Presented below are water quality standards that are in effect for Clean Water Act purposes.

EPA is posting these standards as a convenience to users and has made a reasonable effort to assure their accuracy. Additionally, EPA has made a reasonable effort to identify parts of the standards that are not approved, disapproved, or are otherwise not in effect for Clean Water Act purposes.

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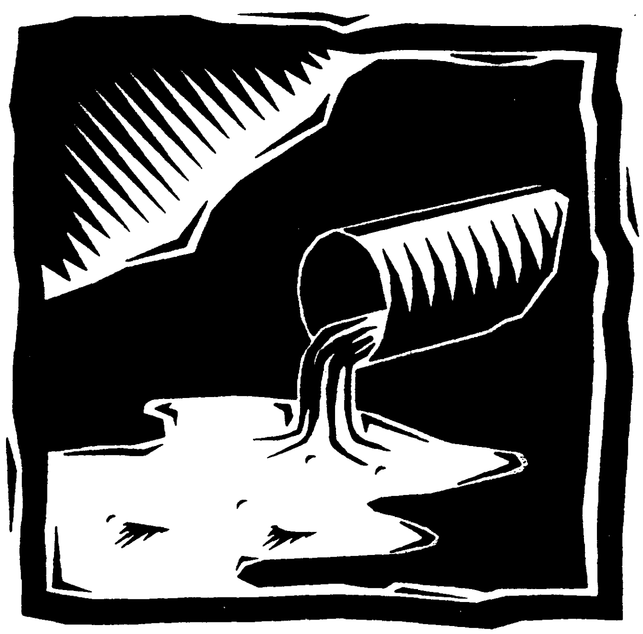
Stormwater Management

Volume Two: Stormwater Technical Handbook

March 1997



Prepared by:

MA Department of Environmental Protection

MA Office of Coastal Zone Management

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Stormwater Management

Volume Two: Stormwater Technical Handbook

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William F. Weld, Governor
Argeo Paul Cellucci, Lieutenant Governor

Executive Office of Environmental Affairs
Trudy Coxe, Secretary

Department of Environmental Protection
David B. Struhs, Commissioner

Bureau of Resource Protection
Arleen O'Donnell, Assistant Commissioner

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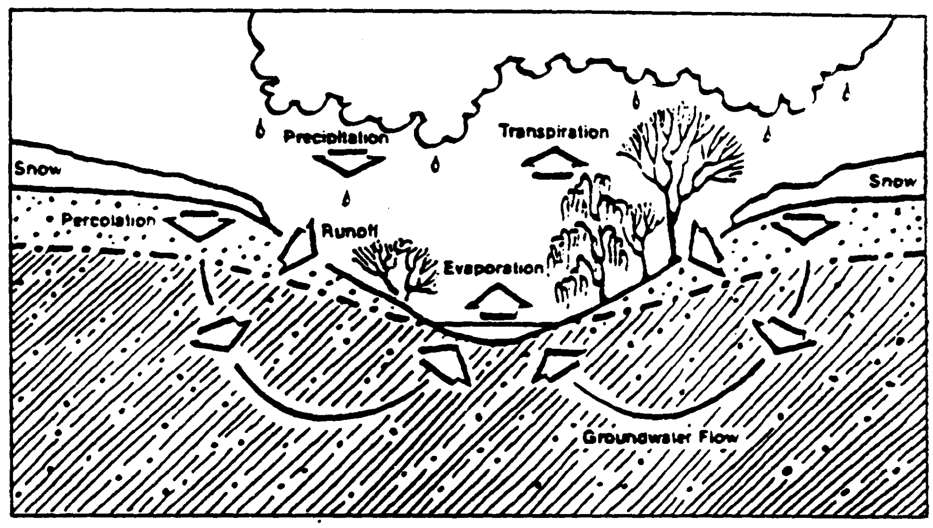
CHAPTER 1: Hydrology and Stormwater Runoff

The Hydrologic Cycle

Hydrology is the movement of water. In the hydrologic cycle, rain or snow from clouds falls to the ground, and as water or snow melt:

- infiltrates or seeps into the ground, a process called percolation;
- is taken up by the trees and vegetation and is returned to the atmosphere through transpiration, or evaporation of water from all surfaces; or
- runs over the ground surface.



The hydrologic cycle (Massachusetts Audubon Society, 1983)

Water that seeps into the ground travels underground until eventually reaching the groundwater table and possibly surface waters such as a lake, stream, or the ocean. This process, called groundwater recharge, helps maintain water flow in streams and wetlands and preserves water table levels that support drinking water supplies. The amount of recharge that occurs on a site is based on slope, soil type, vegetation and other cover, as well as precipitation and evapotranspiration rates. Sites with natural ground cover, such as forest, meadow, or shrubs, typically have greater recharge rates, less runoff, and higher transpiration than sites with pavement and buildings.

The water that runs off the ground surface as overland flow is runoff. Through evaporation from surface waters, water is returned to the atmosphere, new clouds are formed, and the hydrologic cycle begins again.

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Stormwater Runoff

Runoff is a natural part of the hydrologic cycle. The volume and speed of runoff depends on the size of the storm (how much water falls in what amount of time) and the land features at the site. The size of the contributing drainage area, the slope of the land, the types of soils, and the surface conditions (such as woods or pavement) affect water movement. The contributing drainage area establishes the boundary limits for the movement of runoff - from the highest elevations to the lowest point. A watershed is a region that consists of one or more contributing drainage areas to a body of water.

In a natural, undeveloped setting, the ground's surface often is pervious, meaning water can percolate down into the soil. In developed areas, ground surfaces are often asphalt, concrete, and other materials which are impervious and prevent water from infiltrating into the soil. Water which cannot be absorbed into the ground becomes runoff. Water that falls during and immediately after a storm and flows over impervious surfaces or otherwise cannot be absorbed into the ground is called stormwater runoff.

Stormwater runoff that flows into and is discharged through a pipe, ditch, channel, or other structure is considered a point source discharge. Contaminated stormwater runoff that flows over land and is not directed into a defined channel is considered nonpoint source pollution. Both point and nonpoint source pollution significantly degrade water quality and aquatic habitat. The difference between nonpoint and point source types of pollution becomes less clear when stormwater flows over land and then into storm drains and other types of collection systems before it is discharged through a pipe to a water body. In these cases, stormwater runoff begins as a nonpoint source and becomes a point source discharge.

Development and Stormwater Quantity

Development - the construction of homes and other buildings, streets, parking lots, and other man-made features - can alter the hydrology of the landscape and adversely affect water quality. Development changes land use and generally increases the amount of stormwater runoff from a site. Stormwater runoff can cause erosion and flooding. Development can change water flow and the percolation of water into the soil, which affects how much water can infiltrate into the ground to maintain water levels in streams, wetlands, and groundwater aquifers. Stormwater runoff also affects water quality, which can have adverse impacts on aquatic plants and animals.

During development, vegetated and forested land with pervious surfaces are replaced by land uses with impervious surfaces. Impervious surfaces transform hydrology and impact aquatic habitats by changing the rate and volume of runoff and altering natural drainage features, including groundwater levels. Changes in water quantity begin with the initial site clearing and grading. Vegetation which intercepted rainfall and reduced runoff is removed. Natural depressions which provided temporary storage of rainfall are filled and graded. Soils are exposed and compacted resulting in increased sedimentation and decreased infiltration. Having lost much of its natural storage capacity, the cleared, graded site allows rainfall to rapidly become runoff.

Once the development has been completed, the increase in impervious area (rooftops, roads, driveways, and parking lots) reduces the amount of rainfall that can be infiltrated, which increases the volume of runoff. Figure 1.1 shows the relationship of runoff, infiltration, and evaporation with varying degrees of impervious cover. Table 1.1 indicates the typical percentages of impervious cover for various land uses. The percentage of imperviousness in a watershed is a useful measure of land development impacts on streams and aquatic systems. Studies show that hydraulic and biological changes to streams occur when 10 to 20 percent of a watershed has impervious surfaces. Moreover, efforts to restore stream flow and water quality to pre-development conditions appear to be less successful when levels of impervious cover exceed 30 percent.

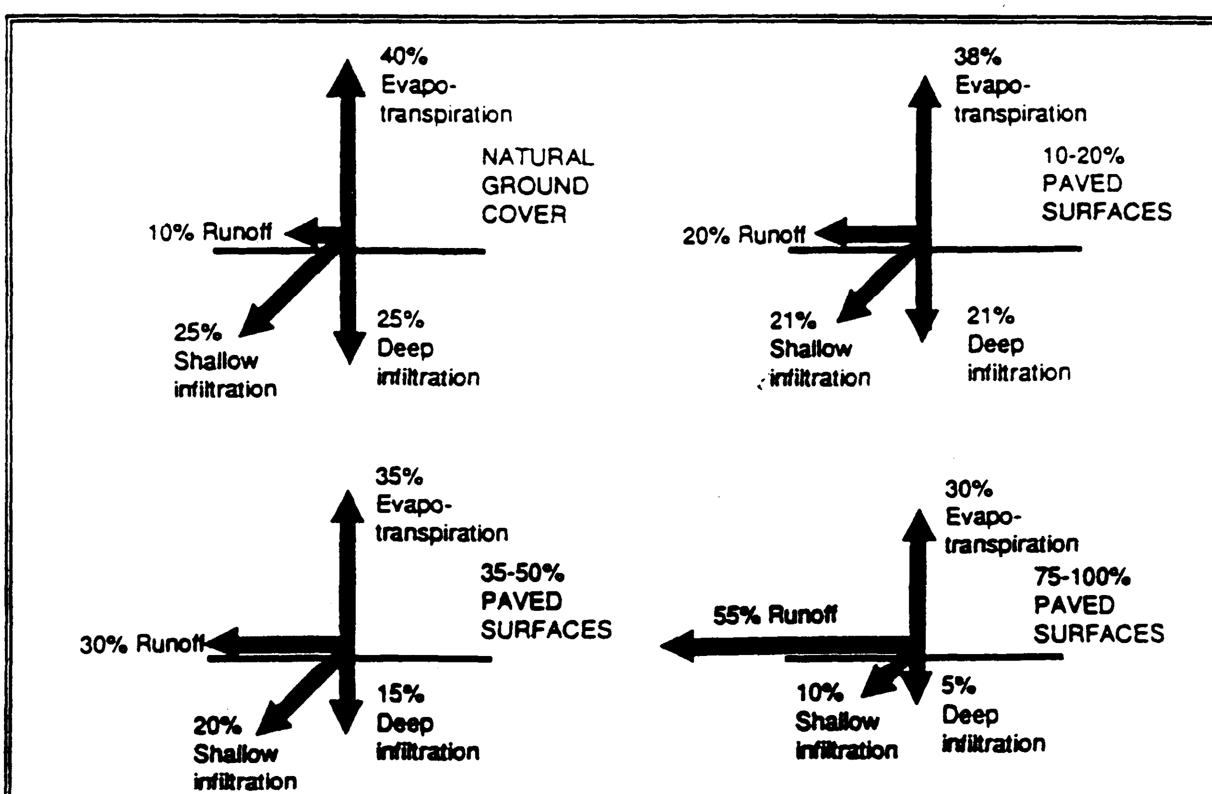

Figure 1.1: Typical Changes in Runoff Flows Resulting From Paved Surfaces (Minnesota Pollution Control Agency (MPCA), 1989)

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Table 1.1: Typical Impervious Area Percentages (MPCA, 1989)

Land Use	**% Impervious Cover**
Business District or Shopping Center	95-100
Residential, High Density	45-60
Residential, Medium Density	35-45
Residential, Low Density	20-40
Open Areas	0-10

The impacts of development on hydrology may include:

- Increased peak discharges of runoff compared to pre-development levels;
- Increased volume of runoff produced by each storm in comparison to pre-development conditions;
- Decreased time in which runoff reaches the stream, particularly if extensive drainage changes are made;
- Increased frequency and severity of offsite downstream flooding;
- Reduced stream flow and lower water table levels during prolonged periods of dry weather due to reduced infiltration in the watershed;
- Loss of wetlands and aquatic habitats due to lower water table levels during dry weather;
- Greater runoff velocity during storms due to increased impervious areas, which move greater volumes of runoff at a faster rate; and
- Increased frequencies and prolonged periods of high stream flow velocities that can significantly increase stream channel erosion.

Development and Stormwater Quality

Stormwater runoff carries a variety of contaminants that affect water quality. These contaminants come from different residential, commercial, and industrial land uses within a watershed. People's daily activities leave pollutants, such as pesticides, fertilizers, animal wastes, sediments, nutrients, and heavy metals, on the surface of the ground. Stormwater runoff carries the pollutants on the ground into nearby water bodies and waterways. As development increases and activities change and intensify, the concentrations and types of contaminants also increase. Although all land uses can affect water quality, in undeveloped areas natural processes can lessen the impacts of contaminants or even remove contaminants from runoff through infiltration and evaporation. Impervious areas reduce the opportunity for natural processes to treat stormwater. Therefore, stormwater runoff must be adequately controlled and treated to reduce pollutants before it is discharged to surface water, groundwater, or wetlands.

A summary of the principal pollutants found in runoff, their sources, and related impacts is provided in Table 1.2. DEP's *Nonpoint Source Management Manual* (1993) provides a detailed description of land use activities that are major contributors of nonpoint source pollution (see Appendix C for more information).

Table 1.2: Stormwater Pollutants, Sources, and Related Impacts

Stormwater Pollutant	Sources	Related Impacts
Nutrients Nitrogen, Phosphorous	Urban runoff, Animal waste, Fertilizers, Failing septic systems	Algal growth; reduced clarity; lower dissolved oxygen; release of other pollutants
Solids Sediment (clean and contaminated)	Construction sites, Other disturbed and/or non-vegetated lands, Eroding banks, Road sanding, Urban runoff	Increased turbidity; reduced clarity; lower dissolved oxygen; deposition of sediments; smother aquatic habitat including spawning sites; sediment and benthic toxicity
Pathogens Bacteria, Viruses	Animal waste, Urban runoff, Failing septic systems	Human health risks via drinking water supplies; contaminated shellfish growing areas and swimming beaches
Metals Lead, Copper, Cadmium, Zinc, Mercury, Chromium, Aluminum, others	Industrial processes, Normal wear of automobile brakelines and tires, Automobile emissions, Automobile fluid leaks, Metal roofs	Toxicity of water column and sediment; bioaccumulation in aquatic species and through food chain
Hydrocarbons Oil and Grease, PAHs (Naphthalenes, Pyrenes)	Industrial processes, Automobile wear, Automobile emissions, Automobile fluid leaks, Waste oil	Toxicity of water column and sediment; bioaccumulation in aquatic species and through food chain
Organics Pesticides, PCBs, Synthetic chemicals	Pesticides (herbicides, insecticides, fungicides, rodenticides, etc.), Industrial processes	Toxicity of water column and sediment; bioaccumulation in aquatic species and through food chain
Salt Sodium Chlorides	Road salting and uncovered salt storage	Toxicity of water column and sediment

Controlling Stormwater Runoff

There are a variety of controls to manage stormwater runoff from a site. These control measures may address different aspects of runoff: storage of runoff water, infiltration of stormwater to groundwater, and treatment of the pollutants in stormwater. Proper peak runoff rate control helps prevent adverse impacts such as stream channel scouring and bank alteration and minimizes downstream flooding and stream bank erosion. In general, protection from stream bank erosion requires the control of frequent flooding events (i.e., the 2-year and smaller storm events). These storms have the most influence on stream channel formation. Protection from less common, offsite flooding requires the control of storm events which exceed stream channel bankfull capacity (i.e., the 10-year and higher events).

Engineers may design drainage systems or other physical structures, such as detention and infiltration basins, pretreatment devices, and swales, to manage stormwater. Nonstructural approaches also may control or reduce stormwater runoff. For example, by reducing the building footprint while increasing the building height, more grassy areas can be preserved and new impervious surfaces can be minimized.

Nonstructural and structural Best Management Practices (BMPs) are recognized as the most effective and practical measures to reduce or prevent pollutants from reaching water bodies and to control the quantity of runoff from a site. However, stormwater BMP technologies range in their ability and effectiveness to treat specific pollutant types. Depending on the receiving resources, the pollutant type of concern will vary. For drinking water supplies, inorganic compounds, volatile organic compounds, pesticides, herbicides, and pathogens (bacteria and viruses) are the main concern. For shellfish growing areas and recreation areas, bacterial contamination and nutrients are primary concerns, while temperature and pH are the major concerns for cold water fisheries.

The Stormwater Management Standards require the use of BMPs based on different site conditions and establish post-development goals for stormwater controls. Applicants have the flexibility to choose the most appropriate controls for a particular site.

CHAPTER 2: Site Planning and Nonstructural Approaches

To meet the Stormwater Management Standards, a project proponent may utilize three basic methods in this order:

- Design the development utilizing site planning techniques to minimize runoff;
- Utilize nonstructural techniques, including pollution prevention and source reduction to minimize the type of treatment the stormwater needs; and
- Construct and maintain structural Best Management Practices (BMPs) to capture and treat the stormwater runoff.

Applicants may select the methodology to meet the Stormwater Management Standards. However, the most cost-effective means is often through site planning and the nonstructural approaches discussed in this Chapter. Maintaining pre-development hydrologic conditions through proper site planning and nonstructural approaches, including implementing erosion and sediment controls, are highly effective pollution prevention and reduction measures which can reduce or even eliminate the need for structural BMPs. This approach will result in a well designed development plan and associated stormwater management system that suits land constraints and minimizes costs.

Site Planning

Site planning that integrates comprehensive stormwater management into the site development process from the outset is the most effective approach to reduce and prevent potential pollution and flooding problems. Early stormwater management planning will generally minimize the size and cost of structural solutions. Stormwater management efforts which incorporate BMP structural technologies into the site design at the final stages frequently result in the construction of unnecessarily large and costly facilities, which may fail due to improper design, siting, engineering, or operation.

Who Does Site Planning for Stormwater?

Site planning is the responsibility of the project proponent. The Stormwater Management Standards will not be the only applicable requirements projects must meet. Certain components of site planning may require technical (hydrology or engineering) expertise, and in such cases, comprehensive site planning should be done by professional consultants and/or design engineers. Before and during the permit review process, collaborative efforts among various parties, including developers, consultants, technical staff, planning boards, and conservation commissions will frequently lead to final design plans that meet mutual goals.

How is Site Planning Required and Who Reviews Site Plans for Stormwater Management?

In most cases, site plan review is conducted at the local level by the planning board and additionally by the conservation commission pursuant to the Wetlands Protection Act when the project is located in a wetland resource area.

Planning boards also ensure proper stormwater management is accomplished through site plan review conducted under the authority of the Subdivision Control Act or local regulations. Local zoning bylaws, for example, may establish special requirements for additional review through zoning districts or special permits that may require more stringent protection than the Stormwater Management Standards in order to minimize the creation of new runoff or provide a higher level of protection for drinking water supplies and other critical resources, such as nitrogen sensitive embayments. The *Nonpoint Source Management Manual* published by DEP (1993) provides additional information on site plan review and stormwater planning.

Site Planning Techniques that will Minimize Runoff

Comprehensive site planning is critical to stormwater management because it can eliminate unnecessary increases in runoff and reduce sediment/ erosion problems. Modern stormwater management and sediment/erosion control have replaced the former approach of treating stormwater as wastewater and moving runoff offsite as quickly as possible with little or no regard for downstream consequences and long-term hydrologic and water quality impacts. Careful site designs will minimize the size and related material, construction, and maintenance costs of structural stormwater controls.

Site planning should include the preparation of accurate and complete site plan maps and narratives. Stormwater controls must be developed for both construction activities and post-construction conditions, which should be addressed separately in the plans and narrative descriptions provided with the Notice of Intent under the Wetlands Protection Act. Site planning techniques that will minimize the creation of new runoff and provide removal of some suspended solids include:

Minimize Impervious Surfaces

Replacing natural cover and soils with impervious surfaces will lead to increased runoff volume and velocity, larger pollutant loads, and may adversely affect long-term hydrology and natural systems through flooding and channel erosion. Research demonstrates a marked drop in fish, amphibian, and insect species when the percent imperviousness within a watershed exceeds the 10 to 15% range. Careful site planning can reduce the impervious area created by pavement and roofs and the volume of runoff and pollutant loading requiring control.

Moreover, as the impervious surface area of a development increases, the size and expense of the quantity control facilities also increase. Techniques to reduce runoff volumes and velocities, such as the minimization of impervious surfaces, will help mitigate this issue. Local zoning codes and development standards, such as road widths or cluster zoning, affect the amount of runoff generated by projects. Development practices that require more than the minimum necessary area of impervious surface and use extensive conveyance networks that increase the flow of stormwater runoff into receiving waters, often end up creating more costly problems than they solve.

While it is generally important to minimize the creation of impervious surfaces, it is absolutely essential in certain recharge areas. Note that the Massachusetts Drinking Water Regulations (310 CMR 22.00) require the delineation of recharge areas (Zone IIs) and place land use prohibitions and restrictions in those areas for new wells (rated for >100,000 gallons per day) and for existing wells that increase pumping by 100,000 gallons per day. One restriction prohibits land uses which render impervious more than 15% or 2,500 square feet of a lot, whichever is greater, unless a system for artificial recharge of precipitation is provided that will not result in the degradation of groundwater quality.

Certain site planning methods will minimize impervious surfaces and reduce the volume of runoff. These include:

- *Maintain natural buffers and drainageways:* Natural buffers located between development sites and wetlands infiltrate runoff, reduce runoff velocity, and remove some suspended solids. Natural depressions and channels act to slow and store water, promote sheet flow and infiltration, and filter pollutants.

- *Minimize the creation of steep slopes:* Steep slopes have significant potential for erosion and increasing sediment loading. Slopes steeper than 2:1 should be avoided unless stringent stabilization methods are employed.

- ***Minimize placement of new structures or roads over porous or erodible*** *soils:* Porous soils provide the best and cheapest mechanism for infiltrating stormwater and reducing runoff volume and peak discharge, as well as providing ground water recharge and treatment by infiltration and adsorption through the soil strata. Disturbance of unstable soils should be avoided due to their greater erosion potential.

- *Reduce frontage and other setbacks.*

- *Establish Planned Unit Developments* through zoning that limits the density of development while maximizing the amount of undisturbed open space.

- *Establish Cluster Developments* through zoning that clusters or groups buildings closer together to maximize the amount of undisturbed open space.

- *Reduce the horizontal footprint of buildings and parking areas.* Foot-print size can be reduced by constructing a taller building, including parking facilities within the building itself, while maintaining the same floor to area (FAR) ratio.

- *Reduce to one lane, or eliminate if practical, on-street parking lanes* on local access roads.

- *Limit sidewalks to one side*, or eliminate if practical, on local low traffic roads.

- *Use shallow grassed roadside swales and parking lot islands with check dams* instead of curb and gutter storm drainage systems to handle runoff and snow storage. Guidelines for the use of drainage channels and water quality swales can be found in Chapter 3 of this Volume.

- *Utilize "turf pavers,"* gravel, or other porous surfaces when possible for sidewalks, driveways, transition areas between pavement edge and swales, or overflow parking areas.

- *Maintain as much of the pre-development vegetation as possible*, especially larger trees that may be on site. Vegetation absorbs water, which will reduce the amount of stormwater runoff. Proposed structures should be sited to minimize shading effects on vegetation and roots should be protected from damage during the construction phase.

Fit the Development to the Terrain

Road patterns should match the landform. For example, in rolling terrain, local streets should branch from collector streets, ending in short loops or cul-de-sacs along ridgelines. In areas where the topography is characteristically flat, the use of grids may be more appropriate. In these schemes, natural drainageways are preserved by interrupting and bending the road grid around them. Grassed waterways, vegetated drainage channels, or water quality swales may then be constructed along street right-of-ways or on the back of lots to channel runoff without abrupt changes in the direction of flow.

Preserve and Utilize Natural Drainage Systems

The standard approach of using curbing on streets and parking areas impairs natural drainage systems. Curbs are widely held to be the signature of quality development: they provide a neat, "improved" appearance and also help delineate roadway edges. Because curb and gutter streets trap runoff in the roadbed, storm inlets and drains are logical solutions to providing good drainage for the roadbed.

Unfortunately, a requirement for curb and gutter streets can create significant stormwater management problems. Because storm drains operate on gravity flow principles, their efficiency is maximized if they are located in the lowest areas of the site. Storm drain pipes are usually located in the valleys and low areas, destroying natural drainageways. Natural filtration and infiltration capacities are lost in the most strategic locations.

Further, in most instances, storm drains are designed for short duration, high frequency storms (1-hour duration with 2, 5, or 10-year return periods) and not for flood flows (24-hour duration, 50 and 100-year return period), which are handled by street and gutter flows after the storm drain capacity is exceeded. The result is that the natural drainageways are converted from slow moving, permeable, absorptive, vegetated waterways to fast moving, impervious, self cleaning, paved waterways. Hydraulic efficiency is increased, as are peak discharges and flood volumes. If the natural waterways are paved and specifically designed to be quickly drained by storm drains, channel storage time is minimized and base flows together with ground water recharge may be sharply reduced. When examined in the context of site planning, the net effect of a seemingly beneficial decision to use curbs can initiate a snowball effect which amplifies the extremes in the hydrologic cycle, increasing flood flows and reducing base flows.

This scenario also has important effects on water quality. Trace metals from automobile emissions and hydrocarbons from automobile crankcase oil and fuel spillage are directly deposited on paved surfaces of the site. For the most frequent rainfalls, the first flush of stormwater runoff washes these deposits into the storm drain system, which is designed to keep in suspension the particles to which the pollutants adhere. The particles together with their attached pollutants are delivered via the runoff water to receiving waters where changes in velocity permit them to settle out. Nutrient rich runoff from surrounding lawns also is quickly moved through the paved system with no opportunity to come into contact with plant roots and soil surfaces. The result is often rapid delivery of these contaminants to lakes, streams, estuaries, and wetlands at the discharge point.

If natural vegetated drainageways are preserved, flood volumes, peak discharges, and base flow will be maintained at pre-development levels. Trace metals, hydrocarbons, and other pollutants will bind to the underlying soils and organic matter. The infiltration process would allow separation of the nutrients and other contaminants from the stormwater, which would percolate through the subsurface soils.

Reproduce Pre-development Hydrologic Conditions

The goal of matching pre-development hydrologic conditions can be addressed at the site planning level. The full spectrum of hydrologic conditions, including peak discharge, runoff volume, infiltration capacity, base flow levels, groundwater recharge, and maintenance of water quality, can be examined through a comprehensive approach involving the entire site and even offsite areas contributing runoff to the site. Peak discharges, runoff volume, infiltration recharge, and water quality are directly related to the amount and location of impervious area required by development plans.

Past efforts focused on the reduction of the frequency and severity of flooding, primarily by lowering peak discharges to match pre-development levels with adequate storage (e.g., detention systems). Some waterways were deliberately designed to increase runoff removal with higher flow rates and smooth conveyances (e.g., storm drains, paved gutters, and waterways) so as to be self-cleaning, while ignoring infiltration and water quality issues. These "solutions" are no longer recommended.

Current recommendations are to maximize infiltration when runoff quality is acceptable and as soil conditions and available space allow, in order to maintain base flow and groundwater recharge. Infiltration of stormwater through the soil will generally remove pollutants and sediments and improve water quality. Infiltration systems require pretreatment of the stormwater to remove larger sediments which could cause the infiltration system to clog and fail. To provide the storage and release of stormwater that most closely matches pre-development conditions, infiltration options should be explored before detention/retention systems.

Examine Specific Structural BMP Requirements

Site planning is essential when planning the installation of structural BMP technologies. Some systems, such as infiltration BMPs, have very specific site and construction requirements. Site constraints, such as depth to groundwater, nearby septic systems, or wells, must be identified through the planning process so the BMP will not fail, or cause the septic system or well to malfunction. Site planning will assist in locating the most appropriate point on the site to direct the discharge from the BMP. For instance, discharge points should be located on low slopes and stable soils back from the edge of a wetland to avoid erosion. Failure to meet these requirements will most likely result in the failure of the system. Infiltration trenches for surface runoff and dry wells for roof runoff should be used where suitable, and the separate collection and treatment of contaminated and uncontaminated runoff should be encouraged. The costs of rehabilitating or retrofitting failed systems can be significant. By addressing stormwater runoff management at the beginning of development planning, the BMP options available for the site are clear. With careful planning, the developer should be able to design a system of multiple structural technologies for the site which collectively meet the Stormwater Management Standards, reduce the cost of stormwater management, and reduce long-term maintenance requirements, while enhancing the marketability and aesthetic qualities of the property. The BMP selection process is discussed in Chapter 3 of this Volume.

Nonstructural Approaches: Source Controls and Pollution Prevention

Source controls can reduce the types and concentrations of contaminants in stormwater runoff, which, in turn, can improve water quality. Source controls cover a wide range of practices, including local bylaws and regulations, materials management at industrial sites, fertilizer management in residential areas, reduced road salting in winter, erosion and sediment controls at construction sites, and comprehensive snow management. Effective site planning as described earlier can be considered a nonstructural source control, since, by reducing runoff volumes, the transport of pollutants is reduced also. The guiding principle for pollution prevention and nonstructural controls is to minimize the volume of runoff and to minimize contact of stormwater with potential pollutants. Since nonstructural practices can reduce the stormwater pollutant loads and quantities, the size and expense of BMPs, or in rare cases even the need for structural BMPs, some of the benefits of nonstructural controls are substantial cost savings in developing structural BMPs and reduced maintenance expenses.

Chapter 1 of this Volume provides a summary of the pollutants associated with runoff, and the Massachusetts *Nonpoint Source Management Manual* (DEP, 1993) provides a detailed summary of the pollutants associated with specific land use activities. These summaries can be used to identify the potential pollutants at a site, so that suitable controls can be implemented.

Street and Parking Lot Sweeping

One effective nonstructural source control is street (and parking lot) sweeping. Many municipalities and some private entities (commercial shopping areas or office parks) already have street sweeping programs in effect. Typically, these street sweeping efforts generally are conducted once a month during the late spring, summer, and early fall seasons. These street sweeping programs provide important nonpoint source pollution control, although, in many instances, peak sediment loads are not captured. The period immediately following winter snowmelt, when road sand and other accumulated sediment is washed off, is frequently missed by street sweeping programs.

The ability of street sweeping efforts to remove pollutants which accumulate on road and parking lot surfaces varies according to frequency, type of sweeping equipment, and the amount of pollutants present. Based on data collected from different areas of the country, total suspended solids (TSS) removal for street sweeping practices range from negligible (<5%) to moderately effective (50-80%). Data indicate that infrequent sweepings (less than 20 times per year) with conventional mechanical sweepers results in average TSS removal efficiencies no greater than 20%. Newer vacuum-type sweepers have demonstrated higher removal efficiencies.

Because this nonstructural control has proven to be an effective source reduction tool, a credit towards the 80% TSS removal standard may be available. Projects subject to the Stormwater Management Standards may incorporate a street sweeping plan, which includes mechanisms to ensure that sweeping is completed on a regular basis and that accumulated sediment is disposed of properly. ***At the discretion of the issuing authority, such a street sweeping program is eligible to receive a 10% credit towards the 80% TSS removal standard.*** Additional information is available in Chapter 3 (see Table 3.2 and the BMP Sizing Process section).

Pollution Prevention Plans

One tool to identify the potential pollutant source(s) and associated control requirement(s) at a site is through the preparation of a Stormwater Pollution Prevention Plan. Under the EPA NPDES Stormwater Permit Program, industrial stormwater dischargers and construction sites with 5 acres or more of land-disturbing activities are required to develop and implement Stormwater Pollution Prevention Plans for their facilities. These plans are intended to:

- Identify potential sources of pollution which may reasonably be expected to affect the quality of stormwater discharges, and

- Describe and ensure the implementation of practices which are to be used to reduce the pollutants in stormwater discharges.

The components of these plans include:

- Identification of a pollution prevention team
- Listing of spills and leaks
- Description of potential pollution sources
- Inventory of exposed materials
- Identification of non-stormwater discharges
- Visual inspections
- Identification of stormwater controls
- Good housekeeping practices
- Development of a preventive maintenance program
- Employee training
- Spill prevention and response procedures
- Sediment and erosion control
- Comprehensive site compliance evaluation
- Record keeping

These plans are required for stormwater discharges for projects which meet the federal permit thresholds described above, but are recommended for other land use activities below the thresholds. Information in Pollution Prevention Plans may also assist towns in evaluating developments and managing runoff once the community accepts responsibility for the roads and drainage systems. By reducing pollutant loads from the site, the developer will increase the likelihood that the stormwater control systems will comply with the Stormwater Management Standards. In addition, by reducing the pollutant load to a BMP structure, the developer also may decrease maintenance burdens and associated costs, reduce the risk of BMP failure, and prolong the life of the structure.

Additional information on preparing and implementing pollution prevention plans is contained in *Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices* (EPA-832-R-92-006) or *Stormwater Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices* (EPA-832-R-92-005), available through Office of Water Resource Center at (202) 260-7786, NTIS at (703) 487-4650, or the Educational Resource Information Center/Clearinghouse at (614) 292-6717.

Catch Basin Cleaning

Both private development managers and local public work managers should incorporate catch basin cleaning into BMP maintenance and source reduction efforts. Street sweeping and catch basin cleaning (or other similar BMP maintenance) often may be required as part of stormwater management or pollution prevention plans. Some municipalities already engage in regular catch basin cleaning. Typically, these efforts are conducted in the summer. In many cases, during a winter thaw or with the onset of an early spring, these activities should be conducted significantly earlier. It is critical to remove the accumulated sediment from the winter months as soon as possible before heavy and frequent spring precipitation, especially for catch basins without deep sumps or basins that have not been maintained in years.

Snow and Snowmelt Management

Proper management of snow and snow melt, in terms of snow removal and storage, use of de-icing compounds, and other practices can prevent or minimize the major runoff and pollutant loading impacts. Please see the DEP "Snow Disposal Guidance" and "Deicing Chemical (Road Salt) Storage" fact sheet. The following techniques can be utilized for comprehensive snow management:

- *Use of de-icing compounds*
  - Use alternative de-icing compounds such as $CaCl_2$ and calcium magnesium acetate (CMA);
  - Designate "low salt" areas on local roads adjacent to streams and wetlands (for state highways, contact MHD for information on designating a low salt area); and
  - Reduce use of de-icing compounds through better driver training, equipment calibration, and careful application.

- *Storage of de-icing compounds*
  - Store compounds on sheltered (protected from precipitation and wind), impervious pads;
  - Direct internal flow within the shelter to a collection system and route external flow around the shelter, and

- Uncovered storage of salt is forbidden by the Massachusetts General Laws Chapter 85, Section 7A in areas that would threaten water supplies.

- *Snow removal and storage*
  - Place plowed snow in pervious areas where it can slowly infiltrate;
  - Remove sediments from the snow storage areas every spring; and
  - Choose areas with adequate soil permeability to prevent ponding.

- *Blow snow from paved areas to grassed or pervious areas*

- *Use level spreaders and berms to spread meltwater evenly over vegetated areas*

- *Plan intensive street and catch basin cleaning in early spring* (as cited above)

Local Bylaws and Regulations

Local bylaws, ordinances, and regulations are one of the best mechanisms to institute nonstructural controls, since they can cover a range of issues such as pollution prevention plans for site development that falls below federal thresholds; requirements for earth removal during construction, including the phasing and timing of earth disturbing activities; pet waste bylaws; septic system inspections and maintenance requirements; road salt storage and use; and general stormwater bylaws adapted to local conditions and resource protection needs.

Zoning and land management bylaws are commonly used by local governments to institute nonpoint pollution controls. These bylaws generally are proposed by planning boards or conservation commissions, in consultation with other local officials.

Stormwater bylaws and earth removal or sediment and erosion control bylaws are among the most common types of local initiatives. Stormwater bylaws establish requirements for site planning and pollution prevention plans in conjunction with design and construction activities. Earth removal or erosion and sediment control bylaws focus specifically on construction activities and controlling soil erosion problems. Pet waste control bylaws have been put in place by a number of local boards of health.

The Nonpoint Source Management Manual offers a number of general suggestions for developing various types of bylaws for nonpoint pollution control, including erosion and sediment controls, impervious surface (or lot clearing) limitations, nutrient loading standards, site plan review, wetlands protection, road salt management, and others. Technical assistance with the development of local bylaws is available from DEP's Division of Watershed Management, the Massachusetts Coastal Zone Management Office, or the NRCS Community Assistance Program. Other groups such as regional planning agencies or nonprofit groups such as Massachusetts Association of Conservation Commissions or the Massachusetts Audubon Society may be able to provide assistance with bylaw development.

Public Education

Educating the public on ways to minimize the impacts of their daily household activities can significantly reduce nonpoint pollution. The public should be informed about state regulations and local bylaws for controlling nonpoint pollution and why these controls were instituted. Guidelines on how to minimize impacts from non-regulated, but pollution-causing activities, such as through the use of setbacks or careful chemical use, can also educate the public.

Examples of education materials are brochures explaining steps to maintain septic systems and why requirements for septic system inspections have been instituted (i.e., to ensure that the system is functioning properly since this cannot be verified from the surface and to protect new homebuyers from faulty systems) or local bylaw requirements for cleaning up pet wastes and why the requirement was instituted (i.e., to protect local shellfish beds, beaches, aesthetics, etc.).

Many educational materials are available from state agencies such as DEP and MCZM and other sources like nonprofit and professional organizations. Other materials which are specific to local bylaws may need to be developed but often can be adapted from existing materials. State agencies and other groups often can provide speakers for community meetings. Additional suggestions for public education efforts are contained in DEP's *Nonpoint Source Management Manual*.

The following types of activities need special attention:

- *Lawn and garden activities*, including application and disposal of lawn and garden care products, and proper disposal of leaves and yard trimmings. Proper pesticide and fertilizer application should be encouraged, including timing application reduction. Buffer areas (preferably natural vegetation) between surface waters and all lawn and garden activities should be encouraged. Limited lawn watering and climate-suitable landscaping should be encouraged. Guidelines for what to expect from landscaping and lawn care professionals should be provided. Composting guidelines, if not covered elsewhere under solid waste efforts, should be given.

- *Turf management* on golf courses, parks, and recreation areas. Many of the same guidelines described above are applicable to turf management but need to be targeted to caretakers responsible for golf courses and parks and recreation areas (municipal employees, in some cases).

- *Pet waste management*
  Pooper-scooper laws for pets need to be explained. Priority resource areas, such as swimming beaches and shellfish beds, may need to exclude pets at least for summer months or other critical use times. Specific controls for horses and the control of manure may be needed.

- *Proper storage, use, and disposal of household hazardous chemicals*, including automobile fluids, pesticides, paints, solvents, etc. Information should be provided on chemicals of concern, proper use, and disposal options. Household hazardous waste collection days should be sponsored whenever feasible. Recycling programs for used motor oil, antifreeze, and other products should be developed and promoted. Also, techniques such as stencilling the street by a catch basin with the name of the receiving wetland or waterway may increase public awareness.

