4.0 Selecting the Best BMP at a Development Site

This section describes additional considerations when selecting and locating BMPs at a development site. These include:

- Physical Feasibility Factors
- Terrain Factors
- Watershed Factors
- Permitting Factors

4.1 Physical Feasibility Factors

Existing physical features in the landscape can impact the performance and design of all stormwater BMPs. In some cases, the existing site characteristics will determine if a stormwater BMP type is excluded from use. In-situ soils, groundwater table elevation, and drainage area impact a BMPs infiltration capabilities and the ability to provide a permanent pool. The slope characteristics of a site will determine if a BMP can drain and if certain considerations for erosion protection are needed. The presence of downstream conveyance systems and utilities in the area of the proposed BMP will impact design as well. Table 4.1 below provides more detailed information on BMP selection based on physical feasibility factors.

Soils. The key evaluation factors are based on an initial investigation of the USDA hydrologic soils groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility during design to confirm permeability and other factors (see Appendix A). The presence of hotspot discharge or the proximity of a drinking water resource (reservoir or wellhead protection) creates an additional restriction on the feasibility of infiltration.

Seasonal High Groundwater Table. This information indicates the minimum depth to the seasonally high groundwater table from the bottom or floor of a stormwater BMP. For areas where seasonally high groundwater tables are present, infiltration BMPs are generally not feasible. BMPs located in most areas of Maryland require a 4-foot buffer from the bottom of the BMP to the seasonal high groundwater table. This buffer reduces to 2 feet on the Eastern shore.

Drainage Area. This information indicates the recommended minimum or maximum drainage area that is considered suitable for the practice. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway is permitted, or more than one practice can be installed. The minimum drainage areas indicated for ponds and wetlands are flexible depending on water availability (baseflow or groundwater) and the mechanisms employed to prevent clogging.

Slope Restriction. This information evaluates the effect of slope on the practice. Specifically, the slope restrictions refer to how steep the area may be where the practice is located. Steep slopes can impact erosion, and the amount of fill needed to impound water for an embankment. For BMPs which include infiltration, setbacks from steep slopes are required to prevent seepage and slope instability.

Head (Elevation Change). This information provides an estimate of the elevation difference needed at a site (from the inflow to the outflow) to allow for gravity operation within the practice.

Infrastructure. The location of existing and proposed buildings and utilities (e.g., water supply wells, sewer, storm drains, drain fields, electricity) will impact the location, design, and construction of all stormwater BMPs. Landscape designers should also consider overhead electrical and telecommunication lines when selecting trees to be planted.

Table 4.1 BMP Selection - Physical Feasibility Factors

BMP LIST	SOILS	SEASONAL HIGH GROUND WATER TABLE BUFFER	DRAINAGE AREA	SLOPE RESTRICTION	HEAD (ELEVATION CHANGE)
Ponds	presence of karst topography requires a liner	wet ponds may require access to groundwater	10 acres min. for wet ponds and wet extended detention ponds	None	3 to 8 ft.
Wetlands	presence of karst topography requires a liner	Wetlands may require access to groundwater	10 acres min	None	3 to 5 ft
Infiltration Trench	$f \geq 0.52$ inch/hr	4 feet[1]	5 acres max	Setback from slope >15% is equal to height of the slope	1 ft
Infiltration Basin			10 acres max		3 ft
Dry Well	HSG A and B soils	4 feet[1]	1,000 ft^2 max	Setback from slope >15% is equal to height of the slope	none
Landscape Infiltration	HSG A and B soils	4 feet[1]	none	For facilities with infiltration the setback from a slope >15% is equal to the height of the slope	
Surface Sand Filter	Applicable for all HSG soils if designed with an underdrain. Without an underdrain soils must have an infiltration rate of 0.52 inches/hr.	2 feet with an underdrain 4 feet without an underdrain	10 acres max		5 ft
Underground Sand Filter					5 to 7ft
Perimeter Sand Filter					2 to 3 ft
Micro Bioretention	All HSG soils	2 feet			5 ft
Bioretention			10 acres max	None	
Pocket Submerged Gravel Wetland	HSG C and D soils	None	1 acre min for submerged gravel wetland	None	none
Submerged Gravel Wetland					
Bioswale	all HSG soils		none	4% max slope	3 to 5 ft
Wet Swale		Below ground water table	none		1 ft

[1] Four foot separation distance is maintained to the seasonally high groundwater table (2 feet on Lower Eastern Shore).

