TABLE OF CONTENTS

SECTION 1

BMP Selection Criteria

1.1. General Information

Post-construction storm water management practices treat runoff from a development site *after* construction is final. Their objectives range from capturing and treating pollutants in runoff to managing the increased frequency, volume and energy of storm water runoff so that water resources are not degraded.

The post-construction best management practices (BMPs) presented within this guidance document are approved structural devices by the City of Akron (City) and provide erosion and sediment control. Information on the City's requirements for erosion/sediment control and post-construction storm water quality are found in Section 50.80 of the City's Code of Ordinances.

Additional non-structural best management practices used in consort with the structural BMPs are strongly encouraged (see Section 3). Practices such as stream setbacks or reduction of impervious areas influence the layout and design of a development site so that important hydrologic areas are maintained and impervious surfaces are limited.

The BMP Guidance Document is a general guideline for selecting a structural management practice based on size, location, soil conditions, and other factors for a particular site. More exhaustive reference sources should be consulted for specific design information, such as the current edition of ODNR's Rainwater and Land Development Manual.

1.2. Process for Selecting BMPs

The City has designed this guidance document to provide a straightforward yet flexible method for selecting water quality treatment structures approved by the City. Designers need to carefully think through many factors to choose the most appropriate, effective and feasible practice(s) at a development site that will best meet local and state storm water objectives.

The following nine factors should be evaluated in the BMP selection process:

1. Investigate Pollution Prevention Opportunities. Evaluate the site to look for opportunities to prevent pollution sources on the land from becoming mobilized by runoff.

2. Design Site to Minimize Runoff. Assess whether any better site design techniques can be applied to minimize runoff and therefore reduce the size of structural BMPs.

3. Check Temporary Construction Sediment Controls. Check to see if the temporary sediment controls proposed for the site during construction can be maintained to prevent erosion and minimize sediment transport during post-construction.

4. Identify Receiving Water Issues. Understand the regulatory status of the receiving water to which the site drains. Depending on the nature of the receiving water, certain BMPs may be restricted or special design or sizing criteria may apply.

5. Identify Climate and Terrain Factors. Terrain and soil conditions can vary widely within the City, and designers need to explicitly consider how each site will influence the proposed BMPs.

6. Evaluate Stormwater Treatment Suitability. Not all BMPs work over the wide range of storm events that need to be managed at the site, so designers need to choose the type or combination of BMPs that will provide the desired level of treatment.

7. Assess Physical Feasibility at the Site. Each development site has many physical constraints that influence the feasibility of different kinds of BMPs.

8. Investigate Community and Environmental Factors. Each group of BMPs provides different economic, community, and environmental benefits and drawbacks; designers need to carefully weigh these factors when choosing BMPs for the site.

9. Determine Any Site Restrictions and Setbacks. Check to see if any environmental resources or infrastructure are present that will influence where a BMP can be located at the development site.

1.3. BMP Selection Criteria

An evaluation matrix is provided below that lists BMP selection criteria for five primary structural BMP categories: water quality ponds, infiltration practices, filtration practices, vegetative practices, and runoff pretreatment practices. Detailed descriptions, siting criteria, planning considerations, and maintenance issues for each BMP are provided in Section 2. This matrix should be used to help screen potential BMPs to be considered for a development site.

BMP EVALUATION MATRIX

	Site Limitations			EPA/ODOT Approved	Construction Cost	O&M	Public/Private
	Drainage Area	Soils	Cold Weather Issues				
STRUCTURAL BMPs					2006 Costs		
Water Quality Ponds							
Dry extended detention ponds	Sized per drainage area		Plugged Outlet	EPA	$1 - $2/CF	Annual inspection of outlet	Public/Private
Wet ponds	Greater than 10 acre drainage area	Soil Type C & D	Plugged Outlet	EPA	$1 - $2/CF	Annual inspection of outlet and embankment	Public/Private
Storm water wetland	Sized per drainage area		Plugged Outlet	EPA	$1.25 - $2.50/CF	Annual inspection, maintaining vegetation	Public/Private
Infiltration practices							
Infiltration trench	Less than 5 acre drainage area	Permeable infiltration rate 0.5 - 2.4 in/hr	Not recommended for cold weather	EPA	$5 - $8/CF	Semi-annual inspection	Private
Infiltration basin	Less than 10 acre drainage area	Permeable infiltration rate 0.5 - 3 in/hr	Not recommended for cold weather	EPA	$2 - $4/CF	Semi-annual inspection	Private
Porous pavement	Less than 5 acre drainage area	Permeable infiltration rate 0.5 - 3 in/hr	Frost Heave	EPA	$4 - $6/SF	Pavement maintenance, annual inspection	Private
Filtration practices							
Biofilter	Small drainage areas < 5 acres		None	EPA/ODOT	$6 - $12/CF	Periodic cleaning, semi-annual inspection	Private
Sand and organic filters	Small drainage areas < 5 acres		Frozen Filter Bed	EPA	$5 - $10/CF	Periodic cleaning, monthly inspection	Private
Vegetative practices							
Grassed swales	Small drainage areas		None	EPA	$1 - $1.50/CF	Annual inspection	Public/Private
Vegetated filter strip	Small drainage areas		None	EPA	$0.5 - $1.75/CF	Annual inspection	Public/Private
Runoff pretreatment devices							
Manufactured products	Less than 5 acre (EPA), sized per drainage area	N/A	None	EPA/ODOT	$6,000-$55,000/unit	Periodic inspections & cleaning (grit, oil & floatable removal) per manufacturers recommendations/ site specific	Public/Private
In-line storage	Sized per drainage area	N/A	None	EPA	Cost vary due to pipe size and storage device	Annual inspection	Public/Private
Catch basin insert	N/A	N/A	None	EPA	$250 - $1,200/Unit	Regular inspection & maintenance (high maintenance item)	Private

SECTION 2

BMP Descriptions, Considerations and Requirements

This section provides detailed descriptions of post-construction BMPs allowed by the City and the types of projects and areas within the City where they can be constructed. Additionally, design requirements and performance standards are provided for each BMP.

2.1 Water Quality Ponds

Water quality ponds are designed to treat storm water runoff for pollutants and control increases in stream discharge and bedload transport. Water quality ponds may be predominantly dry between storm events, have a permanent pool or have wetland features. Water quality ponds remove pollutants by settling, chemical interaction and biological uptake by plants, algae and bacteria. The efficiency of settling suspended solids and the ability to treat dissolved pollutants is improved with the addition of wetlands and permanent pools. Water quality ponds are often designed to provide flood control by including additional detention storage above the volume specified in this practice.

Water quality ponds are appropriate for residential, commercial and industrial areas within the City as space allows and are easily incorporated on sites where a storm water pond is to be constructed for temporary sediment control during construction or to control potential flooding. Even where detention ponds are not necessary for flood control, water quality ponds can be used to address water quality and stream stability concerns.

2.1.1 Dry Ponds

Description

Dry detention ponds (a.k.a. dry ponds, extended detention basins, detention ponds, extended detention ponds) are basins whose outlets have been designed to detain stormwater runoff for some minimum time (e.g., 24 hours) to allow particles and associated pollutants to settle. Unlike wet ponds, these facilities do not have a large permanent pool of water. However, they are often designed with small pools at the inlet and outlet of the basin. They can also be used to provide flood control by including additional flood detention storage.

Dry detention pond

Applicability

Dry detention ponds have traditionally been one of the most widely used stormwater best management practices. However, they should not be used as a one size fits all solution. If pollutant removal efficiency is an important consideration then dry detention ponds may not be the most appropriate choice. Dry detention ponds require a large amount of land. In many instances, smaller-sized best management practices are more appropriate alternatives.

It is difficult to use dry detention ponds in the ultra-urban environment because of the land area each pond consumes. Dry detention ponds can accept runoff from stormwater hot spots, areas with concentrations of pollutants in excess of those typically found in stormwater, but they need significant separation from ground water if they will be used for this purpose.

Dry detention ponds are useful stormwater retrofits, and they have two primary applications as a retrofit design. In many communities in the past, detention basins have been designed for flood control. It is possible to modify these facilities to incorporate features that encourage water quality control and/or channel protection. It is also possible to construct new dry ponds in open areas of a watershed to capture existing drainage.

Siting Criteria

Designers need to ensure that the dry detention pond is feasible at the site in question. In general, dry detention ponds should be used on sites with a minimum area of 10 acres. They can be used on smaller sites, but providing channel or water quality control can be challenging because the orifice diameter at the outlet needed to control small storms becomes very small and prone to clogging.

Dry detention ponds can be used on sites with slopes up to about 15 percent. The local slope needs to be relatively flat, however, to maintain reasonably flat side slopes in the practice. There is no minimum slope requirement, but there does need to be enough elevation drop from the pond inlet to the pond outlet to ensure that flow can move through the system. Dry detention ponds can be used with almost all soils and geology, with minor design adjustments for regions of rapidly percolating soils such as sand. In these areas, extended detention ponds should be designed with an impermeable liner to prevent ground water contamination or sinkhole formation. Except for the case of hot spot runoff, the only consideration regarding ground water is that the base of the extended detention facility should not intersect the ground water table. A permanently wet bottom may become a mosquito breeding ground.