- *Proper operation and maintenance of septic systems*
  Knowledge of proper operation and maintenance of septic systems should be promoted to avoid serious failures.

- *Commercial operations and activities*, including parking lots, gas stations, and other local businesses. Recycling, spill prevention and response plans, and proper material storage and disposal should be promoted. Using dry floor cleaners and absorbent materials and limiting the use of water to clean driveways and walkways should be encouraged. Care should be taken to avoid accidental disposal of hazardous materials down floor drains. Floor drains should be inventoried.

- *Other efforts, including water conservation and litter control*, can be tied to nonpoint pollution control.

CHAPTER 3: Structural Best Management Practices

The chapter presents information about stormwater management techniques that are considered Best Management Practices (BMPs) for achieving the Stormwater Management Standards in the Stormwater Policy Handbook, Volume 1: Chapter 1. This chapter should be used when selecting and evaluating BMPs for appropriate siting, design, construction and maintenance requirements. Conservation commissions and other issuing authorities will want to become familiar with the information presented. The level of understanding should make it possible to decide when a BMP is appropriate for a project site; when a drainage system will meet the Stormwater Management Standards; and when maintenance requirements are reasonable.

The first section in the chapter lays out the basic issues that should be considered when choosing a BMP. Stormwater quantity and quality management issues are summarized. Issues relating to site suitability, maintenance and cost effectiveness are also considered for BMPs in general. The second section provides the basic calculations needed to design a BMP for conformance with the Standards. The steps for estimating the TSS removal rate of the stormwater drainage system are described. Calculations are provided for determining the volume of runoff to be treated for water quality. A procedure also is given for estimating the volume of runoff that should be infiltrated into the ground; it is based on hydrologic soil classification. Lastly, the steps for calculating peak runoff discharge rates are reviewed.

The final section groups individual BMP technologies according to the principal methods of stormwater management: detention/retention, infiltration, filtration and pretreatment. For each BMP, there is a discussion on its purpose, advantages and disadvantages, applicability, expected range of pollutant removal effectiveness, planning considerations, design and construction issues and operation and maintenance concerns. At the end of each discussion is a summary table of the most important points. It should be noted that this section explains most of the current stormwater technologies, but is not an exhaustive review. Increased awareness and attention to stormwater management has encouraged the research and development of new technologies. The three-ring format of this handbook allows for periodic updates on new technologies.

Detention/Retention and Vegetated Treatment:

3.A [Extended] Detention Basins
3.B Wet [Retention] Ponds
3.C Constructed Stormwater Wetlands
3.D Water Quality Swales

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Infiltration	3.E	Infiltration Trenches
	3.F	Infiltration Basins
	3.G	Dry Wells [Rooftop Infiltration]
Filtration:	3.H	Sand Filters and Organic Filters
Pretreatment:	3.I	Water Quality Inlets, Hooded and Deep Sump Catch Basins
	3.J	Sediment Traps [Forebays]
	3.K	Drainage Channels

The BMP Selection Process

Site planning and nonstructural practices outlined in Volume 2: Chapter 2 should precede structural BMP controls that are needed for stormwater management. The following sections provide guidance for choosing the appropriate structural BMPs for a site by explaining the basic considerations for their use. Each BMP technology has certain limitations. When designing a stormwater management system for any site, the project proponent, working together with planners and design engineers, should ask the following questions:

- How can the stormwater management system be designed to meet the standards for stormwater quantity and quality most effectively?
- What are the opportunities to meet the stormwater quality standards andthe stormwater recharge and peak discharge standards simultaneously?
- What are the opportunities to utilize comprehensive site planning in order to minimize the need for structural controls?
- Are there critical areas on or adjacent to the project site?
- Does the project involve stormwater discharge from an area with a higher potential pollutant load?
- What are the physical site constraints?
- Is the future maintenance reasonable and acceptable for this type of BMP?
- Is the BMP option cost effective?

The project proponent should consider whether a system of several BMPs is more appropriate for a site than a single BMP structure. Too often, stormwater controls are added into a site plan in its final stages. Planning for stormwater management as an afterthought does not take into account the fact that a system of BMPs may be a more effective way to control runoff from a site. For example, dry wells could be used for infiltrating roof runoff thereby decreasing the flow to downstream BMPs. Water quality swales might be used in place of curbs and gutters for conveying flow to downstream BMPs, resulting in additional treatment of the runoff and reducing costs for conveying runoff. Infiltration trenches may be used before detention basins or wet ponds to provide recharge, thereby decreasing the size of basins or ponds required for managing runoff volume. Clearly, the focus of site planning and stormwater system design should be on examining the entire site to take advantage of the best available areas where runoff can be reduced, infiltrated, and treated in an integrated stormwater management system.

Stormwater Quantity Management

Because increased post-development runoff rates and volume can result in flooding and channel erosion, controlling post-development stormwater rates and volumes to approximate a site's pre-development (natural cover) hydrology is the primary goal of stormwater quantity management.

Controlling a site's post-development hydrology can be achieved through a combination of streambank/channel erosion control (2-year storm events), flood control (10 and 100-year storm events), and volume control (groundwater recharge). Table 3.1 indicates the types of quantity controls provided by specific BMPs. The following section, the BMP Sizing Process provides basic calculations to be used for compliance with the Stormwater Management Standards.

Table 3.1: Stormwater Quantity Control
(adapted from Schueler 1987, Horner 1994)

BMP	Peak Discharge Rate Control: 2yr Storm	Peak Discharge Rate Control: 10yr Storm	Peak Discharge Rate Control: 100yr Storm	Volume Control: Ground Water Recharge
Extended Detention Basin	○	○	◘	◘
Wet Pond	○	○	◘	X
Constructed Wetland	○	○	◘	X
Water Quality Swale	◘	◘	◘	◘
Infiltration Trench	◘	◘	X	○
Infiltration Basin	◘	◘	X	○
Dry Wells	◘	X	X	○
Sand Filters	◘	X	X	◘
Organic Filters	◘	X	X	◘
Water Quality Inlets	X	X	X	X
Sediment Trap	X	X	X	X
Drainage Channel	◘	◘	X	X
Deep Sump Catch Basin	X	X	X	X

○ = usually provided
◘ = can be provided with careful design
X = seldom or never provided

Stormwater Quality Management

When designing stormwater management systems and screening BMP technologies to meet the water quality management standards, the engineer must answer the following questions:

- Does the project affect a sensitive resource?
- Based on existing and post-development conditions, what are the peak runoff rates and volumes of stormwater to be treated for water quality? Is the water quality volume based on 0.5 inch or 1.0 inch of runoff times the impervious area?
- Based on existing and post-development conditions and soil types, what is the volume of stormwater to be recharged to groundwater?
- Given the site conditions, which BMP types (e.g., detention, filtration) are most suitable?
- What combination of BMP technologies and non-structural practices can be utilized to achieve an 80% reduction of TSS loadings on an average annual basis?

Site Suitability/BMP Suitability

In choosing an effective BMP system, it is necessary to determine the type(s) of BMP(s) technologies that are suitable for the characteristics of the site. Table 3.1 and Table 3.2 address a number of factors that should be considered when selecting BMPs. The basic site requirements for each technology have been included in this handbook.

Site suitability is a major factor in choosing BMPs. Physical constraints at a site may include soil conditions, watershed size, depth to water table, depth to bedrock and slope. In some cases, a BMP may be eliminated as an option because of site constraints. Often, however, BMPs can be modified or combined with other BMPs to adapt to site conditions and to create an efficient system capable of meeting the water quality and quantity standards.

The following sections briefly discuss the physical site conditions which will affect BMP selection.

Soil Suitability

Basic soil requirements for each technology type have been included in the specific technology sections in Chapter 3. Generally, detention/retention technologies are applicable to a broad range of soil conditions, but wet ponds may have difficulty maintaining water levels in very sandy soils.

Soil type is of particular importance to infiltration BMPs, and soils in Massachusetts may be too restrictive for wide application of infiltration practices. Specifically, infiltration technologies should not be applied in areas with soils exhibiting low permeability. This would exclude most "D" soil groups, as defined by the Natural Resources Conservation Service. Where infiltration technologies are planned, soils must be checked and adequate permeability confirmed.

Soil types and characteristics are less important to filtration technologies, as they do not need to maintain water levels or provide recharge. In some cases, where proper soils are present, filtration technologies may be used to recharge a portion of the treated stormwater.

Drainage Area/Watershed To Be Served

The size of the contributing area may be a limiting factor in selecting the appropriate BMP technology. Recommendations for appropriate contributing watershed area requirements have been included in the discussion for each technology. Through proper site planning, area constraints may often be overcome.

Pond BMPs typically require large contributing drainage areas in order to function properly, while infiltration BMPs require smaller drainage areas. For technologies that require large contributing watersheds, additional offsite runoff may be routed to the BMP to increase flows. Conversely, portions of the total runoff can be routed to smaller individual BMPs to allow for the use of lower capacity BMPs. Keep in mind that use of a number of individual BMPs in one drainage area may increase the maintenance and inspection requirements.

Depth to Water Table

Depth to the seasonal high water table is an important factor for stormwater technologies, especially infiltration BMPs. If the seasonal high water table extends to within two feet of the bottom of an infiltration BMP, the site is seldom considered suitable. The water table acts as an effective barrier to exfiltration through the BMP media and soils below and can reduce the ability of an infiltration BMP to drain properly. Contamination potential of the water table is of concern. Depending on soil conditions, depth to groundwater table is also an important factor in reducing the risk of microbial contamination.

For constructed wetlands and wet ponds, a water table at or near the surface is desirable. Areas with high water tables are generally more conducive to siting these types of detention/retention BMPs.

Depth to Bedrock

The depth to bedrock (or other impermeable layers) is a consideration for facilities which rely upon infiltration. The downward exfiltration of stormwater is impeded by bedrock that is near the surface, because infiltration BMPs will not drain properly. A site is generally not suitable for infiltration BMPs if the bedrock is within two feet of the bottom of the BMP.

Similarly, pond BMPs are not feasible if bedrock lies within the area that must be excavated to provide stormwater storage due to the expense of excavation.

Slopes
The slope of a site can restrict the type of BMP that can be used. Water quality swales and infiltration trenches are not practical when slopes exceed 20%. To achieve water quality benefits, wet and dry swales and drainage channels must not be sited on slopes greater than 5%. Where there are slopes, the BMPs must be very carefully designed to avoid erosion and flooding off site due to runoff discharges that bypass water quality treatment BMPs.

Thermal Enhancement
Wet ponds and shallow marshes warm up rapidly in summer months. Warm water released from BMPs can be lethal to cold water aquatic organisms. Unless design modifications such as the use of deep pools can mitigate for thermal impacts, these BMPs should not be considered for use in areas adjacent to designated cold water streams.

Proximity to Wells and Foundations
Infiltration of stormwater can cause seepage into foundations when BMPs are located too close to buildings; a ten foot setback is recommended.

Maintenance Requirements

BMPs must be maintained in order to operate properly. For this reason, the Stormwater Management Standards require that all stormwater management facilities have an operation and maintenance plan. At a minimum, operation and maintenance plans should identify:

- BMP(s) owner(s);
- Party or parties responsible for operation and maintenance;
- Source(s) of funding for continued operation and maintenance of the BMP(s);
- Schedule for inspection and maintenance; and
- Routine and infrequent maintenance tasks.

Too often, BMPs are constructed without plans or obligations for long term maintenance. The maintenance requirements for BMP structures must be considered during the selection process, and the operation and maintenance plan must be submitted for review along with the BMP design.

The basic maintenance requirements for each structural control have been included in this chapter. For most BMPs, the maintenance requirements include visual tasks (e.g., inspection of sediment chambers/traps) and physical upkeep tasks (e.g., sediment removal and disposal, and mowing of grassed swales).

For the developer, the most difficult part of developing a maintenance plan may be identifying a responsible party to perform and pay for the long term maintenance of the BMP. The plan must clearly address the following BMP maintenance issues: how and when maintenance is to be performed, how and when inspections will be performed, and how these tasks will be financed.

For the above reasons, BMPs should be designed to minimize maintenance needs, wherever possible. Future maintenance problems should be anticipated and plans should be developed to alleviate them as much as possible. Preventative design measures, such as the use of forebays to trap sediment inputs, can reduce the future maintenance costs and requirements.

Public Acceptance

Aesthetics are important in gaining acceptance of BMPs. BMPs can either enhance or degrade the amenities of the natural environment and the adjacent community. Careful planning, landscaping and maintenance can make a BMP an asset to a site. Frequently, ownership and maintenance responsibilities for BMPs in new developments fall on adjacent property owners. If adjacent residents will be expected to pay for maintenance, education and acceptance of the BMP are necessary.

Cost Effectiveness

Providing the most effective BMP system for the least cost should be the goal of stormwater system designers. When comparing costs for various BMPs, the designer must take into consideration the long term maintenance expenses, as well as the land acquisition, engineering and construction costs. Table 3.2 summarizes the priority issues associated with BMP technology selection.

Note: This Table is for reference and summary only and is not intended to be used without important narrative, guidelines, and requirements contained in this and other chapters.

Table 3.2: **Comparison of Issues for BMP Selection** (adapted from MWCOG, 1992)

BMP	Pollutant Removal Reliability	Longevity	Maintenance Requirements	Applicability to Sites	Environmental Concerns	Comparative Cost	Special Considerations
[Extended] Detention Basin	Moderate	20+ years	Low	Widely applicable, larger drainage areas (10+ acres)	Possible downstream warming; low bacteria removal	Low to Moderate	Available land area, design considerations; sediment forebay
Wet [Retention] Pond	Moderate to high	20+ years	Low to moderate	Widely applicable, larger drainage areas (7+ acres)	Possible downstream warming; low bacteria removal	Moderate to high	Available land area, design considerations, sediment forebay
Constructed Stormwater Wetland	Moderate to high	20+ years	Low to moderate	Widely applicable, larger drainage areas (7+ acres)	Possible downstream warming; wildlife benefits	Marginally higher than wet ponds	Available land area; design considerations; sediment forebay
Water Quality Swale	Moderate	20+ years	Low to moderate	Widely applicable	Restricted use for hotspots	Low to Moderate	Pretreatment; check dams; careful design
Infiltration Trench	Moderate to high	High rates of failure within first 5 years	High	Highly restricted: small sites, proper soils, depth to water table and bedrock, slopes	Potential for ground water contamination; restricted use for hotspots	High; rehabilitation costs can be considerable	Recommended with careful site (soils) evaluation and pretreatment
Infiltration Basin	Moderate	High rates of failure within first 5 years	High	Highly restricted: small sites, proper soils, depth to water table and bedrock, slopes	Potential for ground water contamination; restricted use for hotspots	Moderate; rehabilitation costs can be high	Not widely recommended until longevity is improved
Organic Filters	Moderate to high	20+ years	High	Widely applicable for small sites	Minor	High; frequent maintenance	Recommended with c design; pretreatme
Sand Filters	Moderate to high	20+ years	High	Widely applicable for small sites	Minor	High; frequent maintenance	Recommended with careful design; pretreatment
Water Quality Inlets	Low	20+ years	Moderate to high	Small, highly impervious areas (<2 acres)	Resuspension of PAH loadings. Disposal of residuals.	Moderate to High	Pretreatment technology, off-line
Sediment Trap [Forebay]	Low	20+ years	Moderate	Widely applicable as pretreatment	Resuspension of accumulated sediment if not maintained	Low to moderate	Pretreatment technology
Drainage Channel	Low	20+ years	Low to moderate	Low density development and roads	Erosion, resuspension	Low	Pretreatment technology, with check dams
Deep Sump [Modified] Catch Basin	Low	20+ years	Moderate	Small, highly impervious areas (<2 acres)	Resuspension of accumulated sediment if not maintained	Low to Moderate	Pretreatment technology, design modified with sump

The BMP Sizing Process

Designing a stormwater management system requires precise sizing to ensure that runoff is controlled at the project site. This section presents the steps for designing a stormwater system that will comply with the Stormwater Management Standards. The following is a list of the types of calculations that are included to address both the water quality and volumetric standards:

Water Quality and Recharge Calculations

I. The expected TSS removal with selected BMPs:

II. The volume of stormwater that is to be treated for water quality;

III. The volume of stormwater that is to be recharged into the groundwater; and

Peak Discharge Rate Calculations

IV. The peak discharge rates from pre- and post-development conditions, and the volume of stormwater that must be retained onsite to control peak discharge rates during specified storm events.

Water Quality and Recharge Calculations

NOTE: I. TSS Removal, II. Water Quality Volume, and III. Stormwater Recharge
The following steps are used to select and size BMPs. The calculations provide the TSS removal rate of a stormwater management system, and they also identify the necessary volumes to meet water quality and recharge standards. Both the 0.5" and the 1.0" of impervious area runoff rules are referenced.

I. TSS Removal and BMP Selection

NOTE: The application of this standard has been simplified to estimate a site's annual TSS load for compliance with this standard. The calculations have been set up so that every site's annual TSS load entering the first BMP in the system is 1 (i.e. 100 %).

(1) For each drainage area, list the stormwater management BMPs and their order in the engineered system, beginning with the first BMP collecting stormwater from the site. For example, pretreatment and conveyance BMPs will typically precede the removal BMPs. For each drainage area, list the BMPs in their respective order with their estimated TSS removal rates from the Stormwater Management Policy (Volume 1: Chapter 1).

(2) The TSS removal rates are not additive from one BMP to the next, instead the estimated removal rates must be applied consecutively as the TSS load passes through each BMP technology. For the purposes of this calculation, and comply with the Stormwater Management Standards, represent the estimated annual TSS load as 1.00 (i.e., 100 %).

(3) For each drainage area, apply the BMP estimated removal rate in the order in which they occur in the stormwater system. The equation for this calculation is:
Final TSS Removal Rate = (TSS Average Annual Load * BMP1 Removal Rate) + (Remaining TSS Load After Preceding BMP * BMP2 Removal Rate) + (Remaining TSS After Preceding BMP * BMP3 Removal Rate).

(4) After all of the BMPs in the initial stormwater system design have been accounted for and their estimated removal rates applied, the Final TSS Removal Rate for each drainage area should be equal to or better than 80% (0.80). If the Final TSS Removal Rate is lower than 80% for any of the drainage areas, the system should be redesigned in order to meet the Standards.

Note: It is imperative to compute the Final TSS Removal Rates for each individual drainage area. Rooftops, if serviced solely by their own BMPs, such as dry wells, should be considered a separate drainage system.

Example 1:
A preliminary stormwater management system design calls for 8 deep sump catch basins to collect runoff from a small commercial parking lot. Stormwater will then be routed to a wet pond for final quantity and quality control. A rigorous parking lot sweeping plan will be followed Rooftop runoff will be infiltrated through dry wells for recharge.

For parking lot and sidewalk drainage area:

Parking lot sweeping	**10% (discretionary)**
Deep sump catch basins	**25%**
Wet pond	**80%**

First, apply the parking lot sweeping credit:

Average Annual Load (1.00) * BMP1 Removal Rate (0.10) = **0.10** [TSS load estimated to be removed].
0.90 of the TSS load remains (1.00 - 0.10).

Next, apply the deep sump catch basin removal:

TSS load remaining (0.90) * BMP2 Removal Rate (0.25) = **0.225** [TSS load estimated to be removed].
0.675 of the TSS load remains (0.90 - 0.225).

Then, apply the wet pond removal:

TSS load remaining (0.675) * BMP3 Removal Rate (0.80) = **0.54** [TSS load estimated to be removed].

0.135 of the TSS load remains (0.675 - 0.54).

Lastly, the remaining TSS load is subtracted from the initial TSS load to derive the Final TSS Removal Rate: 1.00 - 0.135 = 0.865.
The Final TSS Removal Rate can be estimated by adding sediment loads removed by each BMP. For this example, that would be: (0.10 + 0.225 + 0.54) which totals 0.865 or 86.5%.

For this drainage area, this system as designed will remove an estimated 86.5% of the annual TSS load and therefore will meet the TSS removal standard if properly sized, designed, and maintained.

For the rooftop drainage area:

Dry well: 80% (uncontaminated)

Applying the dry well removal rate to the average annual load, results in 80%: Average Annual Load (1.00) * BMP1 Removal Rate (0.80) = 0.80

Relying on dry wells to infiltrate uncontaminated rooftop runoff will remove an estimated 80% of the annual TSS load, and therefore this rooftop system will meet the TSS removal standard. The volume of stormwater infiltrated through dry wells will also be applied to the recharge volume requirement. This is explained below.

Example 2:

Proposed Stormwater Management System: The stormwater management system directs runoff from the parking and roadway areas to catch basins with deep sumps (25% TSS removal). Drainage pipes convey the stormwater to sediment traps (25% TSS removal) and an extended detention basin (60% TSS removal). Discharged runoff from the basin enters a drainage channel (25% TSS removal) with an outlet in the buffer zone.

TSS Removal Requirement: To meet Stormwater Management Standard #4, the system must remove 80 % (0.8 of 1) the average annual load of TSS. To easily compute TSS removal, the average annual TSS load entering the stormwater system from any site is set at 1 (i.e., 100 percent) of the total suspended solids.

Calculation of TSS Removal for the BMPs proposed:

<u>**STEP #1.**</u> Compute the TSS removed by each BMP, using the following formula:
(Removal rate %) X (annual TSS load entering the BMP)

i. BMP1 - Catch basin with deep sump: (.25) X (1) = 25 % of TSS removed by BMP 1

ii. BMP2 - Sediment trap: (.25) X ((1)(total TSS) - (.25)(TSS removed by BMP 1))
(.25) X (.75) = 18.7% TSS removed by BMP 2

iii. BMP3 - Extended detention basin (.60) X (.75-.187)
(.60) X (.60) X (.56) =33.8 % TSS removed by BMP 3

iv. BMP 4 - Drainage channel (.25) X (.56-.338)
(.25) X (.222) = 5.5 % of TSS removed.

<u>**STEP #2.**</u> Add together the amounts removed by each BMP to get the 80 % TSS removal that is required in the Stormwater Management Standards. The formula is as follows:
(TSS removed by BMP1) + (TSS removed by BMP2) + (TSS removed by BMP3) + (TSS removed by each additional BMP) = 80 % of the total annual TSS for the site.

i. (25 % removed) + (18.7 % removed) + (33.8% removed) + (5.5 % removed) = 83 % of TSS removed by the entire system. Since the 80 % removal is required, the stormwater system will achieve the TSS Management Standard when sized to handle either the required 0.5 inch or 1 inch of runoff.

II. Water Quality Volume

WQV = water quality volume
ReV = recharge volume
I = total impervious area (including rooftop)
Ir = rooftop impervious area
RR = rooftop runoff

(1) **Compute total site area in acres (A).**

(2) Compute total impervious area including roofs (I) in acres.

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(3) Find WQV:
  (a) Using 0.5" rule: WQV = 0.5" * I (acres)
  (b) Using 1.0" rule: WQV = 1.0" * I (acres)
  (c) WQV value will be in acre-inches.

(4) Convert to acre feet: WQV divided by 12 (inches).
  (a) WQV value now in acre-feet.

III. Stormwater Recharge

(5) Compute areas of different Hydrologic Group soils and the area of impervious surfaces overlying these soil types in acres: (Note that Hydrologic Group D soils are omitted.)
  (a) Find total area of Hydrologic Group A soils on site = Aa (acres)
  (b) Find total impervious area overlying A soils = Ia (acres)
  (c) Find total area of Hydrologic Group B soils on site = Ab (acres)
  (d) Find total impervious area overlying B soils = Ib (acres)
  (e) Find total area of Hydrologic Group C soils on site = Ac (acres)
  (f) Find total impervious area overlying C soils = Ic (acres)

(6) Compute the recharge volume required for each Hydrologic Group soil:
  (a) Find recharge volume for A soils (ReVa): ReVa = Ia * 0.40
  (b) Find recharge volume for B soils (ReVb): ReVb = Ib * 0.25
  (c) Find recharge volume for C soils (ReVc): ReVc = Ic * 0.10
  (d) *Total recharge volume*: ReV = ReVa + ReVb = ReVc (acre-inches)
  (e) Convert to acre-feet: ReV divided by 12

(7) Compute rooftop runoff (RR):
  (a) Compute rooftop area in acres (Ir)
  (b) Rooftop runoff (RR)
    (0.5" rule) RR = Ir * 0.5"
    (1.0" **rule) RR = Ir** * 1.0"
  (c) Covert to acre-feet: RR divided by 12

(8) Identify how much of recharge volume (ReV) requirement can be met by infiltrating rooftop runoff (RR) [ReV - RR] and remaining recharge volume (if any) to be infiltrated. [NOTE: The remaining volume to be recharged should be runoff that has been conveyed through water quality BMPs.]

(9) Subtract the rooftop runoff volume (RR) from the total water quality volume (WQV) to get the volume of stormwater that must be treated for water quality.

Peak Discharge Rate Calculations

To Calculate Peak Discharge Rates and Volumes of Stormwater to Retain Onsite

The following is a list of the basic steps to be taken in order to calculate the peak discharge rates from pre- and post-development conditions and the volume of stormwater that must be retained onsite to control for peak discharge rates from specified storms. In many cases, engineers will utilize models to conduct these calculations. **The NRCS TR-55 is widely utilized, and many of the steps below have been automated with a computer program and requires only data input. For a more detailed account refer to the NRCS publication, *Urban Hydrology for Small Watersheds*.**

Steps for the Peak Discharge Rate
(calculated for pre- and post-development):

Am = contributing drainage area to site
RCN = runoff curve number
Tc = time of concentration
P = 24-hour site rainfall from specified event
Ia = initial abstraction
Qu = unit peak discharge
Q = site runoff
Fp = pond and wetland adjustment factor
Qp = peak discharge

(1) Calculate the contributing drainage area to site (Am).
- (a) Use USGS topographic maps and site visits.

(2) Calculate the Runoff Curve Number (RCN).
- (a) Use NRCS maps and site visits to determine soils and types within Am.
- (b) Determine the Hydrologic Soils Group (HSG) for the soils identified in (a).
- (c) Determine land use, cover type, treatment, hydrologic condition, % impervious, and % connected/unconnected impervious area ratio.
- (d) Develop a composite land use and HSG map from the information in (a)-(c).
- (d) Select RCNs from appropriate charts (TR-55).
- (e) Compute a weighted RCN for the entire drainage area.

(3) Calculate the site Time of Concentration (Tc).

(a) Determine sheet flow, shallow concentrated flow and channel flow from the most hydraulically distant point in the drainage area to the drainage discharge point at the boundary site.

(4) Determine rainfall distribution type:

(a) Use Type III for Massachusetts.

(5) Determine percentage of ponds and wetlands in the drainage area:

(a) Measure from USGS topographic sheet.

(6) Select design frequency storms to be evaluated:

(a) 2-year, 10- year, 100-year as in Standards and Basis for Evaluations.

(b) Other designs storms commonly evaluated are the 25-year and the 50-year.

(7) Determine the 24-hour site rainfall amounts (P) for each design storm.

(a) From US Weather Bureau charts and listed in TR-55.

(8) Determine Initial Abstraction (Ia). Initial abstraction is a representation of interception, initial infiltration, surface depression storage, and evapotranspiration.

(a) This value obtained from TR-55 chart based on the site's RCN.

(9) Calculate the Ia/P ratio.

(10) Determine the Unit Peak Discharge (Qu).

(a) This value obtained from TR-55 chart based on the Ia/P ratio and the Tc.

(11) Determine the site runoff (Q).

(a) This value obtained from TR-55 based on the RCN and the rainfall P.

(12) Determine the Pond and Wetland Adjustment Factor (Fp).

(a) This value obtained from TR-55 chart based on percentage of ponds and wetlands in Am.

(13) Calculate the final Peak Discharge Rate (Qp) for the site.

(a) Qp = (Qu) * (Am) * (Q) * (Fp)

(b) Calculate pre-development Qp.
Calculate post-development Qp.

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IV. Steps to Calculate Volume to Store Onsite for Control of Peak Discharge Rates:

Qo = peak outflow from detention system
Qi = peak inflow to detention system
Vs = volume of storage for detention system
Vr = volume of runoff

(14) Calculate the contributing drainage area (Am).
- (a) Use value from (1) above.

(15) Determine rainfall distribution type.
- (a) Use Type III for Massachusetts.

(16) Select design frequency storms to be evaluated:
- (a) 2-year, 10-year, 100-year as in Standards and Basis for Evaluations.
- (b) Other designs storms commonly evaluated are the 25-year and the 50-year.

(17) Determine the peak *inflow* (Qi) to the water quantity facility (BMP).
- (a) This value is typically the *post-development* peak discharge rate (Qp) from (12) above.

(18) Determine the peak *outflow* (Qo) from the water quantity facility (BMP).
- (a) This value is the *pre-development* peak discharge (Qp) from (12) above.

(19) Calculate the outflow to inflow ratio (Qo/Qi).

(20) Find the volume of storage to volume of runoff (Vs/Vr) ratio.
- (a) This curve value obtained from TR-55 graph/chart based on the Qo/Qi ratio and the rainfall distribution type. The Vs/Vr ratio will be a value between 0.1 and 0.6.

(21) Determine the site runoff (Q).
- (a) Use value from (10) above.

(22) Calculate the runoff volume (Vr).
- (a) Vr = (Q) * (Am)

(23) Calculate the storage volume (Vs) to be allocated for the water quantity facility (BMP). This is the volume that must be stored onsite to maintain the peak discharge rates from the specified frequency storm events.

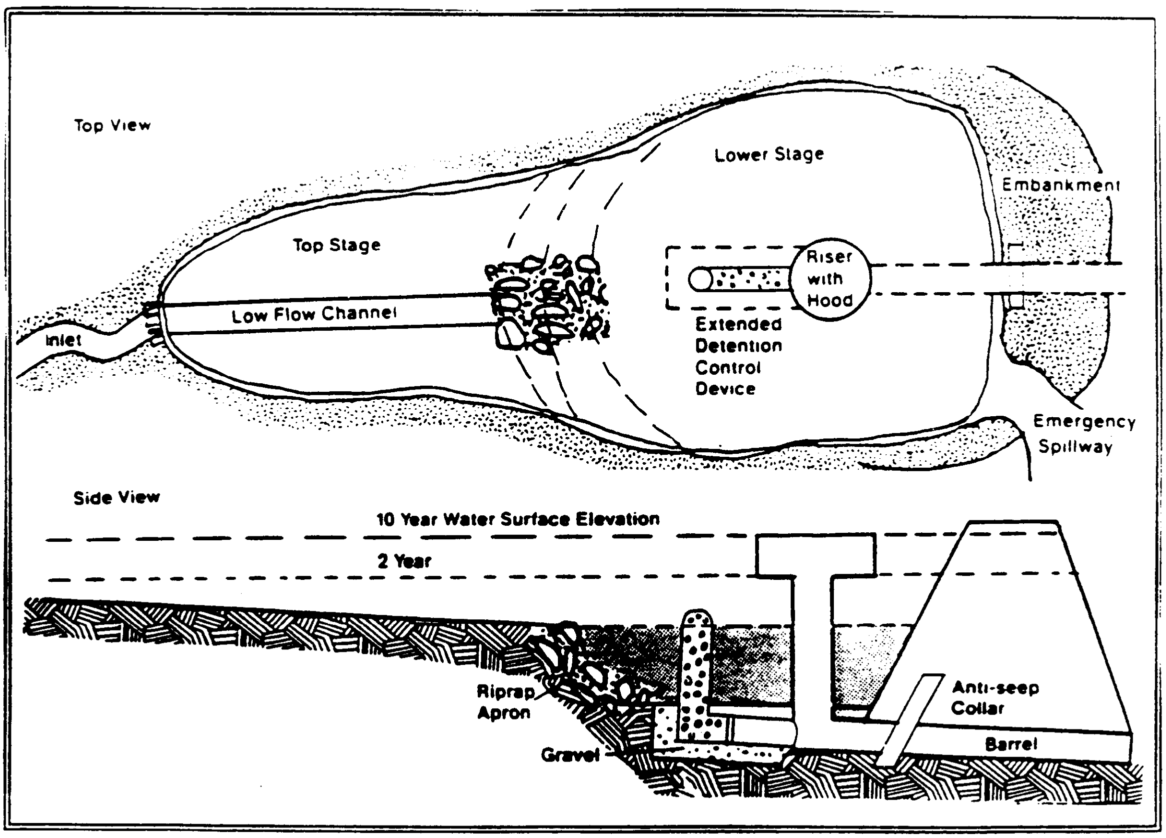
(a) Vs = (Vr) * (Vs/Vr) [Vs/Vr from (19) above].

(24) Repeat steps (16)-(23) to determine the required storage volumes for the design storm frequencies from (6).

[Extended] Detention Basins

Definition

Extended detention basins are modified conventional dry ponds or basins, designed to hold storm water for at least 24 hours to allow solids to settle and to reduce local and downstream flooding. Detention basins may be designed with either a fixed or adjustable outflow device. Pretreatment should be a fundamental design component of a detention pond to reduce the potential for clogging. Other components such as a micropool or shallow marsh may be added to enhance pollutant removal. The extended detention basin is made by constructing an embankment and/or excavating a pit. The detention basin is typically designed with two distinct stages. As shown in Figure 3.A.1, the detention basin should have the capacity to regulate peak flow rates of large, infrequent storms (10, 25, or 100 years), and generally remains dry. The lower stages of the basin are designed to detain smaller storms for a sufficient period of time to remove pollutants from the runoff.



(Schueler, 1987)

Figure 3.A.1: Schematic of an Extended Detention Basin

Purpose

- To reduce peak discharge rates and reduce occurrence of erosive downstream flooding.
- To remove particulate pollutants from runoff.

Advantages

- Least costly BMP that controls both stormwater quantity and quality.
- Good retrofitting option for existing basins.
- Can remove significant levels of sediment and sorbed pollutants.
- Potential for beneficial terrestrial and aquatic habitat.
- Less potential for hazards than deeper permanent pools.

Disadvantages

- Infiltration and groundwater recharge is negligible, resulting in minimal runoff volume reduction.
- Removal of soluble pollutants is minimal.
- Requires relatively large land area.
- Moderate to high maintenance requirements.
- Potential contributor to downstream warming.
- Sediment can be resuspended after large storms if not removed.

Applicability

Generally, detention basins are not practical if the contributing watershed area is less than ten acres. Four acres of drainage area are recommended for each acre-foot of storage in the basin.

Detention basins can be used at residential, commercial and industrial sites. Because they have a limited capability for removing soluble pollutants, detention basins are more suitable for commercial applications where there are high loadings of sediment, metals and hydrocarbons. At low density residential areas, where soluble nutrients from pesticides and fertilizers may be a concern, the use of detention basins alone should be considered very carefully. Combining detention basins with a shallow marsh system or other BMPs may be more appropriate.

Existing basins can be retrofitted as detention basins by modifying the outlet structure, at a relatively low cost. Because of the land requirements for detention basins, they are not feasible at sites where land costs or space is at a premium, however. Soils, depth to bedrock, and depth to water table should be investigated before designing a detention basin for a site. At sites where bedrock is close to the surface, high excavation costs may make detention basins infeasible. If soils on site are relatively impermeable, such as a soil group D, (as defined by the Natural Resource Conservation Service (NRCS)), a detention basin may experience problems with standing water. In this case, the use of a wet [retention] pond may be more appropriate. If the water table is within two feet of the bottom of the detention basin, it can also create problems with standing water. On the other hand, if the soils are highly permeable, such as well drained sandy and gravely soils (NRCS Soil Group A), it will be difficult to establish a shallow marsh component in the basin.

Effectiveness

Pollutant removal rates and design requirements for detention basins are in the Stormwater Management Policy (Volume 1, Chapter 1) . The primary pollutant removal mechanism in dry detention basins is settling; therefore, the degree of pollutant removal is dependent upon whether the pollutant is in the particulate or soluble form. Limited removal can be expected for soluble pollutants, while high removal rates can be expected for particulate pollutants. Removal of soluble pollutants can be enhanced in the lower stage of the basin, if it is maintained as a shallow wetland, where natural biological removal processes occur. The degree of removal by such wetlands appears to be dependent upon wetland size in relation to loading.

When designed properly, detention basins are effective in reducing pollutant loads and controlling post-development peak discharge rates. Detention basins can be used to meet the Stormwater Management Standards. Use of detention basins will not, however, reduce post-development increases in runoff volume.

Planning Considerations

Soils, depth to bedrock and depth to water table should be checked before designing a detention basin. At sites where bedrock is close to the surface, high excavation costs may make detention basins infeasible. If soils on site are relatively impermeable, a detention basin may experience problems with standing water. If the water table is within two feet of the bottom of a detention basin, it can also have problems with standing water. If the soils are highly permeable, it will be difficult to establish a shallow marsh component in the basin, unless a liner is used.

Maximum depth of the detention basins may range from 3 to 12 feet. The depth of the basin may be limited by groundwater conditions or by soils. Detention basins should be above normal groundwater elevation (i.e. should not intercept groundwater). The effects of seepage on the basin need to be investigated, if the basin is to intercept the groundwater table.

To be effective in reducing peak runoff rates, the basin must be located where it can intercept most of the runoff from the site. Usually, this location is found at the lowest elevation of the site where freshwater wetlands are frequently found. The effects of a detention basin on wetland resources must be examined. Altered wetland resources must be mitigated according to local, state and federal regulations. Under the requirements of the state's 401 Water Quality Certification regulations, no detention ponds or other stormwater controls may be located in natural wetlands.

Embankments, or dams, created to store more than 15 acre-feet, or that are more than 6 feet in height, are under the jurisdiction of the state Office of Dam Safety and are subject to regulation.

Design

See the following document for complete design references: *Design of Stormwater Pond Systems*. 1996. Schueler. Center for Watershed Protection.

Detention basin design must account for large, infrequent storm events for runoff quantity control, as well as small, frequent storm events for runoff quality control.

Typically, the first flush of runoff contains the highest concentrations of pollutants. Thus, detention basins should be designed to maximize the detention time for the most frequent storms. Routing calculations for a range of storms should provide the designer with the optimal basin size. Generally, most particulates settle within the first 12 hours of detention; however, additional time is required to settle finer particulates. Twenty four hours is the minimum detention time necessary for optimal pollutant removal.

The design should provide an average of 24 hours detention time for the expected storm events in each year. This can be achieved by setting the maximum detention time for the greatest runoff volume at approximately 40 hours. The average detention time for very small storms should be no less than 6 hours. By incorporating multiple exit points at different elevations, the designer can attain longer detention times for smaller storms.

In determining the size of the basin, the critical parameters are the storage capacity and the maximum rate of runoff released from the basin. The storage volume can be estimated in a number of ways. A typical approach is to limit the peak rate outflow to some predetermined level, such as the pre-development peak level.

To maximize sedimentation, the detention basin should be designed to lengthen the flow path, thereby increasing detention time. To maximize the detention time, the inflow points should be as far from the outlet structure as possible. Long, narrow configurations, with length to width ratios of 2:1

or 3:1, are recommended. Shallow basins with large surface areas also provide better removal efficiencies than small deep basins.