4.2 Watershed Factors

The design of stormwater BMPs shall consider the nature of the downstream water body that will be receiving the stormwater discharge. In some cases, higher pollutant removal or environmental performance is needed to fully protect aquatic resources and/or human health and safety. A shorter list of BMPs may be appropriate for use within these watersheds.

In Maryland, there are several different types of sensitive watersheds, each with unique features or regulatory requirements. In some watersheds, enhanced pollutant removal may be needed to protect drinking water supply or shellfish harvesting. In others, temperature increases caused by new development may need to be mitigated to preserve cold water habitat. Maryland sets water quality standards for different water bodies based on their Use Class designation. Designers should determine the Use Class Designation of the watershed where their project is located for additional criteria prior to designing their project (see COMAR 26.08.02.08).

The purpose of Maryland's water quality standards is to protect, maintain, and improve surface water quality. Two of the components of these standards are the Designated Use Classes and water quality criteria to protect them. Each major stream segment in Maryland is assigned one of the following Designated Use Classes:

- Use Class I & I-P: Water Contact Recreation and Protection of Nontidal Warmwater Aquatic Life where P indicates public water supply or reservoir protection areas
- Use Class II & II-P: Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting
- Use Class III & III-P: Nontidal Cold Water and public water supply
- Use Class IV & IV-P: Recreational Trout Waters and public water supply

For each designated use, specific water quality criteria are designed to protect aquatic life and human health. Typically, there are numeric criteria for toxics, dissolved oxygen, bacteria, and temperature (e.g., 5 mg/l for dissolved oxygen). There are also narrative standards that are used for other pollutants (e.g., oil, grease, odor) where specific values are impractical. For the majority of Maryland's waters, these criteria represent minimum standards for the support of balanced indigenous populations and contact recreation commonly known as "fishable/swimmable." In most cases, the majority of water quality concerns in each watershed can be addressed by meeting the design criteria in this Manual and COMAR 26.17.02. For higher quality waters such as Tier II watersheds that meet or exceed water quality standards, the existing water quality conditions must be maintained and addition management methods may be required.

In addition to the requirements set through water quality standards and use class designations, there are numerous State programs (e.g., Critical Areas, Wetlands and Waterways, Forest Conservation, Critical Area, FEMA floodplain) that regulate activities within and discharging to receiving waters.

Table 4.1 provides a summary list of watershed factors to consider when selecting a stormwater BMP for a development site. The criteria associated with each watershed factor are described in more detail below.

4.2.1 Cold Water Resource Areas (Use III & IV)

Cold and cool water streams have habitat qualities capable of supporting trout and other thermally sensitive aquatic organisms. These watersheds are defined as Use Class III waters, and watersheds where the Maryland Department of Natural Resources (DNR) has identified wild trout or cold water obligate benthic macroinvertebrate taxa (Refer to DNR’s website). Temperature increases caused by changes to land cover from development can have a significant impact on these thermally sensitive aquatic species. For these resources to survive, temperatures must not exceed the ambient temperature or 68º F in Use Class III and 75º F in Use Class IV streams.

The design objective of these watersheds is to maintain natural recharge, prevent stream warming, minimize stream channel erosion, and preserve the natural riparian corridor. Techniques for accomplishing these objectives include:

- Minimizing impervious surfaces
- Using lighter colored materials for impervious surfaces
- Exclusion of permanent pools
- Preserving existing forested areas and buffers
- Bypassing existing baseflow and/or spring flow
- Providing shade-producing landscaping for open conveyance systems
- Limiting extended detention times to 12 hours
- Using ESD practices that infiltrate

1. Stormwater BMPs for Mitigating Thermal Impacts

While thermal impacts are primarily caused by increases in impervious area, the following techniques will help reduce thermal impacts associated with stormwater BMPs:

- Wet ponds, wet extended detention ponds, and stormwater wetlands can have adverse downstream impacts on cold water streams, and their use is highly restricted. In cold water resource areas permanent wet pools and micro pools are not permitted.

- Maximize the infiltration capacity of each BMP. Increasing infiltration reduces the amount of surface runoff and lowers the thermal energy flowing into cold water resources.