Design Considerations

Volume and depth characteristics depend on the type of pond being designed. In all instances, an extended detention volume (portion of the water quality volume, WQv) must be determined and treated.

Specific designs may vary considerably, depending on site constraints or preferences of the designer. However, the following features should be incorporated into most dry extended detention pond designs.

Pretreatment. Pretreatment incorporates design features that help to settle out coarse sediment particles. By removing these particles from runoff before they reach the large permanent pool, the maintenance burden of the pond is reduced. In ponds, pretreatment is achieved with a sediment forebay, which is a small pool, typically about 10 percent of the volume of water to be treated for pollutant removal.

Treatment. Treatment design features help enhance the ability of a stormwater management practice to remove pollutants. Designing dry ponds with a high length-to-width ratio (at least 1.5:1) and incorporating other design features to maximize the flow path effectively increases the detention time in the system by eliminating the potential of flow to short-circuit the pond. Designing ponds with relatively flat side slopes can also help to lengthen the effective flow path. Finally, the pond should be sized to detain the volume of runoff to be treated for between 12 and 48 hours.

Conveyance. Conveyance of stormwater runoff into and through the dry pond is a critical component. Stormwater should be conveyed to and from dry ponds safely in a manner that minimizes erosion potential. The outfall of pond systems should always be stabilized to prevent scour. To convey low flows through the system, designers should provide a pilot channel. A pilot channel is a surface channel that should be used to convey low flows through the pond. In addition, an emergency spillway should be provided to safely convey large flood events. To help mitigate the warming of water at the outlet channel, designers should provide shade around the channel at the pond outlet.

Maintenance Reduction. Regular maintenance activities are needed to maintain the function of stormwater practices. In addition, some design features can be incorporated to ease the maintenance burden of each practice. In dry detention ponds, a "micropool" at the outlet can prevent resuspension of sediment and outlet clogging. A good design includes maintenance access to the forebay and micropool. Maintenance easements must be established to allow access to these facilities and to the embankment, outlet structure and sediment disposal areas.

Another design feature that can reduce maintenance needs is a non-clogging outlet. Typical examples include a reverse-slope pipe or a weir outlet with a trash rack. A reverse slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and determines the water elevation of the micropool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris.

The frequency of sediment cleanout can be reduced by increasing the volume available for sediment storage. Increasing the permanent pool volume by 20% or according to the predicted sediment loads is recommended. Ponds used for sediment control during construction should be cleaned out when the site is stabilized, as the cost of cleanout will be considerably less expensive during construction than in the future.

Transporting dredged sediment is often the largest cost associated with pond cleanout. This can be avoided by providing an area on-site for future sediment disposal. A disposal site should be designated during site design.

Water quality treatment practices are intended to trap pollutants. The fate of these pollutants must be considered. Trapped sediment is usually clean enough for on-site use. The large volume of sediment poses the most common disposal problem. Sediments may also have high concentrations of hydrocarbons, nutrients and heavy metals. Soil tests should be done if the pond has received spills, is in a highly industrial area, or if the watershed has intensive traffic. Sediment should be spoiled in areas, which will keep pollutants bound in the sediment.

Landscaping. Designers should maintain a vegetated buffer around the pond and should select plants within the extended detention zone (the portion of the pond up to the elevation where stormwater is detained) that can withstand both wet and dry periods. The side slopes of dry ponds should be relatively flat to reduce safety risks.

Cold Climate Impacts. Some additional design features can help to treat the spring snowmelt. One such modification is to increase the volume available for detention to help treat this relatively large runoff event. In some cases, dry facilities may be an option as a snow storage facility to promote some treatment of plowed snow. If a pond is used to treat road runoff or is used for snow storage, landscaping should incorporate salt-tolerant species.

Limitations

Although dry detention ponds are widely applicable, they have some limitations that might make other stormwater management options preferable:

- Dry detention ponds have only moderate pollutant removal when compared to other structural stormwater practices, and they are ineffective at removing soluble pollutants.
- Dry extended detention ponds may become a nuisance due to mosquito breeding if improperly maintained or if shallow pools of water form for more than 7 days.
- Although wet ponds can increase property values, dry ponds can actually detract from the value of a home.

Dry detention ponds on their own only provide peak flow reduction and do little to control overall runoff volume, which could result in adverse downstream impacts.

Maintenance Considerations

In addition to incorporating features into the pond design to minimize maintenance, some regular maintenance and inspection practices are needed. On an annual basis, the pond banks and bottom need to be inspected for erosion and damage, the forebay needs to be inspected for sediment accumulation, and the inlet and outlet devices need to be inspected to ensure they are free of debris and operational. Standard ongoing maintenance items include mowing of side slopes, repair of undercut/eroded areas, removal of trash and debris, management of pesticides and nutrients, and seeding/sodding of damaged ground. Long term maintenance items include removal of sediment from the forebay (5-7 years) and dredging of the pond once sediment accumulation has reduced the volume by 25-percent (25-50 years).

Effectiveness

Dry detention basins can provide flood control and channel protection, as well as some pollutant removal.

Flood Control. Dry extended detention basins can easily be designed for flood control (to reduce the flood hazard associated with large storm events by reducing the peak flow associated with these storms), and this is actually the primary purpose of most detention ponds.

Channel Protection. Traditionally, dry detention basins have provided control of the 2-year storm for channel protection. Slightly modifying the design of dry detention basins to reduce the flow of smaller storm events might make them effective tools in reducing downstream erosion.

Pollutant Removal. Dry detention basins provide moderate pollutant removal, provided that appropriate design features are incorporated. Although they can be effective at removing some pollutants through settling, they are less effective at removing soluble pollutants because of the absence of a permanent pool. Typical removal rates, as reported by Schueler (1997), are as follows:

- Total suspended solids: 61%
- Total phosphorus: 19%
- Total nitrogen: 31%
- Nitrate nitrogen: 9%
- Metals: 26%-54%

There is considerable variability in the effectiveness of ponds, and it is believed that properly designing and maintaining ponds may help to improve their performance.

Cost Considerations

The construction costs associated with dry detention ponds range considerably. The cost of dry ponds is generally slightly higher than the cost of wet ponds on a cost per total volume basis. Ponds do not consume a large area compared to the total area treated (typically 2 to 3 percent of the contributing drainage area).

For ponds, the annual cost of routine maintenance is typically estimated at about 3 to 5 percent of the construction cost. Ponds are long-lived facilities (typically longer than 20 years). Thus, the initial investment into pond systems can be spread over a relatively long time period.

2.1.2. Wet Ponds

Description

Wet ponds (a.k.a. stormwater ponds, wet retention ponds, wet extended detention ponds) are constructed basins that have a permanent pool of water throughout the year. Ponds treat incoming stormwater runoff by allowing particles to settle and algae to take up nutrients. The primary removal mechanism is settling as stormwater runoff resides in this pool, and pollutant uptake, particularly of nutrients, also occurs through biological activity in the pond. Traditionally, wet ponds have been widely used as stormwater best management practices.

Wet pond

Applicability

Wet ponds are widely applicable stormwater management practices. Although they have limited applicability in highly urbanized settings, they have few other restrictions.

It is difficult to use wet ponds in ultra-urban areas because of the land area each pond consumes. They can, however, be used in an ultra-urban environment if a relatively large area is available downstream of the site.

Wet ponds can accept runoff from stormwater hot spots, such as heavy industrial areas, but need significant separation from ground water if they will be used for this purpose.

Wet ponds are very useful stormwater retrofits and have two primary applications as a retrofit design. In many communities, detention ponds have been designed for flood control in the past. It is possible to modify these facilities to develop a permanent wet pool to provide water quality control and modify the outlet structure to provide channel protection.

Ponds with dams are regulated under the Ohio Revised Code 1501: 21 Dam Safety Administrative Rules. A dam is exempt from the state's authority (ORC Section 1521.062) if it is 6 feet or less in height regardless of total storage; less than 10 feet in height with not more than 50 acre-feet of storage, or not more than 15 acre-feet of total storage regardless of height. Check with the Ohio Dept. of Natural Resources, Division of Water, for the most current requirements.

Additional upland practices may be needed to reduce nutrient loads that cause problems common to eutrophic ponds (excess algae, low oxygen levels, and odor).

Siting Criteria

In addition to the restrictions and modifications to adapting wet ponds to different land uses, designers need to ensure that this management practice is feasible at the site in question. Permanent pools may be difficult to maintain if the contributing watershed area is less than 20 acres and if the ratio of drainage area to water surface area is less than 6:1. Suitable soils must be available for constructing the embankment and insuring sufficient impermeability to prevent seepage losses. A series of soil borings should be taken at the proposed pond site prior to final design to characterize bedrock, soil infiltration rates, and the adequacy of excavated soils for use as core trench or embankment fill. BMPs that focus on source control such as bioretention, should be considered for smaller drainage areas.