By reducing inflow velocity, detention time is lengthened, resuspension of settled pollutants is minimized, and sedimentation of incoming runoff is enhanced. All inflow points should be designed with riprap or other energy dissipators, such as a baffle below the inflow structure. A sediment forebay will enhance the removal rates of particulates, decrease the velocity of incoming runoff, and reduce the potential for failure due to clogging. Sediment forebays should be designed for ease of maintenance. Hard bottom forebays make sediment removal easier, and forebays should be accessible by heavy machinery, if necessary.

A low flow channel routes the last remaining runoff, dry weather flow and groundwater to the outlet, which should be installed in the upper stage of the basin to ensure that the basin drys out completely. Pervious or impervious channel lining may be used. A pervious lining allows interaction of the runoff with the soil and grass, resulting in increased sorption of pollutants. Design velocities in pervious low flow channels should be high enough to prevent sedimentation and low enough to prevent scouring and erosion. No minimum low flow channel velocity is needed if a forebay is utilized prior to the low flow channel. The maximum flow velocity (which should be set at the 2-year peak discharge rate) is dependent on the nature of the material used to line the channel

Impervious channels are simple to construct, easy to maintain, and empty completely after a storm event. Impervious channels can be undermined by runoff flow and differential settling if not constructed and maintained properly. The top of the impervious channel lining should be located at or below the level of the adjacent grassed areas to ensure thorough drainage of these areas. When designing the channels, settlement of the lining and the adjacent areas must be taken into account; the potential for frost impacts on the lining should also be considered. Impervious lining should be provided with broken stone foundations and weep holes. The potential for erosion or scour along the edges of the lining caused by bankfull velocities must be taken into consideration, when designing a channel. A low outflow discharge rate should be maintained at the downstream end of the channel to ensure sufficient treatment of runoff, which backs up and overflows onto the grassed basin bottom.

Low flow underdrains, connected to the principal outlet structure or other downstream discharge point, are recommended to promote thorough drying of the channel and the basin bottom. Depth of the low flow channel must be taken into account when preparing the final bottom grading plan.

Establishing wetland vegetation in a shallow marsh component or on an aquatic bench in the lower stage of the detention basin will enhance removal of soluble nutrients, increase sediment trapping, prevent sediment resuspension, and provide wildlife and waterfowl habitat. Proper soils and surface or groundwater depth are needed to maintain wetland vegetation. For additional information on establishing wetlands vegetation see Section 3.C.

Detention basin side slopes should be no steeper than 3:1, and the use of intermittent benches is recommended both for vegetation and for safety. Flatter slopes help to prevent erosion of the banks during larger storms, make routine bank maintenance tasks (such as mowing) easier, and allow access to the basin.

A multi-stage outlet structure is necessary to provide an adequate level of water quality and flood control. To meet the water quantity control standards, the required design storm runoff rates should be used as outlet release rates. For water quality control, the release rate will vary with the design storm selected. When used in conjunction with other BMPs to meet the water quality control standards, the release rate for the detention basin may be designed for a smaller storm (i.e., 1-year). For detention basins with shallow marshes or permanent pools, the lowest stage outlet must be placed to allow for the maintenance of a permanent pool of water.

The type of outlet structure will depend on factors, such as the type of spillway, basin configuration and extended detention outflow rate. The outlet must be designed to control the outflow rate without clogging. The outlet structure should be located in the embankment for maintenance, access, safety and aesthetics. The outlet should be designed to facilitate maintenance; the vital parts of the structures should be accessible during normal maintenance and emergency situations. It also should contain a drain-down valve for complete detention basin draining within 24 hours.

To prevent scour at the outlet, a flow transition structure, such as a lined apron or plunge pad, is needed to absorb the initial impact of the flow and reduce the velocity to a level that will not erode the receiving channel or area.

Embankments and spillways should be designed in conformance with the state regulations for Dam Safety (302 CMR 10.00). All detention basins must have an emergency spillway capable of bypassing runoff from large storms without damaging to the impounding structure.

An access for maintenance, minimum width of 10 feet and a maximum slope of 5:1, must be provided by public or private right-of-way. This access should extend to the forebay, safety bench and outflow structure, and should never cross the emergency spillway, unless the spillway has been designed for that purpose.

Vegetative buffers around the perimeter of the basin are recommended for erosion control and additional sediment and nutrient removal.

Maintenance

Detention basins should be inspected at least once per year to ensure that the basins are operating as intended. Inspections conducted at intervals during and after the storm will help to determine if the basin is meeting the expected detention times. The outlet structure should be inspected for evidence of clogging or outflow release velocities that are greater than design flow. Potential problems that should be checked include: subsidence, erosion, cracking or tree growth on the embankment; damage to the emergency spillway; sediment accumulation around the outlet; inadequacy of the inlet/outlet channel erosion control measures; changes in the condition of the pilot channel; and erosion within the basin and banks. Any necessary repairs should be made immediately. During inspections, changes to the detention basin or the contributing watershed should be noted, as these may affect basin performance.

The upper-stage, side slopes, embankment, and emergency spillway should be mowed at least twice per year. Trash and debris should also be removed at this time.

Sediment should be removed from the basin as necessary, and at least once every 5 years. Providing for an on-site sediment disposal area will reduce the overall sediment removal costs.

Summary: Guidelines for [Extended] Detention Basins

Site Criteria

- For each acre-foot of storage in a detention basin, four acres of drain age area are recommended. The contributing drainage area to any individual detention basin should be at least 20 acres if a permanent pool or wetland is part of the design.

- Soils, depth to bedrock and depth to water table at the proposed location of the detention basin must be investigated. Site conditions must be suited to the siting of the detention basin:
  -- Poorly drained soils may result in standing water.
  -- Bedrock close to surface may prevent excavation.

- The following minimum setback requirements should apply to detention basin installations:
  -- Distance from a septic system leach field - 50 feet.
  -- Distance from a septic system tank - 25 feet.
  -- Distance from a private well - 50 feet
  -- Distance from the property line -10 feet.

Design Criteria

- Design of the detention basin should target a 24 hour average detention time for the entire spectrum of storm events in each year. The longest detention time for the maximum runoff volume should be set at approximately 40 hours. The average detention time for very small storms should be no less than 6 hours.

- The size of the detention basin is based on the volume of runoff that needs to be detained over a specific period of time.

- The original design of the detention basin should account for gradual accumulation of sediment.

- Distance between inlets and outlets should be as great as possible to lengthen the flow path and increase detention time.

- Detention basins should be wedge-shaped, if possible, narrowest at the inlet and widest at the outlet.

- Inflow points should be designed with energy dissipators to reduce inflow velocity.

- The inlet should be designed with a forebay or settling zone to trap coarse sediments.

- Detention basin side slopes should be no steeper than 3:1.

- A multi-stage outlet structure is necessary to provide an adequate level of water quality and flood control. For detention basins with shallow marshes or permanent micropools, the lowest stage orifice must be placed to allow for the maintenance of a permanent pool of water.

- The use of a shallow marsh with the detention basin will enhance the pollutant removal performance of the basin. At least 6 to 12 inches of water depth are needed for optimum wetland vegetation growth.

- A low flow channel should be installed in the top stage of the basin to ensure that the basin drys out completely.

- The type of outlet structure used will depend on factors such as the type of spillway, basin configuration, and extended detention outflow rate. The outlet must control the outflow rate effectively, and also be protected from clogging.

- The outlet structure should be designed to facilitate maintenance; structures should be accessible to maintenance personnel during normal and emergency conditions.

- The outlet structure should contain a drain-down valve which will allow complete draining of the detention basin within 24 hours for emergency purposes or routine maintenance.

- Embankments and spillways should be designed in conformance with the state dam safety regulations and criteria. All detention basins must have an emergency spillway capable of bypassing runoff from large storms without damaging the impounding structure.

- To prevent scour at the outlet, a flow transition structure, such as a lined apron or plunge pad, is needed to absorb the initial impact of the flow, and reduce the velocity to a level that will not erode the receiving channel or area.

- An access for maintenance, minimum width of 10 feet and a maximum slope of 15%, must be provided by public or private right-of-way. This access should never cross the emergency spillway, unless the spillway has been designed for that purpose.

Maintenance Criteria

- Maintenance is required for the proper operation of detention basins; plans for detention basins should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule.

- Detention basins should be inspected at least once per year to ensure that the basin is operating as intended. Inspections should be conducted during wet weather to determine if the basin is meeting the targeted detention times.

- At least twice during the growing season the upper-stage, side slopes, embankment, and emergency spillway should be mowed, and accumulated trash and debris removed.

- Sediment should be removed from the basin as necessary, and at least once every 10 years.

Wet [Retention] Ponds

Definition

Wet ponds or retention ponds utilize a permanent pool of water as the primary mechanism to treat stormwater. The pool allows settling of sediments (including fine sediments) and removal of soluble pollutants. Wet ponds also should have additional dry storage capacity to control peak discharge rates. Ponds have a moderate to high capacity for removing most urban pollutants, depending on how large the volume of the permanent pool is in relation to the runoff from the surrounding watershed. Figure 3.B.1 shows a schematic of a typical wet pond. As with detention basins, wet ponds can be created by either constructing an embankment or excavating a pit. The primary component of a wet pond is the deep, permanent pool, but other components, such as a shallow marsh or sediment forebay, may be added to the design. The basic operation of a wet pond allows incoming storm water to displace the water already present in the pool. This stormwater will remain until displaced by runoff from another storm event. Increased settling time allows particulates, including fine sediments, to deposit. The permanent pool also serves to protect deposited sediments from resuspension during large storm events. Another advantage of wet ponds is the biological activity of algae and fringe wetland vegetation, which reduces the concentration of soluble pollutants. Wet ponds may be designed with a multi-stage outlet structure to control discharges from different size storms. When properly designed and maintained, a wet pond can add recreation, open space, fire protection and aesthetic values to a project area.

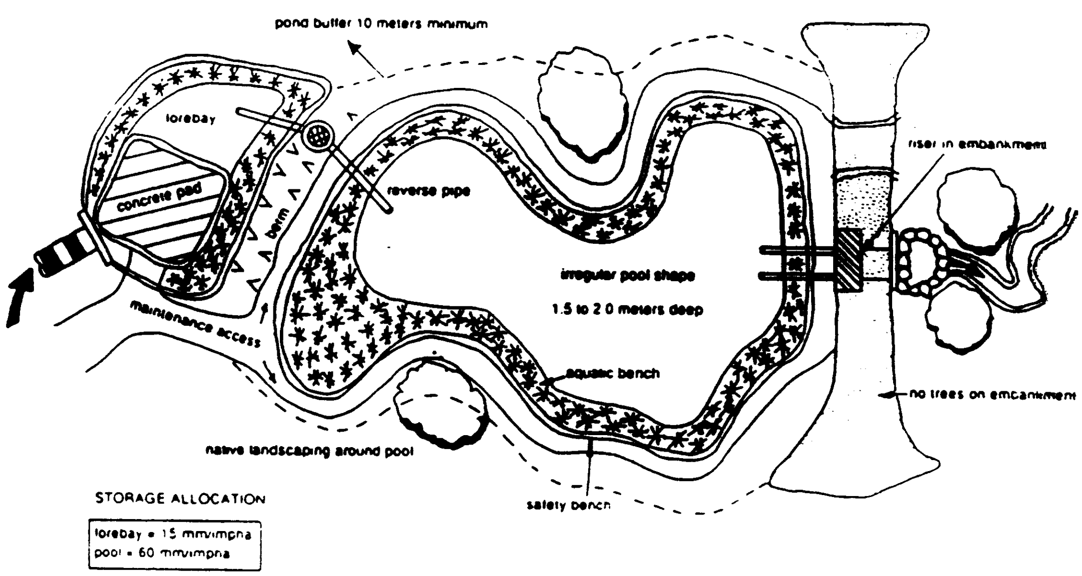


Figure 3.B.1: Schematic of a Wet Pond

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Purpose

- To remove particulate pollutants from runoff.
- To reduce peak discharge and the occurrence of erosive downstream flows. [*Note: Wet ponds must be designed with detention storage capacity to meet this goal*]

Advantages

- Capable of removing both solid and soluble pollutants.
- Aesthetically pleasing BMP.
- Can increase adjacent property values when planned and sited properly.
- Pond sediment removal schedule is generally less frequent than for other BMPs.

Disadvantages

- More costly than extended detention basins.
- Larger storage volumes for the permanent pool and flood control require more land area.
- Infiltration and groundwater recharge is minimal, therefore runoff volume control is negligible.
- Requires relatively large land area.
- Moderate to high maintenance requirements.
- Potential for contributing to downstream warming.

Applicability

Generally, dry weather base flow and/or large contributing drainage areas are required to maintain pool elevations. Minimum contributing drainage area should be at least 10 acres, but not more than one square mile. Sites with less than 10 acres of contributing drainage area may be suitable if sufficient groundwater flow is available.

Wet ponds can be used at residential, commercial and industrial sites. Since wet ponds have the capability of removing soluble pollutants, they are suitable for sites where nutrient loadings are expected to be high.

As for other stormwater BMPs, soils, depth to bedrock, and depth to water table must be investigated before designing a wet pond. At sites where bedrock is close to the surface, high excavation costs may make wet ponds infeasible. If the soils on site are relatively permeable or well drained, such as a soil type in Hydrologic Group A (as defined by the Natural Resource Conservation Service), it will be difficult to maintain a permanent pool. In this situation, it may be necessary to line the bottom of the wet pond to reduce infiltration.

Effectiveness

Table 5.2 shows the range of removal efficiencies for wet ponds. When the wet pond is well planned, designed, constructed, and maintained, pollutant loading reduction should be at the high end of the reported values. Wet ponds can be used to meet the Stormwater Management Standards.

If designed with proper storage capacities, wet ponds may be effective in controlling post-development peak discharge rates at desired pre-development levels. The highest degree of flood control can be attained when multiple design storms are controlled. The upper stages of wet ponds should be designed to provide temporary storage of larger storms (i.e., 10, 25, and 100-year storms). Wet ponds are generally ineffective in controlling the post-development increase in runoff volume, although some infiltration does occur, as well as evaporation in summer months.

Planning Considerations

Soils and depth to bedrock must be checked before designing a wet pond for a site. At sites where bedrock is close to the surface, high excavation costs may make wet ponds infeasible. If the soils are permeable (A and B soils), heavy drawdown of the pond may occur during dry periods. In these situations, the potential for drawdown may be minimized by installing a liner at the bottom of the pond or by compacting the pond soils. Specifications for pond liner materials are as follows (in order of decreasing costs):

- 6 inch clay
- polyvinyl liner
- bentontite
- 6 inches of silt loam or finer.

To be effective in reducing peak runoff rates, the pond must be located where it can intercept most of the runoff from the site. Usually this location is found at the lowest elevation of the site where freshwater wetlands are most often located. The effects of the wet pond on wetland resources must be examined. Altered wetland resources must be mitigated according to local, state, and federal regulations.

Embankments or dams created to store more than 15 acre-feet, or that are more than 6 feet in height, are under the jurisdiction of the state Office of Dam Safety and should be constructed, inspected and maintained according to agency guidelines.

Design

See the following for complete design references:

Wet Extended Detention Pond Design: Step by Step Design. 1995. Calytor. Center for Watershed Protection.

Design of stormwater pond systems. 1996. Schueler. Center for Watershed Protection.

Volume and geometry are the critical parameters in a wet pond design because of the relationship of the volume in the permanent pool to the contributing runoff volume directly affects pollutant removal rates. Generally, bigger is better; however, after a certain threshold size, increasing the pool size results in only marginal increases in pollutant removal. To achieve a meaningful reduction in pollutant loading, the ratio of pool volume to runoff volume must be greater than 2, and preferably 4. The pool: runoff ratio of 4 or greater is recommended for the control of nutrient pollution. A pool:runoff ratio of 4 equates to a hydrologic residence time of approximately two weeks, and is estimated to achieve about 85-90% sediment removal.

For each acre-foot of storage in an wet pond, 4 acres of drainage area are recommended. Generally, dry weather base flow and/or large contributing drainage areas are required to maintain pool elevations. Minimum contributing drainage areas should be at least of 10 acres, but should not exceed one square mile. Sites with less than ten acres of contributing drainage area may be suitable if sufficient groundwater flow is available.

Pool depth is an important design factor, especially for sediment deposition. An average pool depth of 3 to 6 feet is recommended. Settling column studies and modeling analyses have shown that shallow ponds have higher solids removal than deeper ones. However, resuspension of settled materials by wind may be a problem in shallow ponds that are less than 2 feet in depth. Depths in excess of 8 feet may result in thermal stratification. Stratified pools tend to become anoxic (low or no oxygen) more often than shallower ponds.

It is desirable to vary depths throughout the pond. Intermittent benches around the perimeter of the pond are recommended for safety and to promote vegetation. The safety bench should be designed to be at least 10 feet wide and located above normal pool elevations. The aquatic bench should be a minimum of ten feet wide and depths of 12-18 inches should be maintained at normal elevations to support aquatic vegetation. Shallow depths near the inlet will concentrate sediment deposition in a smaller, more accessible area. Deeper depths near the outlet will yield cooler bottom water discharges that may mitigate downstream thermal effects.

A minimum pool surface area of 0.25 acres is recommended. Performance of the wet pond may be enhanced by enlarging the surface area to increase volume, as opposed to deepening the pool. This may result in higher water temperatures and increased evaporation rates, however.

The original design of wet pond depths and volumes should take into account the gradual accumulation of sediment. Accumulation of sediment in the pool will result in a loss of volume and a reduction in pollutant removal efficiency.

As for detention basins, the use of a sediment forebay is highly recommended. Forebays serve to trap sediments before the runoff enters the primary pool, effectively enhancing removal rates and minimizing long term operation and maintenance problems. Periodic sediment removal from the forebay is easier and less costly than removal from the wet pond pool. Sediment forebays should be designed for ease of maintenance. Hard bottom forebays make sediment removal easier, and forebays should be accessible by heavy machinery, if necessary.

To avoid reducing the pollutant removal capability and to maximize travel distance, the inflow points should be as far from the outlet structure as possible. To maximize stormwater contact and retention time in the pool, a length to width ratio of 3:1 is recommended.

The invert elevation of the inlet pipe should be set at or below the surface of the permanent pool; preferably, within one foot of the pool. Pipes which discharge above the pool can erode the banks and side slopes. All inflow points should be designed with riprap or other energy dissipators to reduce the inflow velocity.

Establishing wetland vegetation on the aquatic bench will enhance removal of soluble nutrients, enhance sediment trapping, prevent sediment resuspension, provide wildlife and waterfowl habitat and conceal trash and debris that may accumulate near the outlet. Six to eighteen inches of water depth are needed for wetland vegetation growth. Additional information on planting wetlands vegetation is in Section 3.C, Constructed Stormwater Wetlands.

Slopes of the pools should be no steeper than 3:1. Flatter slopes help to prevent erosion of the banks during larger storms and make routine bank maintenance tasks, such as mowing, easier. Flat slopes also provide for public safety, and allow easier access. Furthermore, the sides of the pool that extend below the safety and aquatic benches to the bottom of the pool should be at a slope that will remain stable, usually no steeper than 2:1 (horizontal: vertical).

The invert of the wet pond outlet pipe should be designed to convey stormwater from approximately one foot below the pool surface and to discharge into the riser in the pond embankment. To prevent clogging, trash racks or hoods should be installed on the riser. To facilitate access for maintenance, the riser should be installed within the embankment. Anti-seep collars or filter and drainage diaphragms should be installed on the outlet barrel to prevent seepage and pipe failure.

The outlet structure should be designed to facilitate maintenance; the vital parts of the structures should be accessible to maintenance personnel during normal and emergency conditions. A bottom drain pipe should be installed for complete draining of the wet pond in case of emergencies or routine maintenance. Both the outlet pipe and the bottom drain pipe should be fitted with adjustable valves at the outer end of the outlet. These valves can be used to adjust the detention time, if necessary. To prevent scour at the outlet, a flow transition structure, such as a lined apron or plunge pad, is needed to absorb the initial impact of the flow and reduce the velocity to a level that will not erode the receiving channel or area.

Embankments and spillways should be designed in conformance with the state guidelines for Dam Safety. All wet ponds must have an emergency spillway capable of bypassing runoff from large storms without damaging the impounding structure.

An access for maintenance, with a minimum width of 10 feet and a maximum slope of 15%, must be provided by public or private right-of-way. This access should extend to the forebay, safety bench, and outflow structure and should never cross the emergency spillway, unless the spillway has been designed for that purpose.

Vegetative buffers around the perimeter of the wet pond are recommended for erosion control and additional sediment and nutrient removal.

Maintenance

Wet ponds should be inspected at least once per year to ensure that it is operating as designed. The outlet structure should be inspected for evidence of clogging or too rapid an outflow release. Potential problems that should be checked include: subsidence, erosion, cracking or tree growth on the embankment, damage to the emergency spillway, sediment accumulation around the outlet, inadequacy of the inlet/outlet channel erosion control measures, changes in the condition of the pilot channel and erosion within the pond and banks. Any necessary repairs should be made immediately. During inspections, changes to the wet pond or the contributing watershed area should be noted as these may affect pond performance.

At least twice a year the upper-stage, side slopes, embankment and emergency spillway should be mowed. At this time, the sediment forebay should also be checked. Accumulated sediment should be removed from the forebay at least once a year. Trash and debris should also be removed at this time.

Sediment should be removed from the pond as necessary, and at least once every 10 years. Providing an on-site sediment disposal area will reduce the overall sediment removal costs.

Summary: Guidelines for Wet Ponds

Site Criteria

- Base flow and/or large contributing drainage areas are necessary to support pool elevations in wet ponds.
- The contributing drainage area to any individual wet pond should be at least 10 acres. Wet ponds should not be utilized for sites with drainage areas of less than 10 acres unless adequate groundwater flow is present.
- For each acre-foot of storage in an wet pond, four acres of drainage area are recommended.
- Soils, depth to bedrock and depth to water table at the proposed location of the wet pond must be investigated. Site conditions must be suited to the siting of a wet pond:
  -- Well-drained soils will not support surface water: sites with these soil types will require the use of lining material.
  -- Bedrock close to the surface may prevent excavation, due to cost.
- The following minimum setback requirements should apply to wet pond installations:
  -- Distance from a septic system leach field - 50 feet.
  -- Distance from a septic system tank - 25 feet.
  -- Distance from a property line - 10 feet.
  -- Distance from a private well - 50 feet.
- The wet pond outfall should not discharge directly to, or cause erosion in, wetland resources or waterways of the Commonwealth.

Design Criteria

- Wet ponds should not be designed or utilized to treat runoff generated during site disturbance or construction.
- The ratio of the wet pond pool volume to runoff volume should be as close to 4 as possible, to achieve effective pollutant removal rates.
- An average wet pond pool depth of 3 to 6 feet is recommended to achieve optimum settling of particulates. Varying depths throughout the pond are recommended. Intermittent benches around the perimeter of the pond are recommended to enhance public safety and to promote the growth of aquatic vegetation.

- Deeper depths near the riser will yield cooler water bottom discharges, which may mitigate downstream thermal effects.
- A sediment forebay or similar pretreatment device is highly recommended to enhance pollutant removal and to prolong pond effectiveness.
- A minimum pool surface area of 0.25 acres is recommended based on the typical drainage area size required to sustain a permanent pool during summer months.
- The original design volume of the wet pond should take into account gradual sediment accumulation.
- Inlets should be as far removed from outlet structures as possible to lengthen the flow path and increase detention time. To maximize stormwater contact and retention time in the pool, a length to width ratio of 3:1 is recommended.
- Reverse slope pipes should be set to discharge stormwater approximately one foot below the normal surface elevation of the permanent pool.
- Inflow points should be designed with energy dissipators to reduce inflow velocity.
- Establishing wetland vegetation on the aquatic bench and in the lower stage of the wet pond will enhance the pollutant removal performance of the pond. Six to eighteen inches of water are needed for optimum wetland vegetation growth.
- Slopes leading to the pond should be no steeper than 3:1.
- To prevent clogging, trash racks or hoods should be installed on the riser. To facilitate access for maintenance, the riser should be installed within the embankment. Anti-seep collars should be installed on the outlet barrel to prevent seeping losses and pipe failure.
- The outlet structure should be designed to facilitate maintenance; the vital parts of the structures should be accessible to maintenance personnel during normal and emergency conditions.
- A bottom drain pipe with an inverted elbow should be installed to prevent sedimentation and for complete draining of the pond in case of emergencies or routine maintenance.

- Both the outlet pipe and the bottom drain pipe should be fitted with adjustable valves at the end of the outlet. These valves can be used to adjust the target detention times if necessary.

- To prevent scour at the outlet, a flow transition structure, such as a lined apron or plunge pad, is needed to absorb the initial impact of the flow and reduce the velocity to a level that will not erode the receiving channel or area.

- Embankments and spillways should be designed in conformance with the state Dam Safety regulations and criteria. All wet ponds must have an emergency spillway capable of bypassing runoff from large storms without damaging the impounding structure.

- An access for maintenance, minimum width of 10 feet and a maximum slope of 15%, must be provided by public or private right-of-way. This access should never cross the emergency spillway, unless the spillway has been designed for that purpose.

- Vegetative buffers around the perimeter of the wet pond are recommended for erosion control and additional sediment and nutrient removal.

Maintenance Criteria

- Maintenance is required for the proper operation of wet ponds. Plans for wet ponds should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule for wet ponds.

- Once constructed, the wet pond should be inspected after several storm events to confirm drainage system functions, bank stability, and vegetation growth. Problems should be addressed immediately.

- Wet ponds should be inspected at least once per year to ensure that they are operating as designed.

- At least twice during the growing season, side slopes, embankment and emergency spillway should be mowed, and accumulated trash and debris removed. Accumulated sediment in the forebay should also be removed at this time.

- Sediment should be removed from the pond as necessary, and at least once every 10 years.

Constructed [Stormwater] Wetlands

Definition

Stormwater wetlands are constructed wetland systems designed to maximize the removal of pollutants from stormwater runoff through wetland vegetation uptake, retention and settling. Stormwater wetlands temporarily store runoff in shallow pools that support conditions suitable for the growth of wetland plants. Like detention basins and wet ponds, stormwater wetlands may be used in connection with other BMP components, such as sediment forebays and micropools.

Stormwater wetlands should not be located within natural wetland areas. These engineered wetlands differ from wetlands constructed for compensatory storage purposes and wetlands created for restoration. Typically, stormwater wetlands will not have the full range of ecological functions of natural wetlands; stormwater wetlands are designed specifically for flood control and water quality purposes.

Similar to wet ponds, stormwater wetlands require relatively large contributing drainage areas and/or dry weather base flow. Minimum contributing drainage areas should be at least ten acres, although pocket type wetlands may appropriate for smaller sites if sufficient ground water flow is available.

There are four basic stormwater wetland design types:

Shallow marsh systems - Figure 3.C.1
Most shallow marsh systems consist of pools ranging from 6 to 18 inches during normal conditions. Shallow marshes may be configured with different low marsh and high marsh areas, which are referred to as cells. Shallow marshes are designed with sinuous pathways to increase retention time and contact area. Shallow marshes may require larger contributing drainage areas than other systems, as runoff volumes are stored primarily within the marshes, not in deeper pools where flow may be regulated and controlled over longer periods of time.

Pond/wetland systems - Figure 3.C.2
Multiple cell systems, such as pond/wetland systems, utilize at least one pond component in conjunction with a shallow marsh component. The first cell is typically the wet pond which provides for particulate pollutant removal. The wet pond is also used to reduce the velocity of the runoff entering the system. The shallow marsh provides additional treatment of the runoff, particularly for soluble pollutants. These systems require less space than the shallow marsh systems and generally achieve a higher pollutant removal rate than other stormwater wetland systems.

Extended detention wetlands - Figure 3.C.3
Extended detention wetlands provide a greater degree of downstream channel protection. These systems require less space than the shallow marsh systems, since temporary vertical storage is substituted for shallow marsh storage. The additional vertical storage area also provides extra runoff detention above the normal elevations. Water levels in the extended detention wetlands may increase by as much as three feet after a storm event and return gradually to normal within 24 hours of the rain event. The growing area in extended detention wetlands expands from the normal pool elevation to the maximum surface water elevation. Wetlands plants that tolerate intermittent flooding and dry periods should be selected for the extended detention area above the shallow marsh elevations.

Pocket wetlands - Figure 3.C.4
These systems may be utilized for smaller sites of one to ten acres. To maintain adequate water levels, pocket wetlands are generally excavated down to the groundwater table. Pocket wetlands which are supported exclusively by stormwater runoff generally will have difficulty maintaining marsh vegetation due to extended periods of drought.

In urban settings, natural wetlands can be altered by increases in runoff volume and rates resulting from upstream development. The existing functions and structure of the natural wetland can be altered severely when runoff becomes a major component of the natural wetland hydrological regime (or water balance). Ultimately, natural wetlands that have been altered by runoff function more like constructed wetlands systems than natural systems. One of the primary goals of comprehensive stormwater management is to protect natural wetlands from the impacts of development and increases in runoff.

Purpose

- To allow for the settlement of particulate pollutants.
- To allow for the biological uptake of pollutants by wetland plants.
- To reduce peak discharges and reduce occurrence of downstream flooding. [*Note: Detention storage capacity must be part of the design in order to meet this goal.*]

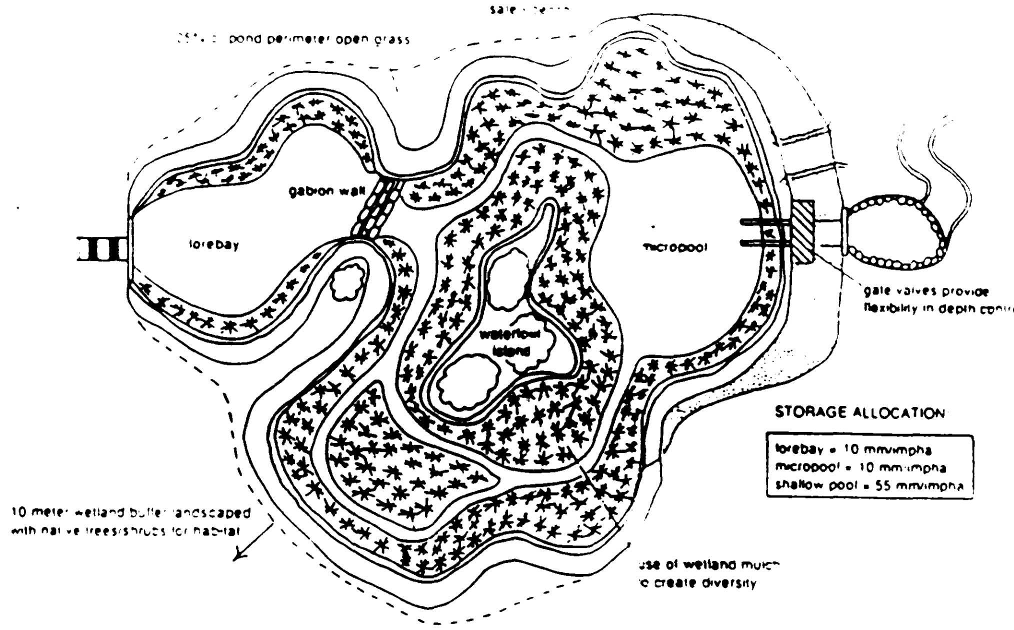

Figure 3.C.1: Schematic of a Shallow Marsh System

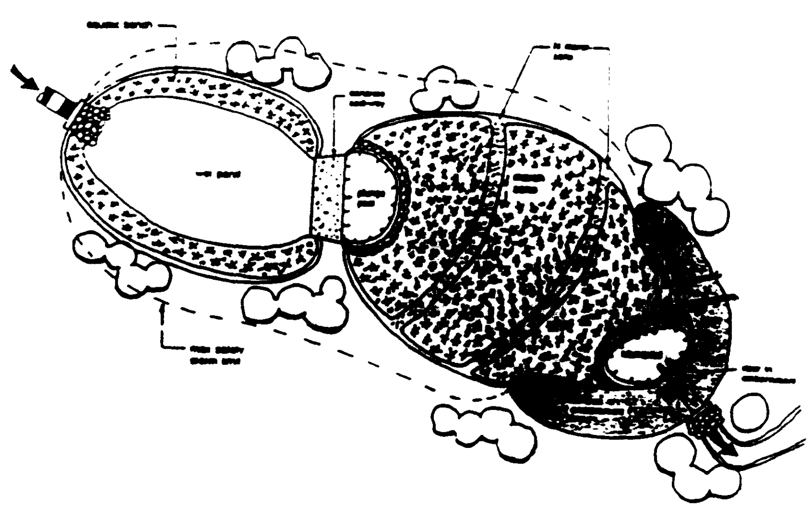

Figure 3.C.2: Schematic of a Pond/Wetland System

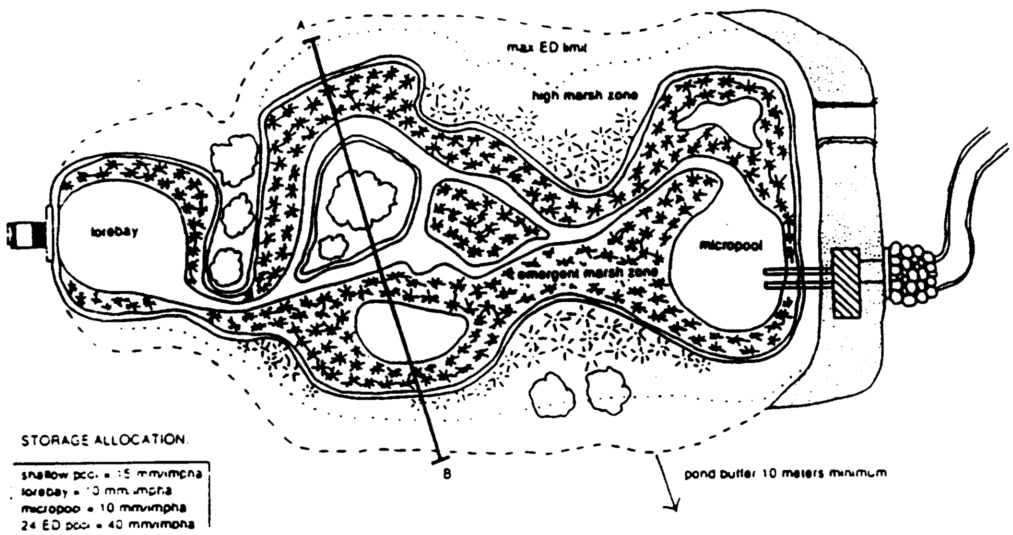

Figure 3.C.3: Schematic of an Extended Detention Wetland

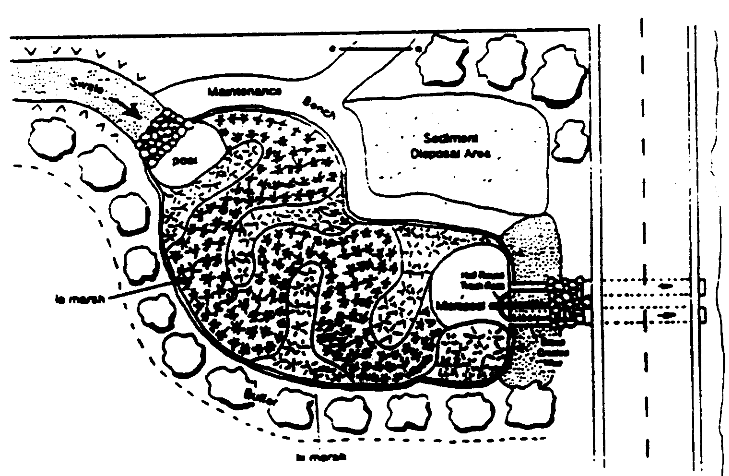

Figure 3.C.4: Schematic of a Pocket Stormwater Wetland

Advantages

- Relatively low maintenance costs.
- Has high pollutant removal efficiency.
- Can enhance the aesthetics of a site and provide recreational benefits.

Disadvantages

- Depending upon design, larger land requirements than for other BMPs.
- Until vegetation is well established, pollutant removal efficiencies may be lower than anticipated.
- Relatively high construction costs in comparison to other BMPs.

Applicability

As for other stormwater BMPs, stormwater wetlands should not be used to manage the runoff during construction and site disturbance.

The use of stormwater wetlands is limited by a number of site constraints, including soils types, depth to groundwater, contributing drainage area, and available land area at site. Where land area is not a limiting factor, the use of several wetland design types is possible; where land area is limited, the use of the pocket type wetland design may be possible.

Soils, depth to bedrock, and depth to water table must be investigated before designing and siting stormwater wetlands. Medium-fine texture soils (such as loams and silt loams) are best to establish vegetation, retain surface water, permit groundwater discharge, and capture pollutants. At sites where infiltration is too rapid to sustain permanent soil saturation, an impermeable liner may be required. Where the potential for groundwater contamination is high, such as runoff from sites with a high potential pollutant load, the use of liners should be required.

At sites where bedrock is close to the surface, high excavation costs may make stormwater wetlands infeasible.

The recommended minimum design criteria for stormwater wetlands are listed in the design section, Table 3.C.1.

Effectiveness

Table 3.2 shows the range of removal efficiencies for stormwater wetlands. When the stormwater wetland is well planned, designed, constructed and maintained, then the reduction of the pollutant loadings should be at the high end of the reported values.

A review of the existing performance data indicates that the removal efficiencies of stormwater wetlands are slightly higher than those of conventional pond systems, e.g. as wet ponds or dry extended detention ponds. Of the four designs described above, the pond/wetland system has shown the most reliable in terms of overall performance. It should be noted that the performance of pocket wetlands has not been thoroughly monitored or reported. Removal efficiencies of pocket wetlands may be lower than other stormwater wetland designs, when they lack forebays. Pocket wetlands maybe prone to resuspension problems, may lack the dense vegetative cover of other stormwater wetland designs, and may lose volume to the groundwater.

Studies have also indicated that removal efficiencies of stormwater wetlands decline if they are covered by ice or receive snow melt. Performance also declines during the non-growing season and during the fall when the vegetation dies back. Until vegetation is well established, pollutant removal efficiencies may be lower than expected.

However, properly designed stormwater wetlands can be used to meet the Stormwater Management Standards. An off-line stormwater wetland design, for runoff quality treatment, in combination with an on-line runoff quantity control BMP may be preferred because large surges of water can damage stormwater wetlands. Furthermore, the shallow depths required to maintain the wetlands are at odds with the storage of large volumes, which are required to control runoff quantity.

Planning Considerations

Sites must be carefully evaluated when planning stormwater wetlands. Soils, depth to bedrock, and depth to water table must be investigated before designing and siting stormwater wetlands.

