil and floating contaminants. In addition, several proprietary designs rely on a vortex to enhance sediment removal. Their primary utility is the removal of coarse sediments as a pretreatment for other BMPs. Since actual pollutant removal does not occur until the chambers are cleaned out, the effectiveness of these systems relies on regular maintenance (Schueler 1992). In addition, re-suspension of sediments in the chambers may limit their effectiveness (Schueler 1992). Pollutant removal may be enhanced for off-line systems.

Figure 5-9 Oil and Grit Chamber (MassHighway, 2004)



ADAPTED FROM SCHUELER, 1987.

6.0 OBTAINING FUNDING

A variety of funding sources are available to support installation of BMPs for stormwater mitigation. Several of these sources are briefly described below with references to websites containing additional information.

6.1 Stormwater Utilities

Many rapidly growing areas of the United States are creating stormwater utilities as a mechanism to generate revenue to support a stormwater program and to better regulate, coordinate, and organize stormwater activities under one program. States and local governments including communities in Georgia, Florida, Colorado, Washington State, and Washington D.C. have developed successful stormwater utilities. Resources for more information on stormwater utilities are listed below.

- The Pioneer Valley Regional Planning Agency in West Springfield, MA has created a how-to manual on developing stormwater utilities for Massachusetts communities. This work is based on a project with the City of Chicopee, MA that was developed in response to a requirement by the USEPA to resolve a CSO problem. Information is available at: http://www.pvpc.org/web-content/docs/landuse/storm_util.pdf
- The Center for Urban Water Policy and the Environment at Indiana University-Purdue University Indianapolis (IUPUI) in cooperation with the Watershed Management Institute, Inc. has created a website that contains numerous documents and provides guidance on stormwater utilities and other mechanisms to finance stormwater controls (http://stormwaterfinance.urbancenter.iupui.edu).

In New England, most cities and towns share the responsibility for implementing stormwater controls between the elected officials (selectmen, mayor), and many different local boards and departments (planning boards, conservation commissions, Department of Public Works, Boards of Health, etc.). The general revenues raised by local property taxes are the primary sources of funds to support stormwater management at the municipal level.

6.2 State Revolving Fund and Section 319 Grants

Several communities are using the State Revolving Loan Fund to provide the basic funding to develop stormwater master plans and to implement stormwater controls. Under this program, funds are distributed by EPA to state environmental agencies. The agencies then distribute these funds on an application and priority basis. Additionally, specific assessment, design and implementation funding is available annually on a competitive basis from the Section 319

Program. These funds can be used to address a wide range of urban nonpoint (diffuse) source pollution problems. However, these funds cannot be used to implement those elements of a community's approved Stormwater Phase II permit program that are specifically required by the permit. Resources for more information on the Section 319 Program and the State Revolving Loan Fund are listed below.

- For more information on the Section 319 funding program and other grant programs available to address nonpoint source pollution see:
  http://www.epa.gov/owow/nps/cwact.html
- For more information on State Revolving Fund funding for stormwater management see: http://www.epa.gov/owmitnet/cwfinance/cwsrf/

6.3 Funding and Grants

Catalog of Federal Funding for Watershed Protection

EPA has an easy to use searchable database that provides information on more than 85 Federal programs that provide funding (cost sharing, loans, etc.) for various watershed protection activities. This searchable database has been updated to include FY 2005 funding information and is posted on EPA's website at: http://www.epa.gov/watershedfunding

National Environmental Finance Centers' Enhanced Database of Funding Sources

This enhanced and updated on-line directory allows users to search for federal, state, local, and private watershed funding sources available for the development and implementation of watershed projects. Information on nationwide funding opportunities, as well as state and local funding opportunities for fund seekers in each EPA region is available at: http://www.epa.gov/efinpage/efp.htm. Information regarding New England's Environmental Finance Center can be found at: http://efc.muskie.usm.maine.edu/

Watershed Academy Web Sustainable Finance On-line Training Module

A finance on-line training module will be created to transfer strategic financial planning tools and case studies to watershed organizations and local governments.

The training module will be available at http://www.epa.gov/watertrain

Plan2Fund

A watershed planning tool that helps organizations track financial information as it relates to their goals, objectives, and tasks. Available at: http://sspa.boisestate.edu/efc/services.htm

Office of Wetlands Oceans and Watersheds (OWOW) Funding Website

This website will serve as a central portal to federal grant information, case studies, the Watershed Academy Web, and other relevant funding and links. The website will be available at http://www.epa.gov/owow/funding.html

Targeted Watersheds Grant Program

The Targeted Watershed Grant Program provides monetary assistance directly to watershed organizations to implement restoration/protection activities within their watershed. Grants are also available to support watershed service providers in their effort to train and educate watershed organizations to become more effective and autonomous. The Targeted Watershed Grant Program website is available at: http://www.epa.gov/owow/watershed/initiative/

7.0 PUBLIC EDUCATION AND OUTREACH

Local and national stormwater education and outreach programs are briefly introduced with links to web-based resources below.