Wet ponds can be used on sites with an upstream slope up to about 15 percent. The local slope should be relatively shallow, however. Although there is no minimum slope requirement, there does need to be enough elevation drop from the pond inlet to the pond outlet to ensure that water can flow through the system.

Wet ponds can be used in almost all soils and geology, with minor design adjustments for areas with highly permeable soils. In areas with well draining soils, wet ponds should be designed with an impermeable liner to prevent ground water contamination or sinkhole formation, and to help maintain the permanent pool. Unless they receive hot spot runoff, ponds can often intersect the ground water table. However, some research suggests that pollutant removal is reduced when ground water contributes substantially to the pool volume.

Design Considerations

Volume and depth characteristics depend on the type of pond being designed. In all instances, an extended detention volume (portion of the water quality volume, WQv) must be determined and treated.

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most wet pond designs.

Pretreatment. Pretreatment incorporates design features that help to settle out coarse sediment particles. By removing these particles from runoff before they reach the large permanent pool, the maintenance burden of the pond is reduced. In ponds, pretreatment is achieved with a sediment forebay. A sediment forebay is a small pool (typically about 10 percent of the volume of the permanent pool). Coarse particles remain trapped in the forebay, and maintenance is performed on this smaller pool, eliminating the need to dredge the entire pond.

Treatment. Treatment design features help enhance the ability of a stormwater management practice to remove pollutants. The purpose of most of these features is to increase the amount of time that stormwater remains in the pond.

One technique of increasing the pollutant removal of a pond is to increase the volume of the permanent pool. Typically, ponds are sized to be equal to the water quality volume (the volume of water treated for pollutant removal). Designers may consider using a larger volume to meet specific watershed objectives. Regardless of the pool size, designers need to conduct a water balance analysis to ensure that sufficient inflow is available to maintain the permanent pool.

Other design features do not increase the volume of a pond, but can increase the amount of stormwater residence time and eliminate short-circuiting. Ponds should always be designed with a length-to-width ratio of at least 1.5:1. In addition, the design should incorporate features to lengthen the flow path through the pond, such as underwater berms designed to create a longer route through the pond. Combining these two measures helps ensure that the entire pond volume is used to treat stormwater.

Another feature that can improve treatment is to use multiple ponds in series as part of a "treatment train" approach to pollutant removal. This redundant treatment can also help slow the rate of flow through the system. Additionally, a vegetated buffer with shrubs or trees around the pond area should provide shading and consequent cooling of the pond water.

If designers of wet ponds are anticipating ponds that stratify in the summer or could be prone to algae blooms, they should consider installing a fountain or other mixing mechanism. This will ensure that the full water column remains oxic.

Conveyance. Stormwater should be conveyed to and from all stormwater management practices safely and to minimize erosion potential. The outfall of pond systems should always be stabilized to prevent scour. In addition, an emergency spillway should be provided to safely convey large flood events. To help mitigate warming at the outlet channel, designers should provide shade around the channel at the pond outlet.

Maintenance Reduction. In addition to regular maintenance activities needed to maintain the function of stormwater practices, some design features can be incorporated to ease the maintenance burden of each practice. In wet ponds, maintenance reduction features include techniques to reduce the amount of maintenance needed, as well as techniques to make regular maintenance activities easier.

One potential maintenance concern in wet ponds is clogging of the outlet. Ponds should be designed with a non-clogging outlet such as a reverse-slope pipe, or a weir outlet with a trash rack. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris. Another general rule is that no orifice should be less than 3 inches in diameter. Smaller orifices are more susceptible to clogging.

Design features are also incorporated to ease maintenance of both the forebay and the main pool of ponds. Maintenance easements must be established to allow access to these facilities to ease routine maintenance activity. In addition, ponds should generally have a pond drain to draw down the pond for the more infrequent dredging of the main cell of the pond.

The frequency of sediment cleanout can be reduced by increasing the volume available for sediment storage. Increasing the permanent pool volume by 20% or according to the predicted sediment loads is recommended. Ponds used for sediment control during construction should be cleaned out when the site is stabilized, as the cost of cleanout will be considerably less expensive during construction than in the future.

Transporting dredged sediment is often the largest cost associated with pond cleanout. This can be avoided by providing an area on-site for future sediment disposal. A disposal site should be designated during site design.

Water quality treatment practices are intended to trap pollutants. The fate of these pollutants must be considered. Trapped sediment is usually clean enough for on-site use. The large volume of sediment poses the most common disposal problem. Sediments may also have high concentrations of hydrocarbons, nutrients and heavy metals. Soil tests should be done if the pond has received spills, is in a highly industrial area, or if the watershed has intensive traffic. Sediment should be spoiled in areas, which will keep pollutants bound in the sediment.

Landscaping. Landscaping of wet ponds can make them an asset to a community and can also enhance the pollutant removal of the practice. A vegetated buffer should be preserved around the pond to protect the banks from erosion and provide some pollutant removal before runoff enters the pond by overland flow. In addition, ponds should incorporate an aquatic bench (a shallow shelf with wetland plants) around the edge of the pond. This feature may provide some pollutant uptake, and it also helps to stabilize the soil at the edge of the pond and enhance habitat and aesthetic value.

Wet Extended Detention Pond. The wet extended detention pond combines the treatment concepts of the dry extended detention pond and the wet pond. In this design, the water quality volume is split between the permanent pool and detention storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 12 to 48 hours. This design has similar pollutant removal to a traditional wet pond and consumes less space. Wet extended detention ponds should be designed to maintain at least half the treatment volume of the permanent pool. In addition, designers need to carefully select vegetation to be planted in the extended detention zone to ensure that the selected vegetation can withstand both wet and dry periods.

Water Reuse Pond. Designers can use wet ponds to act as a water source, usually for irrigation. The water balance should account for the water that will be taken from the pond. A water reuse pond could provide irrigation for substantially less than the cost of buying the equivalent amount of treated water.

Cold Climate Impacts. Cold climates present many challenges to designers of wet ponds. The spring snowmelt may have a high pollutant load and a large volume to be treated. In addition, cold winters may cause freezing of the permanent pool or freezing at inlets and outlets. Finally, high salt concentrations in runoff resulting from road salting may impact pond vegetation as well as reduce the storage and treatment capacity of the pond. Designers should consider planting the pond with salt-tolerant vegetation if the facility receives road runoff.

One option to deal with high pollutant loads and runoff volumes during the spring snowmelt is the use of a seasonally operated pond to capture snowmelt during the winter, and retain the permanent pool during warmer seasons. In this option, the pond has two water quality outlets, both equipped with gate valves. In the summer, the lower outlet is closed. During the fall and throughout the winter, the lower outlet is opened to draw down the permanent pool. As the spring melt begins, the lower outlet is closed to provide detention for the melt event. This method can act as a substitute for using a minimum extended detention storage volume. When wetlands preservation is a downstream objective, seasonal manipulation of pond levels may not be desired. An analysis of the effects on downstream hydrology should be conducted before considering this option. In addition, the manipulation of this system requires some labor and vigilance; a careful maintenance agreement should be confirmed.

Several other modifications may help to improve the performance of ponds in cold climates. In order to counteract the effects of freezing on inlet and outlet structures, the use of inlet and outlet structures that are resistant to frost, including weirs and larger diameter pipes, may be useful. Designing structures on-line, with a continuous flow of water through the pond, will also help prevent freezing of these structures. Finally, since freezing of the permanent pool can reduce the effectiveness of pond systems, it may be useful to incorporate extended detention into the design to retain usable treatment area above the permanent pool when it is frozen.

Limitations

Limitations of wet ponds include:

- If improperly located, wet pond construction may cause loss of wetlands or forest.
- Wet ponds are often inappropriate in dense urban areas because each pond is generally quite large.
- In cold water streams, wet ponds are not a feasible option due to the potential for stream warming.
- Wet ponds may pose safety hazards

Maintenance Considerations

In addition to incorporating features into the pond design to minimize maintenance, some regular maintenance and inspection practices are needed. On an annual basis, owners should inspect for invasive vegetation and harvest wetland plants, inspect the forebay for sediment accumulation, and inspect the inlet and outlet devices to ensure they are free of debris and operational. Standard ongoing maintenance items include mowing of side slopes, repair of undercut/eroded areas, and removal of trash and debris. Long term maintenance items include removal of sediment from the forebay (5-7 years) and dredging of the pond once sediment accumulation has significantly reduced the volume of the pond or it has become eutrophic (20-50 years).

Effectiveness

Wet ponds can provide flood control, channel protection, and pollutant removal.

Flood Control. Wet ponds can easily be designed for flood control by providing flood storage above the level of the permanent pool.