A "pondscaping plan" should be developed for each stormwater wetland. This plan should include hydrological calculations (or water budget), a wetland design and configuration, elevations and grades, a site/soil analysis, and estimated depth zones. The plan should also contain the location, quantity, and propagation methods for the stormwater wetland plants. Site preparation requirements, maintenance requirements and a maintenance schedule are also necessary components of the plan.

The water budget should demonstrate that there will be a continuous supply of water to sustain the stormwater wetland. The water budget should be developed during site selection and checked after preliminary site design. Drying periods of longer than two months have been shown to adversely effect plant community richness, so the water balance should confirm that drying will not exceed two months.

Establishment and maintenance of the wetland vegetation is an important consideration when planning a stormwater wetland. Horner et al. (1994) compiled the following list of recommendations for creating wetlands:

- In selecting plants, consider the prospects for success more than the specific pollutant capabilities. Plant uptake is an important removal mechanism for nutrients, but not for other pollutants. Information on vegetative pollutant removal has been compiled, however. The most versatile genera, with species throughout the country, for pollutant removal appear to be *Carex*, *Scirpus*, *Juncus*, *Lemna*, and *Typha*.

- Selection of native species should avoid those that invade vigorously.

- Since diversification will occur naturally, use a minimum of species adaptable to the various elevation zones within the stormwater wetland.

- Give priority to perennial species that establish rapidly.

- Select species adaptable to the broadest ranges of depth, frequency and duration of inundation (hydroperiod).

- Match site conditions to the environmental requirements of plant selections.

- Take into account hydroperiod and light conditions.

- Give priority to species that have already been used successfully in constructed wetlands and that are commercially available.

- Avoid using only species that are foraged by the wildlife expected on site.

- Establishment of woody species should follow herbaceous species.

- Add vegetation that will achieve other objectives, in addition to pollution control.

The plant community will develop best when the soils are enriched with plant roots, rhizomes, and seed banks. Use of "wetlands mulch" enhances the diversity of the plant community and speeds establishment. Wetlands mulch is hydric soil that contains vegetative plant material. This mulch can be obtained where wetlands soils are removed during dredging, maintenance of highway ditches, swales, sedimentation ponds, retention/detention ponds, clogged infiltration basins, or from natural wetlands that are scheduled to be filled under permit. Wetland soils are also available commercially. The upper 5.9 inches of donor soil should be obtained at the end of the growing season, and kept moist until installation.

Drawbacks to using wetlands mulch are its unpredictable content, limited donor sites, and the potential for the introduction of exotic, opportunistic species. Stormwater wetland vegetation development can also be enhanced through the natural recruitment of species from nearby wetland sites. However, transplanting wetland vegetation is still the most reliable method of propagating stormwater wetland vegetation, and it provides cover quickly. Plants are commercially available through wetland plant nurseries.

Design

See the following reference for complete design references:

Design of stormwater wetland systems. 1992. Schueler. MWCOG Information Center.

Stormwater wetlands can be constructed on-line, to control the runoff volumes from design storms, in conjunction with off-line runoff quality control components. The off-line design requires two pond components and adds to stormwater system costs. Stormwater wetlands may also be designed as on-line systems with a permanent pool area for treatment and a storage area for peak runoff rate control.

Schueler (1992) cites the following basic stormwater wetland design sizing criteria to follow to for optimum pollutant removal. These stormwater wetland design criteria and additional considerations are summarized in Table 3.C.1.

- Size for the prescribed water quality treatment volume.
- Have a minimum surface area in relation to the contributing watershed area. The reliability of pollutant removal tends to increase as the stormwater wetland to watershed ratio increases, although this relationship is not always consistent. The ratios of stormwater wetland to watershed listed in Table 3.C.1 may be reduced when it can be demonstrated that the internal flowpath and microtopography in the stormwater wetland will increase the storage area to volume ratio.
- Design the stormwater wetlands with the recommended proportion of "depth zones." Each of the four stormwater wetland designs has depth zone allocations which are given as a percentage of the stormwater wetland surface area. Target allocations for the four stormwater wetland designs are listed in Table 3.C.2. The four basic depth zones are:

  Deepwater zone
  From 1.5 to six feet deep. This zone supports little emergent vegetation, but may support submerged or floating vegetation. This zone can be further broken down into forebay, micropool and deepwater channels.

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Low marsh zone
Ranges from 18 to six inches below the normal pool. This area is suitable for the growth of several emergent wetland plant species.

High marsh zone
Ranges from six inches below the pool up to the normal pool. This zone will support a greater density and diversity of emergent wetland species than the low marsh zone. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone.

Semi-wet zone
Are those areas above the permanent pool that are inundated on an irregular basis that can be expected to support wetland plants.

- Design each stormwater wetland with the recommended proportion of treatment volumes, which have been represented as a percentage of the three basic depth zones (pool, marsh, extended detention). The allocations of treatment volume per zone are in both Table 3.C.1 and 3.C.2.

- Meet, at least, a minimum standard for the internal flow path through the stormwater wetland. This is intended to create the longest possible flow path through the stormwater wetland, and thereby increase the contact time over the surface area of the marsh. The stormwater wetland should be designed to achieve a dry weather flow path of 2:1 (length: width) or greater. A shorter flow path may be allowable for pocket wetlands.

- Prepare a water budget to demonstrate that the water supply to the stormwater wetland is greater than the expected loss rate.

- Provide extended detention for smaller storms (ED wetlands only). Schueler lists the following design standards for ED wetlands:

  -- **The volume of the extended detention should be no more than 50% of the total treatment volume.**

  -- **The target ED detention time for this volume should be 12 to 24 hours.**

  -- **To ensure constant detention time for all storm events the use of V-shaped or proportional weirs is encouraged.**

  -- Extended detention is defined here as the retention and gradual release of a fixed volume of stormwater runoff. For ED wetlands of less than 100 acres, the extended detention volume can be assumed to fill instantaneously.

-- When using a reverse slope pipe, the actual diameter of the orifice should be increased to the next greatest diameter on the standard pipe schedule, since the pipe will be equipped with a gate valve.

-- The ED orifice should be well protected from clogging.

-- The maximum extended detention water surface elevation should not be greater than three feet above the normal pool.

TABLE 3.C.1: Recommended Design Criteria For Stormwater Wetland Designs

Design Criteria	Shallow Marsh	Pond/ Wetland	ED Wetland	Pocket Wetland
Wetland/Watershed Ratio	0.2	0.01	0.01	0.01 (target)
Minimum Drainage Area (acres)	25	25	10	1 to 10
Length to Width Ratio (minimum)	1:1	1:1	1:1	1:1 (target)
Extended Detention	No	No	Yes	No
Allocation of Treatment Volume (pool/marsh/ED)	30/70/0	70/30/0	20/30/50	20/80/0
Allocation of Surface Area (deep/lo/high)	20/40/40	45/25/30	20/35/45	10/40/50
Cleanout Frequency (years)	2 to 5	10	2 to 5	10
Forebay	Required	No	Required	Optional
Micropool	Required	Required	Required	Optional
Outlet Configuration	Reverse-slope pipe or hooded broad crest weir	Reverse-slope pipe or hooded broad crest weir	Reverse-slope pipe or hooded broad crest weir	Hooded broad crest weir

(Schueler, 1992)

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TABLE 3.C.2: Recommended Allocation of Volumes for Stormwater Wetlands

Target Allocations	Shallow Marsh	Pond/ Wetland	ED Wetland	Pocket Wetland
<u>% of Surface Area</u>				
Forebay	5	0	5	0
Micropool	5	5	5	0
Deepwater	5	40	0	5
Lo Marsh	40	25	40	50
Hi-Marsh	40	25	40	40
Semi-wet	5	5	10	5
<u>% of Treatment Volume</u>				
Forebay	10	0	10	0
Micropool	10	10	10	0
Deepwater	10	60	-	20
Lo Marsh	45	20	20	55
Hi Marsh	25	10	10	25
Semi-wet	0	0	50	0

(Schueler, 1992)

The following are approximate depth ranges cited by Schueler (1992) for the various stormwater wetland designs:

Shallow marsh	0.5 to 1.5 feet
Pond/marsh	2.0 to 2.8 feet
ED Wetland	
Permanent pool	0.8 to 1.0 feet
Extended detention zone	3.3 feet
Pocket wetland	0.5 to 1.3 feet

Each stormwater wetland should be designed with a separate cell near the inlet to act as a sediment forebay. This forebay should have a capacity of at least 10% of the total treatment volume, have a direct and convenient access for cleanout, and will normally have a depth of 4 to 6 feet.

A safety bench, with a minimum width of ten feet, should surround all deep water cells; it should have a depth of zero to 18 inches below the normal water elevation of the pool.

Above ground berms or high marsh wedges should be placed at approximately 50 foot intervals, at right angles to the direction of the flow to increase the dry weather flow path within the stormwater wetland.

Before the outlet, a four to six foot deep micropool, (having a capacity of at least ten percent of the total treatment volume), should be included in the design to prevent the outlet from clogging. A reverse slope pipe or a hooded, broad crested weir is the recommended outlet control. The outlet from the micropool should be located at least one foot below the normal pool surface. To prevent clogging, trash racks or hoods should be installed on the riser. To facilitate access for maintenance, the riser should be installed within the embankment. Anti-seep collars should be installed on the outlet barrel to prevent seeping losses and pipe failures.

A bottom drain pipe with an inverted elbow to prevent sediment clogging should be installed for complete draining of the stormwater wetland and for emergency purposes or routine maintenance. Both the outlet pipe and the bottom drain pipe should be fitted with adjustable valves at the outlet ends to regulate flows.

Embankments and spillways should be designed in conformance with the state regulations and criteria for Dam Safety. All stormwater wetlands must have an emergency spillway capable of bypassing runoff from large storms without damage to the impounding structure.

An access for maintenance, with a minimum width of 15 feet and a maximum slope of 15%, must be provided by public or private right-of-way. This access should extend to the forebay, safety bench and outflow structure and should never cross the emergency spillway unless the spillway has been designed and constructed for this purpose.

Vegetative buffers around the perimeter of the stormwater wetland are recommended for erosion control and additional sediment and nutrient removal.

Construction

Schueler (1992) lists a seven step process for preparation of the wetland bed prior to planting:

- Prepare final pondscaping and grading plans for the stormwater wetland. At this time order wetland plant stock from aquatic nurseries.
- Once the stormwater wetland volume has been excavated, the wetland should be graded to create the major internal features (pool, aquatic bench, deep water channels, etc.).

- Top soil and/or wetland mulch are added to the stormwater wetland excavation. Since deep subsoils often lack the nutrients and organic matter to support vigorous plant growth, the addition of mulch or topsoil is important. If it is available, wetland mulch is preferable to topsoil.

- After the mulch or topsoil has been added, the stormwater wetland needs to be graded to its final elevations. All wetland features above the normal pool should be stabilized temporarily.

- After grading to final elevations, the pond drain should be closed and the pool allowed to fill. A good design recommendation is to evaluate the wetland elevations during a standing period of approximately six months. During this time the stormwater wetland can experience stormflows and inundation, so that it can be determined where the pondscaping zones are located and whether or not the final grade and microtopography will persist over time.

- Before planting, the stormwater wetland depths should be measured to the nearest inch to confirm planting depth. The pondscape plan may be modified at this time to reflect altered depths or availability of plant stock.

- Erosion controls should be strictly applied during the standing and planting periods. All areas above the normal pool elevation should be vegetatively stabilized during the standing period, usually with hydroseeding.

- The stormwater wetland should be de-watered at least three days before planting, as a dry wetland is easier to plant than a wet one.

Maintenance

Stormwater wetlands require considerable routine maintenance, but do not require large, infrequent sediment removal, unlike conventional pond systems that require relatively minor routine maintenance and expensive sediment removal at infrequent intervals.

Careful observation of the system over time is required. In the first three years after construction, twice a year inspections are needed during both the growing and non-growing season. Data gathered during these inspections should be recorded, mapped and assessed. The following observations should be made during the inspections:

- Types and distribution of dominant wetland plants in the marsh;

- The presence and distribution of planted wetland species; the presence and distribution of volunteer wetland species; signs that volunteer species are replacing the planted wetland species;

- Percentage of unvegetated standing water (excluding the deep water cells which are not suitable for emergent plant growth);
- The maximum elevation and the vegetative condition in this zone, if the design elevation of the normal pool is being maintained for wetlands with extended zones.
- Stability of the original depth zones and the microtopographic features;
- Accumulation of sediment in the forebay and micropool; and
- Survival rate of plants in the wetland buffer.

Regulating the sediment input to the wetland is the priority maintenance activity. The majority of sediments should be trapped and removed before they reach the wetlands either in the forebay or in a pond component. Gradual sediment accumulation in the wetland results in reduced water depths and changes in the growing conditions for the emergent plants. Furthermore, sediment removal within the wetland can destroy the wetland plant community.

Shallow marsh and extended detention wetland designs include forebays to trap sediment before reaching the wetland. These forebays should be cleaned out every year.

Pond/wetland system designs do not include forebays as the wet pond itself acts as an oversized forebay. Sediment cleanout of pond/wetland systems is needed every 10 years.

Summary: Constructed [Stormwater] Wetland Guidelines

Site Criteria

- Stormwater wetlands require at least ten acres of contributing drainage area and may require dry weather base flow in order to maintain appropriate shallow marsh water elevations.
- The contributing drainage area to any individual pocket wetland may be one to ten acres. Pocket type design wetlands should be excavated to groundwater.
- Sites should be carefully evaluated before planning stormwater wetlands. Soils, depth to bedrock, and depth to water table must be investigated before siting stormwater wetlands.

- The following minimum setback requirements should apply to stormwater wetland installations:
  - -- Distance from a septic system leach field - 50 feet.
  - -- Distance from a septic system tank - 25 feet.
  - -- Distance from a property line - 10 feet.
  - -- Distance from a private well - 50 feet.

Design Criteria

- Before designing the stormwater wetland, a water budget should be developed to ensure that there is an adequate and steady supply of water to maintain the water elevations. A detailed plan should also be developed for each stormwater wetland.

- Stormwater wetlands should be sized to treat the prescribed water quality volumes and control the peak discharge rates from the 2 and 10 year frequency storm events.

- The surface area and treatment volume of the stormwater wetland should be allocated to meet targets for the depth of components in the wetland (See Table 3.C.2).

- The stormwater wetland should be designed to achieve a dry weather flow path of 2:1 (length:width) or greater. A shorter flow path may be allowable for pocket wetlands.

- Each stormwater wetland should be designed with a separate cell near the inlet to act as a sediment forebay. This forebay should have a capacity of at least 10% of the total treatment volume, have a convenient access for cleanout, and will normally have a depth of 4 to 6 feet.

- A safety bench, with a minimum width of ten feet, should surround all deep water cells; the bench should be at a depth of zero to 18 inches below the normal water elevation of the pool.

- Above ground berms or high marsh wedges should be placed at approximately 50 foot intervals, and at right angles to the direction of the flow to increase the dry weather flow path within the stormwater wetland.

- At the outlet, include a 4 to 6 foot deep micropool, having a capacity of at least ten percent of the total treatment volume, to prevent the outlet from clogging. A reverse slope pipe or a hooded, broad crested weir is the recommended outlet control. The outlet from the micropool should be located at least one foot below the normal pool surface.

- To prevent clogging, trash racks or hoods should be installed on the riser. To facilitate access for maintenance, the riser should be installed near or within the embankment. Anti-seep collars should be installed on the outlet barrel to prevent seeping losses and pipe failures.

- A bottom drain pipe with an inverted elbow should be installed for complete draining of the stormwater wetland for emergency purposes or routine maintenance. Both the outlet pipe and the bottom drain pipe should be fitted with adjustable valves at the outlet ends to regulate flows.

- Embankments and spillways should be designed in conformance with the criteria in the state Dam Safety regulations. All stormwater wetlands must have an emergency spillway capable of bypassing runoff from large storms without damage to the impounding structure.

- An access for maintenance, with a minimum width of 15 feet and a maximum slope of 15%, must be provided by public or private right-of-way. Access must extend to forebays, safety bench and outflow structure.

- Vegetative buffers around the perimeter of the stormwater wetland are recommended for erosion control and additional sediment and nutrient removal.

Construction Criteria

- Once the stormwater wetland volume has been excavated, the wetland should be graded to create the major internal features (pool, aquatic bench, deep water channels, etc.). Top soil and/or wetland mulch are added to the stormwater wetland excavation, and the stormwater wetland is graded to its final elevations. All wetland features above the normal pool should be stabilized temporarily.

- After grading to final elevations, the pond drain should be closed and the pool allowed to fill. Usually nothing should be done to the stormwater wetland for six to nine months or until the next planting season. During this time the stormwater wetland can experience stormflows and inundation, so that it can be determined where the pondscaping zones are located and whether or not the final grade and microtopography will persist over time.

- Before planting, the stormwater wetland depths should be measured to the nearest inch to confirm planting depth. The pondscape plan may be modified at this time to reflect altered depths or availability of plant stock.

- The stormwater wetland should be de-watered at least three days before planting, as a dry wetland is easier to plant than a wet one.

Maintenance Criteria

- Maintenance is required for the proper operation of stormwater wetlands. Plans for stormwater wetlands should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule.

- Stormwater wetlands require considerable routine maintenance, but do not require large, infrequent sediment removal.

- Regulating the sediment input to the wetland is the priority maintenance activity. The majority of sediments should be trapped and removed before they reach the wetland. Sediment accumulation in the wetland gradually results in reduced water depths and changes in the growing conditions for the emergent plants. In addition, sediment removal within the wetland can destroy the wetland plant community.

- Shallow marsh and ED wetland designs should include forebays to trap sediment before reaching the wetland. These forebays should be cleaned out every year.

- Pond/wetland system designs may not include forebays as the wet pond itself acts as an oversized forebay. Sediment cleanout of pond/wetland systems is needed every 10 years.

- Careful observation of the system development over time is required. In the first three years after construction, twice a year inspections are required during both the growing and non-growing seasons. Data gathered during these inspections should be recorded, mapped and assessed.

Water Quality Swales

Definition

The difference between water quality swales and drainage channels is in the design and planned use of the open channel conveyance.

Water quality swales are designed primarily for the prescribed stormwater water quality volume and have incorporated specific features to enhance their stormwater pollutant removal effectiveness. Pollutant removal rates are significantly higher for water quality swales than for drainage channels. Water quality swales include dry swales, wet swales, and grassed swales or "biofilters".

Drainage channels, on the other hand, are designed with sufficient capacity to convey runoff safely, without erosion, during large (10-year frequency) storm events. Other than basic channel size and geometry, there are no specific design modifications to enhance pollutant removal capabilities. Typically, pollutant removal efficiency is very low for drainage channels. See section 3.K for a discussion on drainage channel design.

Figure 3.D.1 provides a schematic of a dry swale, Figure 3.D.2 depicts a typical wet swale, and Figure 3.D.3 illustrates a grassed "biofilter" swale.

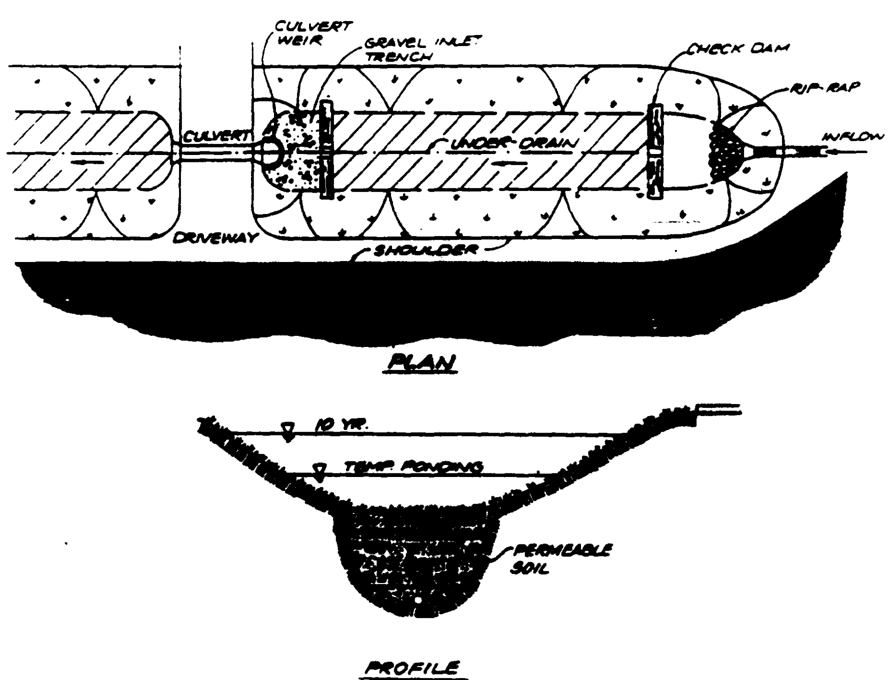


Figure 3.D.1: Schematic of a Dry Swale

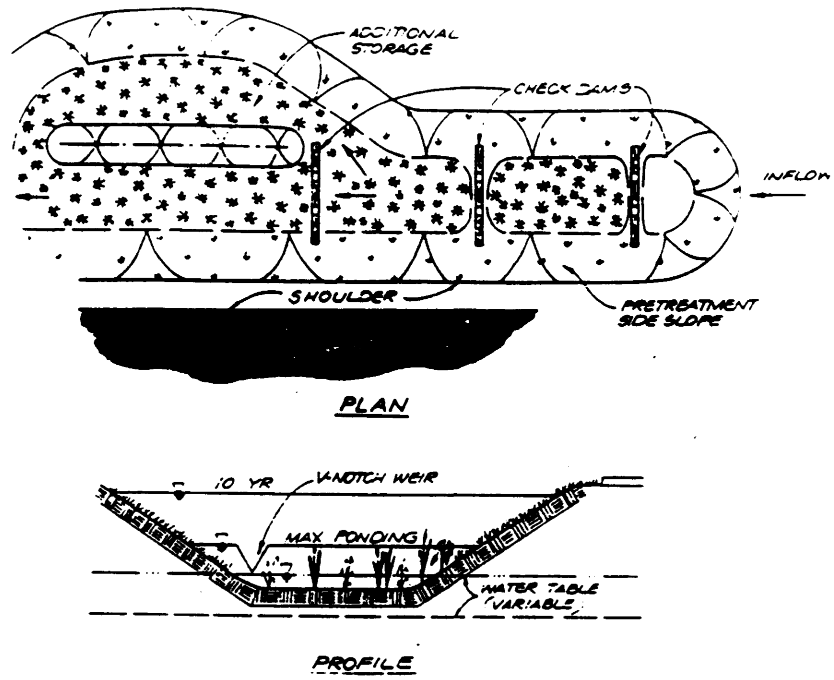


Figure 3.D.2: Schematic of a Wet Swale

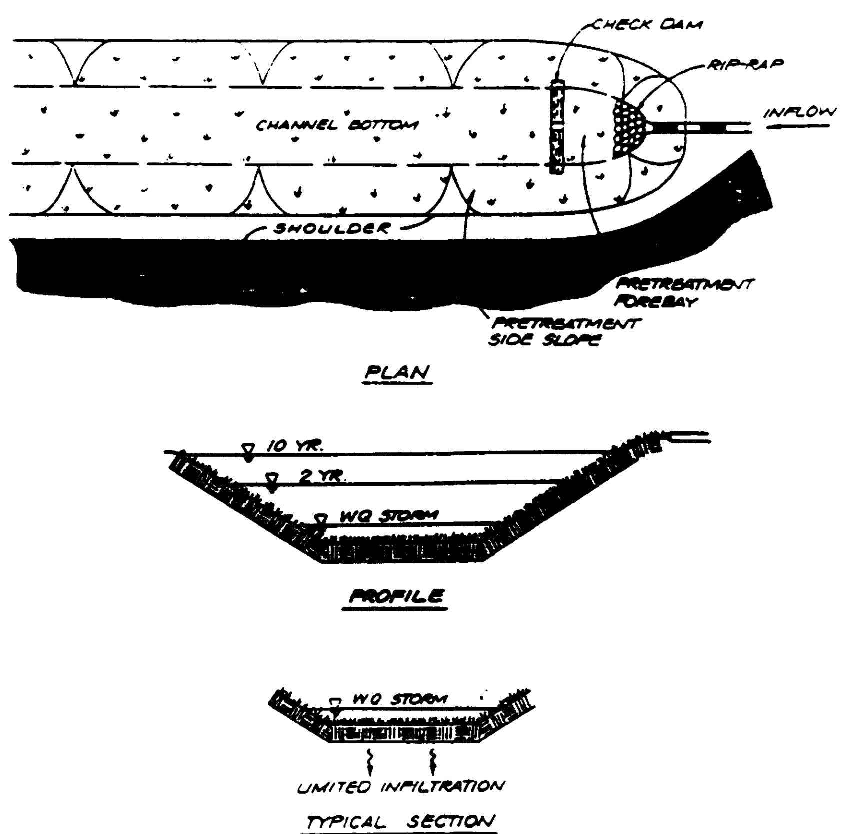


Figure 3.D.3: Schematic of a Grassed "Biofilter" Swale

Purpose

- To provide control for certain peak runoff rates by retarding and impounding stormwater and conveying it downstream at velocities low enough to protect against channel and streambank erosion.
- To provide runoff volume control, (especially for dry swales), by means of gradual infiltration of stormwater, as it passes through the water quality swale.
- To provide moderate to high pollutant removal through sedimentation, filtration, nutrient uptake, and infiltration.

Advantages

- Controls peak discharges by reducing runoff velocity and promoting infiltration (especially for dry swales).
- Provides pretreatment by trapping, filtering and infiltrating particulate and associated pollutants.
- Generally less expensive than curb and gutter systems.
- Roadside swales provide water quality and quantity control benefits, while reducing driving hazards by keeping stormwater flows away from street surfaces.
- Accent natural landscape.

Disadvantages

- Higher degree of maintenance required than for curb and gutter systems.
- Roadside swales are subject to damage from off street parking and snow removal.

Applicability

Water quality swales are widely applicable, especially the three types of modified designs. Swales are most applicable to residential and institutional areas of low to moderate density. The percentage of impervious cover in the contributing areas should be relatively small, however. Water quality swales can also be used in parking lots to break up areas of impervious cover.

It should be noted that wet swales may not be desirable for some residential applications, such as frontage lots, because standing and stagnant water may be present at times.

Along the edge of smaller roadways, water quality swales can be used in place of curb and gutter systems. Water quality swales may be used in connection with drainage channels to overcome space and other constraints. Water quality swales may not be applicable to sites with many driveway culverts or extensive sidewalk systems. When using water quality swales in combination with roadways and sidewalks, it is most appropriate to place the swale between the two impervious areas.

The topography and soils on the site will determine the applicability of certain design modifications for water quality swales. The topography should allow for the design of a swale with sufficient slope and cross-sectional area to maintain nonerosive flow velocities. Porous soils lend themselves to the use of dry swales and grassed "biofilter" swales, while soils with poor drainage are more suited to wet swales. Water quality swales are designed to retain and treat the entire water quality volume, but may also be able to convey additional runoff volume to other downgradient BMPs.

Effectiveness

Table 3.2 shows the range of pollutant removal efficiencies for water quality swales. When the swale is well planned, designed, constructed and maintained, then the reduction of pollutant loadings should be at the high end of the reported values. Based on the probable range of results, careful consideration must be given to design and proper siting to meet the Stormwater Management Standards. Pretreatment devices, such as forebays behind checkdams are necessary.

Water quality swales assist in controlling runoff volumes and peak discharge rates in several ways, depending on the type of swale. Dry swales rely primarily on infiltration through existing or imported soils. Wet swales achieve pollutant removal both from sediment accumulation and mechanical removal, and through trapping and uptake by wetland vegetation. Grassed swales also utilize biological uptake, in addition to sediment trapping.

Planning Considerations

When designing a water quality swale, the primary considerations are soils, capacity, erosion resistance and vegetation. Site conditions and design specifications limit the use of water quality swales. Generally, at least one of the three basic swale types will be suited to the development site.

Swale capacity should be based on the maximum expected reduction in velocity which occurs during the annual peak growth period. Usually the maximum expected drop in velocity occurs when vegetation is at its maximum growth for the year. The minimum level should be used when checking velocity through the swale. This usually occurs during the early growing season and dormant periods.

Other important factors to be considered when planning for water quality swales are land availability, maintenance requirements and soil characteristics. The topography of the site should allow for the design of a swale with sufficient slope and cross-sectional area to maintain a nonerosive flow rate, and to retain/detain the prescribed water quality runoff volume. The longitudinal slope of the swale should be as close to zero as possible and not greater than 5%.

The grass or vegetation types used in swales should be suited to soil and water conditions. Wetland hydrophytes or obligate species are generally more water tolerant than facultative species and are good selections for wet swales, while grassed swales should be planted with species that produce fine and dense cover and are adapted to varying moisture conditions.

Design

See the following for complete design references:
Site Planning for Urban Stream Protection. 1995. Schueler. Center for Watershed Protection.

Watershed Protection Techniques, Volume 2, Number 2, 1996. Center for Watershed Protection.

Biofiltration swale performance, recommendations, and design considerations. 1992. Metro Seattle: Water Pollution Control Department. Seattle, WA.

Dry Swales

Dry swales should be sized to infiltrate the entire prescribed water quality runoff volume, allowing for full filtering or infiltration through the bottom of the swale. It is often necessary to modify the parent soils to improve their infiltration rate.

Dry swales should have a soil bed that is 30 inches deep and composed of approximately 50% sand and 50% loam.

Pretreatment is required to protect the filtering and infiltration capacity of the swale bed. Pretreatment is generally a sediment forebay behind a checkdam with a pipe inlet. For lateral inflows, gentle slopes or a pea gravel diaphragm may be used.

Where soils do not permit full infiltration, a longitudinal perforated underpipe should be placed on the bottom of the swale bed.

Dry swales are parabolic or trapezoidal in cross-section, with side slopes no greater than 3:1 (horizontal:vertical) and bottom widths ranging from 2 to 8 feet.

Channels should be sized to convey the 10-year storm and channel slopes

Summary: Guidelines for Water Quality Swales

Site Criteria

- The topography of the site should allow for a longitudinal slope of no greater than 5%.
- Soils are a consideration for the type of water quality swale planned. In some cases, parent soil may need to be augmented to utilize dry swales and grassed "biofilter" swales.
- Widely applicable to residential and low density commercial and industrial sites. Road applications excellent.

Design Criteria

- Pretreatment is typically a forebay behind a checkdam. Gentle slopes or pea gravel diaphragms for lateral inflows.
- Water quality swales should be designed to capture and treat the entire prescribed stormwater runoff water quality volume.
- The longitudinal slope in the water quality swale should not exceed 5%.
- Side slopes of 3:1 or flatter are recommended for maintenance and to prevent side slope erosion. Runoff velocities should not cause erosion for the 2 year stormwater runoff event. The swale should be sized to convey the 10 year storm volume.
- Dry swales require 30 inch deep bed of well drained soils, consisting of about 50% sand and 50% loam. Onsite soils may be enhanced, and where well drained soils do not exist, a perforated underdrain should be utilized.
- Wet swales require saturated soil conditions to support wetland vegetation. Check dams must be utilized to establish multiple cells.
- Grassed swales should be sandy loam or a similar soil type with no more than 20% clay. Soil augmentation may be necessary. Dense grass cover must be achieved.
- Outlet protection must be used at any discharge point from a water quality swales to prevent scour.

Construction Criteria

- Temporary erosion and sediment controls should be utilized during construction.
- Mulch anchoring should be done immediately after seeding.

Maintenance Criteria

- Maintenance is required for the proper operation of water quality swales. Plans for water quality swales should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule.

- Water quality swales should be inspected at least semi-annually, and maintenance and repairs made as necessary. Additional inspections should be scheduled during the first few months to make sure the vegetation becomes adequately established. Repairs and reseeding should be done as required.

- Swales should be mowed at least once per year. Grass clippings should be removed. The grass must not be cut too often or shorter than four inches, in order to maintain the effectiveness of the swale.

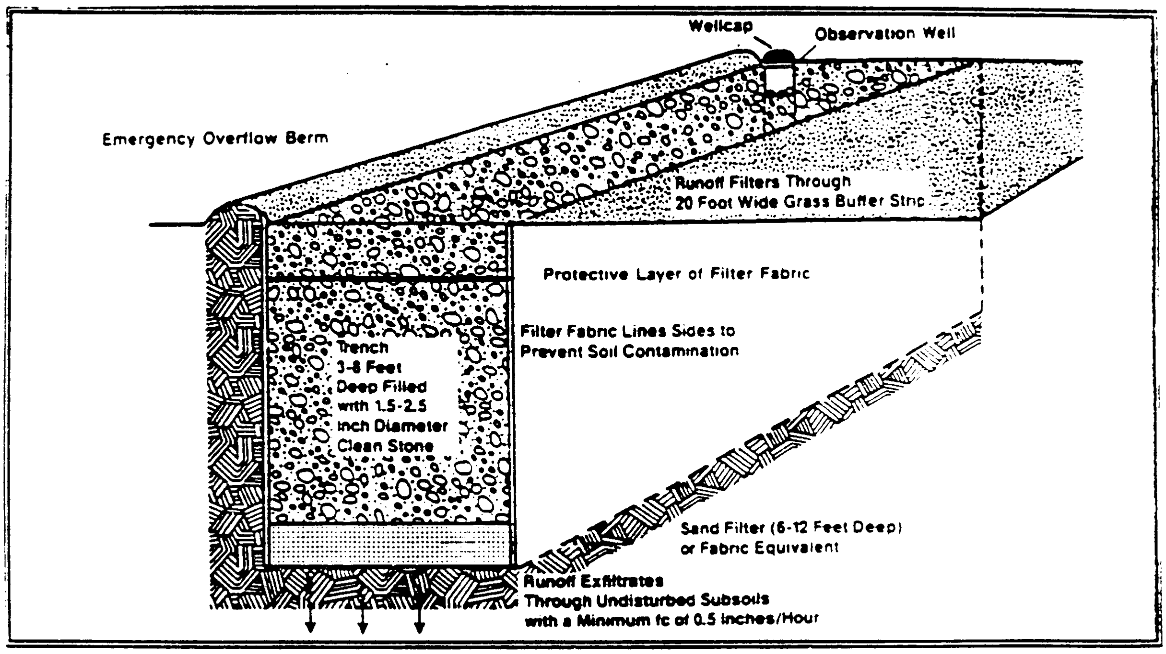
- Sediment and debris should be removed manually, at least once per year, before the vegetation is adversely impacted.

- Care should be taken to protect water quality swales from snow removal and disposal practices and off street parking.

Infiltration Trenches

Definition

Infiltration trenches are shallow, excavations that are filled with stone to create underground reservoirs for stormwater runoff. The runoff gradually exfiltrates through bottom of the trench into the subsoil and eventually into the water table. Figure 3.E.1 provides a schematic of a typical infiltration trench. Trench designs may be modified to include vegetative cover and other features, establishing a biofiltration area.



(Schueler, 1987)

Figure 3.E.1: Schematic of an Infiltration Trench

Infiltration trenches may be designed for complete exfiltration or partial exfiltration where a portion of the runoff volume is routed to the trench and the remainder is conveyed to additional BMPs.

Full Exfiltration Trench Systems

These systems are sized to provide storage and exfiltration for the entire volume of runoff from a design storm. Full exfiltration systems provide total peak discharge, runoff volume and water quality control for all storm events equal to or less than the design storm. An emergency overflow channel is used to discharge runoff volumes in excess of the design storm. Economic and physical constraints can restrict the use of full exfiltration systems. Generally, it is not practical to provide storage for large infrequent storms, such as the 100 year storm.

Partial or Water Quality Exfiltration Trench Systems
This design exfiltrates a portion of the runoff, while the remainder is conveyed to additional BMPs. Two methods of partial infiltration are recommended. The first relies on off-line treatment where a portion of the runoff, or the "first-flush," is routed from the main channel into the trench by means of a weir structure or other diversion. The second method is on-line, and utilizes a perforated pipe at the top of the trench. When the trench has filled to capacity, the excess runoff volumes are discharged through the perforated pipe to other BMP structures.

Purpose

- To reduce runoff volume and peak discharge through infiltration (groundwater recharge).
- To remove soluble and particulate pollutants from runoff.

Advantages

- Promotes groundwater recharge.
- Reduces downstream flooding and protects streambank integrity.
- Preserves the natural water balance of the site.
- Provides a high degree of runoff pollution control when properly designed and maintained.
- Reduces the size and cost of downstream stormwater control facilities and/or storm drain systems by infiltrating stormwater in upland areas.
- Utilized where space is limited.

Disadvantages

- High failure rates due to improper siting, design, construction and maintenance.
- Generally, use is restricted to small drainage areas.
- Depending on soil conditions and aquifer susceptibility, a slight risk of groundwater contamination exists.
- Requires frequent maintenance.
- Susceptible to clogging by sediment.

Applicability

Infiltration trenches are feasible at sites with gentle slopes, permeable soils, and where bedrock and seasonal high groundwater levels are at least four feet below surface. Contributing drainage areas should be relatively small, and should not exceed 5 acres. Infiltration trenches are suitable for parking lots, rooftop areas and small residential developments.

Infiltration trenches should always be constructed with pretreatment. The use of infiltration technologies should be avoided in high potential pollutant loading areas. In groundwater drinking supply recharge areas (Zone II and Interim Wellhead Protection Areas (IWPA)), infiltration technologies may be used for uncontaminated rooftop runoff only.

With these considerations in mind, the most efficient way to encourage infiltration and reduce pollutant loadings in a cost efficient manner is to separate contaminated runoff from uncontaminated runoff. Uncontaminated stormwater runoff may be infiltrated directly, while contaminated runoff (such as from roads, parking areas and driveways) must be collected and treated using an appropriate BMP or BMP combination, and then subsequently routed (after treatment) back into infiltration facilities. In this manner, the infiltration facilities perform double-duty: 1) they infiltrate uncontaminated stormwater during and immediately following the storm event, and 2) they provide infiltration for pretreated stormwater from polluted areas following an appropriate detention/treatment time for the selected design.

Infiltration trenches should always be constructed with pretreatment. The use of infiltration technologies should be avoided in high potential pollutant loading areas. In groundwater drinking supply recharge areas (Zone II and Interim Wellhead Protection Areas (IWPA)), infiltration technologies may be used for uncontaminated rooftop runoff only.

Infiltration trenches are adaptable to many sites because of their thin profile. The recommended site criteria are listed in Table 3.E.1.

Infiltration trenches can be used in upland areas of larger sites to reduce the overall amount of runoff and improve water quality in the lower areas of these sites, thereby reducing the size requirements and costs for downstream BMPs.

With the addition of water tolerant plant species and other design modifications, pollutant removal performance, aesthetic value, and wildlife benefits may be enhanced. This type of biofiltration is a cross between an infiltration trench and an infiltration basin.

