Chapter 4:

Guide to Stormwater Best Management Practices

4.1 Introduction

The specifications included in this manual are intended to be used as design guidance, providing the designer with state-of-the-science information on BMP design, while also allowing as much flexibility for designers as possible. With that in mind, the specifications use the terms “should” and “must.”

- ✧ Where “should” and similar words are used, the information provided should be considered design guidance, and may be deviated from where necessary, but should be done so with care.
- ✧ Where “must” and similar words are used, the directives are considered inherent to the effectiveness and function of the practice.

These specifications may be adopted as design guidance to enhance existing regulations or rules, in which case, some of the credit equations may not apply. Or they may be adopted as a whole, including the credit equations and associated LID Compliance Calculator spreadsheet tool.

The Runoff Reduction Approach

Runoff reduction is defined as “the total annual runoff volume reduced through canopy interception, soil infiltration, evaporation, transpiration, rainfall harvesting, engineered infiltration, or extended filtration.” Many of the BMPs in this manual utilize these mechanisms to either permanently or over a very long period (in the case of extended filtration), reduce the volume of runoff from a site.

Not all BMPs achieve runoff reduction equally. The level to which a BMP provides runoff reduction is indicated in Table 4.1-1. The rates are expressed as a percentage of the storage volume provided by the BMP. Calculations for determining storage volume are included in each BMP’s specifications. The runoff reduction rates in the table are derived from compiled research on the various BMPs’ annual runoff reduction capabilities (Hirschman et al., 2008), as well as an analysis of each BMP’s operation in a single storm event.

Table 4.1-1. Runoff Reduction Rates for LID and Infiltration Practices	
BMP	**Runoff Reduction Rate (% of Storage Volume)**
Bioretention - Enhanced	100%
Bioretention - Standard	60%
Permeable Pavement - Infiltration	100%
Permeable Pavement - Standard	50%
Infiltration	100%
Green Roof	100%
Rainwater Harvesting	100%
Disconnection to A/B or Amended Soils	50%
Disconnection to C/D Soils	25%
Disconnection to Forest Cover/Open Space	75%
Grass Channel in A/B or Amended Soils	20%
Grass Channel in C/D Soils	10%
Dry Swale	60%

LID Design Considerations for Coastal Conditions

While all of the BMPs included in this manual have the capability of meeting state and local water quality requirements, site conditions, costs, and removal goals may dictate the choice of one BMP over another. A screening process that can be used to help decide what BMPs are best suited for a given development site is outlined below. This process is intended to assist designers in selecting the most appropriate BMPs for use on a development site.

For the most part, the factors presented in this chapter represent guidelines, not rules, for which BMP may be most appropriate at a site. It is important to note that certain BMP design modifications or specific site characteristics may allow for a particular BMP to become better suited at a particular location. Several of these design modifications are described in the individual practice specifications.

Site Conditions, *Stormwater Treatment Requirements*, *Physical Feasibility*, and *Site Applicability* are all important information that should be considered when deciding what stormwater management practices can be used on a development site.

Site Conditions:

While some BMPs can be applied almost anywhere, others require specific conditions to be most effective. Coastal environments provide a unique set of constraints that often require more careful design choices and often allow less design flexibility than other locations. Some of the most common coastal design constraints are described below.

Poorly Drained Soils: There are many instances of poorly drained soils in the coastal environment. This can be a major impediment to the use of infiltration-based practices, including permeable pavement and bioretention. In poorly drained soils, these practices must be designed with an underdrain (where sufficient head exists), so they can be de-watered sufficiently to accommodate subsequent storm events. Where sufficient head does not exist, these practices may not be feasible. Other practices, such as green roofs, rain water harvesting, disconnection, wet ponds, or wetlands may be more appropriate.

Well-Drained Soils: Sandy, well-drained soils are often ideal locations for infiltration-based practices. However, if the soils drain too quickly, they may allow stormwater pollutants to reach groundwater. In areas of very well-drained soils, infiltration practices should be used with care. In areas known to provide groundwater recharge to water supply aquifers, practices with underdrains or impermeable liners should be used instead.

Flat Terrain: Flat terrain may make it difficult to provide adequate drainage for practices that require higher head values, particularly those with underdrains, such as bioretention and permeable pavement. Infiltration-based practices, where feasible, are a better option in areas with flat terrain. Where infiltration is not feasible, rooftop-oriented practices, such as green roofs, rainwater harvesting, and disconnection are still options.