Channel Protection. When used for channel protection, wet ponds have traditionally controlled the 2-year storm. It appears that this control has been relatively ineffective, and research suggests that control of a smaller storm may be more appropriate.

Pollutant Removal. Wet ponds are among the most effective stormwater management practices at removing stormwater pollutants. A wide range of research is available to estimate the effectiveness of wet ponds. Typical removal rates are:

- Total Suspended Solids: 67%
- Total Phosphorous: 48%
- Total Nitrogen: 31%
- Nitrate Nitrogen: 24%
- Metals: 24-73%
- Bacteria: 65%

There is considerable variability in the effectiveness of ponds, and it is believed that properly designing and maintaining ponds may help to improve their performance.

Cost Considerations

The construction costs associated with wet ponds range considerably. The cost of wet ponds is generally slightly lower than the cost of dry ponds on a cost per total volume basis. Ponds do not consume a large area compared to the total area treated (typically 2 to 3 percent of the contributing drainage area). It is important to note, however, that these facilities are generally large and require a relatively large contiguous area

For ponds, the annual cost of routine maintenance is typically estimated at about 3 to 5 percent of the construction cost. Ponds are long-lived facilities (typically longer than 20 years). Thus, the initial investment into pond systems can be spread over a relatively long time period. In addition to the water resource protection benefits of wet ponds, there is some evidence to suggest that they may provide an economic benefit by increasing property values.

2.1.3. Stormwater Wetlands

Description

Stormwater wetlands (a.k.a. constructed wetlands) are structural practices similar to wet ponds that incorporate wetland plants into the design. As stormwater runoff flows through the wetland, pollutant removal is achieved through settling and biological uptake within the practice. Wetlands are among the most effective stormwater practices in terms of pollutant removal and also offer aesthetic and habitat value. Although natural wetlands can sometimes be used to treat stormwater runoff that has been properly pretreated, stormwater wetlands are fundamentally different from natural wetland systems. Stormwater wetlands are designed specifically for the purpose of treating stormwater runoff, and typically have less biodiversity than natural wetlands in terms of both plant and animal life. Several design variations of the stormwater wetland exist, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland.

Constructed wetlands

A distinction should be made between using a constructed wetland for stormwater management and diverting stormwater into a natural wetland. The latter practice is not recommended because altering the hydrology of the existing wetland with additional stormwater can degrade the resource and result in plant die-off and the destruction of wildlife habitat. In all circumstances, natural wetlands should be protected from the adverse effects of development, including impacts from increased stormwater runoff. This is especially important because natural wetlands provide stormwater and flood control benefits on a regional scale.

Applicability

Constructed wetlands are widely applicable stormwater management practices. It is difficult to use stormwater wetlands in the ultra-urban environment because of the land area each wetland consumes. They can, however, be used in an ultra-urban environment if a relatively large area is available downstream of the site.

Because stormwater wetlands are shallow, a large portion is subject to evaporation relative to the volume of the practice. This makes maintaining the permanent pool in wetlands more challenging and important than maintaining the pool of a wet pond Wetlands can accept runoff from stormwater hot spots, but need significant separation from ground water if they will be used for this purpose. Caution also needs to be exercised, if these practices are designed to encourage wildlife use, to ensure that pollutants in stormwater runoff do not work their way through the food chain of organisms living in or near the wetland.

When retrofitting an entire watershed, stormwater wetlands have the advantage of providing both educational and habitat value. One disadvantage to wetlands is the difficulty of storing large amounts of runoff without consuming a large amount of land. It is also possible to incorporate wetland elements into existing practices, such as wetland plantings.

Siting Criteria

Designers need to consider conditions at the site level and to incorporate design features to improve the longevity and performance of the wetlands, while minimizing the maintenance burden.

Wetlands need sufficient drainage area to maintain the permanent pool. This is typically about 20 acres. BMPs that focus on source control such as bioretention, should be considered for smaller drainage areas.

Wetlands can be used on sites with an upstream slope of up to about 15 percent. The local slope should be relatively shallow, however. While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 feet).

Wet ponds can be used in almost all soils and geology, with minor design adjustments for areas with highly permeable soils. In well draining soils, wetlands should be designed with an impermeable liner to prevent ground water contamination or sinkhole formation, and to help maintain the permanent pool.

Design Considerations

Volume and depth characteristics depend on the type of wetland being designed. In all instances, an extended detention volume (portion of the water quality volume, WQv) must be determined and treated.

Specific designs may vary considerably, depending on site constraints or preferences of the designer. However, the following features should be incorporated into most stormwater wetland designs.

Pretreatment. In wetlands, pretreatment is achieved with a sediment forebay. A sediment forebay is a small pool (typically about 10 percent of the volume of the permanent pool). Coarse particles remain trapped in the forebay, and maintenance is performed on this smaller pool, eliminating the need to dredge the entire pond.

Treatment. Treatment design features help enhance the ability of a stormwater management practice to remove pollutants. Some typical design features include:

- The surface area of wetlands should be at least 1 percent of the tributary drainage area.
- Wetlands should have a length-to-width ratio of at least 1.5:1. Making the wetland longer than it is wide helps prevent "short circuiting".
- Effective wetland design displays "complex microtopography." In other words, wetlands should include zones of both very shallow (<6 inches) and moderately shallow (<18 inches) water, using underwater earth berms to create the zones. This design will provide a longer flow path through the wetland to encourage settling, and it provides two depth zones to encourage plant diversity.

Conveyance. The outfall of wetlands should always be stabilized to prevent scour. In addition, an emergency spillway should be provided to safely convey large flood events. To help mitigate warming at the outlet channel, designers should provide shade around the channel at the wetland outlet.

Maintenance Reduction. In wetlands, maintenance reduction features include techniques to reduce the amount of maintenance needed, as well as techniques to make regular maintenance activities easier.

One potential maintenance concern in wetlands is clogging of the outlet. Wetlands should be designed with a nonclogging outlet such as a reverse-slope pipe or a weir outlet with a trash rack. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris. Another general rule is that no orifice should be less than 3 inches in diameter. Smaller orifices are generally more susceptible to clogging, without specific design considerations to reduce this problem. Another feature that can help reduce the potential for clogging of the outlet is to incorporate a small pool, or "micropool" at the outlet.

Design features are also incorporated to ease maintenance of both the forebay and the main pool of wetlands. Wetlands should be designed with maintenance easements to allow access to for routine maintenance activities. In addition, the permanent pool should have a drain to draw down the water for the more infrequent dredging of the main cell of the wetland.

The frequency of sediment cleanout can be reduced by increasing the volume available for sediment storage. Increasing the permanent pool volume by 20% or according to the predicted sediment loads is recommended. Ponds used for sediment control during construction should be cleaned out when the site is stabilized, as the cost of cleanout will be considerably less expensive during construction than in the future.

Transporting dredged sediment is often the largest cost associated with pond cleanout. This can be avoided by providing an area on-site for future sediment disposal. A disposal site should be designated during site design.

Water quality treatment practices are intended to trap pollutants. The fate of these pollutants must be considered. Trapped sediment is usually clean enough for on-site use. The large volume of sediment poses the most common disposal problem. Sediments may also have high concentrations of hydrocarbons, nutrients and heavy metals. Soil tests should be done if the pond has received spills, is in a highly industrial area, or if the watershed has intensive traffic. Sediment should be spoiled in areas, which will keep pollutants bound in the sediment.

Landscaping. Landscaping of wetlands can make them an asset to a community and can also enhance the pollutant removal of the practice. In wetland systems, landscaping is an integral part of the design. To ensure the establishment and survival of wetland plants, a landscaping plan should provide detailed information about the plants selected, when they will be planted, and a strategy for maintaining them. The plan should detail wetland plants, as well as vegetation to be established adjacent to the wetland. Native plants should be used if possible.

A variety of techniques can be used to establish wetland plants. The most effective techniques are the use of nursery stock as dormant rhizomes, live potted plants, and bare rootstock. A "wetland mulch," soil from a natural wetland or a designed "wetland mix," can be used to supplement wetland plantings or alone to establish wetland vegetation. Wetland mulch carries with it the seed bank from the original wetland, and can help to enhance diversity in the wetland. The least expensive option to establish wetlands is to allow the wetland to colonize itself. One disadvantage to this last technique is that invasive species such as cattails or Phragmites (common reed) may dominate the wetland.

When developing a plan for wetland planting, care needs to be taken to ensure that plants are established in the proper depth and within the planting season.

Shallow Marsh. In the shallow marsh design, most of the wetland volume is in the relatively shallow high marsh or low marsh depths. The only deep portions of the shallow wetland design are the forebay at the inlet to the wetland and the micropool at the outlet. One disadvantage to this design is that, since the pool is very shallow, a large amount of land is typically needed to store the water quality volume (the volume of runoff to be treated in the wetland).