Effectiveness

Infiltration trenches are not intended to remove coarse particulate pollutants; these must be removed by a pretreatment device before entering the trench. The pollutant removal efficiency is dependent upon how much runoff is exfiltrated by the trench. Thus, full exfiltration systems provide greater pollutant removal than partial exfiltration systems, which, in turn, are more efficient than water quality exfiltration systems.

- Infiltration trenches are prone to failure due to clogging. The use of pretreatment BMPs will minimize failure and maintenance requirements. Aggressive maintenance plans and schedules should also help to preserve the effectiveness of the system.

- After construction, infiltration trenches should be inspected after every major storm for the first few months to ensure proper stabilization and function. Thereafter, the trench should be inspected at least twice per year. Water levels in the observation well should be recorded over several days to check trench drainage.

- Preventive maintenance should be performed at least twice a year, and ideally sediment should be removed from pretreatment BMPs after every major storm event.

- Ponded water inside the trench (as visible from the observation well) after 24 hours or several days most likely indicates that the bottom of the trench is clogged.

- Water ponded at the surface of the trench may indicate only surface clogging.

- Clogging in trenches occurs most frequently on the surface. Grass clippings, leaves, and accumulated sediment should be removed as frequently as possible from the surface of the trench.

- Pretreatment BMPs should be inspected and cleaned at a minimum during the regular bi-annual checks, and more frequently if possible. Vegetated swales should be cleared of accumulated sediment, mowed, and then grass clippings, leaves, and trash should be removed. Tree seedlings that become established should be removed. Water quality inlets should be cleared of accumulated sediment, leaves, and debris at each regular inspection, and more frequently if possible. Inlet and outlet pipes should be checked for clogging.

- When ponding occurs at the surface or in the trench, corrective maintenance is required immediately.

- For surface clogging, the topsoil or first layer of stone aggregate and the filter fabric must be removed and replaced.

- Ponding water in the trench indicates infiltration failure from the bottom. In this case, all of the stone aggregate and filter fabric or media must be removed and replaced. Accumulated sediment should be removed from the trench bottom. The bottom should be scarified or tilled to help induce infiltration.

Infiltration Basins

Definition

Infiltration basins are stormwater runoff impoundments that are constructed over permeable soils. Pretreatment is critical for effective performance of infiltration basins. Pretreatment is critical for effective performance of infiltration basins. Runoff from the design storm is stored until it exfiltrates through the soil of the basin floor. Figure 3.F.1 provides a schematic of the typical infiltration basin.

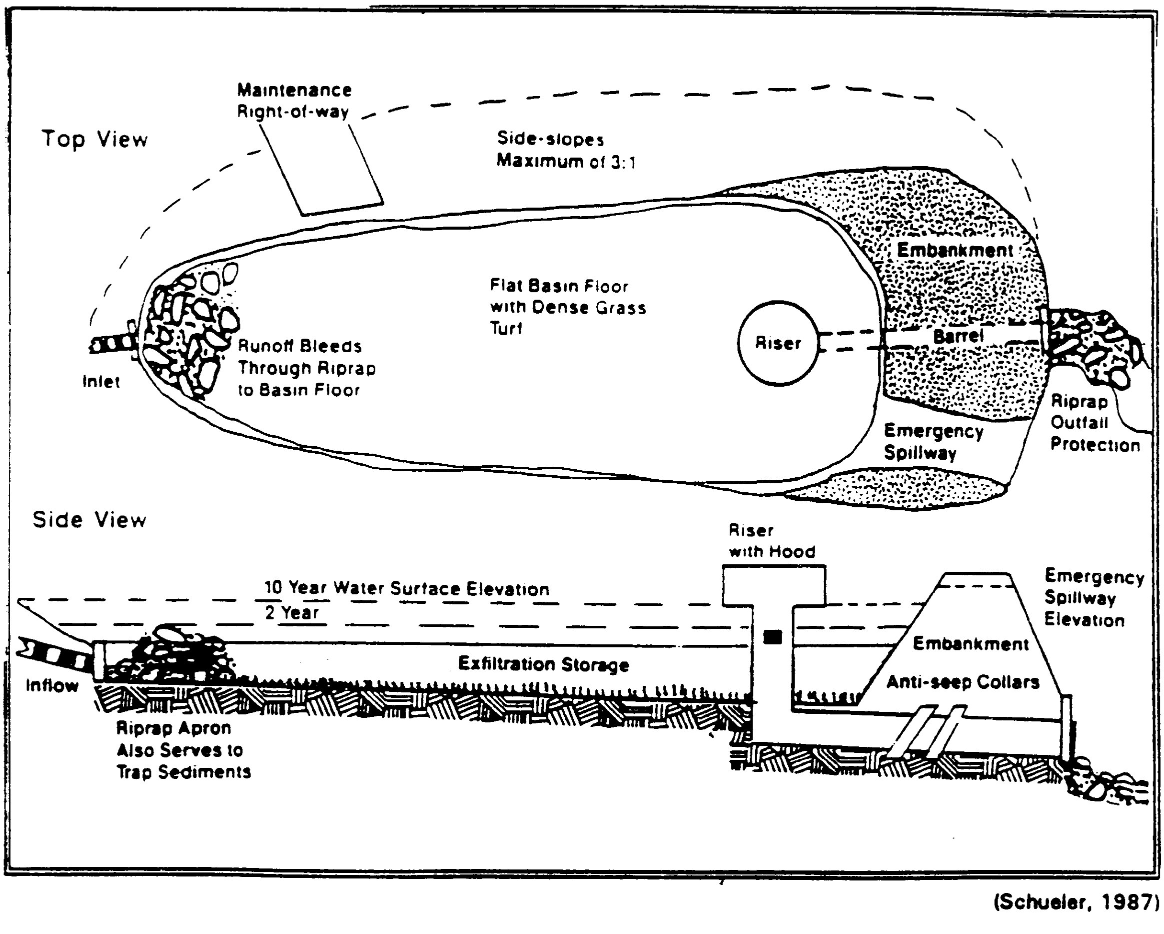


Figure 3.F.1: Schematic of an Infiltration Basin

The following are variations of the infiltration basin design.

Full Exfiltration Basin Systems

These basin systems are sized ized to provide storage and exfiltration for the entire volume of runoff from the water quality design storm. They provide total peak discharge, runoff volume and water quality control for all storm events equal to or less than the design storm. An emergency overflow channel is used to discharge runoff volumes in excess of the design storm.

Partial or Off-line Exfiltration Basin Systems
Partial basin systems exfiltrate a portion of the runoff (usually the first flush or the first half inch), while the remaining runoff is conveyed to other BMPs. The use of a flow splitter or weir diverts the first flush into the infiltration basin. This design is useful at sites where exfiltration cannot be achieved by downstream detention BMPs because of site condition limitations.

Purpose

- To collect and store the runoff from a specific design storm and allow exfiltration of this runoff.
- To remove soluble and particulate pollutants.
- To provide groundwater recharge, reduce runoff volume and reduce peak discharge.

Advantages

- Provides groundwater recharge.
- Reduces local flooding.
- Preserves the natural water balance of the site.

Disadvantages

- High failure rates due to improper siting, design and lack of maintenance.
- Restricted to fairly small drainage areas.
- Depending on soil condition and aquifer susceptibility, a slight risk of groundwater contamination exists.
- Not appropriate for treating significant loads of sediment and other pollutants.
- Requires frequent maintenance.

Applicability

The application of infiltration basins is restricted by numerous site factors including, soils, slope, depth to water table, depth to bedrock or impermeable layer, contributing watershed area, proximity to wells, surface waters, foundations, and others. The recommended site criteria for infiltration basins are listed in Table 3.F.1.

Generally, infiltration basins are suitable to sites with gentle slopes, permeable soils, relatively deep bedrock and groundwater levels, and a contributing watershed area of approximately 2 to 15 acres.

Infiltration basins should are not appropriate for areas which contribute high concentrations of sediment, or suspended solids, without adequate pretreatment.

With these considerations in mind, the most efficient way to encourage infiltration and reduce pollutant loadings in a cost efficient manner is to separate contaminated runoff from uncontaminated runoff. Uncontaminated stormwater runoff may be infiltrated directly, while contaminated runoff (such as from roads, parking areas and driveways) must be collected and treated using an appropriate BMP or BMP combination, and then subsequently routed (after treatment) back into infiltration facilities. In this manner, the infiltration facilities perform double-duty: 1) they infiltrate uncontaminated stormwater during and immediately following the storm event, and 2) they provide infiltration for pretreated stormwater from polluted areas following an appropriate detention/treatment time for the selected design.

Effectiveness

Table 3.2 shows the range of pollutant removal efficiencies for infiltration basins. When if the infiltration basin is well planned, designed, constructed, and maintained, then the reduction of pollutant loadings should be at the high end of the reported values. With pretreatment and adequate maintenance, infiltration basins can be used to meet the stormwater quality standards.

Infiltration basins are not intended to remove coarse particulate pollutants; these must be removed by a pretreatment device before they enter the basin. The pollutant removal efficiency of the basin is dependent upon how much runoff is exfiltrated by the basin.

Infiltration basins have limited capabilities for controlling peak discharge. Generally, it is not feasible, physically or economically, to provide storage for large infrequent storms, such as the 100-year storm. Infiltration basins can control peak discharges to pre-development levels for the design and smaller storms, however. Like all infiltration systems, infiltration basins are valuable in reducing the runoff volume from a site.

Planning Considerations

Sites must be carefully evaluated before planning infiltration basins. Soils, depth to bedrock, and depth to water table must be investigated. Suitable parent soils should have a minimum percolation rate of 0.5 inches per hour.

Slopes of the contributing drainage area should not be steep and generally should not exceed five percent.

Pretreatment (water quality inlets or sump pits, swales with check dams, or sediment forebays/traps) should be a fundamental component of any BMP system relying on infiltration. In many cases, to perform as designed and to achieve the expected pollutant removal rates, engineered stormwater controls require pretreatment. Infiltration BMPs, for instance, have poor performance and high failure rates due to clogging from sediments, and therefore require pretreatment of stormwater in order to remove as much of the suspended solids as possible before entering the system. It is important to note that this general practice applies also when infiltrating rooftop runoff, even though in most cases it is presumed to be uncontaminated. It is a practical decision to implement some form of pretreatment to remove sediments, leaf litter, and debris. This pretreatment will help to ensure the proper functioning of the infiltrating facility and allow for longer periods between maintenance. Some examples of pretreatment controls include water quality inlets, vegetated drainage systems, and sediment traps. These controls, when designed properly, may remove some 25-30% of sediment loads. These pretreatment controls alone will not suffice to meet the 80% standard.

Designs for infiltration basins should emphasize accessibility and ease of maintenance

The use of infiltration methods for stormwater management should be cautioned in recharge areas of groundwater drinking water supplies. These is a potential risk of groundwater contamination from polluted runoff.

Design

See the following for complete design references:

Stormwater Infiltration. 1994. Ferguson. CRC Press. 2000 Corporate Blvd. NW, Boca Raton, FL. 33431.

Standards and Specifications for Infiltration Practices. 1984. Maryland Dept. of Environment. Baltimore, MD.

Infiltration basins should be provided with a sediment forebay or another pretreatment device designed to capture coarse particulate pollutants, and where necessary, oil and grease, from the contributing watershed.

Site conditions must be investigated. Infiltration basins must have a minimum separation from seasonal high groundwater or bedrock of 2 feet.

To prevent incoming flow velocities from reaching erosive levels, which can scour the basin floor, inlet channels to the basin should be stabilized. Riprap may be used for this purpose. The riprap should be designed to terminate in a broad apron, which spreads the runoff more evenly over the basin surface to promote better infiltration.

The required storage volume of an infiltration basin is the sum of the quantity of runoff entering the basin from the contributing area and the precipitation directly entering the basin.

Soil infiltration rates should be determined by specific samples at the location of the basin. One soil boring for every 5,000 feet of basin area is recommended, with a minimum of three borings for each infiltration basin. Borings should be taken at the actual location of the proposed infiltration basin so that any localized soil conditions are detected. The design of the infiltration basin should be based on the slowest rates obtained from the infiltration tests performed at the site. The minimum acceptable final soil infiltration rate is 0.5 inches per hour.

A storage time of 72 hours is recommended. Forty eight hours is recommended as the minimum storage time.

The bottom of the basin should be graded as flat as possible to provide uniform ponding and exfiltration of the runoff across the floor. Enhanced deposition of sediment in low areas may clog the surface soils, resulting in reduced infiltration and wet areas. The side slopes of the basin should be no steeper than 3:1 (horizontal: vertical), to allow for proper vegetative stabilization, easier mowing, easier access, and better public safety.

Immediately following basin construction, the bottom and side slopes of the basin should be stabilized with a dense turf of water tolerant grass. Use of low maintenance, rapidly germinating grasses, such as fescues and reed canary grass, are recommended. During the first two months, the newly established vegetation should be inspected several times to determine if any remedial actions (reseeding, irrigation, etc.) are necessary. Trees and shrubs should not be planted within the basin or on the impounding embankments, in order to reduce the chance of basin failure due to root decay or subsurface disturbance. The root penetration and thatch formation of the turf maintains and may enhance the original infiltration capacity. Soluble nutrients are taken up by the turf for growth, improving the pollutant removal capacity. The dense turf will impede soil erosion and scouring of the basin floor.

In place of turf, a basin liner of 6 to 12 inches of fill material, such as coarse sand, may be used. This material can be cleaned or replaced as needed. Loose stone, riprap, and other irregular materials requiring hand removal of debris and weeds should not be used.

Embankments and spillways should be designed to conform with the regulatory guidelines of the state's Office of Dam Safety (302 CMR 10.00). All infiltration basins must have an emergency spillway capable of bypassing runoff from large storms without damage to the impounding structure.

Vegetative buffers around the perimeter of the basin are recommended for erosion control and additional sediment and nutrient removal.

Construction

The minimum construction criteria for infiltration basins are presented in Table 3.D.1. Care should be taken during construction to minimize the risk of failure of the infiltration basin.

Infiltration basins should never be used as temporary sediment traps for construction activities.

Light earth-moving equipment should be used to excavate the infiltration basin. Use of heavy equipment causes compaction of the soils beneath the basin floor and side slopes, resulting in reduced infiltration capacity. Since some compaction of soils will occur during construction, the basin floor should be deeply tilled with a rotary tiller or a disc harrow to restore infiltration rates after final grading.

Proper erosion/sediment control should be utilized during construction.

Immediately following basin construction, the floor and side slopes of the basin should be stabilized with a dense turf of water tolerant grass. Use of low maintenance, rapidly germinating grasses, such as fescues and reed canary grass, are recommended.

Maintenance

As infiltration basins are prone to failure due to the clogging of porous soils, it is imperative that aggressive maintenance plans and schedules be developed and implemented for these BMPs. The use of pretreatment BMPs will significantly minimize maintenance requirements for the basin.

Preventive maintenance should be performed at least twice a year, and ideally sediment should be removed from pretreatment BMPs after every major storm event.

Once the basin has gone online, inspections should occur after every major storm for the first few months to ensure proper stabilization and function. Attention should be paid to how long water remains standing in the basin after a storm; standing water within the basin 48 to 72 hours after a storm indicates that the infiltration capacity may have been overestimated. Factors responsible for clogging (such as upland sediment erosion, excessive compaction of soils and low spots) should be repaired immediately.

Thereafter, the infiltration basin should be inspected at least twice per year. Important items to check for include: differential settlement, cracking, erosion, leakage, or tree growth on the embankments, condition of riprap, sediment accumulation and the health of the turf.

At least twice a year, the buffer area, side slopes and basin bottom should be mowed. Grass clippings and accumulated organic matter should be removed to prevent the formation of an impervious organic mat. Trash and debris should also be removed at this time. Deep tilling can be used to break up a clogged surface area. Any tilled areas should be revegetated immediately.

Sediment should be removed from the basin as necessary. Removal procedures should not take place until the floor of the basin is thoroughly dry. Light equipment, which will not compact the underlying soil, should be used to remove the top layer. The remaining soil should be deeply tilled, and revegetated as soon as possible. Pretreatment devices associated with basins should be inspected and cleaned at least twice a year, and ideally every other month.

Summary: Infiltration Basin Guidelines

Site Criteria

- The contributing drainage area to any individual infiltration basin should be restricted to 15 acres or less.

- The minimum depth to the seasonal high water table, bedrock, and/or impermeable layer should be 2 feet from the bottom of the basin.

- The minimum acceptable soil infiltration rate should be 0.5 inches per hour. Maximum soil infiltration rates should not exceed 2.4 inches per hour to ensure adequate pollutant removal.

- One soil sample for every 5,000 feet of basin area is recommended, with a minimum of three samples for each infiltration basin. Samples should be taken at the actual location of the proposed infiltration basin so that any localized soil conditions are detected.

- Infiltration basins should not be used at sites where soils have 30% or greater clay content, or 40% or greater silt clay content.

- Infiltration basins should not be placed over fill materials.

- The following setback requirements should apply to infiltration basin installations:
  - -- Distance from any slope greater than 15% - a minimum of 50 feet.
  - -- Distance from any septic system component - a minimum of 100 feet.
  - -- Distance from any private well - a minimum of 100 feet, additional setback distance may be required depending on hydrogeological conditions.

- Distance from any public groundwater drinking supply wells - Zone I radius, additional setback distance may be required depending on hydrogeological conditions.

- Distance from any surface drinking water supply - Zone A, and 100 feet from tributaries.

- Distance from any surface water of the Commonwealth (other than surface water supplies and their tributaries) - a minimum of 100 feet.

- Distance from any building foundations - a minimum of 10 feet downslope and 100 feet upslope.

Design Criteria

- Infiltration basins should be provided with a sediment forebay or another pretreatment device designed to capture coarse particulate pollutants, and, where necessary oil and grease. In addition, vegetative buffers around the perimeter of the basin are recommended for erosion control and additional sediment and nutrient removal.

- To prevent incoming flow velocities from reaching erosive levels, which can scour the basin floor, inlet channels to the basin should be stabilized. Riprap may be used for this purpose. The riprap should be designed to terminate in a broad apron, which spreads the runoff more evenly over the basin surface to promote better infiltration.

- The design of the infiltration basin should be based on the slowest rates obtained from the infiltration tests performed at the site.

- The depth of the infiltration basin should be adjusted so that maximum drain time is 72 hours for the total runoff volume, with a minimum retention time of 48 hours.

- The floor of the basin should be graded as flat as possible for uniform ponding and exfiltration of the runoff across the floor.

- The side slopes of the basin should be no steeper than 3:1 (horizontal: vertical).

- Embankments and spillways should be designed in conformance with the state Office of Dam Safety regulations. All infiltration basins must have an emergency spillway capable of bypassing runoff from large storms without damage to the impounding structure.

- The bottom and side slopes of the basin should be stabilized with a dense turf of water tolerant grass. In place of turf, a basin liner of 6 to 12 inches of fill material, such as coarse sand, may be used. Loose stone, riprap and other irregular materials requiring hand removal of debris and weeds should not be used.

Construction Criteria

- Before the development site is graded, the area of infiltration basin should be roped off to prevent heavy equipment from compacting the underlying soils.
- Infiltration basins should not be used as temporary sediment traps during construction.
- Infiltration basins should not be constructed until the entire contributing drainage area has been stabilized.
- During and after excavation, all excavated materials should be placed downstream, away from the infiltration basin, to prevent redeposition during runoff events. All excavated materials should be properly handled and disposed, during and after construction.
- Light earth-moving equipment should be used to excavate the infiltration basin. Use of heavy equipment causes compaction of the soils beneath the basin floor and side slopes, resulting in reduced infiltration capacity. Since some compaction of soils will occur during construction, the basin floor should be deeply tilled with a rotary tiller or a disc harrow to restore infiltration rates, after final grading.

Maintenance Criteria

- Maintenance is required for the proper operation of infiltration basins - plans for infiltration basins should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule for infiltration basins.
- Infiltration basins should be inspected after every major storm for the first few months after construction to ensure proper stabilization and function. Thereafter, the basin should be inspected at least twice a year.
- Pretreatment BMPs should be inspected and the accumulated sediment removed at least twice a year, ideally after every major rainfall event or every other month.
- The grass in the basin, on the sideslopes and in the buffer areas should be mowed, and grass clippings, organic matter, and accumulated trash and debris removed, at least twice during the growing season.
- Eroded or barren spots should be reseeded immediately after inspection to prevent additional erosion and accumulation of sediment.

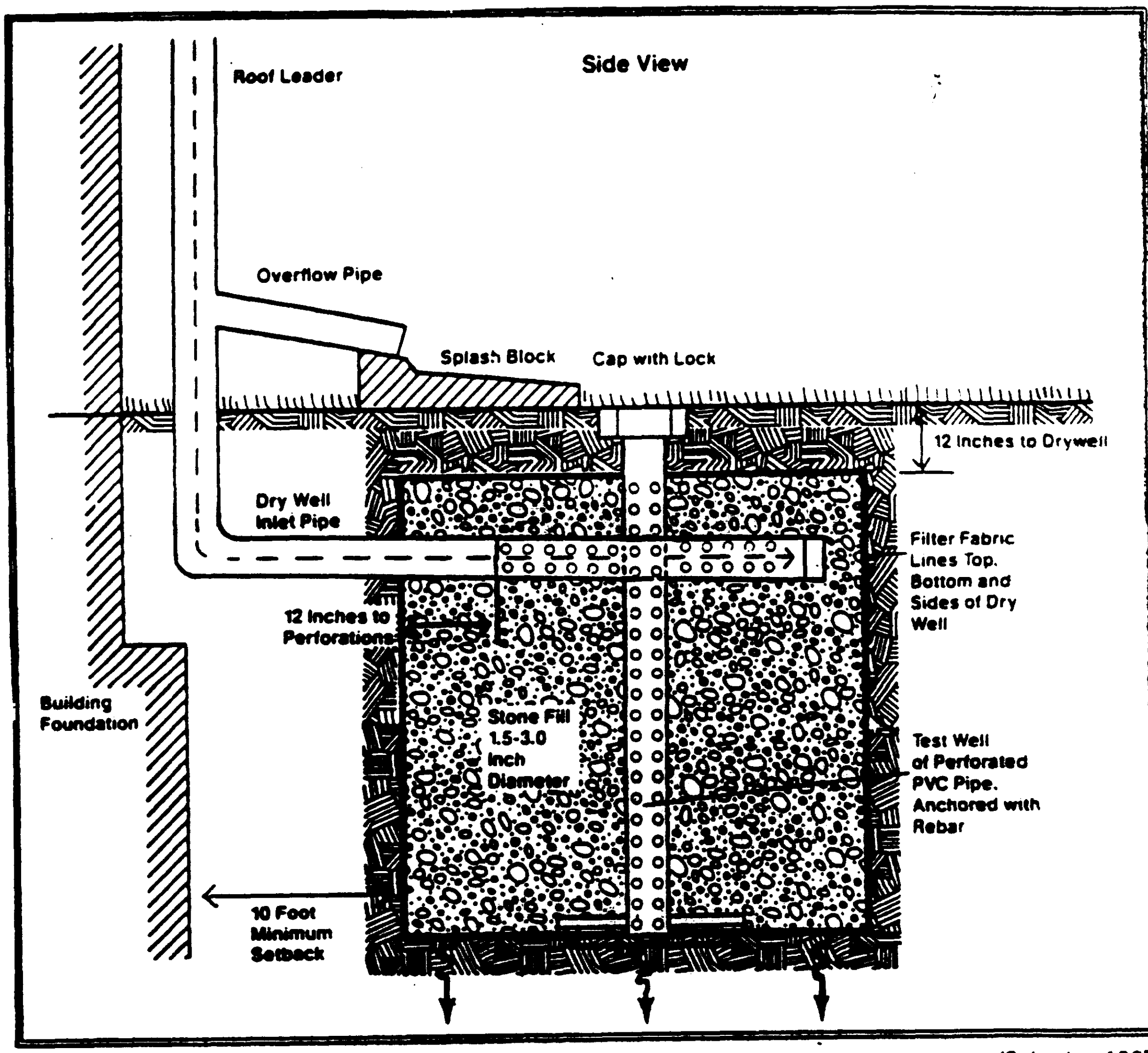
- Deep tilling can be used to break up a clogged surface area. Any tilled areas should be revegetated immediately.

- Sediment should be removed from the basin as necessary. Removal procedures should not take place until the floor of the basin is thoroughly dry.

Dry Wells

Definition

Dry wells are small excavated pits, backfilled with aggregate, and used to infiltrate "good quality" stormwater runoff, such as uncontaminated roof runoff. Dry wells are not to be used for infiltrating any runoff that could be significantly contaminated with sediment and other pollutants, such as runoff from high potential pollutant loading areas (as explained in Chapter 2) and parking lot runoff. Figure 3.G.1 provides a schematic of a typical dry well.



(Schueler, 1987)

Figure 3.G.1: Schematic of a Dry Well

Purpose

- To infiltrate rooftop runoff.
- To reduce the stormwater runoff volume to be treated by other BMPs.

Advantages

- Can be used at sites where storm drains are not available, or at any site where it is acceptable and desirable to dispose of runoff in this manner.
- Can result in a reduction in the size and cost of downstream BMPs and/ or storm drains.
- Can be utilized in retrofit areas where space is limited and where additional runoff control is necessary.
- Can provide groundwater recharge for uncontaminated rooftop runoff.

Disadvantages

- Not intended for general stormwater runoff quantity or quality control, and therefore has limited applicability.
- May experience high failure rate due to clogging.
- Only applicable in small drainage areas of one acre or less.

Applicability

The use of dry wells is limited by a number of site constraints, including soil type, contributing drainage area, depth to bedrock, and depth to groundwater. The recommended minimum site criteria for dry wells are listed in Table 3.G.1. Generally, dry wells should not be used alone but in conjunction with other BMPs to meet the Stormwater Management Standards.

Runoff from high potential pollutant loading areas or contaminated rooftop runoff should not be infiltrated.

Dry wells are intended to infiltrate roof runoff that is unlikely to contribute significant loadings of sediment or pollutants. Dry wells are not to be used for infiltrating any runoff that could transport sediment and pollutants, such as parking lot runoff and also are meant to be used only in areas where there are no significant sources of depositional air pollution.

Dry wells can be used in retrofit areas where space is limited and where additional runoff control is necessary. Use of dry wells can reduce the volume of runoff from a site, thereby reducing the size and cost of downstream stormwater control facilities.

Dry wells are applicable to sites where storm drains are not available.

Effectiveness

These small systems can be effectively used to infiltrate rooftop runoff, thereby reducing flows to downstream BMPs or storm sewers and contributing towards the treatment of the prescribed water quality runoff volume. When designed properly and coordinated with other BMPs, dry wells can help to manage peak discharges from design storms, reduce runoff volume, and provide good quality groundwater recharge.

Planning Considerations

The minimum site criteria listed in Table 3.G.1 should be met in planning dry well installations.

Soils should have a minimum infiltration rate of 0.5 inches/hour and maximum permeability of 5 inches/hour. Where soils exceed the maximum rate, water quality treatment should be provided prior to infiltration.

Dry wells are intended to infiltrate only rooftop runoff. Runoff that contains sediments and other pollutants should be directed away from the dry well, and controlled by another type of BMP.

Design

Dry wells are basically a variation of the infiltration trench, designed to infiltrate good quality runoff only. Roof top runoff is discharged to the dry well through the roof leader, which extends directly into a stone filled reservoir. Roof top gutter screens are needed to trap particles, leaves and other debris, and must be cleaned regularly. The dry well should be sited a minimum of 10 feet from the building foundation. Dry wells should not be constructed until the drainage area has been stabilized.

Dry wells can be designed with a surface inlet to capture runoff from the upland drainage area. This is not recommended however, because extreme measures must be taken to prevent sediment and pollutant loading from causing system failure or degradation of water quality. Dry wells designed with surface inlets should have a minimum 20 foot vegetated filter strip on each side of the inlet.

The volume and surface area of dry wells is a function of the quantity of runoff entering the dry well from the contributing area and the overlying soil, the void space and the infiltration rate. Since the dry well is filled with stone, only the space between the stone is available for runoff storage. Dry wells are to be filled with 1.5 - 3.0 inch diameter, clean washed stone. This size stone will yield a void space of approximately 30 - 40%. The final soil infiltration rate below the dry well is determined by the results of the soil sampling. At least one soil sample for each dry well is recommended. Samples should be taken at the actual location of the proposed dry well that any localized soil conditions are detected. The minimum acceptable infiltration rate should be 0.5 inches per hour.

The maximum depth of the dry well can be determined from the infiltration rate, the allowable storage time, and the void space. A maximum storage time of 72 hours is recommended. Forty eight hours is recommended as the minimum storage time.

The bottom of the dry well must be at least two feet above the seasonal high water table and bedrock, and below the frost line.

Excavated material should be placed away from the excavated sides to increase wall stability. Large roots should be trimmed flush with the sides to prevent fabric puncturing or tearing during installation. Side walls should be roughened where sheared and sealed by heavy equipment.

An observation well should be installed to monitor the runoff clearance from the system. This well should consist of a well anchored, vertical perforated PVC pipe with a lockable above ground cap.

Construction

The minimum construction criteria for dry wells are presented in Table 3.G.1. Care should be taken during construction to minimize the risk of failure of the dry well.

Maintenance

Since these structures are often installed at single family dwellings, it is important that developers outline the maintenance requirements to property purchasers clearly.

Dry wells should be inspected after every major storm in the first few months after construction to ensure proper stabilization and function. Thereafter, the dry well should be inspected at least once per year. Water depth in the observation well should be measured at 0, 24, and 48 hour intervals after a storm. Clearance rates are calculated by dividing the drop in water level (inches) by the time elapsed (hr). A comparison of clearance rate measurements taken over the years provides a useful tool for tracking any clogging problems within the dry well.

Summary: Guidelines for Dry Wells

Site Criteria

- The contributing drainage area to a dry well should be restricted to one acre or less.
- The minimum depth to the annual mean high water table, bedrock, and/ or impermeable layer should be two feet from the bottom of the dry well.
- The minimum acceptable soil infiltration rate should be 0.5 inches per hour. The maximum rate is 5 inches per hour.

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- One soil boring for each dry well is recommended. Borings should be taken at the actual location so that any localized soil conditions are detected.

- Not to be used at sites where soils have 30% or greater clay content, or 40% or greater silt clay content.

- Should not be placed over fill materials.

- The following setback requirements should apply:

  -- Distance from any slope greater than 15%: minimum of 50 feet.

  -- Distance from any septic system component: minimum of 100 feet.

  -- Distance from any private well: minimum of 100 feet, additional setback distance may be required depending on hydrogeological conditions.

  -- Distance from any public groundwater drinking supplies well: Zone I radius, additional setback distance may be required depending on hydrogeological conditions.

  -- Distance from any surface drinking water supply: Zone A, and 100 feet from tributaries.

  -- Distance from any surface water of the Commonwealth (other than surface water supplies and their tributaries): minimum of 100 feet.

  -- Distance from any building foundations: minimum of 10 feet.

- The depth should be adjusted so that maximum drain time is 72 hours for the total runoff volume, with a minimum retention time of 48 hours.

- An observation well should be installed to monitor the runoff clearance from the system. This well should consist of a well anchored, vertical perforated PVC pipe with a lockable above ground cap.

Construction Criteria

- Before the development site is graded, the area for the dry well should be roped off to prevent heavy equipment from compacting the underlying soils.

- Diversion berms should be placed around the perimeter during all phases of construction. Sediment and erosion controls should be used to keep runoff and sediment away from the dry well area.

- During and after excavation, all excavated materials should be placed downstream, away from the dry well, to prevent redeposition of these materials during runoff events. All excavated materials should be properly handled and disposed, during and after construction.

- Light earth-moving equipment should be used for excavation. Use of heavy equipment causes compaction of the soils beneath the dry well floor, resulting in reduced infiltration capacity.

- Once excavated, the top, sides and bottom should be lined with geotextile fabric (filter fabric). The geotextile fabric must be selected to ensure compatibility with the surrounding soil textures and application purposes. The cut width of the filter fabric must include sufficient material to include a minimum 12 inch overlap. Place the fabric roll over the dry well, and unroll sufficient length to allow placement of the fabric down into the dry well. When overlaps are required between rolls, the upstream roll must lap a minimum of two feet over the downstream roll to provide a shingled effect. The bottom of the dry well can be covered with a six to twelve inch layer of clean sand (VDOT Fine Aggregate-Grading A or B) in place of filter fabric.

- Fill with 1.5 - 3.0 inch diameter, clean washed stone only. The stone should be placed in the dry well in lifts and lightly compacted with plate compactors to form the coarse base.

Maintenance Criteria

- Maintenance is required for the proper operation; plans should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule.

- Inspect the dry well after every major storm for the first few months to ensure proper stabilization and function. Thereafter, inspect them at least once per year. Water levels in the observation well should be recorded over several days to check the dry well drainage.

Sand Filters/Organic Filters

Definition

Also known as filtration basins, sand and organic filters consist of self contained beds of sand or peat (or combinations of these and other materials) either underlain with perforated underdrains or designed with cells and baffles with inlets/outlets. Stormwater runoff is filtered through the sand, and in some designs may be subject to biological uptake. Runoff is discharged or conveyed to another BMP for further treatment. Where the potential for groundwater contamination is low and proper soils are present, the treated runoff may be allowed to exfiltrate into the subsoil. Figure 3.H.1 provides a schematic of the typical sand filter.

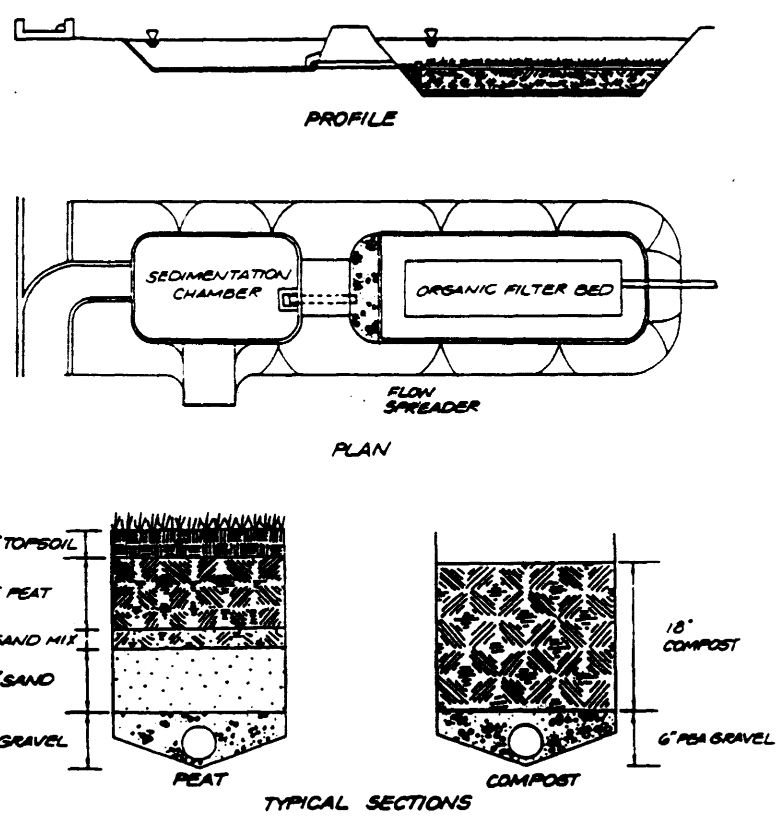

Figure 3.H.1: Schematic of an Organic Filter

A number of designs currently are available for sand filters. Organic filters utilize layers of peat, limestone, and/or topsoil to improve pollutant removal rates; designs may also feature wetland vegetation or grass cover. Sand filters have also been designed as trench systems to receive and treat parking lot runoff, and have been used in place of water quality inlets.

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Purpose

- To control stormwater runoff quality, by utilizing filtration, (in some cases infiltration and/or biological uptake), in order to provide high removal of sediment and trace metals, and moderate removal of nutrients, BOD and coliform bacteria.
- Depending on design, can provide groundwater recharge, reduce runoff volume, and reduce peak discharge.

Advantages

- Applicable in small drainage areas of 1 to 10 acres; although some designs may accept runoff of up to 50 acres.
- Have few constraints; therefore, can be applied to most development sites.
- Good retrofit capability.
- Longevity of sand filters is high.
- Flexibility to provide groundwater recharge if conditions and situations allow.

Disadvantages

- Pretreatment required to prevent the filter media from clogging.
- Frequent maintenance required.
- Relatively costly to build and install.
- Without grass cover, the surface of sand filters can be extremely unattractive.
- May have odor problems, which can be overcome with design and maintenance.

Applicability

Sand filters are very adaptable, and have few site constraints. They can be applied to in areas with thin soils, high evaporation rates, low soil infiltration rates and limited space.

Sand filters can be used in ultra-urban sites with small drainage areas that are completely impervious (such as small parking lots and fast food restaurants). They can be applicable to many areas that are difficult to retrofit due to space limitations.

Sand filters that are not designed to exfiltrate into the subsoil, but can be applied to areas with poor soil infiltration rates, where groundwater concerns restrict the use of infiltration, or for high pollutant loading areas.

Sand filters are designed as off-line BMPs; they are intended primarily for quality control not quantity control. A diversion structure, such as a flow splitter or weir, is provided to route a portion of the runoff into the sand filter, while the remainder continues on to a stormwater quantity control BMP. With careful design, or a number of units, peak discharge rates may be controlled.

Because of the potential for clogging, sand filters should only be applied to sites that have been stabilized, and should never be used as sedimentation traps or basins during construction. Any disturbed areas within the sand filters drainage area should be identified and stabilized to the maximum extent possible.

Effectiveness

Table 5.2 shows the range of pollutant removal efficiencies for sand filters. When the sand filter is well planned, designed, constructed, and maintained, then the reduction of the pollutant loadings should be at the high end of the reported values. Sand filters can be used to meet the storm water quality standards.

Pollutant removal is achieved primarily by straining pollutants through the filtering media and by settling on top of the sand bed and/or in a pretreatment basin. Organic filters may have slightly higher pollutant removal rates due to the adsorptive properties of peat. Designs with grass cover or wetland vegetation can provide additional nutrient removal by plant uptake.

Sand filters are designed for water quality control, and generally not for quantity control. Some sand filters that are designed to exfiltrate to the subsoil will provide runoff volume reduction and can aid in meeting volume control requirements.

Sand filters can be used with downstream quantity control structures to meet both the storm water quality and quantity standards.

Planning Considerations

The surface of sand filters can be unattractive, and therefore, may not be appropriate for residential areas without a grass cover. Odors may also be a problem with sand filters.

To avoid clogging, sand filters should only be applied to sites that have been stabilized, and should never be used as sedimentation basins during construction. Any disturbed areas within the sand filters drainage area should be identified and stabilized to the maximum extent possible. Generally, sand filters should be located off-line from primary conveyance/ detention systems and should be preceded by a pretreatment device.