- Design filtering practices (micro-bioretention, bioretention, sand filters) so that underdrains are at least four feet below the surface. Soil temperatures at this depth are cooler and fluctuate little in response to surface weather conditions. As runoff flows through, thermal energy is dissipated, and effluent temperatures are decreased.

- Use shade-producing plants in landscaped practices (bioretention, landscape infiltration, rain gardens, micro-bioretention, infiltration berm).

2. At-Source Techniques for Mitigating Thermal Impacts

For development sites located in Use Class III and IV watersheds, the following additional site design practices should be considered:

- **Impervious surface reduction:** Reducing impervious surfaces will help reduce thermal impacts. Studies show that as watershed imperviousness increases, progressively smaller rainfall depths are needed to produce large stream temperature fluctuations (Galli, 1990).

- **Lighter impervious materials:** The color of impervious surfaces affects the ability of a surface to absorb the sun's energy, and thus cause temperature increases. The Solar Reflectivity Index (SRI) measures how well a material reflects sunlight. Darker surfaces like asphalt pavement or shingles low SRI values, while concrete and white EDPM roofing has higher values. In thermally sensitive watersheds, designers should consider using materials with SRI values greater than 29 for paving and steep-sloped (≥2:12) roofing, and materials with SRI values greater than 65 for low-sloped (≤2:12) roofing (see Table 4.2).

- **Shade through landscaping:** Shading buildings and paved areas using trees and large shrubs can help to allow cooling through evapotranspiration. However, the full benefits of shading may not be realized until the trees and shrubs mature. Depending on the age and type of plants used, this may be several years. When using this technique, designers should strive to provide shade within five years of project completion.

Table 4.2 Solar Reflectance Indices (SRI) for Typical Paving & Roofing Materials

Paving Materials:	**Condition**	**SRI**
Asphalt	New	0
	Weathered	6
Gray Cement Concrete	New	35
	Weathered	29
White Cement Concrete	New	86
	Weathered	45
Roofing Materials:		
Gray Asphalt Shingles		22
Gray EPDM (Rubber)		21
Light Gravel on Built-Up Roof		37
White-Coated Gravel on a Built-Up Roof		79
White EPDM (Rubber)		84
White PVC		104

Source: LEED-NC for New Construction Reference Guide Ver. 2.2 (USGBC, October 2005)

4.2.2 Wellhead Protection

Areas that recharge existing public water supply wells present a unique management challenge. The key design constraint is to prevent possible groundwater contamination by preventing infiltration of hotspot runoff. At the same time, recharge of unpolluted stormwater is needed to maintain flow in streams and wells. Stormwater BMPs that promote infiltration are most appropriate in wellhead protection areas. However, for BMPs treating hotspot runoff, an impermeable liner or presence of HSG D soils with an underdrain is appropriate. For these hotspot areas, maintain at least 2 feet of buffer distance from the seasonally high groundwater elevation.

4.2.3 Reservoir Protection (Use I-P, III-P and IV-P)

Watersheds that deliver surface runoff to a public water supply reservoir are of special concern for maintaining groundwater recharge and providing water quality treatment. Therefore, maintaining an adequate separation distance between the BMP bottom and the seasonally high groundwater table is required. Depending on the treatment available at the water intake, it may be necessary to achieve a greater level of pollutant removal for the pollutants of concern such as bacteria, pathogens, nutrients, sediment or metals. Stormwater hotspots located in these watersheds shall be adequately treated so that they do not contaminate a drinking water source. Natural stream channel erosion is also a concern in these watersheds.

4.2.4 Tier II Watersheds

Streams in Tier II watersheds are currently meeting water quality standards. These waterbodies are high quality waters that require extra protection measures to prevent degradation. In addition, these watersheds may also possess high quality cool water aquatic resources. The design objectives are to maintain habitat quality through the same techniques used for cold water streams. In addition, enhanced criteria such as additional water quality or channel protection storage volumes may be required. MDE provides information on its website on criteria for development sites located in Tier II watersheds.

4.2.5 Maryland Critical Area Intensely Developed Areas.

Maryland Critical Area is a zone extending 1000 feet landward from mean high tide and the landward edge of tidal wetlands. The Critical Area Commission sets special stormwater management requirements for land development within Maryland's Critical Area. There are 3 designations for land area within the Critical Area – Resource Conservation Area (RPA), Limited Development Area (LDA), Intensely Developed Area (IDA). In these areas, infiltration practices may be limited due to a high ground water table. Stormwater BMPs located within any of these areas shall demonstrate compliance with the requirements set forth by the Critical Area Commission. Refer to DNR's website for more information.