Extended Detention Wetland. This design is the same as the shallow marsh, with additional storage above the surface of the marsh. Stormwater is temporarily ponded above the surface in the extended detention zone for between 12 and 24 hours. This design can treat a greater volume of stormwater in a smaller space than the shallow wetland design. In the extended detention wetland option, plants that can tolerate wet and dry periods should be specified in the extended detention zone.

Pond/Wetland System. The pond/wetland system combines the wet pond design with a shallow marsh. Stormwater runoff flows through the wet pond and into the shallow marsh. Like the extended detention wetland, this design requires less surface area than the shallow marsh because some of the volume of the practice is in the relatively deep (6-8 feet) pond.

Pocket Wetland. In this design, the bottom of the wetland intersects the ground water, which helps to maintain the permanent pool. Some evidence suggests that ground water flows may reduce the overall effectiveness of stormwater management practices. This option may be used when there is not significant drainage area to maintain a permanent pool.

Gravel-Based Wetlands. In this design, runoff flows through a rock filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the rocks and pollutant uptake by the plants. This practice is fundamentally different from other wetland designs because, while most wetland designs behave like wet ponds with differences in grading and landscaping, gravel-based wetlands are more similar to filtering systems.

Cold Climate Impacts. Cold climates present many challenges to designers of wetlands. During the spring snowmelt, a large volume of water runs off in a short time, carrying a relatively high pollutant load. In addition, cold winter temperatures may cause freezing of the permanent pool or freezing at inlets and outlets. Finally, high salt concentrations in runoff resulting from road salting may impact wetland vegetation.

One of the greatest challenges of stormwater wetlands, particularly shallow marshes, is that much of the practice is very shallow. Therefore, much of the volume in the wetland can be lost as the surface of the practice freezes. Sediment and pollutants in snowmelt and rainfall events can “skate” over the surface of the wetland, depositing at the outlet of the wetland. Several design features can help minimize this problem, including:

- "On-line" designs allowing flow to move continuously can help prevent outlets from freezing.

- Wetlands should be designed with multiple cells, with a berm or weir separating each cell. This modification will help to retain storage for treatment above the ice layer during the winter season.

- Outlets that are resistant to freezing should be used. Some examples include weirs or pipes with large diameters.

The salt used to remove ice from roads and parking lots may also create a challenge to designing wetlands in cold climates. When wetlands drain highway runoff, or parking lots, salt-tolerant vegetation, such as pickle weed or cord grass should be used. (Contact a local nursery or extension agency for more information in your region). In addition, designers should consider using a large forebay to capture the sediment from road sanding.

Limitations

Some features of stormwater wetlands that may make the design challenging include the following:

- Each wetland consumes a relatively large amount of space, making it an impractical option on some sites.

- Improperly designed wetlands might become a breeding area for mosquitoes.

- Wetlands require careful design and planning to ensure that wetland plants are sustained after the practice is in place.

- It is possible that stormwater wetlands may release nutrients during the nongrowing season.

- Designers need to ensure that wetlands do not negatively impact natural wetlands or forest during the design phase.

Maintenance Considerations

In addition to incorporating features into the wetlands design to minimize maintenance, some regular maintenance and inspection practices are needed. On an annual basis, owners should inspect for invasive vegetation, harvest wetland plants, monitor sediment accumulation, repair undercut/eroded areas, inspect for damage to embankment and inlet/outlet structure, and inspect the inlet and outlet devices to ensure they are free of debris and operational. A onetime replacement of wetland vegetation to maintain a 50+ percent surface area coverage should be made after the second growing season. Long term maintenance items include removal of sediment from the forebay (5-7 years) and dredging of the wetlands once sediment accumulation has significantly reduced the wetland volume (20-50 years).

Effectiveness

Wetlands can provide flood control, channel protection, and pollutant removal.

Flood Control. Wetlands can easily be designed for flood control by providing flood storage above the level of the permanent pool.

Channel Protection. When used for channel protection, wetlands have traditionally controlled the 2-year storm. It appears that this control has been relatively ineffective, and research suggests that control of a smaller storm may be more appropriate.

Pollutant Removal. Wetlands are among the most effective stormwater management practices at removing stormwater pollutants. Removal ranges vary depending on the type of wetlands used. Typical removal ranges, as reported by (Winer, 2000), are as follows:

- Total Suspended Solids: 69-83%
- Total Phosphorous: 39-64%
- Total Nitrogen: 19-56%
- Nitrate Nitrogen: 35-81%
- Metals: 0-85%
- Bacteria: 76-78%

The effectiveness of wetlands varies considerably, but many believe that proper design and maintenance help to improve their performance.

Cost Considerations

Wetlands are relatively inexpensive stormwater practices. Construction cost data for wetlands are rare, but one simplifying assumption is that they are typically about 25 percent more expensive than stormwater ponds of an equivalent volume.

Wetlands consume about 3 to 5 percent of the land that drains to them, which is relatively high compared with other stormwater management practices.

For wetlands, the annual cost of routine maintenance is typically estimated at about 3 percent to 5 percent of the construction cost. Wetlands are long-lived facilities (typically longer than 20 years). Thus, the initial investment into these systems may be spread over a relatively long time period.

Although no studies are available on wetlands in particular, there is some evidence to suggest that the “pond frontage” or perceived value of wet ponds may provide an economic benefit by increasing property values.

2.2 Infiltration Practices

Infiltration practices are generally rock-filled storage areas that receive storm water runoff, allowing it to infiltrate into the ground. These structures provide temporary underground storage in the form of a trench or other storage chamber filled with uniform graded stone. Infiltration devices are used in conjunction with sediment removal practice so that most suspended solids are removed before passing runoff into the structure. This is typically accomplished by passing runoff through a forebay (see water quality ponds), a grass filter strip or swale prior to the device.

Infiltration is the single most efficient post-construction storm water practice, providing several benefits other control practices don’t. Most notably, infiltration tends to reverse the hydrologic consequences of urban development by reducing peak discharge and increasing base flow to local streams. Unfortunately, infiltration devices must be very carefully constructed to ensure they will continue to function, and they often have high long-term maintenance requirements. Infiltration practices also are limited by site constraints, particularly soils, which must be within a narrow range of permeability.

In general, infiltration practices are allowed on private sites within the City but are not to be used on public projects.

2.2.1. Infiltration Trench

Description

An infiltration trench is a rock-filled trench with no outlet that receives stormwater runoff. Stormwater runoff passes through some combination of pretreatment measures, such as a swale and detention basin, and into the trench. There, runoff is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix. The primary pollutant removal mechanism of this practice is filtering through the soil.

Infiltration trench

Applicability

Infiltration trenches have select applications. Their use is sharply restricted by concerns due to common site factors such as potential ground water contamination, soils, and clogging.

Some design modifications may be needed in cold climates due to freezing and snow melt and areas with highly permeable soils due to concerns of sink hole formation and ground water contamination.

Infiltration trenches can sometimes be applied in the ultra-urban environment. Two features that can restrict their use are the potential of infiltrated water to interfere with existing infrastructure, and the relatively poor infiltration capacity of most urban soils.

Infiltration trenches should not receive runoff from stormwater hot spots, such as industrial discharges, unless the stormwater has already been treated by another stormwater management practice, because of potential ground water contamination.

Siting Criteria

Infiltration trenches have select applications. Although they can be applied in a variety of situations, the use of infiltration trenches is restricted by concerns over ground water contamination, soils, and clogging.

Infiltration devices are generally not considered practical for sites larger than 5 acres. Used in small areas they offer flexibility in incorporating water quality treatment into a site’s drainage system. They may be used prior to runoff entering the site’s drainage system, such as along parking lot perimeters. They also can be located in small areas, which cannot readily accommodate wet ponds or similar facilities.

Infiltration rates must be at least 0.52 inches per hour but not more than 2.4 inches per hour. These rates represent average or saturated soil conditions, not dry conditions. Rates slower than the minimum will lead to structure sizes that are unreasonably large and are more prone to failure. Higher infiltration rates will not provide adequate runoff treatment or protection against ground water contamination. Higher infiltration rates will not provide adequate runoff treatment and protection against groundwater contamination. Infiltration devices should not be constructed on undisturbed soils, which have been filled.

Infiltration trenches should not be used in heavy industrial developments, areas with chemical storage, pesticide storage or fueling stations.

Infiltration devices should not be used in slip prone areas where they may cause slope instability.

Infiltration practices help reduce runoff and may help support recharge of groundwater and baseflow to streams. This practice may be a particularly desirable option when the receiving stream is a cold water habitat.

Design Considerations

Sediment Clogging. The principle threat to infiltration devices and a common reason for their failure is sediment clogging and sealing off of the permeable soil layer. An effective sediment trapping system is an essential part of all infiltration designs. Vegetated swales, buffer strips or sediment settling ponds should be planned so that most sediment is removed from runoff prior to reaching the infiltration device. Additionally infiltration devices may not be installed until disturbance from construction has ended and soils are stabilized.