As previously mentioned, sand filters are generally designed as off-line BMPs because they are intended primarily as stormwater quality control. Sand filters should be sized for the water quality design storm and stormwater conveyance should be fitted with flow splitters or weirs to route design runoff to the sand filter. Excess runoff bypasses the sand filter and continues to another quantity BMP. In cases where designs and site conditions allow for infiltration into the subsurface, some quantity control may be achieved through volume and rate reductions.

Design

See the following for complete design references:

Design of Stormwater Filtering Systems. 1996. Claytor. Center for watershed Protection.

Biofiltration swale performance, recommendations and design considerations. 1992. Washington Department of Ecology: Publications Office. Mailstop PV-11, Olympia, WA. 98504-8711.

Design guidelines for water quality control basins. 1988. City Of Austin (TX). Environmental Resources Management Division.

Design of peat sand filters: A proposed stormwater management practice. 1990. Galli. MWCOG Information Center.

Two key design principles should apply: the first is visibility; the second is simplicity. A visible sand filter is more apt to adequately maintained and operated. Complex designs are more expensive and difficult to operate and maintain.

Typically, sand filter systems are designed with two components, a pretreatment sedimentation component and a filtering component. The sedimentation component is a presettling basin or vegetated swale, designed to reduce the sediment load to the filtering component. Presettling also slows the runoff velocity and spreads it evenly across the top of the filter component. Generally, the volume of the pretreatment basin should be equal to or greater than the filtering capacity. The filtering component is designed to capture the finer silt and clay particles and other pollutants in the runoff.

Sand filters are designed to function as a stormwater quality control practice, and not to provide detention for downstream areas. Therefore, they should be located to be off-line systems, away from the primary conveyance/detention system.

The pretreatment component should be designed to allow for the settling of coarse sediment that may clog the sand filter and reduce its effectiveness.

A design filtration rate of 2 inches/hour is recommended. This value is low compared to the published values for sand; however, it reflects actual rates achieved by sand filters in urban areas.

The sand filter should be designed to completely drain in 24 hours or less. This drainage time is recommended as there is very little storm storage available in the sand filter.

Concrete structures are not always necessary for sand filters. Where site conditions allow and infiltration is possible, lining the excavated pit or trench with geotextile fabric may suffice and reduce costs. Where infiltration is not possible, the sand filter structure must be constructed of impermeable media, such as concrete.

Eighteen inches of 0.02-0.04 inch diameter sand (smaller sand is acceptable) is the recommended final thickness for the sand bed. Consolidation of the sand that is likely to occur during construction must be taken into consideration. The depth of the bed can be stabilized by wetting the sand periodically, allowing it to consolidate, and then adding extra sand.

There are several possible sand bed configurations, most utilize a gravel bed at the bottom and then a layer sand and/or peat, leaf compost, or topsoil/grass. In all configurations, the top surface layer of the bed should be level to ensure equal distribution of the runoff in the bed.

The gravel bed layer is generally 4 to 6 inches of 1/2 to 2 inch diameter gravel. The gravel and top media layers must be separated by a layer of geotextile fabric to prevent the sand from infiltrating into the gravel layer and the underdrain piping.

Ease of access for maintenance is an important consideration in sand filter designs. Some designs utilize a geotextile layer, surface screen, or grating at the top to filter coarse sediment and debris and for ease of maintenance. The typical maintenance of the sand filter is to remove the top several inches of discolored sand and replace this with clean media. Designs should allow for a maintenance worker to manually remove this material, by providing ramps, manhole steps, or ringbolts. In addition, heavy grates or manhole covers that cannot be lifted manually should be avoided.

The trench design has the lateral underdrain pipes that are covered with 1/2 to 2 inch diameter gravel and geotextile fabric. The underdrains are underlain with drainage matting, which is necessary to provide adequate hydraulic conductivity to the lateral pipes.

The underdrain piping must be reinforced to withstand the weight of the overburden. The minimum grade of the piping should be 1/8 inch per foot (at 1% slope). An impermeable liner (clay, geomembrane, concrete) may be required under the filter to protect groundwater. If the impermeable liner is not required, a geotextile liner should be installed, unless the bed has been excavated to bedrock.

Side slopes of earthen embankments should not exceed 3:1 (horizontal: vertical). Fencing around sand filters may be recommended for some designs to reduce safety hazards.

The careful selection of topsoil and sod for natural cover will help reduce the potential for failure. Sod with fine silts and clays will clog the top of the sand filter, however.

Maximum longevity of the sand filter may be achievable by limiting its use only to impervious areas.

Construction

The minimum construction criteria for sand filters are presented in Table 3.H.1. Sand filters should not be used as temporary sediment traps for construction.

Care should be taken during construction to minimize the risk of premature failure of the sand filter. Construction of the sand filters should take place after the site has been stabilized and sediment/erosion controls should be utilized during construction.

Consolidation of the sand or other filtration media is likely to occur during or shortly after construction of the sand filter. The depth of the sand bed or other media layers can be adjusted properly by wetting the sand, allowing it to consolidate, and then adding addition media.

Maintenance

Sand filters should be inspected after every major storm in the first few months after construction to ensure proper function. Thereafter, the sand filter should be inspected at least once every 6 months.

Sand filters require frequent manual maintenance. Raking of the sand and removal of surface sediment, trash and debris are the primary maintenance tasks.

Eventually a layer of sediment will accumulate on the top of the sand. This sediment can be easily scraped off using rakes or other devices. Finer sediments will penetrate deeper into the sand over time, and replacement of some (several inches) or all of the sand will be necessary. Discolored sand is an indicator of the presence of fine sediments. Sand removed from the filter component should be de-watered and then disposed properly.

Summary: Guidelines for Sand Filters

Site Criteria

- The typical drainage area served by sand filters is from 0.5 to 10 acres. Depending on design, the contributing drainage area may be up to 50 acres.

- Depending on soil types, sand filters may be designed to exfiltrate all or a portion of treated runoff. Caution should be used in recharge areas of public drinking water supplies.

Design Criteria

- Sand filters should be preceded by pretreatment to allow for the settling of coarse sediment that may clog the sand filter and reduce its effectiveness.

- Generally, sand filters are designed to function as a storm water quality controls, and not to provide detention for downstream areas. Therefore, they should be designed as off-line components from the primary conveyance/detention system.

- A design filtration rate of 2 inches/hour is recommended.

- The sand filters should be designed to completely drain in 24 hours or less.

- Eighteen inches of 0.02-0.04 inch diameter sand (smaller sand is acceptable) is recommended for the sand bed. 4 to 6 inches of gravel is recommended for the bed of the filter.

- Designs using a geotextile layer, surface screen, or a grating at the top are recommended to filter coarse sediment and debris and for ease of maintenance.

- The careful selection of topsoil and sod for natural cover will help reduce the potential for failure; sod with fine silts and clays will clog the top of the sand filter.

Construction Criteria

- Diversion berms should be placed around the perimeter of the sand filters during all phases of construction. Sediment and erosion controls should be used to keep runoff and sediment away from the dry well area.

- Sand filters should not be used as temporary sediment traps for construction activities.

- Consolidation of material in the sand filters during construction must be taken into consideration. The depth of the bed can be stabilized by wetting the sand periodically, allowing it to consolidate, and then adding extra sand.

- During and after excavation, all excavated materials should be placed downstream, away from the sand filters, to prevent redeposition during runoff events. All excavated materials should be handled properly and disposed, during and after construction.

Maintenance Criteria

- Maintenance is required for the proper operation of sand filters; plans for sand filters should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule.

- Sand filters should be inspected after every major storm in the first few months to ensure proper function. Thereafter, the sand filter should be inspected at least once every 6 months.

- Sand filters require frequent manual maintenance, primarily raking of the sand and removal of surface sediment, trash, and debris.

- Sediments, trash and debris should be removed from the from the presettling basin on a regular basis to reduce the risk of clogging.

- Replacement of the top several inches of sand should occur yearly, or more frequently when drawdown does not occur within 36 hours after the presettling basin has emptied.

Water Quality Inlets/Deep Sump Catch Basins

Definition

Deep sump catch basins, known as oil and grease or hooded catch basins, and water quality inlets are underground retention systems designed to remove trash, debris, and some amount of sediment and oil and grease from stormwater runoff.

Figure 3.I.1 provides a schematic of the typical three chamber water quality inlet. Figure 3.I.2 illustrates a deep sump catch basin.

In the water quality inlet, runoff enters the top of the first chamber, which contains a permanent pool of water (minimum depth of four feet). Pollutants are removed in this first chamber by trapping floatable debris (leaves and litter) and by gravity settling of sediment. Stormwater flows through screened orifices to the second chamber, which also contains a permanent pool of water (minimum depth of 4 feet). The stormwater must then pass through the bottom opening of an inverted pipe into the third chamber. The opening of this pipe is located at least three feet below the second chamber permanent pool. Oil and grease float on the permanent pool water, and are trapped in the second chamber. Eventually the oil and grease will attach to sediment and settle out. If the outlet of the third chamber is above the chamber floor, then a permanent pool will form, providing another settling area. Otherwise, there will be little pollutant removal in the third chamber. Lastly, stormwater is routed out of the third chamber into the storm drain system or into another BMP.

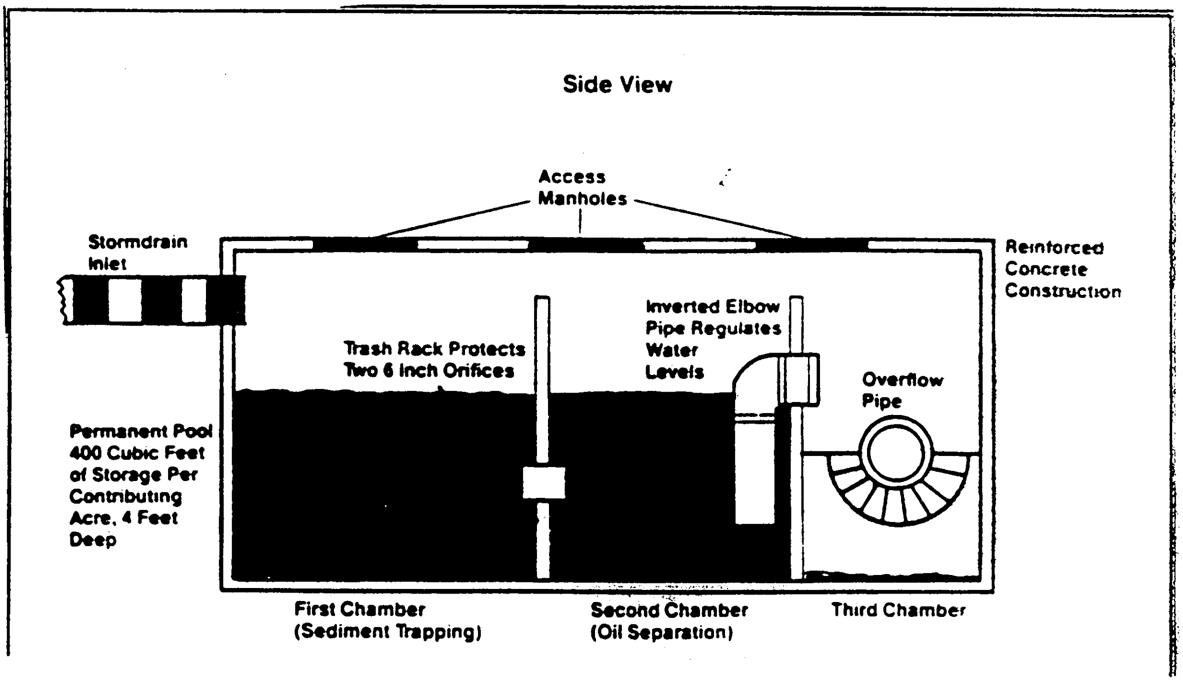


Figure 3.I.1: Schematic Design of a Water Quality Inlet

The deep sump catch basin operates in a similar manner. Functioning as a modified catch basin, the deep sump design has the stormwater runoff inflow at the top of the basin. The discharge point is located at least 4 feet below the inflow point. Generally, the volume rule is to size the sump four times the diameter of the inflow pipe. Stormwater flows through screened orifices to the chamber, which may contain a permanent pool of water. The stormwater must pass through the bottom opening of an inverted pipe. Oil and grease float on the permanent pool water, and are trapped in the chamber. Eventually, the oil and grease will attach to sediment and settle out.

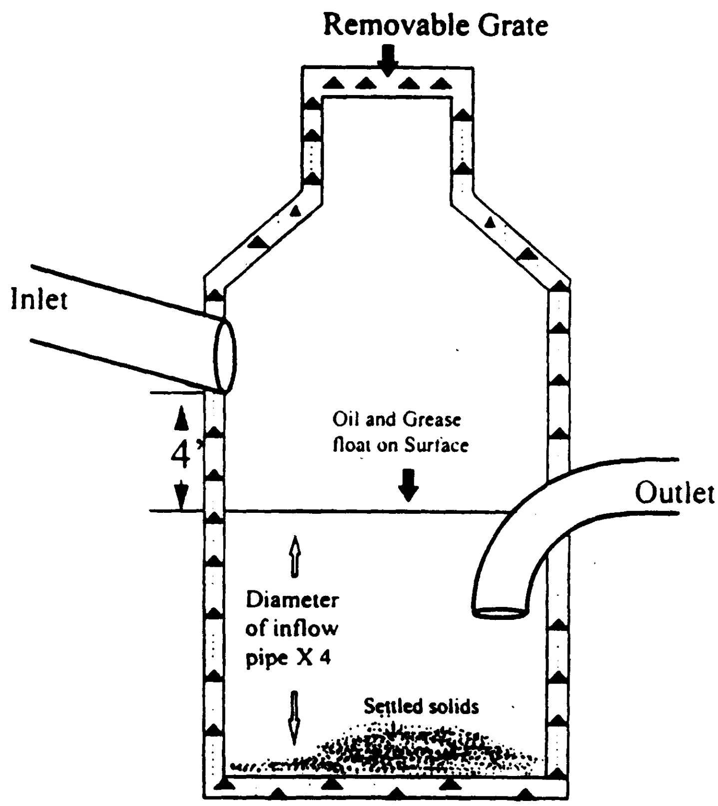


Figure 3.I.2: Schematic Design of a Deep Sump Catch Basin

Purpose

- To remove debris, sediment and hydrocarbons from stormwater runoff.
- To provide pretreatment for other BMPs.
- In retrofit situations, to provide water quality treatment for small urban lots where larger BMPs are not feasible due to site constraints.

Advantages

- Usually located underground, so limited lot size is not a deterrent.
- Compatible with storm drain systems.
- Can be used for retrofitting small urban lots where larger BMPs are not feasible.
- Provides pretreatment of runoff before it is delivered to other BMPs.
- Easily accessed for maintenance.
- Longevity is high, with proper maintenance.

Disadvantages

- Limited pollutant removal.
- Expensive to install and maintain, resulting in high cost per unit area treated.
- No volume control.
- Frequent maintenance is necessary.
- Proper disposal of trapped sediment and oil and grease.

Applicability

Water quality inlets and deep sumps are applicable to parking lots, gas stations, convenience stores, and other areas with substantial vehicular traffic. Generally the contributing area contains a large portion of impervious cover that is expected to receive high sediment and hydrocarbon loadings. It is recommended that the contributing area to any individual inlet be limited to one acre or less of impervious cover. Multiple inlets can be used for larger impervious areas, before routing excess stormwater flows to other BMPs. Water quality inlets and deep sumps are recommended as pretreatment devices only.

Effectiveness

The range of pollutant removal efficiencies for water quality inlets and deep sumps is provided in the Stormwater Policy (Volume 1, Chapter 1). Since they have limited storage capacity, detention time, and pollutant removal, *water quality inlets and deep sump, catch basins cannot be used alone to meet Stormwater Management Standards*. Therefore, these BMPs should only be used as pretreatment devices for other technologies.

As pretreatment devices, water quality inlets and deep sumps can be effective in removing sediments and oil and grease that may impair the operation of other BMPs, provided that they are designed and maintained properly.

Water quality inlets and deep sumps rely primarily on settling for pollutant removal. Because of the small storage capacity and brief retention time, only coarse sediments are likely to be trapped. In addition, resuspension of the sediments is likely, unless an aggressive maintenance program is followed. The current inlet designs have low to moderate removal rates for particulate pollutants, and zero to low removal of soluble pollutants. Moderate hydrocarbon removal can be expected because of their strong affinity to adsorb onto sediment.

Pollutants are not actually removed from water quality inlets or sumps until they are cleaned out. Regular maintenance is required to reduce the risk of resuspension of sediments during large storm events.

Planning Considerations

Because of their limited pollutant removal and storage capacity, water quality inlets and deep sumps should be considered only for pretreatment applications or as a last alternative. Inlets are able to prolong the effectiveness of larger BMPs such as detention, retention, or infiltration basins which have sedimentation problems. Inlets and sumps are most frequently used in ultra-urban areas where space or storage are not available for more effective BMPs.

Provisions need to be made for frequent cleaning and inspection. Generally, ordinary catch basin cleaning equipment (vacuum pumps available to most public works departments) can be used to clean water quality inlets. Manual removal of sediments may be necessary, as well.

Catch basin materials often include various concentrations of oil and hazardous materials such as petroleum hydrocarbons and metals. Catch basin cleanings are classified as solid waste by DEP and must be handled and disposed in accordance with all DEP regulations, policies, and guidance. In the absence of written approval from the DEP, catch basin cleanings must be taken to a facility permitted by the DEP to accept solid waste. Catch basin cleanings may be disposed at any landfill that is permitted by the DEP to accept solid waste. Materials containing free draining liquids are prohibited from being accepted at landfills.

The DEP encourages beneficial reuse of this material whenever possible. However, any use of the material outside a landfill requires a Beneficial Reuse Determination from the DEP.

A secondary concern is the pulse loading of trapped residuals during longer storm events due to resuspension of sediments.

Longevity of the systems is high, and standardized designs allow for relatively easy installation. Compared to other BMPs, water quality inlets are moderately expensive.

Design

Water quality inlets and deep sump catch basins should be designed and constructed as off-line systems only. Runoff in excess of the prescribed water quality treatment volume should be routed around (bypass) the pretreatment BMP.

The inflow pipe should be sized and constructed to pass the design storm volume into the water quality inlet or deep sump, and excess flows should be directed to another BMP of sufficient capacity to meet the water quantity requirements or to a storm drain system. An off-line design should enhance pollutant removal.

To achieve consistent removal of pollutants, the volume of the permanent pools in the chambers of the inlets should be maximized. The combined volume of these pools should equal at least 400 cubic feet per acre of contributing impervious area. The pools should be at least four feet deep for settleability. Where feasible, the third chamber should also be used as a permanent pool. Vertical baffles at the bottom of the permanent pools can help to minimize sediment resuspension.

To keep out floatables, a trash rack or screen should cover the discharge outlets. To trap hydrocarbons in the water quality inlets, an inverted elbow pipe should be located between the second and third chambers and the bottom of the pipe should be at least three feet below the second chamber permanent pool. For deep sumps, the four times sizing rule (i.e. depth equals 4X pipe diameter) must be followed. Manholes should be included for each chamber to provide access for cleaning.

Maintenance

The actual removal of sediments and associated pollutants and trash occurs only when inlets or sumps are cleaned out; therefore, regular maintenance is required. Most studies have linked the failure of inlets to the lack of regular maintenance. The more frequent the cleaning, the less likely sediments will be resuspended and subsequently discharged. In addition, frequent cleaning also results in more volume available for future storms and enhances the overall performance. Ideally, in areas of high sediment loading, inlets should be inspected, and cleaned, after every major storm event. At a minimum, water quality inlets and deep sumps should be cleaned four times per year (although one study found maximum benefits from monthly cleaning), and inspected monthly. Disposal of the accumulated sediment and hydrocarbons must be in accordance with applicable local, state, and federal guidelines and regulations.

Summary: Guidelines for Water Quality Inlets and Deep Sumps

Site Criteria

- The contributing drainage area to any individual inlet or sump should be one acre or less of impervious area.

Design Criteria

- Inlets and sumps are recommended as pretreatment devices only, and should not be used as primary BMPs.
- The volume of the permanent pools in the chambers should be maximized - the combined volume of pools should equal at least 400 cubic feet per acre of contributing impervious area.
- The minimum depth of the permanent pools should be four feet.
- A trash rack or screen should cover the discharge outlets (including between the chambers).
- For inlets, the bottom of the elbow pipe connecting the second and third chambers should be at least three feet below the second chamber permanent pool.
- The inflow pipe should be sized and constructed to pass the water quality design storm volume into the inlet, and excess flows should be directed to another BMP.
- Manholes should be included for each chamber to provide access for cleaning.

Maintenance Criteria

- Maintenance is essential for the proper operation of water quality inlets - plans should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule.
- Inlets should be cleaned a minimum of four times per year and inspected monthly.
- All sediments and hydrocarbons should be properly handled and disposed, in accordance with local, state and federal guidelines and regulations.

Sediment Traps [Forebays]

Definition

A sediment trap or forebay is an excavated pit or cast structure designed to slow incoming stormwater runoff and settle suspended solids. Stormwater is routed through the sediment trap before continuing to the primary water quality and quantity control BMP. Typically, sediment forebays are components of effective stormwater pond and wetland designs. Cast sediment traps may also be used in connection with water quality swales. Designs incorporate simple access and other features for ease of accumulated sediment removal. Figure 3.J.1 provides a schematic of a sediment trap [forebay].

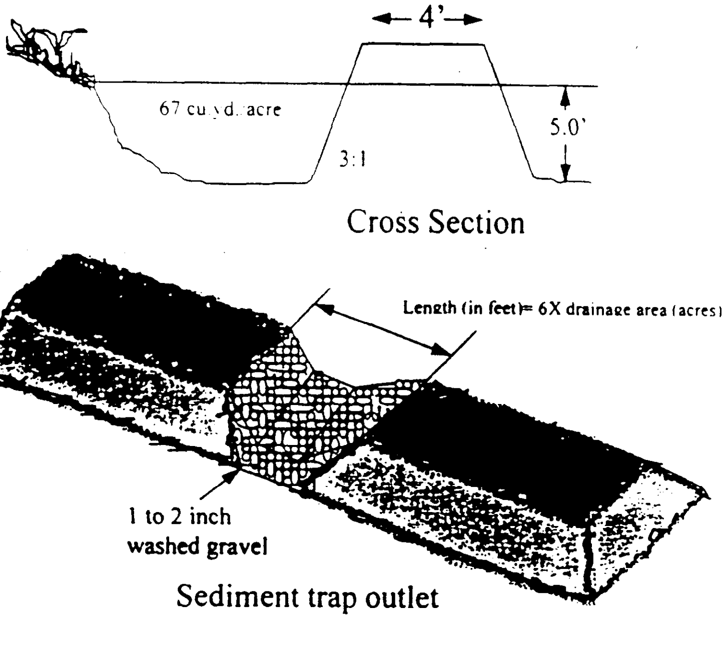


Figure 3.J.1: Schematic of a Sediment Trap

Purpose

- To pretreat for removal of debris, sediment and associated pollutants from stormwater, before another BMP technology.

Advantages

- Compatible with a wide array of BMPs.
- Can be used to expand existing BMPs, especially pond and wetland systems.
- Provide pretreatment of runoff before delivery to other BMPs.
- Slows velocities of incoming stormwater.
- Easily accessed for sediment removal.
- Longevity is high with proper maintenance.

Disadvantages

- Limited pollutant removal.
- No removal of soluble pollutants.
- No volume control.
- More space required than water quality inlets and deep sumps.
- Frequent maintenance is necessary.
- Proper disposal of trapped sediment and oil and grease.

Applicability

Sediment traps and forebays are widely applicable and can be used with most other BMP technologies. Sediment forebays are widely used in connection with pond and wetland designs. Sediment traps may consume more space than water quality inlets or deep sump catch basins. The volume of the forebay is generally a minimum of 0.1 inch per contributing acre.

Effectiveness

The range of pollutant removal efficiencies for sediment traps and forebays is in the Stormwater Management Policy (Volume 1, Chapter 1). Since they have limited storage capacity, detention time and pollutant removal, sediment raps cannot be used alone to meet the stormwater performance standards. Therefore, these BMPs should be used only as pretreatment devices for other technologies.

As pretreatment devices, sediment traps can be effective in removing sediments and oil and grease that may impair the operation of other BMPs, provided that they are designed and maintained properly.

Sediment traps rely primarily on settling for pollutant removal. Because of the relatively small storage capacity and brief retention times, only coarse sediments are likely to be trapped. Resuspension of the sediments is likely, unless an aggressive maintenance program is followed.

Pollutants are not actually removed from sediment traps until they are cleaned out. Regular maintenance is required to reduce the risk of resuspension of sediments during large storm events.

Planning Considerations

Sediment traps should be considered only for pretreatment applications, because of their limited pollutant removal and storage capacity. Traps are most frequently used in connection with pond and wetland BMPs.

Provisions need to be made for frequent cleaning and inspection. Sediment traps and forebays are designed for ease of maintenance.

Provisions should be made for the handling and disposal of trapped sediments and hydrocarbons removed from the traps. A secondary concern is the pulse loading of trapped materials during longer storm events due to resuspension of sediments.

Longevity of the systems is high, and standardized designs allow for easy installation. Relative to other BMPs, sediment traps are inexpensive.

Design

Sediment traps are typically on-line units, designed to slow stormwater runoff and settle sediments. Volume sizing should be for the prescribed water quality volume, at a minimum, and can accommodate the 2 and 10 year storms. Sediment traps should be designed for 0.1 inch/acre.

Sediment traps and forebays should incorporate design features to make maintenance accessible and easy. Concrete floors or pads make shoveling accumulated sediment very easy. If machinery is to be utilized, access should be planned carefully and included in the design. Sediment forebays may require excavation; therefore, concrete flooring may not be appropriate. A sediment depth marker makes inspections simple and identifies when sediment removal is due.

Generally, sediment traps and forebays are no deeper than 3 to 6 feet.

Side slopes for sediment forebays should not be steeper than 3:1. Channel geometry should prevent erosion from the 2 year peak discharge.

Discharge or outflow velocity from the sediment trap or forebay should also control for the 2 year peak discharge.

Maintenance

The actual removal of sediments and associated pollutants occurs only when sediment traps and forebays are cleaned; therefore, regular maintenance is required. Frequent the removal of accumulated sediments will make it less likely that sediments will be resuspended. At a minimum, sediment traps should be cleaned four times per year and inspected monthly.

Summary: Guidelines for Sediment Traps and Forebays

Site Criteria

- Sediment traps and forebays are widely applicable. Generally, a minimum of 0.1 inch/acre is required.

Design Criteria

- Sediment traps and forebays should incorporate design features to make maintenance accessible and easy.
- Concrete floors or pads for sediment traps.
- If machinery is to be utilized for sediment removal, plan for access.
- For sediment forebays, concrete floors may not be feasible.
- Floor or bottom drains to dewater accumulated sediment.
- A sediment depth marker makes inspection simple and identifies when sediment removal is due.
- Traps and forebays are no deeper than 3 to 6 feet.
- Side slopes not steeper than 3:1.
- Channel geometry should prevent erosion from the 2 year peak discharge.
- Discharge, or outflow velocity, from the sediment trap or forebay should also control for the 2 year peak discharge.

Maintenance Criteria

- Maintenance is required for the proper operation of sediment traps and forebays; plans should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule.

- Traps should be cleaned four times per year and inspected monthly.

- All sediments and hydrocarbons should be handled properly and disposed in accordance with local, state and federal guidelines and regulations.

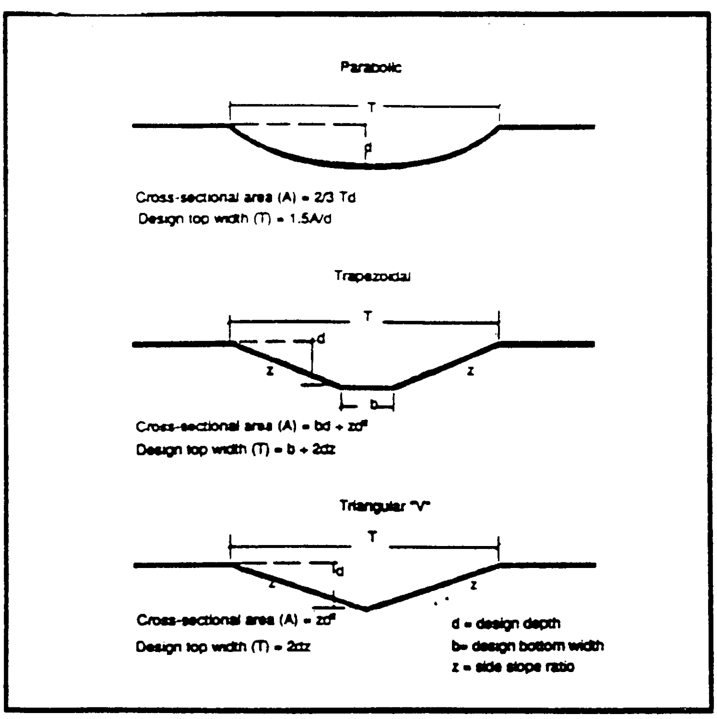
Drainage Channels

Definition

The distinction between drainage channels and water quality swales lies in the design and planned use of the open channel conveyance. Drainage channels are designed to have sufficient capacity to safely convey runoff during large storm events without causing erosion. Drainage channels typically have a cross-section with sufficient hydraulic capacity to handle the peak discharge for the 10 year storm event. Channel dimensions (slope and bottom width) should not exceed a critical erosive velocity during the peak discharge. Drainage channels should maintain some type of grass or channel lining to maintain bank and slope integrity. Other than basic channel size and geometry, there are no other design modifications to enhance pollutant removal capabilities. Therefore, pollutant removal efficiency is typically very low for drainage channels.

Water quality swales, on the other hand, are designed only for the prescribed water quality volume and incorporate specific features to enhance their stormwater pollutant removal effectiveness. Pollutant removal rates are significantly higher for water quality swales. See 3.D for discussions on design criteria for water quality swales.

Figure 3.K.1 provides a schematic of a typical drainage channel.



(MPCA, 1989)

Figure 3.K.1: Schematic of a Drainage Channel

Purpose

- To control runoff rates by retarding and impounding stormwater and conveying it downstream at velocities which protect against channel and streambank erosion.
- To provide some runoff volume control, by allowing stormwater to gradually infiltrate as it flows through the drainage channel.
- To provide limited (pretreatment) pollutant removal through low rates of sedimentation, filtration, nutrient uptake and exfiltration.

Advantages

- Can assist in controlling peak discharges by reducing runoff velocity and promoting infiltration.
- Provides pretreatment by trapping, filtering and infiltrating particulate and associated pollutants.
- Generally less expensive than curb and gutter systems.
- Roadside channels reduce driving hazards by keeping stormwater flows away from street surfaces during storms.
- Accent natural landscape.

Disadvantages

- Higher degree of maintenance required than for curb and gutter systems.
- Roadside channels are subject to damage from off street parking and snow removal.

Applicability

Drainage channels are applicable to residential and institutional areas of low to moderate density. The percentage of impervious cover in the contributing areas should be relatively small. Drainage channels can also be used in parking lots to break up areas of impervious cover.

Along the edge of roadways, drainage channels can be used in place of curb and gutter systems. However, the effectiveness of drainage channels may be reduced as the number of driveway culverts increase. They are also generally not compatible with extensive sidewalk systems. When using open channels in combination with roadways and sidewalks, it is most appropriate to place the channel between the two impervious covers.

The topography of the site should allow for the design of a channel with sufficient slope and cross-sectional area to maintain nonerosive flow velocities. The longitudinal slope of the swale should be as close to zero as possible and not greater than 5%.

Effectiveness

The range of pollutant removal efficiencies for drainage channels are provided in the Stormwater Management Standards (Volume 1, Chapter 1). When if the channel is well planned, designed, constructed and maintained, then the reduction of pollutant loadings should be at the high end of the reported values. Based on the probable range of results, ***channels cannot be used alone to meet the Stormwater Management Standards***. The use of channels as pretreatment devices or as components in a BMP system is encouraged.

Channels assist in controlling runoff volumes and peak discharge rates in two ways. First, the limited infiltration within the channel reduces runoff volumes slightly. Secondly, peak discharge rates are reduced by the grass or vegetated lining of the channel, which slows the velocity and increases the time of concentration.

Planning Considerations

When designing a drainage channel the two primary considerations are channel capacity and minimization of erosion. The maximum expected retardance should be used when checking channel capacity. Usually the greatest flow retardance occurs when vegetation is at its maximum growth for the year. The minimum expected retardance should be used when checking velocity through the channel. This usually occurs during the early growing season and dormant periods.

Other factors to be considered when planning for channels are land availability, maintenance requirements and soil characteristics. The topography of the site should allow for the design of a channel with sufficient slope and cross-sectional area to maintain a nonerosive flow velocity, generally less than five feet per second. The longitudinal slope of the channel should be as close to zero as possible and not greater than five percent.

The shape of cross-sectional channel is also an important planning consideration. Figure 3.K.2 shows three different designs.

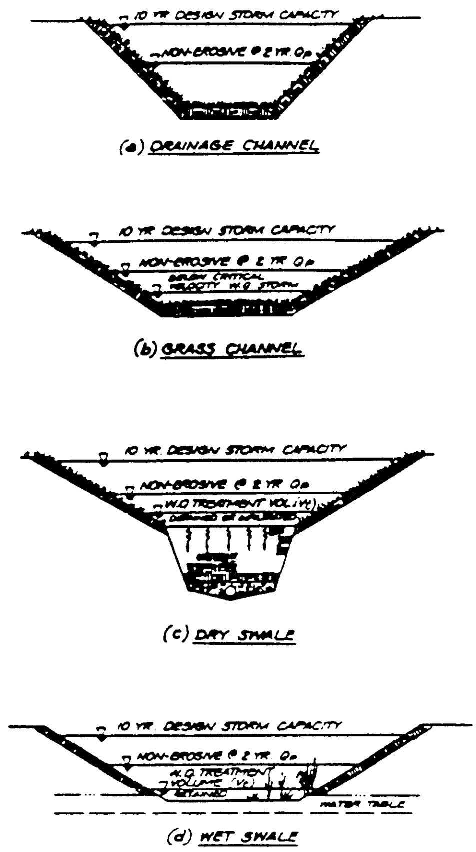


Figure 3.K.2: Drainage Channel Cross-Sections

The V-shaped or triangular cross-section can result in higher velocities than other shapes, especially when steeper side slopes are used. Thus, it should be used only if the quantity of flow is relatively small. The parabolic cross-section results in a wide shallow channel that is suited to handling large flows and blends in well with natural settings. When deeper channels are needed to carry large flows and conditions require relatively high velocities, trapezoidal channels can be used.

The grass type used as a channel lining must be appropriate for the site conditions, i.e., shade tolerant, drainage tolerant and low maintenance requirements. The vegetation used should be water tolerant and have a dense root system.

Design

See the following for complete design references:
Site Planning for Urban Stream Protection. 1995. Schueler. Center for Watershed Protection.

A minimum channel length of 100 feet is generally recommended for sufficient contact time and flow dissipation are necessary for pretreatment level pollutant removal. The minimum channel length is dependent on the slope as well as contributing surface area and runoff volume.

Since low velocity channels may act as sediment traps, extra capacity should be added for sediment accumulation, without reducing design capacity. An extra 0.3 to 0.5 feet of depth is recommended if sediment storage is expected.

Side slopes of 3:1 or flatter are recommended for maintenance and to prevent side slope erosion. The longitudinal slope of the channel should be as close to zero as possible and not greater than five percent.

Check dams may be installed in channels to provide temporary storage upstream of the dam, thereby promoting additional infiltration and pollutant removal. These dams can be created by sinking a railroad tie halfway into the channel, and placing stone on the downstream side to prevent scouring. Earthen check dams are not recommended since they tend to erode on the downstream side, and it is difficult to establish and maintain grass on the dams. The maximum ponding time behind the check dam should not exceed 24 hours.

Outlet protection must be used at discharge points from a drainage channels to prevent scour at the outlet.

Construction

Temporary erosion and sediment controls should be used during construction. The vegetation mix should be selected to suit the characteristics of the site. Seeding will require mulching with appropriate materials, such as, mulch matting, straw and wood chips. Mulch should be anchored immediately after seeding. New seedlings should be provided with adequate water until they are well established. Refer to the *"Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas: A Guide for Planners, Designers, and Municipal Officials"* on sediment/erosion control for information regarding seeding and mulching.

Maintenance

A maintenance and inspection schedule should take into consideration the effectiveness of the drainage channels. Drainage channels should be inspected on a semi-annual basis; additional inspections should be scheduled during the first few months to make sure that the vegetation in the channels is established adequately. The drainage channels should be inspected for slope integrity, soil moisture, vegetative health, soil stability, soil compaction, soil erosion, ponding, and sedimentation.

Regular maintenance tasks include mowing, fertilizing, liming, watering, pruning and weed and pest control. Channels should be mowed at least once per year. The grass must not be cut shorter than four inches. Excessive mowing is discouraged, as this may keep the grass too short, decreasing flow velocity and pollutant removal effectiveness.

Sediment and debris should be removed manually, at least once per year, before the vegetation is impacted adversely. Periodic reseeding may be required to maintain the dense growth of vegetation. Care should be taken to protect drainage channels from snow removal procedures and off street parking. Since channels may be located on private residential property, it is important that developers clearly outline the maintenance requirements to property purchasers.

Summary: Guidelines for Drainage Channels

Site Criteria

- The topography of the site should allow for the design of a channel with sufficient slope and cross-sectional area to maintain a nonerosive flow velocity of less than 5 feet per second.

Design Criteria

- A minimum channel length of 100 feet is recommended to result in sufficient contact time and flow dissipation to provide pollutant removal.
- The longitudinal slope of the channel should be as close to zero as possible and not greater than five percent.
- Side slopes of 3:1 or flatter are recommended for maintenance reasons and to prevent side slope erosion.
- The grass type used as a channel lining must be appropriate for the site conditions. The vegetation used should be water tolerant and have a dense root system.
- Extra capacity should be added for sediment accumulation, without reducing design capacity. An extra 0.3 to 0.5 feet of depth is recommended if sediment storage is anticipated.
- If check dams are used, the maximum ponding time behind the dam should not exceed 24 hours.
- Outlet protection must be used at any discharge points from drainage channels to prevent scour at the outlet.
- Generally, the maximum design velocity for drainage channels should not exceed 5 feet per second.

Construction Criteria

- Temporary erosion and sediment controls should be used during construction.

- Mulch anchoring should be done immediately after seeding.

Maintenance Criteria

- Maintenance is required for the proper operation of drainage channels - plans for drainage channels should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule.

- Drainage channels should be inspected at least semi-annually, and maintenance and repairs made as necessary. Additional inspections should be scheduled during the first few months and years to make sure the vegetation becomes adequately established. Repairs and reseeding should be done as required.

- Channels should be mowed at least once per year. Grass clippings should be removed. The grass must not be cut shorter than four inches. Excessive mowing is discouraged, as this may keep the grass too short.