4.2.6 FEMA Floodplains

BMPs constructed within the FEMA floodplain may result in a change in the FEMA 100-year boundaries or elevations. Any fill in a FEMA floodplain will require both state and local approvals. Two important considerations to siting stormwater BMPs in a FEMA floodplain are impacts to floodplain water surface elevations and ensuring proper function of the BMP during a 100-year design storm. BMPs that are designed to provide extreme flood protection (Qf_{100}) shall not be located in a FEMA floodplain.

Table 4.3 BMP Selection - Watershed Factors

BMP GROUP	COLD WATER RESOURCE AREAS (USE III & IV)	WELLHEAD PROTECTION	RESERVOIR PROTECTION (USE I-P, III-P, IV-P)	SENSITIVE STREAM (TIER II; USE II)	CRITICAL AREA (RCA, LDA, IDA)	FEMA FLOODPLAIN
Ponds (Dry detention; wet extended detention; dry extended detention; wet pond; multiple pond system)	Permanent pools not acceptable	May require liner if HSG A soils are present. Pretreat hotspots. 2-4 ft groundwater separation distance	Require control of Cp_{v}.	Require additional storage for control of Cp_{v}.	Drainage Area may limit use.	Not acceptable for Q_{f100} management. Ensure fill does not increase floodplain elevation or extent.
Stormwater Wetlands (pocket submerged gravel wetland; submerged gravel wetland; shallow wetland; extended detention wetland)	Shallow wetland and extended detention shallow wetland are restricted. SGW and pocket SGW are not restricted.	May require liner if HSG A soils are present. Pretreat hotspots. 2-4 ft groundwater separation distance.	Require control of Cp_{v}.	Require additional storage for control of Cp_{v}.	Drainage area may limit use.	Not acceptable for Q_{f100} management. Ensure fill does not increase floodplain elevation or extent.
Infiltration (Alternative surfaces; dry well; infiltration berm; infiltration trench; infiltration basin)	Ok with no permanent surface storage.	Separation distance from wells and water table. No untreated hotspot runoff. OK to infiltrate rooftop runoff.	Separation distance from bedrock and water table.	Ok	Often infeasible due to soils or water table in tidal areas.	Not acceptable for Q_{f100} management. Ensure fill does not increase floodplain elevation or extent.
Filtering Systems (Non-structural disconnection; raingarden; micro-bioretention; landscape infiltration; bioretention; surface sand filter; perimeter sand filter; underground sand filter)	Ok with no permanent surface storage.	Separation distance from wells and water table. No untreated hotspot runoff. OK to infiltrate rooftop runoff.	May be necessary for pretreatment prior to another BMP.	May be necessary for pretreatment.	Ok	Not acceptable for Q_{f100} management. Ensure fill does not increase floodplain elevation or extent.

Open Channels (grass swale; wet swale; bioswale)	OK with no permanent storage	OK, but hotspot runoff must be adequately pretreated	OK, but hotspot runoff must be adequately pretreated	Should be linked w/basin to provide Cp_v	OK	Not acceptable for Q_{f100} management. Ensure fill does not increase floodplain elevation or extent.

4.3 Terrain Factors

There are three key terrain factors to consider when selecting and designing stormwater BMPs: low relief (flat areas with limited slope), karst topography, and hilly terrain (areas with steep slopes). The terrain regions shown in Figure 4.1 are approximate. Table 4.3 provides information on BMP selection based on terrain factors and the following provides additional detail.

- **Low Relief Areas:** In Maryland, Low Relief Areas are found on the lower Eastern Shore, particularly below the Chester River. These areas exhibit limited change in elevation across the development site making it difficult to convey stormwater. In addition, these areas typically have seasonally high-water tables located very close to the land surface. Therefore, these areas are less conducive to using infiltration and filtering BMPs, and those requiring deeper ponding.