High Groundwater: It can often be difficult to achieve the minimum required 0.5-foot separation between the bottom of a filtering or infiltration-based practice and the seasonal high groundwater table. Where the groundwater table is too high, rooftop-oriented practices (green roofs, rainwater harvesting, and disconnection) are still feasible, as are wet ponds and wetlands that will benefit from having a groundwater connection.

Tidally Influenced Drainage Systems: Tidally influenced drainage systems can prevent the conveyance of stormwater through a BMP and reduce the BMP's effective volume. Some BMPs can be implemented in tidally influenced drainage systems, although portions of the practice below the tidal mean high water elevation cannot be included in the volume calculations. Also, salt-tolerant vegetation may be necessary in these areas.

Pollutants of concern: Sediment, phosphorus, nitrogen, and bacteria are all pollutants of concern in the coastal environment. While all of the BMPs described in this manual have removal capabilities for all of the pollutants, some BMPs are more suited to specific pollutants.

- Sediment and phosphorus are typically removed via gravitational settling and filtration. All of the practices in the manual have high sediment removal potential.
- Nitrogen removal generally requires anaerobic conditions, which makes wet ponds and wetlands better options. Anaerobic zones can also be included in bioretention areas and permeable pavement to improve their nitrogen removal.
- BMP effectiveness for bacteria removal is less understood. Mechanisms for removal typically include settling, exposure to sunlight, and drying. Filtering practices, such as infiltration, bioretention, and green roofs provide all of these mechanisms. Wet ponds and wetlands also provide some of these mechanisms, but also can attract wildlife, which may make these BMPs a source of bacteria in some cases.

Stormwater Treatment Requirements:

Stormwater management requirements for a given site vary based on the site's location. The various rules that may apply are summarized below, and outlined in Figure 4.1-1. Please note that the summaries below are merely a guide, and not intended as a substitute for the actual rule or regulation. It is important to note that this manual, and the associated compliance calculators, make a distinction between treatment and runoff reduction. In particular, runoff reduction is required in the coastal zone when infiltration practices are used, and on sites regulated by the MS4 permit. While all practices included in this manual are assumed to provide treatment for their entire design volume, the runoff reduction percentage depends on the practice design (See Table 4.1-1).

- ✧ Coastal Zone Requirements: All projects, regardless of size, that are located within ½ mile of a coastal receiving water, as defined in the SC Coastal Zone Management Program Refinements, must catch and store onsite the first ½ inch of runoff from the site's disturbed area, or the first 1 inch of runoff from the site's built-upon portion, whichever is greater. Storage may be accomplished through retention, detention, or infiltration practices. Storage designs are selected as appropriate for the specific site.
- ✧ Shellfish Bed Requirements: For projects located within 1,000 feet of shellfish beds, the first 1½ inches of runoff from the built-upon portion of the property must be retained onsite.
- ✧ Small Municipal Separate Storm Sewer Systems (SMS4): Communities subject to the SMS4 Permit are required to develop new development and redevelopment standards for sites greater than 1 acre that "demonstrate the runoff reduction and pollutant removal necessary to approximate pre-development conditions to the MEP [Maximum Extent Practicable] and to protect water quality." Infiltration, evapotranspiration, rain harvesting, and stormwater reuse and recharge are all suggested as means to achieve this requirement.

Note: While a variety of post-construction stormwater standards are suggested as possibilities to meet this requirement, for crediting purposes, this chapter assumes that the following standard will be used, as it is most applicable to the Runoff Reduction approach described above:

> Design, construct, and maintain stormwater management practices that manage rainfall on-site, and prevent the off-site discharge of 1 inch of runoff from the site's disturbed area.

- ✧ Water Quality Treatment and Water Quantity Control Requirements Statewide: For projects that are not subject to an SMS4's rules and are greater than 5 acres:
  - Ponds with a permanent pool must store and release over 24 hours the first ½ inch of runoff from the site based upon respective drainage area(s).
  - Ponds without a permanent pool must store and release over 24 hours the first 1 inch of runoff from the site based upon the respective drainage area(s).
  - Infiltration practices must accept the first 1 inch of runoff from impervious surfaces.
- ✧ For Water Quantity Control, post-development discharge rates cannot exceed the pre-development rates for the 2- and 10-year, 24 hour storm event for all sites regulated by the Statewide Stormwater Regulations (this requirement also exists in most SMS4 communities). All BMPs address water quantity to some extent, but many BMPs whose main purpose is water quality treatment typically do not have enough volume to manage larger storm events.