- Sediment and debris should be removed manually, at least once per year, before the vegetation is adversely impacted.

- Care should be taken in protecting drainage channels from snow removal procedures and off-street parking.

APPENDIX A: Glossary

Note: Some definitions from the Massachusetts Wetlands Protection and Drinking Water Regulations are included for convenience and are summarized below. Please see the regulations for the full definitions.

"A" SOIL: SEE HYDROLOGIC SOIL GROUP "A."

ABSORPTION: The process by which one substance is taken into and included within another substance, as the absorption of water by soil or nutrients by plants.

ADSORPTION: The increased concentration of molecules or ions at a surface, including exchangeable cations and anions on soil particles.

AESTHETICS: All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.

ALTER: Under the Massachusetts Wetlands Protection Regulations, 310 CMR 10.04, to change the condition of any wetland resource area subject to protection under the Massachusetts Wetlands Protection Act (MGL c.131, s.40). Examples of alterations include, but are not limited to: a) changing drainage characteristics, flushing characteristics, salinity distribution, sedimentation patterns, flow patterns, and flood retention areas; b) lowering the water level or water table; c) destruction of vegetation; d) changing the water temperature, biochemical oxygen demand (BOD), and other physical, biological, or chemical characteristics of the receiving water.

ANTIDEGRADATION PROVISION: Portion of Massachusetts Water Quality Standards stating that in all cases, the existing uses and level of water quality must be maintained and protected. Antidegradation is implemented in three tiers. Tier I protects all existing uses. Tier II and Tier III are special cases of Tier I where waters are better than prescribed standards. Tier II sets the rules for justified lowering of high quality waters (the floor being the minimum specified by the class). Tier III protects Outstanding Resource Waters from any lowering of water quality.

ANTI-SEEP COLLAR: A plate that is attached to the barrel running through an embankment of a pond that prevents water seepage around the pipe.

AREA OF CRITICAL ENVIRONMENTAL CONCERN (ACEC): An area that has been formally designated by the Commonwealth's Secretary of Environmental Affairs pursuant to 301 CMR 12.00, which contains highly significant environmental resources.

AQUIFER: Geologic formation that is saturated and sufficiently permeable to transmit large quantities of water.

"B" SOIL: SEE HYDROLOGIC SOIL GROUP "B."

BANK (INLAND): Under the Massachusetts Wetlands Protection Regulations, 310 CMR 10.54(2), the portion of the land surface which normally abuts and confines a water body. It occurs between a water body and a bordering vegetated wetland and adjacent flood plain, or, in the absence of these, it occurs between a water body and an upland. The upper boundary of a bank is the first observable break in the slope or the mean annual flood level, whichever is lower. The lower boundary of a bank is the mean annual low flow level.

BARREL: A concrete or corrugated metal pipe that passes runoff from the riser, through the embankment, and to the pond outfall.

BASE FLOW: The portion of stream flow that is supported by groundwater seepage into a channel, rather than by stormwater runoff.

BASIN: See WATERSHED.

BEDROCK: Solid rock, commonly called "ledge", that forms the earth's crust. It is locally exposed at the surface but more commonly is buried beneath a few inches to more than 300 feet of soil and other material.

BENTHIC: Bottom of a sea or a lake. Organisms living on sea or lake bottoms.

BEST MANAGEMENT PRACTICES (BMPs): For purposes of stormwater management, structural, nonstructural, and managerial techniques that are recognized to be the most effective and practical means to prevent or reduce nonpoint source pollutants from entering receiving waters.

BIOACCUMULATION: Accumulation of metals or other toxics in living organisms.

BIOFILTRATION: The use of a series of vegetated swales to provide filtering treatment for stormwater as it is conveyed through the channel. The swales can be grassed, or contain emergent wetlands or high marsh plants.

BORDERING VEGETATED WETLAND: Under the Massachusetts Wetlands Protection Regulations, 310 CMR 10.55(2), a freshwater wetland which borders on creeks, rivers, streams, ponds, and lakes, such as wet meadows, marshes, swamps, and bogs.

BUFFER STRIPS: Areas of grass or other close growing vegetation that separates a waterway (ditch, stream, brook) from an intensive land use area (subdivision, farm); also referred to as filter strips, vegetated filter strips, and grassed buffers. Buffer strips can either be natural or man-made.

"C" SOIL: SEE HYDROLOGIC SOIL GROUP "C."

CATCH BASIN: A conventional structure for the capture of stormwater utilized in streets and parking areas. It typically includes an inlet, sump, and outlet and provides minimal removal of suspended solids. In most cases a hood also is included to separate oil and grease from the stormwater.

CERTIFIED VERNAL POOL: Under the Massachusetts Wetlands Protection Regulations, 310 CMR 10.57(a)(5)-(6), these are pools that have been certified by the Massachusetts Division of Fisheries and Wildlife, and the area 100 feet from the boundary of said pool. If the pool has not been certified, the wetlands regulations contain procedures for determining the probable extent of said habitat. These pools provide crucial habitat to several vertebrate and many invertebrate species of wildlife.

CHANNEL: In hydrology, the bed of a river or stream through which water is moved or directed. Channels may be either natural or man-made (e.g., a concrete lined box channel).

CHECK DAM: An earthen or log structure used in grass swales (perpendicular to the runoff flow) to reduce water velocity, promote sedimentation, and enhance infiltration.

COLLOIDS: The finely divided suspended matter that will not settle.

COMBINED SEWER OVERFLOW: A sewer pipe or system through which both sanitary wastewater and stormwater flows. During low frequency storms, both flows remain separate. During higher frequency precipitation events, the stormwater is mixed with the sanitary flow and may bypass wastewater treatment and be released to a receiving water body without treatment.

CONTAMINATED: As defined in 314 CMR 3.04, stormwater that has come in contact with process waste, raw materials, toxic pollutants, hazardous substances, or oil and grease, or which could be subject to case-by-case designation by DEP.

CONTRIBUTING WATERSHED AREA: The portion of a watershed contributing runoff to a BMP.

CONVEYANCE: System of pipes, conduits, ditches, and channels.

CRITICAL AREAS: For purposes of the DEP Stormwater Management Policy, critical areas are Outstanding Resource Waters (ORWs), shellfish growing areas, public swimming beaches, cold water fisheries, and recharge areas for public water supplies.

"D" SOIL: SEE HYDROLOGIC SOIL GROUP "D."

DESIGN STORM: A rainfall event of a specific size and return frequency (e.g., 2-year, 24-hour storm) that is used to calculate runoff volume and peak discharge rate to a BMP.

DETENTION TIME: The amount of time that a unit volume of stormwater actually remains in a BMP. Greater detention times will provide increased removal of suspended solids.

DISCHARGE: Water or effluent released to a receiving water body.

DISCHARGE RATE: The volume of water flowing in a stream or conveyance or through an aquifer past a specific point in a given period of time, usually denoted as the letter "Q" in hydrologic equations.

DRAINAGE AREA: Land area from which water flows into a stream or lake (see also watershed).

DRAIN DOWN VALVE: A valve located at the outlet structure of a detention basin. Normally closed, it is used to drain the detention basin for emergency purposes or routine maintenance.

DRY WELL: A type of BMP comprised of a small, excavated pit, backfilled with aggregate, which is used to infiltrate high quality runoff.

ENHANCED VEGETATIVE FILTER STRIPS: A natural buffer or Vegetative Filter Strip which has been engineered and maintained to improve pollutant removal capabilities. Also known as an Enhanced Vegetative Buffer Area.

EROSION: Weathering of soil by running water, wind, or ice.

EVAPORATION: The process by which precipitation is returned to the atmosphere as vapor.

EVENT: An actual storm or a computer program that models a single storm response.

EXFILTRATION: The downward movement of runoff from the bottom of an infiltration BMP into the soil layer.

EXTENDED DETENTION BASIN: An area surrounded by an embankment, or an excavated pit, designed to temporarily hold stormwater long enough to allow settling of solids and reduce local and downstream flooding.

FACULTATIVE: From the U.S Fish and Wildlife Service plant classification system of wetlands plants, facultative plants are those which grow in wetlands but also may grow in non-wetland areas. This is contrasted with OBLIGATE plants which are found almost exclusively within wetland areas.

FILTER FABRIC: Permeable or impermeable textile of a very small mesh or pore size. Permeable filter fabric allows water to pass through while keeping sediment out. Impermeable filter fabric prevents both water and sediment from passing through it.

FIRST FLUSH: Pollutant concentrations, including suspended sediments, carried by stormwater in the beginning of a storm. These concentrations are typically higher than at the middle or end of the storm. For purposes of the Massachusetts Stormwater Management Policy, the first flush is the first half-inch of precipitation, and in Critical Areas, the first inch of precipitation.

FLOATABLES: Materials in stormwater or sanitary flows which float to the surface.

FREEBOARD: The space between the top of an embankment and the highest water elevation expected for the largest design storm stored. The space is required as a safety margin in a pond or basin.

GRATE INLET: Structure used to cover an inlet to a sewer system to keep out debris.

GROUNDWATER: The water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined aquifer.

GROUNDWATER TABLE: See WATER TABLE.

GROUNDWATER RECHARGE: The return of water to an underground aquifer by either natural or artificial means such as exfiltration of a BMP.

HI MARSH: For purposes of stormwater management, the area in a stormwater wetland located at the surface of the normal pool to six inches in depth.

HYDRAULIC RADIUS: The ratio of the cross-sectional area of a stream and the wetted perimeter.

HYDRAULIC SURFACES: The surfaces of a channel or pipe over or through which water flows. If the surfaces are smooth, as in a concrete pipe or culvert, there is less friction and water will flow faster. If the surfaces are rough, the velocity of the flowing water is slower.

HYDROPERIOD: The extent and duration of inundation and/or saturation of wetland systems.

HYDROLOGIC SOIL GROUPS: U.S. Natural Resources Conservation Service (NRCS, formerly SCS) soil classification system for estimating the runoff potential of soils as a result of precipitation. Soils not protected by vegetation are assigned to one of four groups (A-D). They are grouped according to the intake of water when the soils are thoroughly wet and receive precipitation from long duration storms. The NRCS county soil surveys classify which soil belongs in which hydrologic soil group.

HYDROLOGIC SOIL GROUP "A" : Soils having a high infiltration rate when thoroughly wet, with a low runoff potential. These consist mainly of deep, well-drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission, and include sand, loamy sand, or sandy loam.

HYDROLOGIC SOIL GROUP "B": Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission, and include silt loam or loam.

HYDROLOGIC SOIL GROUP "C": Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission, and include sandy clay loams.

HYDROLOGIC SOIL GROUP "D": Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

HYDROLOGY: The science that deals with the occurrence and behavior of water in the atmosphere, on the earth's surface, and below its surface.

HYDROPHYTES: A plant that grows in and is adapted to an aquatic or very wet environment.

IMPERVIOUS AREA: Impermeable surface, such as pavement or roof top, which prevent the infiltration of water into the soil.

INFILTRATION: The entry of water (from precipitation, irrigation, or runoff) into the soil.

INFILTRATION BASIN: An impoundment where incoming stormwater runoff is stored gradually until it exfiltrates through the soil of the basin floor.

INFILTRATION BMP: A type of BMP designed to enhance the movement of stormwater runoff from the surface to the subsoil.

INFILTRATION RATE: The quantity of water that can enter the soil in a specified time interval.

INFILTRATION TRENCH: Shallow, excavated trench that is filled with stone to create an underground reservoir for stormwater runoff. The runoff gradually exfiltrates through the bottom of the trench, into the subsoil, and eventually into the water table.

INTERCEPTOR: Conduit at downstream end of a combined sewer that carries sewage to a treatment plant.

INTERIM WELLHEAD PROTECTION AREA (IWPA): For public water systems using wells or wellfields that lack a DEP approved Zone II, DEP will apply an interim wellhead protection area (IWPA). This interim wellhead protection area shall be a one-half mile radius measured from the well or wellfield for sources whose approved pumping rate is 100,000 gallons per day (gpd) or greater. For wells or wellfields that pump less than 100,000 gpd, the IWPA radius is proportional to the approved pumping rate which may be calculated according to the following equation: IWPA radius in feet = (32 x pumping rate in gallons per minute) + 400. A default IWPA radius or an IWPA radius otherwise computed and determined by the DEP shall be applied to transient non-community (TNC) and non-transient non-community (NTNC) wells when there is no metered rate of withdrawal or no approved pumping rate. The default IWPA radius shall be 500 feet for TNC wells and 750 feet for NTNC wells.

INVERT: Bottom of a channel or pipe.

LAND UNDER WATER BODIES AND WATERWAYS: In the Wetlands Protection Regulations, 310 CMR 10.10.25(2) and 10.56(2), the bottom of, or land under the surface of the ocean or any estuary, creek, river, stream, pond, or lake. This land may be composed of organic muck or peat, fine sediments, rocks, or bedrock.

LEVEL SPREADER: A device used to spread out stormwater runoff uniformly over the ground as sheetflow. Level spreaders are used to prevent concentrated, erosive flows and to enhance infiltration.

LO MARSH: For purposes of stormwater management, the area in a stormwater wetland that exists from six to 18 inches below the normal pool.

LOADING: The quantity of a substance entering the environment (soil, water, or air).

MASSACHUSETTS DRINKING WATER REGULATIONS: Regulations promulgated under 310 CMR 22.00 intended to promote public health and general welfare by ensuring that public water systems in Massachusetts provide water that is safe, fit, and pure to drink.

MICROPOOL: A small permanent pool used in a stormwater pond due to extenuating circumstances, i.e. concern over thermal impacts of larger ponds, impacts on existing wetlands, etc.

MICROTOPOGRAPHY: The contours along the bottom of a stormwater wetland system.

MULCH: Any substance spread or allowed to remain on the soil surface to conserve soil moisture and shield soil particles from the erosive forces of raindrops and runoff.

NATURAL HYDROLOGIC REGIMES: Stream channel, land form, and vegetative conditions that have not been altered by man.

NONPOINT SOURCE (NPS) POLLUTION: Pollution of surface or groundwater supplies originating from land use activities and/or the atmosphere, having no well-defined point of entry.

OBSERVATION WELL CLEARANCE RATE: The drop in water level per unit time in a test well installed in an infiltration device. Tracking the pattern of measurements over a series of years may indicate potential clogging problems.

OIL AND GREASE: This includes hydrocarbons, fatty acids, soaps, fats, waxes, and oils. Tests for oil and grease are determined on the basis of their common solubility in freon.

OIL AND GREASE SEPARATOR: Also known as a Water Quality Inlet (WQI).

100-YEAR, 24-HOUR EVENT: Precipitation from a storm that occurs with a predicted statistical frequency of once every 100 years over a 24-hour period. This storm has a 1% chance of happening in any one given year. Because this is a statistical storm, it could occur twice in the same year. The predicted statistical frequency may be based on actual data collected over a 100-year period or on a synthetic record based on partial data or data extrapolated from a nearby area.

100-YEAR FLOODING EVENT: The flood elevation that has a predicted statistical frequency of occurring once every 100 years This flood elevation has a 1% chance of happening in any one given year. Please note there is no correlation between the 100-year flood and the 100-year 24-hour precipitation event.

OPERATION AND MAINTENANCE PLAN: This plan outlines the regular inspection/cleaning schedule necessary to keep a BMP in good repair and operating efficiently and is a critical component to the success of either a stormwater runoff control BMP or a PPP required under the NPDES program.

OUTFALL: The end of the pipe which discharges stormwater, sanitary flows, or effluent to a receiving water body.

OUTSTANDING RESOURCE WATER (ORW): Waters designated as ORWs include all Class A designated public water supplies and vernal pools certified by the Natural Heritage Program of the Massachusetts Department of Fisheries and Wildlife and Environmental Law Enforcement. These waters have exceptional socioeconomic, recreational, ecological, and/or aesthetic values, and are subject to more stringent requirements under both the Massachusetts Water Quality Standards (314 CMR 4.00) and the Stormwater Management Standards.

OVERLAND FLOW: Flow of water across the land surface.

PARTICULATES: Sand, silt, or clay soil particles and organic matter found in stormwater.

PEAK DISCHARGE: The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

PERCOLATION: The flow or trickling of a liquid downward through soil or filtering medium. The liquid may or may not fill the pores of the medium.

PERVIOUS: Surfaces or soils which are permeable, allowing water to pass or migrate downward.

PHYSICAL SITE SUITABILITY: Factors to be considered when selecting/designing BMPs, including but not limited to soil suitability, the size of the watershed, depth to the water table, depth to bedrock, slope of the site, the potential for thermal enhancement, and proximity to wells and foundations.

PILOT CHANNEL: A paved or riprap channel that routes runoff through a BMP to prevent erosion of the surface.

PLUG FLOW: A flow value which is used to describe a constant hydrologic condition.

POCKET WETLAND: A stormwater wetland design for small drainage areas with no reliable base flow source.

POND/WETLAND SYSTEM: A two-cell stormwater wetland design with a wet pond in combination with a shallow marsh.

PONDSCAPING: A technique that uses wetlands vegetation, native trees, shrubs, and herbaceous plants to meet specific functional design objectives in a stormwater wetland system.

POINT SOURCE POLLUTION: Pollution of ground or surface water supplies at well-defined, usually manufactured, "points" or locations; discharges of treated wastewater from municipal and industrial treatment plants are common point sources of pollution.

POLLUTANT: Any substance of such character and in such quantities that upon reaching the environment (soil, water, or air), is degrading in effect so as to impair the environment's usefulness or render it offensive.

POLLUTANT REMOVAL MECHANISM: One factor which must be considered in the stormwater runoff management plan at a site. This factor considers the means by which expected contaminants at a site will be eliminated/controlled through the use of appropriate BMP(s).

POROUS PAVEMENT: A manufactured surface that allows water to penetrate through and percolate into the soil (as in porous asphalt pavement or concrete). Porous asphalt pavement is comprised of irregular-shaped crushed rock, pre-coated with asphalt binder. Water seeps through into the lower layers of gravel for temporary storage, then filters naturally into the soil.

PRECIPITATION: Water that falls to the earth in the form of rain, snow, hail, or sleet.

RECEIVING WATERS: Bodies of water that receive runoff or wastewater discharges, such as streams rivers, ponds, lakes, and estuaries.

RECHARGE: Water that infiltrates to an aquifer, usually from above.

RECURRENCE INTERVAL OR RETURN PERIOD: Time interval in which an event will occur on the average.

RETROFIT: The installation of a new BMP or improvement of an existing BMP in an already developed area.

RIPARIAN HABITAT: Area in or near a stream or river in which an organism or biological population normally lives or occurs.

RIPRAP: A combination of boulders, large stones, and cobbles used to line channels, stabilize banks, filter out sediments, or reduce runoff velocities.

RISER: A vertical pipe extending from the bottom of a pond BMP that is used to control the discharge rate from the BMP for a specific design storm.

RUNOFF: Precipitation, snow melt, or irrigation that flows over the land, eventually making its way to a surface water (such as a stream, river, pond).

RUNOFF RATE OR VELOCITY: The speed of runoff from a storm, expressed in units of distance per unit of time.

RUNOFF VOLUME: The volume of runoff as a direct result of a storm, usually expressed in units of cubic feet..

SAND FILTER: Self-contained beds of sand underlain with perforated underdrains. Runoff is filtered through the sand and is collected in the underdrain system and discharged to a receiving water or to another BMP for further treatment.

SCOURING: The clearing and digging action of flowing water, especially the downward erosion caused by stream water in sweeping away mud and silt from the streambed and outside bank of a curved channel.

SEDIMENT: Eroded soil and rock material and plant debris, transported and deposited by runoff.

SEDIMENT FOREBAY: Component of a stormwater runoff BMP that uses a small settling basin which allows sediments to settle out prior to flowing to a subsequent BMP. They are often used in tandem with infiltration devices, wet ponds, or marshes. Also known as a sediment trap.

SEDIMENTATION: The deposition of transported soil particles due to a reduction in the rate of flow of water carrying these particles.

SHEETFLOW: Runoff that flows over the ground as a thin, even layer rather than concentrated in a channel.

SIPHON: A closed conduit (pipe) a portion of which lies above the hydraulic grade line, resulting in a pressure less than atmospheric and requiring a vacuum within the conduit to start flow. A siphon utilizes atmospheric pressure to effect or increase the flow of water through the conduit.

SITE PLANNING: In terms of stormwater management, a preliminary component of a development plan, where appropriate BMP structures are well and properly sited.

SORB OR SORBTION: The attraction and adherence of moisture or metals onto soil particles. See ADSORPTION. The binding, or holding, of pollutants.

SLOPE: One factor to be considered as part of the physical site suitability assessment when designing and selecting a BMP. The slope, or incline, at a site limits the type(s) of BMP which may be employed in treating the stormwater runoff.

SOIL SUITABILITY: One factor to be considered under the physical site suitability assessment for selecting an appropriate BMP. Refer to HYDROLOGIC SOIL GROUP A, B, C, or D.

SOLUBLE: Refers to material which can be dissolved in water.

SOURCE CONTROLS OR SOURCE REDUCTION: A practice or structural measure to prevent pollutants from entering stormwater runoff or other environmental media.

SPREADER: See Level Spreader

STORM DRAIN: An inlet for the capture of stormwater.

STORMWATER: Runoff from a storm event, snow melt runoff, and surface runoff and drainage.

STORMWATER DISCHARGE: For the purpose of this document, a stormwater discharge is defined as any stormwater that culminates in a point source which discharges directly to a water of the Commonwealth, or to a separate stormwater sewer which in turn discharges to a water of the Commonwealth.

STORMWATER MANAGEMENT SYSTEM: A conveyance system for the capture, treatment and discharge of stormwater.

STORMWATER MANAGEMENT STANDARDS: Management standards to protect water bodies from the adverse impacts of stormwater runoff.

STORMWATER POLLUTION PREVENTION PLANS (PPP): Pollution prevention plans include planning; assessment; BMP identification; implementation; and evaluation and monitoring.

STORMWATER RUNOFF: For the purpose of this document, any stormwater that flows overland before infiltrating into the ground.

STORMWATER RUNOFF MANAGEMENT FACILITY: A physical structure designed to prevent and reduce nonpoint source pollution.

STORMWATER RUNOFF MANAGEMENT PLAN: The overall management plan to prevent and reduce the release of pollutants from a site. The management plan includes techniques to control the quality and quantity of stormwater and preparing and implementing Pollution Prevention Plans (PPP). The site specific structural and nonstructural BMPs and operation and maintenance plans are part of the management plan.

STORMWATER WETLAND: A constructed wetland system designed to maximize pollutant removal through uptake of pollutants by wetlands plants, retention, and settling.

STREAM BANK EROSION: The process which occurs when stream banks are gradually undercut, and slump into the channel.

STREAM CHANNEL: The bed of a river or stream.

STREAM FLOW VELOCITIES: Speed of flowing water in a stream or river measured in distance per unit of time.

STREAM MORPHOLOGY: The study of the structure and form of a stream or river (e.g. bank, bed, channel, depth, width, roughness of the channel, etc.).

SUBBASIN: See WATERSHED

SUBSIDENCE: The process of sinking to a lower level. For example, the elevation of the land surface above an aquifer may sink or subside when groundwater is withdrawn from the underlying aquifer. Subsidence also refer to the process by which sediment in solution settles out.

SURFACE WATER: Water which is visible from the land surface (e.g., streams, rivers, lakes, ponds, etc.).

SURFACE WATER QUALITY STANDARDS: Under 314 CMR 4.00, the Standards designate the most sensitive uses for which the various waters of the Commonwealth shall be enhanced, maintained, and protected; prescribe minimum water quality criteria required to sustain the designated uses; and contain regulations necessary to achieve the designated uses and maintain existing water quality including, where appropriate, the prohibition of discharges.

SUSPENDED SOLIDS: See TOTAL SUSPENDED SOLIDS

TECHNICAL RELEASE 55 (TR55): A US NRCS (formerly Soil Conservation Service) publication entitled "Urban Hydrology for Small Watersheds" which provides simplified procedures to calculate storm runoff volumes, peak rates of discharge, hydrographs, and storage volumes required for flood water reservoirs.

10-YEAR, 24-HOUR EVENT: Precipitation from a storm that has a predicted statistical frequency of occurring once every 10 years over a 24-hour period. This storm has a 10% chance of happening in any one given year.

THERMAL ENHANCEMENT: A raise in temperature of a surface water. This factor must be considered in the physical site suitability assessment when selecting/designing a BMP, particularly when the classification of the receiving stream is a cold water fishery. The Massachusetts Surface Water Quality Standards provide the minimum water quality criteria which must be maintained in order to support the designated use(s) of the states waterbodies.

TIDE GATE: Structure installed at the outlet of a sewer system that discharges into tidal waters to prevent the backflow of the receiving water into the conduits.

TIME OF CONCENTRATION (T_c): The time it takes for runoff to travel from the hydraulically most distant point of a watershed until it reaches an outlet or other specified point within the watershed. It is used to estimate peak discharge or to develop a hydrograph. The time includes sheet flow, shallow concentrated flow, and channel flow.

TIME OF TRAVEL (T_t): The time it takes surface water to travel from one location to another in a watershed. Sheet flow is not included. Travel time is a component of time of concentration).

TOTAL SOLIDS: The sum of the dissolved and suspended solids in a water or wastewater. Usually expressed as milligrams per liter.

TOTAL SUSPENDED SOLIDS (TSS): Matter suspended in water or stormwater; when water is filtered for laboratory analysis, TSS are retained by the filter, dissolved solids pass through.

TURBIDITY: Cloudiness in water due to suspended and colloidal organic and inorganic material.

2-YEAR, 24-HOUR EVENT: Precipitation from a storm that has a predicted statistical frequency of occurring once every 2 years, over a 24-hour period. This storm has a 50% chance of happening in any one given year.

TYPE I DISTRIBUTION STORM EVENT: U.S. NRCS precipitation distribution used in TR55. Not applicable in New England.

TYPE IA DISTRIBUTION STORM EVENT: U.S. NRCS precipitation distribution used in TR55. Not applicable in New England.

TYPE II DISTRIBUTION STORM EVENT: U.S. NRCS precipitation distribution used in TR55.

TYPE III DISTRIBUTION STORM EVENT: U.S. NRCS precipitation distribution used in TR55. A given rainfall amount, areal distribution, and time distribution used to estimate peak runoff. Type III storms represent tropical storms that move along the Atlantic coast and bring large 24 hour rainfall amounts.

URBAN RUNOFF: Surface runoff from urbanized areas (such as streets, parking lots, retail malls, residential developments, subdivisions. etc.).

UNTREATED STORMWATER: Stormwater which has not been treated to remove solids, nutrients, or other pollutants.

VEGETATIVE BUFFER AREAS: Refer to Vegetative Filter Strip (VFS).

VEGETATIVE FILTER STRIP (VFS): A type of BMP which EPA defines as a "permanent, maintained strip of planted or indigenous vegetation located between nonpoint sources of pollution and receiving water bodies for the purpose of removing or mitigating the effects of nonpoint source pollutants such as nutrients, pesticides, sediments, and suspended solids". A VFS, which both decreases velocity and removes pollutants from the stormwater, is designed to receive overland flow from an upland development. Also referred to as a Vegetative Buffer Area.

VEGETATIVE SWALE: A natural depression or wide, shallow vegetated ditch used to temporarily store, route, or filter runoff.

WASTEWATER: Typically liquid discharged from residential, business or industrial sources that contains a variety of wastes (fecal matter, by-products).

WASTEWATER TREATMENT FACILITY: A physical plant and its processes utilized for the purpose of treating waterborne pollutants from industrial and/or municipal wastewater.

WATER BODY: Includes oceans, estuaries, ponds, lakes, rivers, and streams.

WATER COLUMN: Water in a receiving water body or wetland.

WATER QUALITY: The physical, chemical, and biological characteristics of a water in regards to its suitability for a particular use.

WATER QUALITY BMP: A BMP that is specifically designed for pollutant removal.

WATER QUALITY INLET (WQI): An underground retention system, also known as an oil/grease separator, designed to separate trash, debris, sediments, and oil and grease from stormwater runoff.

WATERS OF THE COMMONWEALTH: Broadly defined to include all waters within the jurisdiction of the Commonwealth, including, rivers, streams, lakes, ponds, springs, impoundments, estuaries, wetlands, coastal waters, and groundwater.

WATERSHED: An area of land that contributes runoff to one specific delivery point; large watersheds may be composed of several smaller "subwatersheds," each of which contributes runoff to different locations that ultimately combine at a common delivery point.

WATER TABLE: The upper level of a saturated zone below the soil surface, often the upper boundary of a water table aquifer. The water table rises and falls according to the season, and the amount of rain and snow melt that occurs.

WETLAND BUFFER ZONE: Area of land extending one hundred (100) feet horizontally outward from the boundary of any resource area defined under the Wetland Protection Act Regulations (310 CMR 10.00) except for land under water bodies, land subject to tidal action, land subject to coastal storm flowage and land subject to flooding.

WETLAND MULCH: A technique for establishing marsh areas by spreading the top 12 inches of wetland soil from a donor wetland over the surface of a constructed stormwater wetland as a mulch.

WETLAND RESOURCE AREA: Protected areas specified in the Wetlands Protection Act. Specifically, these areas are banks, bordering vegetated wetlands, land under waterbodies and waterways, land subject to flooding, coastal areas, and riverfront areas specified in the Act.

WETLANDS: Tidal and non-tidal areas characterized by saturated or nearly saturated soils most of the year that are located between terrestrial (land-based) and aquatic (water based) environments; includes freshwater marshes around ponds and channels (rivers and streams), brackish and salt marshes; common names include marshes, swamps, and bogs.

WETLANDS NOTICE OF INTENT: Permit application filed with the local conservation commission and DEP regional office by any person intending to fill, dredge, or alter an area subject to protection under the Massachusetts Wetlands Protection Act.

WETLANDS PROTECTION ACT: The Massachusetts Wetlands Protection Act, MGL c.131, s.40. Under the provisions of the Act, no person may remove, fill, dredge, or alter certain resource areas without first filing a Notice of Intent and obtaining an Order of Conditions. The Act requires that the Order contain conditions to preserve and promote the protection of public or private water supply and groundwater supply, flood control, storm damage protection, the prevention of pollution and the protection of fisheries, land containing shellfish, and wildlife habitat.

WET POND: An area surrounded by an embankment, or an excavated pit, designed with a permanent pool of water. Runoff entering the wet pond displaces the water already present in the pool and remains there until displaced by the next storm event. Detention of the runoff in the pool allows for settling of solids and reduces local and downstream flooding.

ZONE A: Zone "A" means a) the land area between the surface water source and the upper boundary of the bank; (b) the land area within a 400-foot lateral distance from the upper boundary of the bank of a Class A surface water source, as defined in 314 CMR 4.05(3)(a); and (c) the land area within a 200 foot lateral distance from the upper boundary of the bank of a tributary or associated surface water body.

ZONE B: Means the land area within one-half mile of the upper boundary of the bank of a Class A surface water source, as defined in 314 CMR 4.05 (3)(a), or edge of watershed, whichever is less. However, Zone B shall always include the land area within a 400 foot lateral distance from the Class A surface water source.

ZONE I: Means the protected radius required around a public water supply well or wellfield. For public water supply system wells with approved yields of 100,000 gallons per day (gpd) or greater, the protective radius is 400 feet. Tubular wellfields require a 250 foot protective radius. Protective radii for all other public water supply system wells are determined by the following equation: Zone I radius in feet = [150 x log of pumping rate in gpd] - 350. This equation is equivalent to the chart in the DEP Water Supply Guidelines. A default Zone I radius or a Zone I radius otherwise computed and determined by the DEP shall be applied to transient non-community (TNC) and non-transient non-community (NTNC) wells when there is no metered rate of withdrawal or no approved pumping rate. The default Zone I radius shall be 100 feet for TNC wells and 250 feet for NTNC. wells.

ZONE II: Means that area of an aquifer which contributes water to a well under the most severe pumping and recharge conditions that can be realistically anticipated (180 days of pumping at approved yield, with no recharge from precipitation). It is bounded by the groundwater divides which result from pumping the well and by the contact of the aquifer with less permeable materials such as till or bedrock. In some cases, streams or lakes may act as recharge boundaries. In all cases, Zone II shall extend upgradient to its point of intersection with prevailing hydrogeologic boundaries (a groundwater flow divide, a contact with till or bedrock).

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United States Environmental Protection Agency. 1992. "Storm Water Management For Construction Activities, Developing Pollution Prevention Plans and Best Management Practices." Office of Water, Washington, D.C.

United States Environmental Protection Agency. 1992. "Storm Water Management For Industrial Activities, Developing Pollution Prevention Plans and Best Management Practices." Office of Water, Washington, D.C.

United States Environmental Protection Agency. 1991. "Guidance Manual For the Preparation of NPDES Permit Applications For Storm Water Management Discharges Associated With Industrial Activity." Office of Water, Washington, D.C.

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Wong, S.L. and R.H. McCuen. 1982. "Stormwater Management in Coastal Areas." Tidewater Administration, Maryland Department of Natural Resources, Annapolis, MD.

Woodward-Clyde Consultants. 1990. "Urban Targeting and BMP Selection." Oakland, CA.

APPENDIX C : Contacts

Questions about applying the Stormwater Management Standards:

MA Department of Environmental Protection

DEP Boston Office
Division of Watershed Management
One Winter Street
Boston, MA 02108
Tel: (617) 292-5695
Contact: Rich Tomczyk

DEP Northeast Regional Office
Division of Wetlands and Waterways
10 Commerce Way
Woburn, MA 01801
Tel: (617) 932-7600
Contact: BRP Stormwater Specialist

DEP Southeast Regional Office
Division of Watershed Management
20 Riverside Drive
Lakeville, MA 02346
Tel: (508) 946-2700
Contact: BRP Stormwater Specialist

DEP Central Regional Office
Division of Watershed Management
627 Main St.
Worcester, MA 01605
Tel: (508) 792-7650
Contact: BRP Stormwater Specialist

DEP Western Regional Office
Division of Watershed Management
4th Floor, State House West
436 Dwight St.
Springfield, MA 01101
Tel: (413) 784-1100
Contact: BRP Stormwater Specialist

MA Office of Coastal Zone Management

MA Office of Coastal Zone Management (CZM)
100 Cambridge Street
Boston, MA 02202
Tel: (617) 727-9530
Contact: Jan Smith

CZM North Shore
State Fish Pier
Gloucester, MA 01930
Tel: (508) 281-3972
Contact: Andrea Cooper

CZM South Coastal
20 Riverside Drive
Lakeville, MA 02347
Tel: (508) 946-8990
Contact: David Janik

CZM Metro Boston
100 Cambridge St.
Boston, MA 02202
Tel: (617) 727-9530 x459
Contact: Elizabeth Grob

CZM Cape and Islands
3225 Main St.
Barnstable, MA 02630
Tel: (508) 362-3828
Contact: Truman Henson

Questions about EPA NPDES Permits:

EPA Region 1
JFK Federal Building
Boston, MA 02203
Tel: (617) 565-3420

Locations of Critical Areas

Outstanding Resource Waters (ORW)

The location of each ORW is described in the Massachusetts Surface Water Quality Standards, 314 CMR 4.00, available for sale at the State House Book Store, Boston, telephone (617) 727-2834 and Springfield (413) 784-1376, and Designated Outstanding Resource Waters of Massachusetts (DEP), which is available for sale at the State House Book Store.

Shellfish Growing Areas

The location of the shellfish growing areas are described in the Massachusetts Surface Water Quality Standards, 314 CMR 4.00, available for sale at the State House Book Store, Boston, telephone (617) 727-2834 and Springfield (413) 784-1376. Maps of the shellfish growing areas are available for sale from Massachusetts Geographical Information Systems (MassGIS), Boston, telephone (617) 727-5227. Information about shellfish growing areas may be obtained from the municipal Shellfish Warden. Additional information may be available from the Massachusetts Division of Marine Fisheries at (617) 727-3193.

Public Swimming Beaches

Please contact the local municipality. A list of public swimming beaches inventoried through the State Comprehensive Outdoor Recreation Program (SCORP) in 1988 is available in data base form from MassGIS, telephone (617) 727-5227. In the future, public swimming beach maps will be available for sale from MassGIS.

Cold Water Fisheries

The location of the cold water fisheries are described in the Massachusetts Surface Water Quality Standards, 314 CMR 4.00, available for sale at the State House Book Store, Boston, telephone (617) 727-2834 and Springfield (413) 784-1376. Questions regarding the specific boundaries of the cold water fisheries may be directed to the Massachusetts Division of Fisheries and Wildlife at (617) 727-3151.

Recharge Areas for Public Water Supplies

Contact DEP Drinking Water Program, Boston, (617) 292-5770 or the DEP Regional Office (see list and phone numbers above) or a map available for sale at MassGIS at (617) 727-5227. The local public water supplier may also have maps available.

DEP Nonpoint Source Management Manual (Mega-Manual)

Copies of this manual were sent to each municipality and should be on file at the City or Town Hall.

Erosion-Sedimentation Manual

Copies of *The Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas: A Guide for Planners, Designers, and Municipal Officials* (EOEA) were sent to each municipality and should be on file at the City or Town Hall.