- **Karst Topography:** Karst topography and major carbonaceous rock areas are found in portions of Alleghany, Baltimore, Carroll, Frederick, Garrett, Montgomery, and Washington Counties. Karst topography includes areas of significant limestone that can dissolve when in contact with stormwater runoff. When the limestone areas dissolve voids in the ground remain causing sinkholes. Therefore, infiltration is not recommended in these areas and liners are to be used to prevent stormwater from coming into contact with limestone whether on the surface underground. In addition, due to the instability that karst topography can create, special geotechnical testing requirements may be needed, and additional stabilization techniques may be necessary. (see Appendix B).

- **Hilly Terrain Areas:** The steepest mountainous areas are found in the Western part of the State. These and other areas can have slopes of 15% or greater. Erosion into and from stormwater BMPs is a concern in these areas. BMPs with fill embankments may be limited due to increases in embankment heights and subsequent hazard classification. Embankments higher than 3 feet will require small pond approval by the local SCD or may require a dam safety permit from MDE. Stormwater conveyance systems and swales located on steep slopes may require additional erosion protection such as step pools, stilling basins, and other energy dissipating techniques.

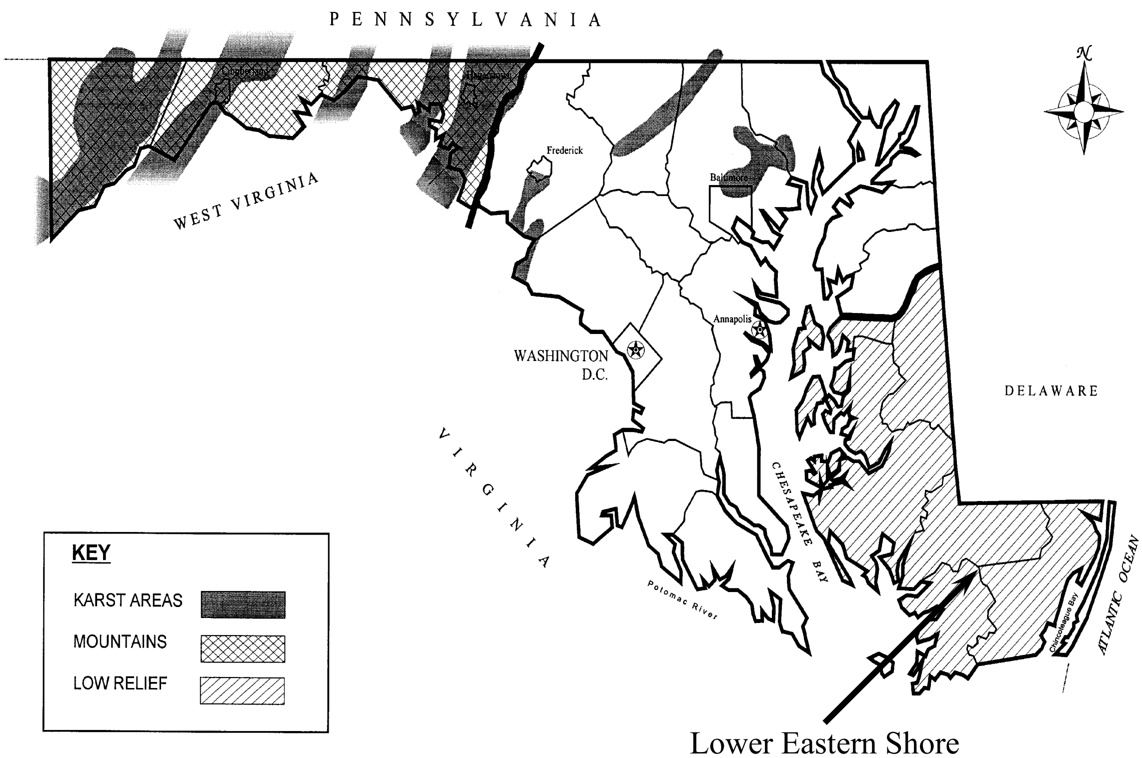

Figure 4.1 Map of Maryland Showing Key Terrain Factors

Table 4.4 BMP Selection - Terrain Factors

<table>
<tr><th>BMP GROUP</th><th>LOW RELIEF (FLAT SLOPES)</th><th>KARST TOPOGRAPHY</th><th>HILLY (STEEP SLOPES)</th></tr>
<tr><td>Ponds</td><td>Maximum normal pool depth of 4 feet (dugout).</td><td rowspan="2">Requires geotechnical tests.
Limited ponding depth.
Requires poly or clay liner.</td><td>Embankment heights restricted.</td></tr>
<tr><td>Wetlands</td><td>Ok</td><td>Embankment heights restricted.</td></tr>
<tr><td>Infiltration</td><td>Minimum distance to water table of 2 feet.</td><td>May be prohibited. Consult with local approval authority.</td><td>Max slope 15%
trenches must have flat bottom.</td></tr>
<tr><td>Filtering Systems</td><td>Several designs limited by low head.</td><td>Require poly-liner or impermeable membrane to seal bottom.</td><td>Ok</td></tr>
<tr><td>Open Channels</td><td>Generally feasible due to low slopes.</td><td>Ok. May require a poly or clay liner or impermeable membrane to seal bottom.</td><td>Often infeasible on steeper slopes.</td></tr>
</table>

4.4 Permitting Factors

Additional permitting requirements may affect stormwater BMP selection. Table 4.5 provides a list to consider as a starting point. However, consult the appropriate regulatory agency for specific restrictions and permit conditions.

Table 4.5 Permits to Consider

SITE FEATURE	Permitting Agency
Jurisdictional Wetland	U.S. Army Corps of Engineers Section 404 Permit, MDE Wetlands Permit
Waterways (waters of the U.S or waters of the State)	U.S. Army Corps of Engineers (COE) Section 404 Permit, MDE Wetlands and Waterways Permit
Stream Buffer	Check with appropriate review authority whether stream buffers are required
100 Year Floodplain	Local Stormwater and/or floodplain approval authority MDE Wetlands and Waterways Permit
Forest Conservation	District Forest Conservation review authority