Groundwater Protection. Precautions must be taken to guard against the facility introducing contaminants into water supply aquifers. Excessively permeable soils will not effectively stop pollutants and should not be used for infiltration practices. Infiltration devices should be used with caution in well-head protection areas. At a minimum, infiltration structures should not be located within 100 feet of an active water supply well. A minimum vertical separation of 3 feet between the bottom of the infiltration trench or pond and the seasonal high water elevation of the ground water must be maintained, although larger separations are recommended where achievable. Normally, infiltration through soil is a highly effective and safe means of removing pollutants and protecting groundwater from contamination. Removal mechanisms involve sorption, precipitation, trapping, and bacterial degradation or transformation and are quite complex.

Cold Climate Impacts. The design volume of the infiltration device may need to be increased in order to treat snowmelt. In addition, if the practice is used to treat roadside runoff, it may be desirable to divert flow around the structure in winter to prevent infiltration of chlorides from road salt. Finally, a minimum setback of 20 feet from road subgrade is required to ensure that the practice does not cause frost heaving.

Maintenance Issues

It is recommended that infiltration devices be inspected twice per year. Inspection should be performed following three days of dry weather. Failure to percolate within this time indicates clogging.

Pretreatment devices and diversion structures should be inspected for sediment build-up and structural damage. Sediment and oil/grease should be removed from pretreatment devices as well as the overflow structure. Device walls should be excavated to expose clean soil. Trees adjacent to the infiltration structure should be trimmed annually to assure that the drip-line does not extend over the surface of the device.

Upon failure, total rehabilitation of the device should be conducted to maintain storage capacity within 67% of the design treatment volume and 72-hour exfiltration rate limit.

2.2.2. Infiltration Basin

Description

An infiltration basin is a shallow impoundment which is designed to infiltrate stormwater into the soil. This practice is has a high pollutant removal efficiency and can also help recharge the ground water. Infiltration basins can be a challenge on many sites because of soils requirements and can have a relatively high failure rate compared with other management practices.

Infiltration basin

Applicability

Infiltration basins have select applications. Their use is often sharply restricted by concerns over ground water contamination, soils, and clogging at the site. Some design modifications may be needed in cold climates due to freezing and snow melt and areas with highly permeable soils due to concerns of sink hole formation and ground water contamination.

Infiltration basins can rarely be applied in the ultra-urban environment. Two features that can restrict their use are the potential of infiltrated water to interfere with existing infrastructure, and the relatively poor infiltration capacity of most urban soils. In addition, while they consume only the space of the infiltration basin site itself, they need a continuous, relatively flat area. Thus, it is more difficult to fit them into small unusable areas on a site.

Infiltration basins should never receive runoff from stormwater hot spots, unless the stormwater has already been treated by another practice. This caution is due to potential ground water contamination.

Infiltration basins should only be used to treat small sites (less than 5 acres). They have limited applications as a stormwater retrofit on redevelopment sites because they are generally a high-cost retrofit option in terms of construction cost and the maintenance burden. Infiltration basins are an excellent option for treatment before discharge to streams because they encourage infiltration of stormwater, maintain dry weather flow and have little opportunity to increase in temperature.

Siting Criteria

Infiltration practices need to be located extremely carefully. In particular, designers need to ensure that the soils on the site are appropriate for infiltration, and that designs minimize the potential for ground water contamination and long-term maintenance problems.

Infiltration basins have historically been used as regional facilities, serving for both quantity and quality control. This practice is feasible, particularly if the soils are particularly sandy. In most areas, however, infiltration basins experience high rates of failure when used in this manner. In general, the practice is best applied to relatively small drainage areas (i.e., less than 10 acres).
The bottom of infiltration basins need to be completely flat to allow infiltration throughout the entire basin bottom.

Soils and topography are strongly limiting factors when locating infiltration practices. Soils must be significantly permeable to ensure that the practice can infiltrate quickly enough to reduce the potential for clogging, and soils that infiltrate too rapidly may not provide sufficient treatment, creating the potential for ground water contamination. The infiltration rate should range between 0.5 and 3 inches per hour. In addition, the soils should have no greater than 20 percent clay content, and less than 40 percent silt/clay content (MDE, 2000).

Designers always need to provide significant separation distance (2 to 5 feet) from the bottom of the infiltration basin and the seasonally high ground water table, to reduce the risk of contamination. Infiltration practices should also be separated from drinking water wells.

Design Considerations

Pretreatment. Pretreatment is important for all structural management practices, but it is particularly important for infiltration practices. In order to ensure that pretreatment mechanisms are effective, designers should incorporate "multiple pretreatment," using practices such as grassed swales, sediment basins, and vegetated filter strips in series.

Treatment. For infiltration practices, designers need to stabilize upland soils to ensure that the basin does not become clogged with sediment. In addition, the facility needs to be sized so that the volume of water to be treated infiltrates through the bottom in a given amount of time. Because infiltration basins are designed in this manner, infiltration basins designed on less permeable soils should be significantly larger than those designed on more permeable soils.

Conveyance. In general, infiltration basins should be designed to treat only small storms (i.e., only for water quality). Thus, these practices should be designed "off-line," using a flow separator to divert only small flows to the practice.

Maintenance Reduction. Designers need to provide access to the basin for regular maintenance activities. Where possible, a means to drain the basin, such as an underdrain, should be provided in case the bottom becomes clogged. This feature allows the basin to be drained and accessed for maintenance in the event that the water has ponded in the basin bottom or the soil is saturated.

Landscaping. In infiltration basins, the most important purpose of vegetation is to reduce the tendency of the practice to clog. Upland drainage needs to be properly stabilized with a thick layer of vegetation, particularly immediately following construction. In addition, providing a thick turf at the basin bottom helps encourage infiltration and prevent the formation of rills in the basin bottom.

Cold Climate Impacts. In most cold climates, infiltration basins can be a feasible practice, but there are some challenges to its use. First, the practice may become inoperable during some portions of the year when the surface of the basin becomes frozen. Other design features also may be incorporated to deal with the challenges of cold climates. One such challenge is the volume of runoff associated with the spring snowmelt event. The capacity of the infiltration basin might be increased to account for snowmelt volume.

A seasonally operated infiltration/detention basin combines several techniques to improve the performance of infiltration practices in cold climates. Two features, the underdrain system and level control valves, are useful in cold climates. These features are used as follows: At the beginning of the winter season, the level control valve is opened and the soil is drained. As the snow begins to melt in the spring, the underdrain and the level control valves are closed. The snowmelt is infiltrated until the capacity of the soil is reached. Then, the facility acts as a detention facility, providing storage for particles to settle.

Other design features can help to minimize problems associated with winter conditions, particularly concerns that chlorides from road salting may contaminate ground water. The basin may be disconnected during the winter to ensure that chlorides do not enter the ground water in areas where this is a problem, or if the basin is used to treat roadside runoff. Designers may also want to reconsider application of infiltration practices on parking lots or roads where deicing is used, unless it is confirmed that the practice will not cause elevated chloride levels in the ground water. If the basin is used for snow storage, or to treat roadside or parking lot runoff, the basin bottom should be planted with salt-tolerant vegetation.

Limitations

Although infiltration basins can be useful practices, they have several limitations. Infiltration basins are not generally aesthetic practices, particularly if they clog. If infiltration basins are designed and maintained so that standing water is left for no more than 3 days, mosquitoes should not be a problem. However, if an infiltration basin becomes clogged and takes 4 or more days to drain, the basin could become a source for mosquitoes. In addition, these practices are challenging to apply because of concerns over ground water contamination and sufficient soil infiltration. Finally, maintenance of infiltration practices can be burdensome, and they have a relatively high rate of failure.

Maintenance Considerations

Regular maintenance is critical to the successful operation of infiltration basins. Historically, infiltration basins have had a poor track record. It is recommended that infiltration devices be inspected twice per year. Inspection should be performed following three days of dry weather. Failure to percolate within this time indicates clogging.

Pretreatment devices and diversion structures should be inspected for sediment build-up and structural damage. Sediment and oil/grease should be removed from pretreatment devices as well as the overflow structure. Device walls should be excavated to expose clean soil. Trees adjacent to the infiltration structure should be trimmed annually to assure that the drip-line does not extend over the surface of the device.

Upon failure, total rehabilitation of the device should be conducted to maintain storage capacity within 67% of the design treatment volume and 72-hour exfiltration rate limit.

Effectiveness

Very little data is available regarding the pollutant removal associated with infiltration basins. However, it is generally assumed that they have very high pollutant removal because runoff is treated for water quality by filtering through the soil and none of the stormwater entering the practice remains on the surface. The average pollutant removal, assuming the infiltration basin is sized to treat the runoff from a 1-inch storm, is:

- TSS 75%
- Phosphorous 60-70%
- Nitrogen 55-60%
- Metals 85-90%
- Bacteria 90%

These removal efficiencies assume that the infiltration basin is well designed and maintained.