Table 4.1-2 indicates each BMP's capability to meet each category of requirements described above. As with the descriptions above, this table is a summary only. It is not a substitute for the actual rules and regulations. It is strongly recommended that a designer discuss potential designs with the appropriate plan reviewer to ensure compliance.

Table 4.1-2: Stormwater Management Capability for BMPs

BMP	Coastal Zone Requirements[1]	Shellfish Bed Requirements[1]	SMS4 Standard[1]	Water Quality Treatment[2]	Water Quantity Control[1]
Bioretention	Yes	Yes	Yes	Infiltration via Runoff Reduction	Partial
Permeable Pavement	Yes	Yes	Yes	Infiltration via Runoff Reduction	Yes
Infiltration	Yes	Yes	Yes	"Infiltration"	Partial
Green Roof	Yes	Yes	Yes	Infiltration via Runoff Reduction	Partial
Rainwater Harvesting	Yes	Yes	Yes	Infiltration via Runoff Reduction	Partial
Disconnection	Partial	Partial	Partial	Infiltration via Runoff Reduction	Partial
Open Channels	Partial	Partial	Partial	Infiltration via Runoff Reduction	Partial
Filtration	Yes	No	No	Pond without Permanent Pool	No
Dry Detention Practices	Yes	No	No	Pond without Permanent Pool	Yes
Wet Detention Ponds	Yes	No	No	Pond with Permanent Pool	Yes
Stormwater Wetlands	Yes	No	No	Pond with Permanent Pool	Yes

[1] "Yes" means that a given BMP could feasibly be designed to meet a given requirement. It does not mean that all variations and sizes of the BMP will automatically meet the requirement.
[2] This column indicates which of the Water Quality Treatment standards is likely to apply to each BMP. Since the water quality treatment regulations only indicate "ponds with a permanent pool," "ponds without a permanent pool," and "infiltration practices," as the available options, classification of the other BMPs is somewhat difficult. For the sake of presenting complete LID guidance and a unified calculation method, this chapter assumes that the runoff reduction volume provided by certain BMPs can be counted toward meeting the infiltration practice requirement. However, actual treatment capability of a BMP depends greatly upon design of the BMP relative to individual site circumstances.