7.1 Local Outreach Efforts

Educating the public on stormwater issues can help reduce their contribution to stormwater impairment. Local groups such as watershed associations and schools can be partners in the outreach efforts. Educational materials can be distributed via pamphlets, fact sheets, brochures, and public service announcements. Discussion topics can include methods to decrease or disconnect impervious cover and residential LIDS. Also, storm drain stenciling indication "No Dumping Drains to River" can be used raise awareness.

The public can also be involved in the TMDL process by serving as volunteer stream, lake, or coastal monitors. As described in the next section, monitoring the receiving water and noting changes throughout the BMP implementation process is an important step. By including the public in this process they will take more pride in protecting their watershed.

7.2 National Outreach Efforts

Adopt Your Watershed

EPA maintains a searchable, on-line database of local watershed protection efforts, which allows users to find information easily about watershed protection efforts in their communities. Users can click on a map or type in a zip code to find their 8-digit Hydrologic Unit Code (HUC) or watershed address and then link to information about groups active in their communities. The database includes over 3,500 groups, including broad-based watershed partnerships involved in developing and implementing watershed protection plans as well as school and community groups doing stream cleanups, restoration, and monitoring projects. We now offer an on-line editing feature that allows groups to up-date their own information. Website can be found at: www.epa.gov/adopt/

Water Drop Patch Project

This project, developed by OWOW in partnership with the Girl Scouts of the USA, is part of a broader interagency Linking Girls to the Land Initiative designed to engage Girl Scouts in hands-on conservation and environmental stewardship programs. The Girl Scout Water Drop booklet includes twenty community-based watershed protection activities, including water quality monitoring, stream cleanups, stream assessments, water festivals, and storm drain stenciling to help build stewardship for local waters. More information can be found at: http://www.epa.gov/adopt/ and http://www.epa.gov/linkinggirls/

8.0 CONDUCTING MONITORING ACTIVITIES

Stream monitoring activities should be conducted on a routine basis beginning pre-BMP installation and continuing until stormwater impairment is removed. A meaningful environmental monitoring project requires definition of monitoring objectives and a review of existing data. Monitoring objectives might include establishing baseline water quality conditions or locating significant stormwater inputs to use as a benchmark for future comparisons. Field measurements may consist of: collecting in-stream water quality parameters, flow monitoring, riparian and/or biological assessments, or watershed surveys. Monitoring to evaluate the effectiveness of BMPs installed to address water quality impairments would be expected to focus on the parameters that would change with the reduction of effective impervious cover, such as streamflow during rainfall events, sedimentation, and/or stream scouring, as well as monitoring the instream biological community to determine the effectiveness of mitigation measures in achieving water quality standards.

Compilation of locally available maps of watershed resources and engineering sites plans should be done prior to any field based monitoring. Maps would identify potential stormwater inputs and hone in on areas vulnerable to stormwater influence. Stakeholders need to coordinate with state environmental staff prior to conducting monitoring activities in order to assure that the monitoring planned is appropriate and that it follows state protocols.

Regulated stakeholders, such as MS4s, may want to refine measurements of %IC to insure the application of appropriate BMPs that will become part of any watershed management strategy. Not all impervious surfaces are created equally and understanding the hydrologic contributions of existing land use will set the stage for effective stream restoration. The first step is to compile maps and plans of stormwater conveyances to determine which sites are directly connected to the stream and which already have effective BMPs. This will establish a more accurate estimate of 'effective' %IC, existing hydrologic inputs, and provide a benchmark for post-BMP monitoring. These benchmarks will then gauge the effectiveness of BMP implementation and application of low impact development techniques, until water quality standards are met. Further, this approach can also be useful to establish a priority system for restoration efforts. For example, it may be beneficial to focus BMP efforts in areas with a high percentage of directly connected IC first.

Stakeholders, including volunteer monitoring groups, are encouraged to conduct in-stream and riparian habitat assessments to support a stream restoration component of the implementation plan. Restoration of physical habitat will enable a more rapid and complete recovery of the aquatic biological community as BMPs and/or habitat restoration offset the impacts of IC. All of the New England States have volunteer stream monitoring programs that offer training and technical assistance in conducting such stream assessments, as well as instream measurements for other useful water quality data. The New England States' volunteer monitoring programs can be found at:

CT: http://dep.state.ct.us/wtr/volunmon/volmonindex.htm;

MA: http://www.mass.gov/dfwele/river/programs/adoptastream/index.htm;

ME: http://www.maine.gov/dep/blwq/docstream/team/streamteam.htm;

NH: http://www.des.state.nh.us/wmb/VRAP/ and http://www.des.state.nh.us/wmb/vlap/;

RI: http://www.uri.edu/ce/wq/ww/html/ww.html; and

VT: http://www.anr.state.vt.us/dec/waterq/lakes/htm/lp_monitoringguide.htm.