Cost Considerations

Infiltration basins are relatively cost-effective practices because little infrastructure is needed when constructing them. They typically consume about 2 to 3 percent of the site draining to them, which is relatively small. Maintenance costs are estimated at 5 to 10 percent of construction costs.
One cost concern associated with infiltration practices is the maintenance burden and longevity. If improperly maintained, infiltration basins have a high failure rate. Thus, it may be necessary to replace the basin after a relatively short period of time.

2.2.3. Porous Pavement

Description

Porous pavement is a permeable pavement surface, often built with an underlying stone reservoir that temporarily stores surface runoff before it infiltrates into the subsoil. Porous pavement replaces traditional pavement, allowing parking lot stormwater to infiltrate directly and receive water quality treatment. There are various types of porous surfaces, including porous asphalt, pervious concrete, and even grass or permeable pavers.

From the surface, porous asphalt and pervious concrete appear to be the same as traditional pavement. However, unlike traditional pavement, porous pavement contains little or no "fine" materials. Instead, it contains voids that encourage infiltration. Porous asphalt pavement consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Pervious concrete typically consists of specially formulated mixtures of Portland cement, uniform, open-graded coarse aggregate, and water. Pervious concrete has enough void space to allow rapid percolation of liquids through the pavement. Grass or permeable pavers are interlocking concrete blocks or synthetic fibrous grids with open areas that allow grass to grow within the voids. Some grid systems fill the voids with sand or gravel to allow infiltration. Other alternative paving surfaces can help reduce runoff from paved areas, but do not incorporate a stone trench for temporary storage below the pavement. While porous pavement can be a highly effective treatment practice, maintenance and proper installation are necessary to ensure its long-term effectiveness.

Like all BMPs, porous pavement should be combined with other practices to capitalize on each technology's benefits and to allow protection in case of BMP failure. However, construction using pervious materials may not require as much treatment as other BMP approaches. It may increase the amount of open space for public use and it may also lead to an increase in environmental benefits.

Porous pavement

Application

Medium traffic areas are the ideal application for porous pavement. It may also have some application on highways, where it is currently used to reduce hydroplaning. In some areas, such as truck loading docks and areas of high commercial traffic, porous pavement may be inappropriate.

Cold climates present special challenges for porous pavement. Road salt contains chlorides that may migrate through the porous pavement into ground water. Plowing may present a challenge to block pavers, because snow plow blades can catch the block's edge and damage its surface. Infiltrating runoff may freeze below the pavement causing frost heave, though design modifications can reduce this risk. These potential problems do not mean that porous pavement cannot be used in cold climates. Experience suggests that rapid drainage below porous surfaces increases the rate of snow melt above.

Since porous pavement is an infiltration practice, it should not be applied at stormwater hot spots due to the potential for ground water contamination.

The best retrofit application for porous pavement is parking lot replacement on individual sites. If many impervious lots are replaced with pervious concrete, pavers, or porous asphalt, then overall stormwater peak flows can be reduced.

Porous pavement can help lower high water temperatures commonly associated with impervious surfaces. Stormwater pools on the surface of conventional pavement, where it is heated by the sun and the hot pavement surface. By rapidly infiltrating rainfall, porous pavement reduces stormwater's exposure to sun and heat.

Siting Criteria

Porous pavement needs to meet the following criteria:

- Soils need to have a permeability of at least 0.5 inches per hour. An acceptable alternative design for soils with low porosity would be the installation of a discharge pipe from a storage area to the storm sewer system. The modified design allows the treatment of stormwater from small to medium stormwater events while allowing a bypass for large events, which will help prevent flooding.
- The bottom of the stone reservoir should be flat, so that runoff can infiltrate through the entire surface.

- If porous pavement is used near an industrial site or similar area, the pavement should be sited at least 2 to 5 feet above the seasonally high ground water table and at least 100 feet away from drinking water wells.

- Porous pavement should be sited on low to medium traffic areas, such as residential roads and parking lots.

Design Considerations

Pretreatment. In porous pavement designs, the pavement itself acts as pretreatment to the stone reservoir below. Because of this, frequent maintenance of the surface, such as sweeping, is critical to prevent clogging. A layer of fine gravel can be laid atop the coarse gravel treatment reservoir as an additional pretreatment item. Both of these pretreatment measures are marginal.

Treatment. If used, the stone reservoir below the pavement surface should be composed of layers of small stone laid directly below the pavement surface. The stone bed below the permeable surface should be sized to attenuate storm flows for the storm event to be treated. Typically, porous pavement is sized to treat a small event. As in infiltration trenches, water can be stored in the voids of the stone reservoir. With certain designs in warm weather climates, the pavement can also store stormwater if it is properly maintained.

Conveyance. Water conveyed to the stone reservoir though the pavement surface infiltrates into the ground below. A geosynthetic liner and a sand layer may be placed below the stone reservoir to prevent preferential flow paths and to maintain a flat bottom. Designs also need a means to convey larger amounts of stormwater to the storm drain system. Storm drain inlets set slightly above the pavement surface is one option. This allows for some ponding above the surface, but bypasses flows too large to be treated by the system or when the surface clogs.

Maintenance Reduction. One nonstructural component that can help ensure proper maintenance of porous pavement is a carefully worded maintenance agreement providing specific guidance, including how to conduct routine maintenance and how the surface should be repaved. Ideally, signs should be posted on the site identifying porous pavement areas. One design option incorporates an "overflow edge," which is a trench surrounding the edge of the pavement. The trench connects to the stone reservoir below the pavement surface. Although this feature does not in itself reduce maintenance requirements, it acts as a backup in case the surface clogs. If the surface clogs, stormwater will flow over the surface and into the trench where some infiltration and treatment will occur.

Landscaping. For porous pavement, the most important landscaping feature is a fully stabilized upland drainage. Reducing sediment loads entering the pavement can help to prevent clogging.

In one design variation, the stone reservoir below the filter can also treat runoff from other sources, such as rooftop runoff. In this design, pipes are connected to the stone reservoir to direct flow throughout the bottom of the storage reservoir. However, treating stormwater from other areas with porous pavement can cause failures, as it is more likely to carry clogging sediments. If used to treat off-site runoff, porous pavement should incorporate pretreatment, as with all structural management practices. Off site runoff should never come from areas that carry high sediment loadings.

Cold Climate Impacts. The base of the stone reservoir should be below the frost line or other accommodations should be designed to facilitate the drainage of stormwater away from the aggregate recharge bed. Such modification will help reduce the risk of frost heave.

Limitations

In addition to the siting requirements of porous pavement, a major limitation to the practice is the poor success rate it has experienced in the field. Newer studies, particularly with permeable pavers and pervious concrete, indicate that success rates can be reasonably high if the paving medium is properly installed.

Maintenance Considerations

Owners should be aware of a site's porous pavement because failure to perform maintenance is a primary reason for failure of this practice. Furthermore, using knowledgeable contractors skilled in techniques required for installation of pervious concrete, permeable pavers, or porous asphalt will increase performance and longetivy of the system.

On a monthly basis, the porous pavement should be inspected to ensure that the paving area is clean of debris and sediment, and that the paving dewaters between storms. As part of routine maintenance, the pavement should be vacuum swept frequently to keep the surface free of sediment, upland and adjacent areas should be mowed, and bare areas seeded. The surface should be inspected on an annual basis for deterioration.

Effectiveness

Porous pavement can be used to provide ground water recharge and to reduce pollutants in stormwater runoff. Some data suggest that as much as 70 to 80 percent of annual rainfall will go toward ground water recharge. These data will vary depending on design characteristics and underlying soils. Other studies suggest that porous pavement provides high pollutant removal.

Cost Considerations

Porous pavement is more expensive than traditional asphalt. While traditional asphalt and concrete costs between \$0.50 to \$3.00 per ft^2, porous pavement can range from \$2 to \$8 per ft^2, depending on the design. However, porous pavement, when used in combination with other techniques such as bioretention cells, vegetated swales, or vegetated filter strips, may eliminate or reduce the need for land intensive BMPs, such as dry extended detention or wet retention ponds. Finally, if not designed and maintained properly, porous pavment's effective lifespan may be short because of the potentially high risks of clogging.

2.3 Filtration Practices

Sand, organic and biofilters are post-construction practices that all treat storm water in two stages, regardless of design variation. The first stage removes large particles from storm water by allowing them to settle out of suspension while the second stage removes finer particles by filtering them through a bed composed of sand or other material. The media used for filtering is chosen based on the pollutants which are being treated, however filters are used to primarily remove suspended solids. Filters have also been shown to reduce the concentration of nutrients, oil and grease, metals and bacteria in storm water. However, nitrate removal is generally poor because of mineralization of organic nitrogen within the filter bed.