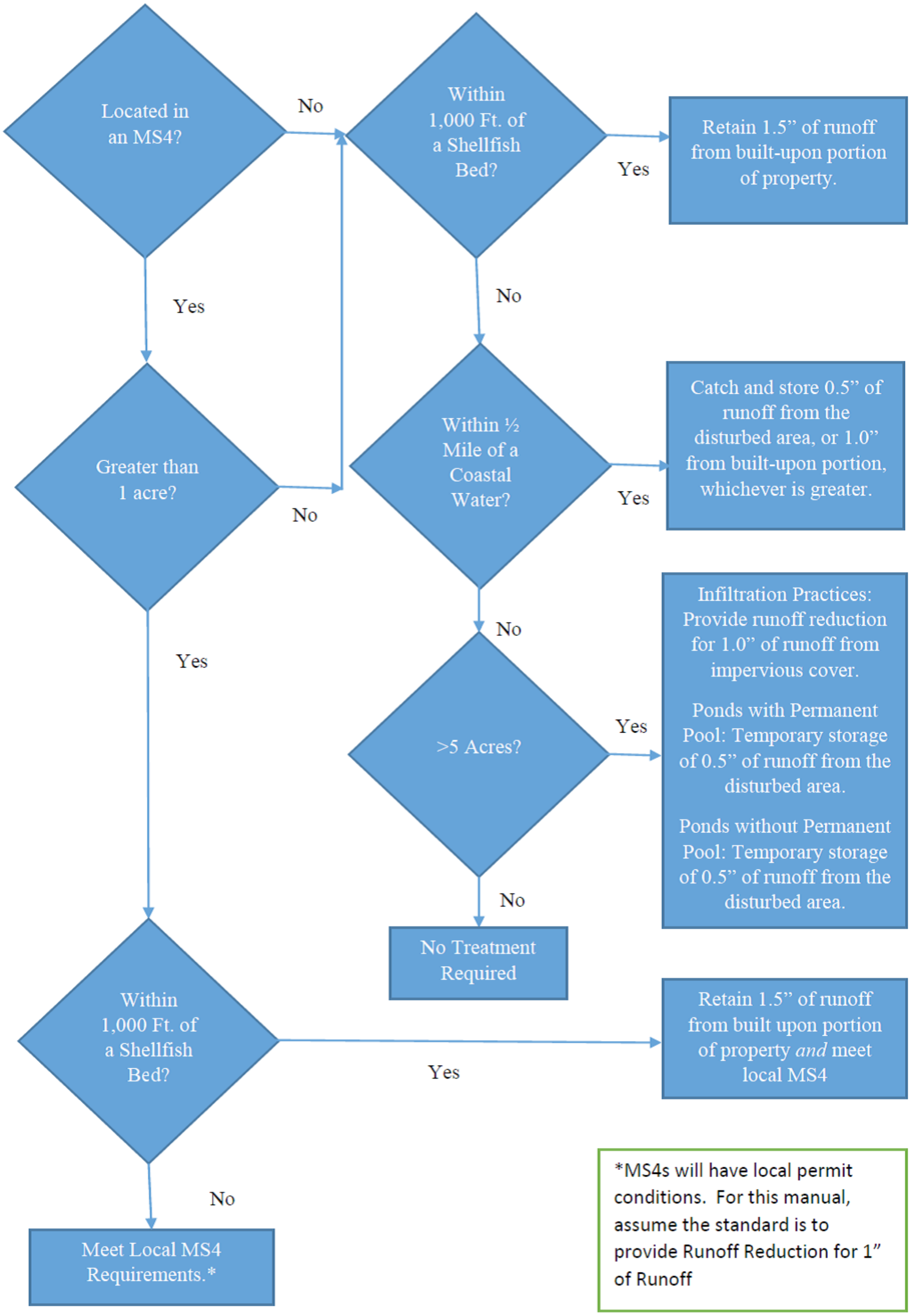

Figure 4.1-1. Flowchart to Determine Stormwater Management Requirements

The Treatment Train

In many LID designs, the concept of the "treatment train" is employed to maximize the utility of each BMP and improve water quality. A treatment train is a group of BMPs designed in series so that runoff flows from one to the next, providing multiple opportunities for both runoff reduction and pollutant removal. When used in conjunction with runoff reduction designs and calculations, treatment trains can provide greater flexibility in the sizing of individual BMPs, as each BMP only needs to achieve a portion of the total runoff reduction or treatment volume.

There can be many additional advantages to utilizing a treatment train approach:

- Different elevations and land use types on site may lend themselves to the use of different BMPs.
- The natural topography of a site can be accounted for, with less need for mass site grading.
- A series of smaller BMPs may be easier to fit within a proposed site design.
- Using different types of BMPs in series provides multiple pollutant removal mechanisms, which can greatly enhance water quality.
- BMPs that do not treat or remove the entire water quality volume can be used in conjunction with other more effective BMPs.

While there are many advantages to using treatment trains, there are some important challenges to be considered as well:

- Complexity is added to a site design when multiple BMPs are used.
- Practice depth can be a difficult limitation when underdrains are utilized. For a fully effective treatment train, the "downstream" BMP must receive both the overflow and the underdrain flow from the first practice.
- BMPs based on disconnection can be difficult to "re-connect" in order to convey them to the next BMP in series.
- Vegetation selection becomes very important for the "downstream" BMP, as it will be drier than it otherwise would be, since the first BMP may remove a lot of the runoff from small storm events.

Many different combinations of treatment trains are possible, but some BMPs work better than others in treatment trains, and for some, the position in the treatment train is very important. Rooftop-based BMPs, like green roofs and rainwater harvesting, are great as the first practice in a treatment train – since they are located at higher elevations, overflow from them can be easily conveyed to an on-the-ground practice. Other qualities of first-in-line BMPs include an absence of underdrains (again, due to the elevation issue), and a concentrated outflow or overflow, allowing easy conveyance to the "downstream" BMP. "Downstream" BMPs have fewer restrictions, beyond typically needing to be at ground level or below. Storage BMPs like dry or wet detention are often used as the last practice in a treatment train so they can collect all of the water from a site after it has been treated for water quality, and provide the required detention for larger storm events.

A few examples of treatment train designs include:

- Overflow from a green roof or rainwater harvesting system could be directed to imperviou surface disconnection.
- An open channel could be used to convey runoff to a bioretention area.
- A stormwater filtering system could provide pretreatment for a stormwater infiltration BMP.
- Overflow from a stormwater infiltration BMP could be routed to a dry detention practice.

Calculations for properly crediting each BMP in a treatment train are included in the Coastal South Carolina LID Compliance Sheet, and described in Appendix A.