Questions about BMP Efficiency or to Submit Information to BMP Efficiency Database

New England Interstate Water Pollution Control Commission
255 Ballardvale St.
Wilmington, MA 01887
Tel: (508) 658-0500
e-mail: neiwpcc@aol.com
Contact: Scott Lussier

To Obtain U.S. NRCS County Soil Surveys

U.S. Natural Resources Conservation Service

U.S. Natural Resources Conservation Service (NRCS)
451 West St.
Amherst, MA 01002-2995

NRCS Barnstable Office
Flint Rock Rd., PO Box 709
Barnstable, MA 02630-0709
(508) 362-9332

NRCS Greenfield Field Office
55 Federal St., Hayburne Building, Room 270
Greenfield, MA 01301-2546
(413) 772-0384

NRCS Holden Field Office
Medical Arts Center Building
Room 100, 52 Boyden Rd.
Holden, MA 01520-2587
(508) 829-6628

NRCS Northampton Field Office
Potpourri Mall
243 King St., Room 39
Northampton, MA 01060-2329
(413) 586-5440

NRCS Pittsfield Field Office
78 Center Street (Arterial)
Pittsfield, MA 01201-6117
(413) 443-6867

NRCS W. Wareham Field Office
15 Cranberry Highway
West Wareham, MA 02576
(508) 295-7962

NRCS Westford Field Office
319 Littleton Rd.
Westford, MA 01886-4104
(508) 692-1904

Massachusetts Conservation Districts

Cape Cod Conservation District
PO Box 296
West Barnstable, MA 02668
(508) 362-6327

Dukes Conservation District
Box 1010
Edgartown, MA 02539
(508) 627-9088

Nantucket Conservation District
PO Box 1146, Candlehouse Lane
Nantucket, MA 02554
(508) 228-0714

Franklin Conservation District
243 King St., Room 39
Northampton, MA 01060-2329
(413) 584-1464

Worcester Conservation Districts
Medical Arts Center Building
Room 100, 52 Boyden Rd.
Holden, MA 01520-2587
(508) 829-0168

Hampden and Hampshire Conservation Districts
243 King St., Room 39
Northampton, MA 01060-2329
(413) 584-1464

Berkshire Conservation District
78 Center Street (Arterial)
Pittsfield, MA 01201-6117
(413) 443-1776

Bristol Conservation District
PO Box 475, 84 Center Street
Dighton, MA 02715
(508) 669-6558

Norfolk County Conservation District
460 Main St.
Walpole, MA 02081
(508) 668-0995

Plymouth Conservation District
15 Cranberry Highway
West Wareham, MA 02576
(508) 295-5495

Essex Conservation District
562 Maple St.
Hathorne, MA 01937
(508) 774-5578

Middlesex Conservation District
319 Littleton Road, Suite 205
Westford, MA 01886-4104
(508) 692-9395

Suffolk County Conservation District
PO Box 248
Boston, MA 02121-0248
(617) 265-6647

Sources of Hydrologic Information

U.S. National Weather Service
Boston, MA
Tel: (617) 561-5754

MA Department of Environmental Management
Office of Water Resources
100 Cambridge St.
Boston, MA 02202
Tel: (617) 727-3267

U.S. Army Corps of Engineers
New England Division
424 Trapelo Road
Waltham, MA 02254-9149
Tel: (617) 647-8220

U.S. Geological Survey
Water Resources Division
28 Lord Road, Suite 280
Marlborough, MA 01752
Tel: (508) 485-6360

Questions about grants available to municipalities for Water Quality Improvement Projects

Coastal Pollution Remediation Grant (Remediating roadway stormwater pollution, boat pumpout programs - includes Massachusetts Transportation Bond Funds)	CZM, Steve Barrett (617) 727-9530 x 413
Gulf of Maine Council Debris Reduction Mini-Grant (Small grants to reduce/clean up marine debris)	CZM, Steve Barrett (617) 727-9530 x 413
Coastal Monitoring Grant (Small grants to fund local water quality monitoring efforts)	CZM, Steve Barrett (617) 727-9530 x 413
Clean Water Act Section 319 Grants (Nonpoint Source Pollution Remediation Funds)	DEP, Steve McCurdy (617) 292-5779
Clean Water Act Section 604(b) Grants (Water Quality Management Planning - Funds water quality assessment and planning projects)	DEP, Steve McCurdy (617) 292-5779
Clean Water Act Section 104(b)3 Grants (Water Quality Demonstration Projects)	DEP, Steve McCurdy (617) 292-5779
Lake and Pond Grants (Lake and pond management, protection and restoration)	DEM, Steve Asen (617) 727-3267 x 524

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Mass. Environmental Trust (M.E.T.) General Grants (Focus on building citizen awareness and action regarding water quality issues)	M.E.T., Robin Peach (617) 727-0249
Clean Vessel Act Grants and (Funds boat pumpout facilities and dump stations)	Dept. of Fish and Wildlife, Environmental Law Enforcement (DFWELE), Buell Hollister (617) 727-3193 x 334
USF&WS National Coastal Wetlands Conservation Grants (Funds acquisition, restoration, enhancement or management of coastal wetlands)	EOEA - Wetlands Restoration and Banking Program, Christy Foote-Smith (617) 292-5991
ISTEA - Transportation Enhancement Funds (Funds for remediation and assessment of roadway stormwater runoff -- apply through Regional Planning Authority)	Executive Office of Transportation and Construction (EOTC), Shawn Holland (617) 973-8070
Septic Betterment Program (provides funds to towns to establish septic betterment programs)	DEP, Steve McCurdy (617) 292-5779
State Revolving Loan Fund (Various community infrastructure improvements)	DEP, Steve McCurdy (617) 292-5779

Questions About Applying For Verification of Performance of Alternative or Innovative Stormwater Treatment Technologies

Massachusetts Office of Business Development
Strategic Envirotechnology Partnership (STEP Program)
1 Ashburton Place - Room 2101
Boston, MA 02202
Contact: David Lutes, (617) 727-3206

APPENDIX D: Reviewing and Conditioning Innovative Stormwater Control BMPs

Conservation commissions are likely to see alternative technologies proposed to meet the Stormwater Management Standards, perhaps in situations where site constraints make it difficult to achieve the Stormwater Management Standards with conventional systems, when a new technology may provide a higher level of treatment, or when a technology is less-expensive. **If the operating parameters of an alternative technology have been verified by the Commonwealth's Strategic Envirotechnology Partnership (STEP) program, commissions shall presume the system will function within those parameters, provided the conditions under which it is to be used are similar to those in which its performance was verified (see page D-5).** If the operating parameters of an alternative technology have not been verified by the STEP program, this appendix outlines the information that should be submitted to conservation commissions to evaluate those innovative systems.

A. Information Commissions should require from the Applicant for Review of Innovative Systems:

1. Complete Description of the Innovative Technology or Product:

This information should include:

- Whether the operating parameters of the innovative system have been verified through the STEP program. If they have, presume the system will operate within those parameters. If the innovative system has not been verified through the STEP process, the follow ing is needed for the commission to evaluate the technology:
  - Size (What volume does it hold and/or treat?);
  - Technical description (How does it work?);
  - Capital costs;
  - Installation process and costs (How is it installed? What happens if it is installed improperly? What mistakes can happen during installation?); and
  - Operating and maintenance (O&M) requirements and costs (new technologies will not have long-term data on O&M requirements, so its particularly important that an applicant provide all available information for evaluation).

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2. Data on How Well the Innovative Technology Works:

- Data from laboratory testing and pilot or full-scale operations;
- If applicable, calculation of TSS removal rate. If a claim is made for a higher TSS removal rate than for a similar system listed in the DEP Stormwater Management Policy, the Applicant must provide sufficient data to support the claim;
- Operational details on any full-scale installations: e.g., locations, length of time in operation, maintenance logs and costs. Maintenance logs should record the dates of inspections and cleaning, actions performed, quantities of solids removed, and time required for work; and
- Information on any system failures, what those failures were, and how were they corrected.

3. Additional Information:

- Articles from peer-review, scientific or engineering journals (more credible than advertising materials);
- Any approvals or permits from other authorities; and
- References from other installations.

B. Conservation Commission Evaluation of the Information

The key evaluation criterion is the technology's ability to meet the Stormwater Management Standards, such as the TSS removal rate, effective runoff infiltration, or its ability to perform as well as standard technologies on sites with higher potential pollutant loads or in critical areas. Be aware that technology developers typically document the advantages of their system, whether standard or innovative. It is the responsibility of the conservation commission, however, to determine the disadvantages of the technology and to decide whether the technology will perform as well as the alternatives. The conservation commission should look at the following issues when evaluating whether the proposed innovative technology will work, assuming that it has not been verified by the STEP program.

1. Purpose of the Technology

- Why was this technology proposed? Possible reasons are the innovative technology provides a higher level of environmental protection, uses less land area, is less expensive on a capital or operating/maintenance cost basis. The performance data and other information provided with the application need to support these claims. For instance, if the applicant proposes an innovative technology because it is less expensive to maintain than a conventional BMP system, the information will need to support that claim.

2. Analysis of Data

- Are the data complete? If there are any gaps, why? Are you satisfied with the reasons given as to why there are gaps? For example, if maintenance data are provided for a two-year period, and there is a six-month gap in the record, a reasonable explanation for the gap should be provided.

- If applicable, do the data and calculations support the claim of a higher TSS removal rate? Applicants must be able to demonstrate that their calculations show satisfactory performance in a laboratory, and preferably, adequate field testing results.

- Is the site similar to other locations where the innovative technology is already properly operating? The greater the similarity in key factors (e.g., soil conditions, climate, sediment loading rates, surficial geography, slopes), the greater the likelihood that the technology will properly work at the proposed site.

- Were performance data (laboratory or field) collected by the technology developer or by independent organizations? Independent data are preferable, but may not always be available.

3. Operation and Maintenance

- The more performance data that are available, the greater the assurance that it will meet the Stormwater Management Standards. As noted earlier, you are not likely to see as much data for a new technology as for a standard one, and the commission will need to decide if the data available are sufficient to allow the use proposed. If seasonality is an issue, the commission should see data collected over a full change of seasons that reflect a normal weather year, or at least an estimate of normal annual operations based on available data. If only limited data are available, is it possible to assess how the technology will work over its expected life? Can the technology function well for the full range of storm events that need to be controlled? If not, is there a way to address this problem?

- A number of new technologies perform very well, but only if they a are installed and maintained as specified by the manufacturer and when performance is verified in the field. For example, some innovative deep sump technologies may be able to achieve an 80% TSS removal rate, but only if they are cleaned often enough to prevent clogging of the outlet. A reliable, verifiable plan to perform and pay for maintenance is important for any stormwater management project, but particularly so for a new technology.

4. Impact on Stormwater Management Standards

- Will the proposed technology, either stand alone or in combination with other technologies, meet all of the Stormwater Management Standards? Is it possible that a technology may effectively meet one Standard, but hamper compliance with other Standards? For example, a technology might increase the rate of TSS removal, but limit the annual recharge. Documentation should have be provided by the applicant to help the commission evaluate this issue.

5. Failures

- Technologies may not work all the time or at all locations, and therefore, failures may be expected. If there have been failures, either in the laboratory or in real settings, is the applicant able to adequately explain the reasons for the failure? Examples could be poor design, improper sizing, higher sediment loading than anticipated, extreme hydrologic events, poor installation, or poor maintenance. If it was a design problem, has the design of the technology been modified to address the problem? For failures that were not design related, what corrections were made to prevent future failure? Were systems rechecked to see if they were functioning properly after corrections were made?

6. References and Other Sources of Information

- Check any references provided by the applicant to find out whether previous installations are properly functioning.

- If the information indicates that other conservation commissions have previously approved this technology for use in their municipalities, check with that commission to verify that the system has performed properly. Were there unexpected operating/maintenance costs? If there were problems, did the vendor assist in resolving them?

- If there are no references or if the innovative technology has not been previously approved by other conservation commissions, federal, state, or other organizations may be able to provide information on new technologies. For further assistance, contact the Massachusetts Office of Coastal Zone Management, U.S. Natural Resources Conservation Service, Mass. Community Assistance Partnership, Eight Towns & the Bay, and the New England Interstate Water Pollution Control Commission (is establishing a data base for stormwater control BMPs). See Appendix C for more information.

C. Conservation Commission Decisions On Innovative Systems: Dealing With the Uncertainties of New Technologies

After evaluating the innovative system, the conservation commission must issue a decision, approving or denying the use of the proposed technology to meet the Stormwater Management Standards. There may be instances where the conservation commission may want to add conditions to the Order of Conditions to ensure the proper functioning of the innovative technology and, if covered in a local wetlands bylaw, require a bond to be posted to pay for any repairs that may be necessary if the innovative system does not perform as designed. However, in Notice of Intent (NOI) filings where insufficient information exists, such that the commission can not adequately evaluate the proposed technology, the commission may either deny the project based on the lack of information (specify the specific information lacking in the denial), provide verification from an independent party that the system will function as designed, or ask the applicant to conduct more testing.

1. Verification:

- Referral to the STEP Program: The Commonwealth's Strategic Envirotechnology Partnership (STEP) provides resources to encourage the appropriate use of new and innovative technologies. If the technology has not been previously reviewed through STEP, commissions should recommend that the applicant contact STEP to inquire about verification procedures. STEP will provide verification of technology performance, demonstration support, and business assistance.

  Technology verification will give conservation commissions an independent evaluation of a technology's ability to perform under specified conditions. If the operating parameters of an innovative or alternative system have been verified by through STEP, commissions shall presume the system will function within those parameters, provided the conditions under which it is to be used are similar to those in which its performance was verified. Verification through STEP will relieve commissions from evaluating an innovative technology's performance. For more information, call David Lutes, Massachusetts Office of Business Development, (617) 727-3206.

- Referral to DEP's Watershed Management Nonpoint Source Program: This program provides grants to public agencies and private entities for implementing measures which prevent, control, or abate nonpoint source pollution. This program can provide information on stormwater management projects already funded. If the innovative technology needs further bench, pilot, or full-scale testing, the municipality, applicant, or technology vendor may apply for grants to verify that the technology works. For more information, contact Leslie O'Shea at DEP's Division of Municipal Services at (508) 767-2796.

2. More Testing:

- If the operating parameters of the innovative technology have not been verified through the above procedures, the commission may require more testing of the innovative system to ensure it will function as proposed.

- Additional laboratory, pilot (small-scale) installation, or a trial period for a full-size system can be established. Specifics that will need to be agreed upon may include the following:

  - Suitable timeframe;
  - Performance standards that must be met to determine that the technology is successful or the installation has been done successfully;
  - Performance data to be collected;
  - What will happen if the technology performs as required: will it be installed on a full-scale?; and
  - Conditions that will trigger a failure and provisions for replacing the technology in case of failure.

APPENDIX E: NPDES Stormwater Permit Program

In response to the need for comprehensive National Pollutant Discharge Elimination System (NPDES) requirements for storm water, the U.S. Environmental Protection Agency (EPA) has established phased NPDES requirements for storm water discharges. Phase one of the NPDES Storm Water Permits Program provides a mechanism for establishing appropriate controls for certain categories of storm water discharges associated with industrial activity and land disturbing activities exceeding five acres and discharges from municipal separate storm sewer discharges located in municipalities with a population of 100,000 or more. In Massachusetts, only Boston and Worcester are included in the municipal category. For more information about the Municipal, Industrial, and Construction Storm Water Permits, contact EPA Region I at (617) 565-3580.

Federal Stormwater Permit Program

The EPA is responsible for issuing NPDES permits in Massachusetts, as Massachusetts has not assumed NPDES program delegation. The NPDES permit program is administered by EPA Region I, with the Massachusetts Department of Environmental Protection (the Department) certifying permit conditions according to the requirements of Section 401 of the Federal Clean Water Act. In addition, the Department signs each NPDES permit, thus creating separate state and federal permits which provide equal regulatory and enforcement authority for both agencies. The Massachusetts Storm Water Permit Program, and its requirements, is discussed later in this Appendix.

Table E.1 lists the facilities and activities with storm water discharges covered by the NPDES Storm Water Permit Program. All storm water associated with these activities that culminates in a point source which discharges directly to a Water of the United States or to a separate storm water sewer which in turn discharges to a Water of the United States is required to obtain permit coverage. Attachment E.1 at the end of this Appendix provides an easy question and answer reference for determining if an industrial facility is required to be covered under this program.

TABLE E.1: Storm Water Discharge Associated With Industrial Activity
[Adapted from: Do I Need An NPDES Permit For Storm Water (EPA, 1993)]

The term "Storm Water Discharge Associated With Industrial Activity" includes the discharge from any conveyance which is used for collecting and conveying storm water and which is directly related to manufacturing, processing or raw materials storage areas at an industrial plant. The term does not include discharges from facilities or activities excluded from the NPDES program under 40 CFR Part 122.

For the following industrial categories (i) through (x), the term includes, but is not limited to, storm water discharges from industrial plant yards; immediate access roads and rail lines used or traveled by carriers of raw materials, manufactured products, waste material, or by-products used or created by the facility; material handling sites; refuse sites; sites used for the application or disposal of process waste waters (as defined at 40 CFR 401); sites used for the storage and maintenance of material handling equipment; sites used for residual treatment, storage, or disposal; shipping and receiving areas; manufacturing buildings; storage areas (including tank farms) for raw materials, and intermediate and finished products; and areas where industrial activity has taken place in the past and significant materials remain and are exposed to storm water.

For the following industrial category (xi), the term includes only storm water discharges from all the areas (except access roads and rail lines) that are listed in the previous sentence where material handling equipment or activities, raw materials, intermediate products, final products, waste material, by products, or industrial machinery are exposed to storm water.

As used here, material handling activities include the storage, loading and unloading, transportation, or conveyance of any raw material, intermediate product, finished product, by-product or waste product.

The term "Storm Water Discharge Associated With Industrial Activity" excludes areas located on plant lands separate from the plant's industrial activities, such as office buildings and accompanying parking lots as long as the drainage from the excluded areas is not mixed with storm water drained from the above described areas.

The following categories of facilities are considered to be engaging in "industrial activity":

Category i **Industries for which National Effluent Guidelines have been promulgated for storm water**

GUIDELINES	FACILITY TYPE
40 CFR 411	Cement Manufacturing
40 CFR 412	Feedlots
40 CFR 418	Fertilizer Manufacturing
40 CFR 419	Petroleum Refining
40 CFR 422	Phosphate Manufacturing
40 CFR 423	Steam Electric Power Generation
40 CFR 434	Coal Mining
40 CFR 436	Mineral Mining & Processing
40 CFR 440	Ore Mining & Dressing
40 CFR 443	Asphalt

Category ii **Facilities with Standard Industrial Codes (SIC) 24 (except 2434), 26 (except 265 and 267), 28 (except 283), 29, 311, 32 (except 323), 33, 3441, and 373**

SIC CODE	FACILITY TYPE
24	Lumber & Wood Products (except Furniture)
26	Paper & Allied Products
28	Chemical & Allied Products
29	Petroleum Refining & Related Industries
311	Leather Tanning & Finishing
32	Stone, Clay, Glass, & Concrete Products
33	Primary Metal Industries
3441	Fabricated Structural Metal
373	Ship & Boat Building & Repairing
2434	Wood Kitchen Cabinets
265	Paperboard Containers & Boxes
267	Converted Paper & Paperboard Products (except Containers & Boxes)
283	Drugs
323	Glass Products Made of Purchased Glass

Category iii **Facilities with Standard Industrial Codes 10-14**

SIC CODE	FACILITY TYPE
10	Metal Mining
12	Coal Mining
13	Oil and Gas Extraction
14	Mining and Quarrying of non-metallic minerals (except Fuels)

Category iv **Hazardous Waste Treatment, Storage, or Disposal Facilities, including those that are operating under interim status or a permit under Subtitle C of RCRA**

Category v **Landfills, Land Application Sites, and Open Dumps that receive or have received and industrial wastes including those that are subject to regulation under Subtitle D of RCRA**

Category vi **Facilities Involved in the Recycling of Materials, including Metal Scrap Yards, Battery Reclaimers, Salvage Yards, and Automobile Junkyards, Including but Limited to those classified under Standard Industrial Codes 5015 and 5093**

SIC CODE	FACILITY TYPE
5015	Motor Vehicle Parts, Used (Dismantling Motor Vehicles for Scrap)
5093	Scrap and Waste Materials

Category vii **Steam Electric Power Generating Facilities Including Coal Handling Sites**

Category viii **Transportation Facilities with Standard Industrial Codes 40, 41, 42 (except 4221-25), 43, 44, 45, and 5171 which have Vehicle Maintenance Shops, Equipment Cleaning Operations, or Airport Deicing Operations, only those operations that are either involved in vehicle maintenance, equipment cleaning operations, airport deicing operations, or which are otherwise identified under paragraphs (i)-(vii) or (ix)-(xi) are associated with industrial activity**

SIC CODE	FACILITY TYPE
40	Railroad Transportation
41	Local & Suburban Transit & Interurban Highway Passenger Transit
42	Motor Freight Transportation & Warehousing
43	U.S. Postal Service
44	Water Transportation
45	Transportation by Air
5171	Petroleum Bulk Stations & Terminals

Category ix **Treatment works treating domestic sewage or any other sewage or wastewater treatment device or system, used in the storage, treatment, recycling, and reclamation of municipal or domestic sewage, including land dedicated to the disposal of sewage sludge that are located within the confines of the facility, with a design flow of 1.0 MGD or more, or required to have an approved pretreatment program under 40 CFR 403**

Category x **Construction activity (except for disturbances of less than five acres of total land area which are not part of a larger common plan of development or sale)**

Category xi **Facilities where materials are exposed to storm water with Standard Industrial Codes 20, 21, 22, 23, 2434, 25, 265, 27, 283, 285, 30, 31 (except 311), 323, 34 (except 3441), 35, 36, 37 (except 373), 38, 39, and 4221-25**

SIC CODE	FACILITY TYPE
20	Food & Kindred Products
21	Tobacco Products
22	Textile Mill Products
23	Apparel & Other Finished Products Made from Fabrics & Similar Materials
2434	Wood Kitchen Cabinets
25	Furniture & Fixtures
265	Paperboard Containers & Boxes
267	Converted Paper & Paperboard Products (except Containers & Boxes)
27	Printing, Publishing, & Allied Industries
283	Drugs
285	Paints, Varnishes, Lacquers, Enamels, & Allied Products
30	Rubber & Miscellaneous Plastics Products
31	Leather & Leather Products
323	Glass Products Made of Purchased Glass
34	Fabricated Metal Products (except Machinery & Transportation Equipment)
35	Industrial & Commercial Machinery & Computer Equipment
36	Electronic & Other Electrical Equipment & Components (except Computer Equipment)
37	Transportation Equipment
38 &	Measuring, Analyzing, & Controlling Instruments; Photographic, Medical, & Optical Goods; Watches Clocks
39	Miscellaneous Manufacturing Industries
4221	Farm Product Warehousing & Storage
4222	Refrigerated Warehousing & Storage
4223	Household Goods Warehousing & Storage
4225	General Warehousing & Storage

There are three permit application options for storm water discharges associated with industrial activity. The first option is to file a Notice of Intent (NOI) to be covered under the EPA general storm water permit. The second was to participate in a group application by facilities that have similar industrial operations, waste streams, or other characteristics. The third option is to file an application for an individual permit. Construction activities which exceed the threshold of disturbance of five acres or more are able to use either the first or third options. These options are discussed in greater detail below.

It should be noted that the Transportation Act of 1991 provided an exemption from the storm water permit requirements for certain industrial activities owned or operated by municipalities with a population of less than 100,000. Only airports, power plants, and uncontrolled sanitary landfills owned by these municipalities are required to apply for a storm water permit. The Act also revised the group application deadlines for these facilities; the deadlines for submitting Part 1 and Part 2 of the group application were May 18, 1992 and May 17, 1993, respectively.

Storm Water General Permit

To address the pollutant problem of storm water discharges, and to ease the administrative burden on the EPA and the permittees, the EPA has issued General Permit for construction sites of five (5) acres or more, and another for storm water associated with industrial activity. These permits were promulgated by EPA under the authority of the Clean Water Act and were published in the Federal Register on September 25, 1992 (47 CFR 44412 and 47 CFR 44438).

The majority of storm water discharges associated with industrial activity can be covered by EPA's General Permits. Storm water discharges associated with industrial activities that cannot be authorized by the General Permit include those:

- With an existing effluent guideline for storm water (see Category i in Table E.1 above);
- That are mixed with non-storm water, unless the non-storm water discharges are in compliance with a different NPDES permit or are authorized by these permits;
- With an existing NPDES individual or General Permit for the storm water discharges;
- That are or may reasonably be expected to be contributing to a violation of a water quality standard;
- That are likely to adversely affect a listed or proposed to be listed endangered or threatened species or its critical habitat;
- From inactive mining, or inactive oil and gas operations or inactive landfills occurring on Federal lands where an operator cannot be identified (industrial permit only).

To apply for coverage under the EPA General Permit, a facility must submit a Notice of Intent (NOI) to receive authorization for the discharge. The NOI is a one page form that requires the following information:

- Street address or latitude/longitude;
- SIC Code or identification of industrial activity;
- Operator's name, address, telephone number, and status as Federal, State, private, public, or other entity;
- Permit number(s) of any existing NPDES permit(s);
- Name of receiving water(s);
- Indication of whether the owner or operator has existing monitoring data quantifying pollutant concentrations for the storm water discharges;
- A certification that a storm water pollution prevention plan (PPP) has been prepared for the facility (for industrial activities that begin after October 1, 1992).

In addition this information, NOIs for construction sites of five (5) acres or more require:

- An estimate of the project start date and completion dates and estimates of the number of disturbed acres.

Applicants are not required to collect discharge monitoring data in order to submit a NOI. Facilities which discharge to a large or medium municipal separate storm sewer system must also submit signed copies of the NOI to the operator of the municipal system. Operators of construction activities must also submit signed copies of the NOI to local agencies approving sediment and erosion or storm water management plans under which the construction activity is operating.

For facilities or construction activities which started after October 1, 1992, an NOI is to be submitted at least two days prior to the Commencement of the industrial activity. Existing facilities and construction activities which started before October 1, 1992 were required to submit an NOI by October 1, 1992. To be covered under the EPA General Permit NOIs must be submitted to the following address: Storm Water Notice of Intent, P.O. Box 1215, Newington, VA 22122.

Copies of the NOI form and the General Permit are found in the September 25, 1992 Federal Register (57 FR 44412 and 57 FR 44438). Copies can also be obtained by calling the EPA Office of Water Resources Center at (202) 260-7786.

The Pollution Prevention Plan is considered to be the most important requirement of the General Permit. Each industrial facility or construction activity covered by the General Permit must develop a plan, tailored to the site specific conditions and designed with the goal of controlling the amount of pollutants in storm water discharges from the site. Each facility will select a pollution prevention team that will be responsible for developing and implementing a PPP.

The general components of pollution prevention plans are described in Chapter 2 of this Handbook. The Federal Register notices of the permits also detail the components of the PPPs, and outline special PPP requirements for EPCRA (Emergency Planning and Community Right-to-know Act) Section 313 sites and construction sites. PPPs can incorporate other plans, such as Spill Prevention Control and Countermeasure (SPCC) plans, or Best Management Practices (BMP) programs. Copies of **Storm Water Management for Industrial Activities: Developing Pollution Prevention Plan and Best Management Practices** (EPA-832-R-92-006) or **Storm Water Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices** (EPA-832-R-92-005) are available through Office of Water Resources Center at (202) 260-7786, NTIS at (703) 487-4650, and the Education Resource Information Center/Clearinghouse at (614) 292-6717.

The Pollution Prevention Plan must ensure that the plant equipment and industrial areas are inspected on a regular basis. At least once a year a comprehensive site compliance evaluation must be conducted. This evaluation includes looking for evidence that pollutants have or could be entering the drainage system, evaluating pollution prevention measures, identifying areas of the plan that can be improved, and reporting on the inspections and the actions taken.

Under the General Permit certain facilities are required to conduct semi-annual monitoring and report the results to EPA each year; others are required to sample each year and keep the results on file. Specific monitoring requirements and testing parameters for facilities are listed in the General Permit. If a facility can certify that there is no exposure of industrial areas or activities to storm water, they are not required to sample the discharge.

The Department has certified the EPA General Permit with special conditions; these conditions are discussed below in the **Massachusetts Storm Water Permit Program** section.

Storm Water Multi-Sector Permit

Under the group application process, similar industrial facilities were allowed to group together and submit a single application for the development of a storm water discharge permit. Group applications included descriptions of industrial activities, material stored outside, best management practices, and storm water sampling data. Representative facilities submitted monitoring data, thus distributing the effort and cost of the application and compliance among the group. The deadlines for submitting Part 1 and Part 2 of the group application were September 30, 1991 and October 1, 1992, respectively, for all industrial activities except those owned or operated by a municipality with a population of less than 250,000. For industrial activities owned or operated by a municipality with a population of less than 250,000 the deadlines were May 18, 1992 and May 17, 1993. Nationwide, approximately 700 groups covering 44,000 industrial facilities are in the group application process.

Using the group application information, EPA drafted a storm water General Permit covering 29 industrial sectors based on similar industrial activity. These 29 sectors are listed in Table A.2. This draft storm water multi-sector group permit was published in the Federal Register on November 19, 1993 (59 FR 61146). For more information on the status of the multi-sector permit, contact the EPA Region I office at (617) 565-3580.

Once the final multi-sector is issued by EPA, a NOI must be submitted to gain coverage under the multi-sector permit. Any industrial discharger described by one of the 29 sectors meeting the eligibility provisions of the permit can apply. Excluded from coverage under the multi-sector permit are:

- Unpermitted process wastewater;
- Combined storm water and unpermitted process wastewater;
- Discharges not in compliance with:
  1. Endangered Species Act
  2. National Historic Preservation Act
  3. National Environmental Policy Act.

TABLE E.2: Industries Covered by EPA'S Storm Water Multi-Sector Permit

EPA SECTOR #	FACILITY TYPE
1	Timber Products
2	Paper & Allied Products
3	Chemical & Allied Products
4	Asphalt Paving & Roofing Materials & Lubricant Manufacturers
5	Glass, Clay, Cement, Concrete, & Gypsum Products
6	Primary Metals
7	Metal Mining (Ore Mining & Dressing)
8	Coal Mines & Coal Mining-Related Facilities

9	Oil & Gas Extraction
10	Mineral Mining & Processing
11	Hazardous Waste Treatment, Storage, or Disposal
12	Landfills & Land Application Sites
13	Automobile Salvage Yards
14	Scrap & Waste Material Processing & Recycling
15	Steam Electric Power Generating, Including Coal Handling Areas
16 & 17	Motor Freight Transportation, Passenger Transportation, Rail Transportation, & U.S. Postal Service Transportation
18	Water Transportation Facilities that have Vehicle Maintenance Shops &/or Equipment Cleaning Operations
19	Ship & Boat Building or Repair Yards
20	Vehicle Maintenance Areas, Equipment Cleaning Areas, or Deicing Areas Located at Air Transportation Facilities
22	Treatment Works
23	Food & Kindred Products
24	Textile Mills, Apparel, & Other Fabric Products
25	Wood & Metal Furniture & Fixture Manufacturing
26	Printing & Publishing
27	Rubber, Miscellaneous Plastic Products, & Miscellaneous Manufacturing
28	Leather Tanning & Finishing
29	Fabricated Metal Products
30	Facilities That Manufacture Transportation Equipment, Industrial, or Commercial Machinery
31	Facilities That Manufacture Electronic & Electrical Equipment & Components, Photographic & Optical Goods

[Adapted from: Storm Water Multi-Sector General Permit - Press Package (EPA, 1993)]

As with the General Storm Water Permit described above, the pollution prevention plan is the basic storm water control mechanism in the multi-sector permit. All facilities applying for coverage under the multi-sector permit must prepare and implement storm water pollution prevention plans using industry-specific BMPs aimed at controlling known sources of contamination, such as de-icing compounds at airports. EPCRA Section 313 sites have special PPP requirements under the multi-sector permit.

Discharge monitoring is required for 17 high priority industrial sectors, including EPA Sector #s 1, 3, 5, 6, 7, 11, 12, 13, 14, 15, 18, 19, 20, 22, 23, 28, and 29 (see Table A.2). Monitoring for these industrial sectors is required because the group application data indicated at least three pollutants above benchmark levels. Quarterly storm water grab samples are required for the 17 sectors in the second and forth year of the permit. The chemical monitoring provisions of the multi-sector permit have been designed to give feedback on the effectiveness of the PPP and to provide an incentive to implement the most effective BMPs. If the 2nd year monitoring data shows that BMPs have reduced pollutant levels to below the benchmarks, further sampling is not required.

Storm Water Individual Permit

Operators of facilities with storm water discharges associated with industrial or construction activity who did not participate in a group application and who are not included for coverage under the General Permit must submit an individual storm water permit application. The individual permit application process is considerably more lengthy than the General Permit NOI. The **Guidance Manual For The Preparation of NPDES Permit Applications for Storm Water Discharges Associated with Industrial Activity** (Order #PB92199058), available from NTIS, (703) 487-4650, is recommended as a good reference for operators who are preparing individual storm water permit applications. To complete the monitoring data required by the application, **NPDES Storm Water Sampling Guidance Document**, available from the EPA Office of Water Resources Center at (202) 260-7786, is recommended. As with the General Permit, the deadline for an individual permit application for existing facilities was October 1, 1992. For new industrial discharges the application deadline is 180 days prior to the commencement of the new discharge. For construction activities the application deadline is 90 days prior to the date construction begins. An individual storm water permit for a facility will be developed based on the information received in the application from that facility.

Massachusetts Stormwater Permit Program

The Massachusetts Department of Environmental Protection Surface Water Discharge Permit Program regulations (314 CMR 3.00) address storm water contamination and require discharge permits to control the amount of pollutants discharged from storm water systems. Section 3.04(2)(a)(1) defines storm water discharges as "...a conveyance or system of conveyances primarily used for collecting and conveying storm water runoff... and which discharges storm water contaminated by contact with process wastes, raw materials, toxic pollutants, hazardous substances, or oil and grease...(or) located in an industrial plant or in plant associated areas...". Such storm water discharges must have a current, valid permit to discharge into waters of the Commonwealth. The Director of the Office of Watershed Management (OWM) may designate other discharges as "storm water discharges" on a case-by-case basis if it is determined that the discharge is or may be a significant contributor of pollution..." This regulatory authority allows the Department to require storm water permits where appropriate.

As stated above, the NPDES permit program in Massachusetts is administered by EPA Region I, with the Department certifying permit conditions according to the requirements of Section 401 of the Federal Clean Water Act. The Department reviews the conditions of each NPDES permit and certifies the permit unconditionally or with special conditions, if appropriate. In addition, the Department signs each NPDES permit, thus creating separate state and federal permits which provide equal regulatory and enforcement authority for both agencies.

In order to facilitate the administration of the Storm Water Permit Program in Massachusetts, the Department's certification of the EPA General Permit was published in the Federal Register on September 25, 1992. Under the Department's certification of the EPA General Permit, storm water outfalls will be designed to eliminate direct discharge and minimize the contamination. New discharge outfall pipes shall be designed to be set back from the receiving water. Existing discharge outfall pipes shall be set back from the receiving water when the system is modified. For the setback, a receiving swale, infiltration trench or basin, filter media dikes or other BMPs should be used to minimize erosion, maximize infiltration, and otherwise improve water quality prior to discharge. In addition, the conditions of the Department's certification contain provisions to ensure the protection of water segments and wetlands designated as Outstanding Resource Waters (ORW), including coastal water segments and wetlands designated as Areas of Critical Environmental Concern (ACEC).

Public water supplies, tributaries to public water supplies, certain wetlands, and certain other waters with outstanding socioeconomic, recreational, ecological and/or aesthetic values are designated as ORWs in the Massachusetts Surface Water Quality Standards (WQS) (314 CMR 4.00). The provisions of 314 CMR 4.00 are specifically designed to protect and provide safeguards and regulatory control for ORWs. These regulations prohibit discharges which are likely to cause degradation due to runoff and other pollutant inputs. Section 4.04(3) of the WQS contains the antidegradation provisions which prohibit the discharge of new or increased discharge to an ORW, unless the discharge is determined by the Director "...to be for the express purpose and intent of maintaining or enhancing the resource water for its intended use...". The antidegradation provisions also require that existing discharges to ORW's shall cease and be diverted to a POTW (publicly owned treatment works). If the connection to a POTW is not reasonably available or feasible, then the existing discharge must be provided with the highest and best practical method of treatment determined by the Department as necessary to protect and maintain the ORW.

New or increased storm water discharges to ORWs are not allowed under the Storm Water Permit Program in Massachusetts unless they have met the provisions of 314 CMR 4.04(3). If a facility has met these provisions, then the facility may apply for coverage under EPA's General Permit (or an individual or multi-sector permit). According to the Department's certification of the General Permit, eligible new or increased discharge must be set back from the receiving water as feasible, and BMPs must be utilized to protect and maintain the ORW resources. It should be noted that new or increased discharges to *coastal* ACECs are *not* allowed under the Department's certification of the General Permit.

Existing discharges to ORWs must also meet the setback provisions and utilize BMPs to protect the receiving water. The Department's certification of EPA's General Permit emphasizes the requirements of 314 CMR 4.04 by requiring that: "All discharges to Outstanding Resource Waters authorized under this permit must be provided the best practical method of treatment to protect and maintain the designated use of the outstanding resource."

Discharges to ORWs applying for coverage under the General Permit must submit a copy of the NOI, a fee transmittal form, and $50.00 fee to the Department, P.O. Box 4062, Boston, MA, 02108, in addition to submitting the NOI to EPA. NOI's submitted to the Department will be reviewed to ensure that the discharge is in compliance with the certification provision.

Compliance and Enforcement

The Department has the ability to take enforcement action against dischargers who are in violation of the storm water regulations or who circumvent the regulations. Enforcement is initiated by the Department regional offices and often involves the State Attorney General's Office.

The Department will take a proactive approach to storm water control, that is to inform all parties of the permit requirements and to review compliance with storm water policy and management standards and the implementation of BMPs as required. Storm water pollution preventions plans are generally required to be developed, and will be reviewed as part of the OWM watershed approach to permitting.

The Department will utilize the EPA General Permit for storm water control and to require individual NPDES storm water permits when conditions are such that the General Permit will not sufficiently control the impact of storm water. The storm water NPDES permits do not directly address the Department wetland regulations; however, those regulations, when properly applied, contribute to the overall control of water quality and resource protection. The Department views the wetland regulations as complementary to the storm water permit program.

ATTACHMENT E.1: Do I Need an NPDES Storm Water Permit?

An NPDES Storm Water Permit is needed for your facility if you answer YES to all three of the following questions:

1. Does your facility have a storm water discharge?

   The answer to this is YES if there is a positive collection/conveyance system,
   AND it culminates in a point source (pipe/ditch/swale).

2. Is this a point source discharge to the Waters of the United States?

   The answer to this is YES if the point source discharges to a river, pond, ocean, wetland, etc.
   OR the point source discharges to a separate storm sewer which, in turn, discharges to the Waters of the United States.

3. Does your facility engage in an activity which is considered an industrial or construction activity subject to regulations?

   The answer to this is YES if the SIC code for the primary activity which your facility engages in is listed in Table E.1 under Categories i - xi. If the SIC code for the primary activity which your facility engages in is listed in Table E.1 under Category xi, you must ask one more question: Are raw materials, finished products, by-products, or material handling equipment exposed to storm water? You must be conservative in determining this; you may be subject to the regulations if there is the potential for exposure.

If your facility needs an NPDES Storm Water Permit:

Submit a NOI for the General Permit,

OR submit an application for an individual permit.

An NPDES Storm Water Permit is not needed for your facility if:

Your facility does not have a point source discharge,

OR your facility does not discharge to the Waters of the United States or a separate storm sewer system (for example the storm water is discharged to a combined sewer system, a treatment plant, an infiltration pond, etc.), OR your facility is not mentioned in the regulations at 40 CFR 122.26(a) (1) (i-v). 40 CFR 122.26(a) (1) (i-v) requires permits for: (i) discharges permitted prior to 2/4/87; (ii) discharges associated with industrial activities; (iii & iv) large and medium municipal separate storm sewer systems; (v) discharges which cause or contribute to a water quality standards violation.

If your facility does not need an NPDES Storm Water Permit, it is recommended that you:

1. Document why you believe your facility is not subject to the regulations and keep this on file.

2. Institute a pollution prevention plan as found in the federal general permit.

If you are still not sure if your facility needs an NPDES Storm Water Permit contact:

1. EPA Region I: (617) 565-3580

2. MA Department of Environmental Protection: (508) 792-7470

[Adapted from: Do I Need An NPDES Permit For Storm Water? (EPA, 1993)]