Critical Area	Local Critical Area review authority
Utilities	Local Review Authority
Roads	Local DOT, DPW, or State Highway Administration
Structures	Local Review Authority
Septic Drain fields	Local Health Authority
Water Wells	Local Health Authority

4.5 Hot Spots

A stormwater hotspot is defined as a land use or activity that generates higher concentrations of hydrocarbons, trace metals or toxicants than are found in typical stormwater runoff, based on monitoring studies. Table 4.6 provides a list of designated hotspots for the State of Maryland. If a site is designated as a hotspot, it has important implications for how stormwater is managed. First and foremost, untreated stormwater runoff from hotspots cannot be allowed to infiltrate into groundwater where it may contaminate water supplies. A greater level of stormwater treatment is needed at hotspot sites to prevent pollutant discharge after construction. This typically involves preparing and implementing a stormwater pollution prevention plan that involves a series of operational practices at the site that reduces the generation of pollutants.

Under EPA's NPDES stormwater program, some industrial sites are required to prepare and implement a stormwater pollution prevention plan. A list of industrial categories that are subject to the pollution prevention requirement can be found on MDE's website. In addition, Maryland's requirements for preparing and implementing a stormwater pollution prevention plan are described in the general discharge permit provided on MDE's website. The stormwater pollution prevention plan requirement applies to both existing and new industrial sites.

In addition, if a site falls into a "hotspot" category outlined in Table 4.6, a pollution prevention plan may also be required by the appropriate reviewing authority. Golf courses and commercial nurseries may also be required to implement a plan by the appropriate approval authority.

Table 4.6 Classification of Stormwater Hotspots

The following land uses and activities are deemed ***stormwater hotspots:***

- vehicle salvage yards and recycling facilities*
- vehicle service and maintenance facilities
- vehicle and equipment cleaning facilities*
- fleet storage areas (bus, truck, etc.)*
- industrial sites (for SIC codes outlined on MDE's website)
- marinas (service and maintenance)*
- outdoor liquid container storage
- outdoor loading/unloading facilities
- public works storage areas
- facilities that generate or store hazardous materials*
- commercial container nursery
- other land uses and activities as designated by an appropriate review authority

* stormwater pollution prevention plan implementation is required for these land uses or activities under the EPA NPDES stormwater program.

The following land uses and activities are not normally considered hotspots:

- residential streets and rural highways
- residential development
- institutional development
- commercial and office developments
- non-industrial rooftops
- pervious areas, except golf courses and nurseries [which may need an Integrated Pest Management Plan (IPM)].

While large highways [average daily traffic volume (ADT) greater than 30,000] and retail gasoline outlet facilities are not designated as stormwater hotspots, it is important to ensure that highway and retail gasoline outlet stormwater management plans adequately protect groundwater.