Physical Feasibility:

Physical feasibility refers to the physical site conditions necessary to effectively design and install a BMP. Table 4.1-3 includes the feasibility factors listed below. With the exception of minimum depth to water table, none of these factors should be considered inflexible limits. Modifications to BMP design may often be made to account for divergence from the stated minimum and/or maximum values.

- Contributing Drainage Area (CDA): Volume of water received by a practice can affect BMP performance. This column indicates the contributing drainage areas that typically apply for each BMP.
- Slope: This column describes the influence that site slope can have on the performance of the BMP. It indicates the maximum or minimum slope on which the BMP should be installed.
- Minimum Head: This column provides an estimate of the minimum amount of elevation difference needed within the BMP, from the inflow to the outflow, to allow for gravity operation.
- Minimum Depth to Seasonal High Water Table: This column indicates the minimum distance that should be provided between the bottom of the stormwater management practice and the top of the water table.
- Soils: This column describes the influence that the underlying soils (i.e., hydrologic soil groups) can have on the performance of the stormwater management practice.

Table 4.1-3: Feasibility Limitations for BMPs					
BMP	**Contributing Drainage Area**	**Slope**	**Minimum Head**	**Minimum Depth to Water Table**	**Soils**
Bioretention	Up to 5 acres	Up to 5%[2]	2.5 – 4 feet	0.5 feet	All soils[3]
Permeable Pavement	Up to 5 times practice surface area	Up to 5%	2 – 4 feet	0.5 feet	All soils[3]
Infiltration	Up to 5 acres	Up to 5%[2]	2 – 4 feet	0.5 feet	Must drain within 72 hours
Green Roof	Green roof area + 25%	No limit	N/A	N/A	N/A
Rainwater Harvesting	No limit	No limit	N/A	N/A	N/A
Disconnection	Up to 1,000 ft^2 per downspout	Up to 5%	N/A	N/A	All soils
Open Channels	Up to 5 acres	Up to 5%[2]	1 – 2 feet	0.5 feet	All soils
Filtration	Up to 10 acres	Up to 5%	2 – 4 feet	0.5 feet	All soils
Dry Ponds	No limit	Up to 15%	4 – 8 feet	0.5 feet	All soils
Wet Ponds	Greater than 10 acres[1]	Up to 15%	4 – 8 feet	No limit	Slow-draining soils preferred
Stormwater Wetlands	Greater than 10 acres[1]	Up to 15%[2]	2 – 5 feet	No limit	Slow-draining soils preferred

[1]CDA can be smaller if practice intersects the water table.
[2]Check dams may be necessary to create sufficient ponding volume.
[3]Slow-draining soils may require an underdrain.

Site Applicability:

Not all BMPs are appropriate for all situations. Table 4.1-4 describes the site applicability for each BMP for the following factors:

- Rural Use: This column indicates whether or not the stormwater management practice is typically suited for use in rural areas and on low-density development sites.
- Suburban Use: This column indicates whether or not the stormwater management practice is typically suited for use in suburban areas and on medium-density development sites.
- Urban Use: This column identifies the stormwater management practices that are typically suited for use in urban and ultra-urban areas where space is at a premium.
- Construction Cost: This column assesses the relative construction cost of each of the stormwater management practices.
- Maintenance: This column assesses the relative maintenance burden associated with each stormwater management practice. It is important to note that all stormwater management practices require some kind of routine inspection and maintenance.

Table 4.1-4: Site Applicability for BMPs

BMP	Rural Use	Suburban Use	Urban Use	Construction Cost	Maintenance
Bioretention	Yes	Yes	Yes	Medium	Medium
Permeable Pavement	Maybe	Yes	Yes	High	High
Infiltration	Yes	Yes	Yes	Medium	Medium
Green Roof	Maybe	Yes	Yes	High	Low
Rainwater Harvesting	Yes	Yes	Yes	Medium	Medium
Disconnection	Yes	Yes	Maybe	Low	Low
Open Channels	Yes	Yes	No	Low-Medium	Medium
Filtration	Maybe	Yes	Yes	High	High
Dry Ponds	Yes	Yes	No	Low	Low
Wet Ponds	Yes	Yes	No	Low	Low
Stormwater Wetlands	Yes	Yes	No	Low	Medium

References

1. Hirschman, D., Collins, K., and T. Schueler. 2008. Technical Memorandum: The Runoff Reduction Method. Center for Watershed Protection and Chesapeake Stormwater Network. Ellicott City, MD. Available online: http://vwrrc.vt.edu/SWC/documents/pdf/CWP%20Technical%20Memo%20RRMethod_041808%20w_Apps.pdf