Volunteers could be helpful in monitoring the effectiveness and maintenance of specific BMPs, as well. If the BMPs are municipally owned, volunteers could be helpful in the actual maintenance (e.g., adopt a BMP).

The state environmental agency has responsibility to formally assess whether water quality standards are met, the ultimate test of the effectiveness of implementation efforts. An ongoing biological monitoring program is critical for this assessment, and progress towards attainment of water quality standards will be evaluated by monitoring the instream biological community (e.g., macroinvertebrates, fish, periphyton). In many states, this monitoring is done on a rotating basin schedule. The state may also collect water chemistry samples during stormflow conditions to detect in-stream sediment trends and levels for certain toxic contaminants. Implementation of stormwater remedial measures is expected to continue until aquatic life criteria are met, in accordance with state water quality standards.

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10.0 LIST OF ACRONYMS AND GLOSSARY OF TERMS

LIST OF ACRONYMS

BMP	Best Management Practice
CSO	Combined Sewer Overflow
CWA	Federal Clean Water Act
CWP	Center for Watershed Protection
DCIA	Directly Connected Impervious Area
EPA	United States Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System
HUC	Hydrological Unit Code
IC	Impervious Cover
ICM	Impervious Cover Model
IDDE	Illicit Discharge Detection and Elimination
LIDS	Low Impact Development Strategies
MA DEP	Massachusetts Department of Environmental Protection
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System (typically in reference to a state and federal discharge permit to surface water)
NPS	Non Point Source
NRCS	Natural Resources Conservation Service
OWOW	Office of Wetlands, Oceans, and Watersheds
SCS	USDA Soil Conservation Service
SWMP	Stormwater Management Plan
Tc	Time of Concentration
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
WQM	Water Quality Management
WQS	Water Quality Standards
WWTP	Waste Water Treatment Plan

GLOSSARY OF TERMS

Bankfull – The condition where streamflow just fills a stream channel up to the top of the bank and at a point where the water begins to overflow onto a floodplain.

Baseflow – Stream discharge derived from the ground water that supports flow in dry weather.

Combined Sewer Overflow (CSO) – Excess flow discharged to a receiving water body from a stormwater and sanitary sewage interconnected system.

Detention - Temporarily storing water and releasing it to surface waters over a period of time. The detention process results in release of water to surface waters in contrast to the retention process which results in release of water to the ground.

Directly connected impervious cover – Impervious cover that drains runoff directly to the receiving water.

Disconnected impervious cover – Impervious cover that drains runoff to pervious surfaces.

Effective Impervious Cover – Impervious cover that contributes to stormwater impairment.

Exfiltration – Water flow into the ground, typically from a storage basin. In the context of this document, exfiltration differs from infiltration in perspective only. Exfiltration is flow out of the storage basin and infiltration is flow into the ground. Infiltration may also have other meanings (see Infiltration).

Flow Duration Curve – A cumulative frequency curve for streamflow that plots streamflow vs. exceedence probability.

Hydraulic Conductivity – A measure of soil's ability to permeate water.

Illicit Discharge – Any discharge to a municipal storm sewer systems that is not composed entirely of storm water (unless under NPDES permit).

Impervious Cover – Any surface that cannot effectively absorb or infiltrate rainfall.

Infiltration – Water movement into the ground, in the context of this document. Infiltration is a term that may also describe other types of subsurface flow, such as flow from a groundwater aquifer to a river or other water body.

Initial Abstraction – The amount of water that is stored on site before runoff occurs.

Orthophotograph – An aerial photograph in which the displacement of images has been removed and that has the distortion due to tilt, curvature, and ground relief corrected. It is a "scale corrected" aerial image, depicting ground features in their exact ground positions, in which distortion caused by camera and flight characteristics and relief displacement have been removed using photogrammetric techniques. (Definition Source: Data West Research Agency)

Peak Discharge (or Peak Runoff) – The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Permeable – Having pores or openings that permit liquids or gases to pass through.

Pre-existing – Time period before present, signifying the period before development occurred.

Retention – Holding water in a storage basin and releasing it to the ground over time. The retention process results in slow release of water to the ground in contrast to the detention process which results in release of water to surface waters.

Roughness – A measurement of the resistance that streambed materials, vegetation, and other physical components contribute to the flow of water in the stream channel and flood-plain.

Runoff – Stormwater that exits a site

Stormwater – Water produced as a result of a storm

Sub-watershed – A smaller geographic section of a larger watershed unit

Total Suspended Solids (TSS) – The total amount of particulate matter suspended in the water column.