ODOT has a filtration practice for use on roadway projects called an exfiltration trench. It is a trench with an underdrain backfilled with various sizes of aggregate. The trench is topped with permeable concrete pavement and is placed either in the paved shoulder or in front of the curb. The exfiltration trench treats water before it enters any storm water pipe. Although this practice is currently being used on ODOT projects, it is not approved for use on City of Akron projects.

In general, filtration practices are allowed on private sites within the City but are not to be used on public projects.

2.3.1. Sand and Organic Filters

Description

Sand/organic filters are usually designed as two-chambered stormwater practices; the first is a settling chamber, and the second is a filter bed filled with sand or an organic filtering media such as peat. As stormwater flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as stormwater flows through the filtering medium. There are several modifications of the basic filter design, including the surface sand filter, underground sand filter, perimeter sand filter, organic media filter, and Multi-Chamber Treatment Train. All of these filtering practices operate on the same basic principle. Modifications to the traditional surface sand filter were made primarily to fit sand filters into more challenging design sites or to improve pollutant removal.

Sand filter

Applicability

Surface or perimeter filters will not be effective during the winter months, and unintended consequences might result from a frozen filter bed. Using alternative conveyance measures such as a weir system between the sediment chamber and filter bed may avoid freezing associated with the traditional standpipe. Where possible, the filter bed should be below the frost line. Some filters, such as the peat/sand filter, should be shut down during the winter. These media will become completely impervious during freezing conditions. Using a larger under drain system to encourage rapid draining during the winter months may prevent freezing of the filter bed.

Sand filters in general are good options in ultra-urban areas because they consume little space. Underground and perimeter sand filters in particular are well suited to the ultra-urban setting because they consume no surface space.

Sand filters are an excellent option to treat runoff from stormwater hot spots because stormwater treated by sand filters has no interaction with, and thus no potential to contaminate, the groundwater.

Sand filters are a good option to achieve water quality goals in retrofit area where space is limited because they consume very little surface space and have few site restrictions. It is important to note, however, that sand filters cannot treat a very large drainage area. Using small-site BMPs in a retrofit may be the only option for a retrofit study in a highly urbanized area, but it is expensive to treat the drainage area of an entire watershed using many small-site practices, as opposed to one larger facility such as a pond.

Sand filters can be a good treatment option for discharges directly to streams. In some stormwater treatment practices, particularly wet ponds, runoff is warmed by the sun as it resides in the permanent pool. Surface sand filters are typically not designed with a permanent pool, although there is ponding in the sedimentation chamber and above the sand filter. Underground and perimeter sand filter designs have little potential for warming because these practices are not exposed to the sun.

Siting Criteria

Sand filters are best applied on relatively small sites (up to 10 acres for surface sand filters and 5 acres or less for perimeter or underground filters. Filters have been used on larger drainage areas, of up to 100 acres, but these systems can clog when they treat larger drainage areas unless adequate measures are provided to prevent clogging, such as a larger sedimentation chamber or more intensive regular maintenance. Because of clogging concerns, filters should not be used on sites which will generate a large amount of suspended solids or where soils are permanently disturbed. Filters should not be constructed on a site until the contributing drainage area has been permanently stabilized. No storm water should enter the filter system while it is under construction.

Sand filters can be used on sites with slopes up to about 6 percent. It is challenging to use most sand filters in very flat terrain because they require a significant amount of elevation drop, or head (about 5 to 8 feet), to allow flow through the system. One exception is the perimeter sand filter, which can be applied with as little as 2 feet of head.

When sand filters are designed as a stand-alone practice, they can be used on almost any soil because they can be designed so that stormwater never infiltrates into the soil or interacts with the ground water. Alternatively, sand filters can be designed as pretreatment for an infiltration practice, where soils do play a role.

Designers should provide at least 2 feet of separation between the bottom of the filter and the seasonally high ground water table. This design feature prevents both structural damage to the filter and possibly, though unlikely, ground water contamination.

Design Considerations

Pretreatment. In sand filters, pretreatment is achieved in the sedimentation chamber that precedes the filter bed. In this chamber, the coarsest particles settle out and thus do not reach the filter bed. Pretreatment reduces the maintenance burden of sand filters by reducing the potential of these sediments to clog the filter. Designers should provide at least 25 percent of the water quality volume in a dry or wet sedimentation chamber as pretreatment to the filter system. The water quality volume is the amount of runoff that will be treated for pollutant removal in the practice. Typical water quality volumes are the runoff from a 1-inch storm or ½ inch of runoff over the entire drainage area to the practice.

The area of the sedimentation chamber may be determined based on the Camp-Hazen equation. The Center for Watershed Protection used a settling of 0.0004 ft/s for drainage areas greater than 75% impervious and 0.0033 ft/s for drainage areas less than or equal to 75% impervious to account for the finer particles that erode from pervious surfaces.

Treatment. Treatment design features help enhance the ability of a stormwater management practice to remove pollutants. In filtering systems, designers should provide at least 75 percent of the water quality volume in the practice including both the sand chamber and the sediment chamber. The filter bed should be sized using Darcy's Law, which relates the velocity of fluids to the hydraulic head and the coefficient of permeability of a medium. In sand filters, designers should select a medium sand as the filtering medium.

Conveyance. Conveyance of stormwater runoff into and through the filter should be conducted safely and in a manner that minimizes erosion potential. Ideally, some stormwater treatment can be achieved during conveyance to and from the filter. Since filtering practices are usually designed as "off-line" systems, meaning that they have the smaller water quality volume diverted to them only during larger storms, using a flow splitter, which is a structure that bypasses larger flows to the storm drain system or to a stabilized channel. One exception is the perimeter filter; in this design, all flows enter the system, but larger flows overflow to an outlet chamber and are not treated by the practice. All filtering practices, with the exception of exfilter designs are designed with an under drain below the filtering bed. An under drain is a perforated pipe system in a gravel bed, installed on the bottom of filtering practices and used to collect and remove filtered runoff.

Maintenance Reduction. Filter systems require intense and frequent maintenance. Design considerations that can help reduce maintenance problems follow:

- Providing access to the filtering system
- Addressing confined space issues for underground systems
- Where observation wells and grates are used, lifting rings or threaded sockets should be provided to allow for easy removal by lifting equipment. Access for the lifting equipment must be provided.

Landscaping. Landscaping can add to both the aesthetic value and the treatment ability of stormwater practices. In sand filters, little landscaping is generally used on the practice, although surface sand filters and organic media filters may be designed with a grass cover on the surface of the filter. In all filters, designers need to ensure that the contributing drainage has dense vegetation to reduce sediment loads to the practice.

Cold Climate Impacts. Sand/organic filters may not be effective during winter months if the filter bed freezes. Alternative conveyance systems such as a weir system between the sediment chamber and the filter bed may prevent the filter bed from freezing in more mild cold climates. Where possible, the filter bed should be placed below the frost line. Filter systems which make use of peat/sand or compost as filter media should be shut down during winter by diverting all flows around the system.

Limitations

Sand filters can be used in unique conditions where many other stormwater management practices are inappropriate, such as in highly urbanized settings. There are several limitations to these practices, however. Sand filters cannot control floods and generally are not designed to protect stream channels from erosion or to recharge the ground water. In addition, sand filters require frequent maintenance, and underground and perimeter versions of these practices are easily forgotten because they are out of sight. Perhaps one of the greatest limitations to sand filters is that they cannot be used to treat large drainage areas. Surface sand filters are generally not aesthetically pleasing practices but underground and perimeter sand filters are not visible, and thus do not add or detract from the aesthetic value of a site.

Maintenance Considerations

Typical annual maintenance requirements are:

- Check to see that the filter bed is clean of sediments, and the sediment chamber is no more than one-half full of sediment; remove sediment if necessary
- Make sure that there is no evidence of deterioration, sailing, or cracking of concrete
- Inspect grates (if used)
- Inspect inlets, outlets, and overflow spillway to ensure good condition and no evidence of erosion
- Repair or replace any damaged structural parts
- Stabilize any eroded areas
- Ensure that flow is not bypassing the facility
- Replace the sorbent pillows used in Multi-Chamber Treatment Trains (twice per year)

Routine maintenance typically includes:

- Ensure that contributing area, filtering practice, inlets, and outlets are clear of debris
- Ensure that the contributing area is stabilized and mowed, with clippings removed
- Check to ensure that the filter surface is not clogging (also after moderate and major storms)
- Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system
- If a permanent pool is present, ensure that the chamber does not leak and that normal pool level is retained
- Ensure that no noticeable odors are detected outside the facility

Effectiveness

Filtering practices are for the most part adapted only to provide pollutant removal, although in exfilter designs, some ground water recharge can be provided. Sand filters are effective for pollutant removal with the exception of nitrates, which appear to be exported from filtering systems. The export of nitrates from filters may be caused by mineralization of organic nitrogen in the filter bed.

Typical percent removals rates or ranges are:

- TSS: 65 - 90+
- TP: 40 – 85
- TN: 44 – 47
- Metals: 25 – 90+
- Bacteria: 55

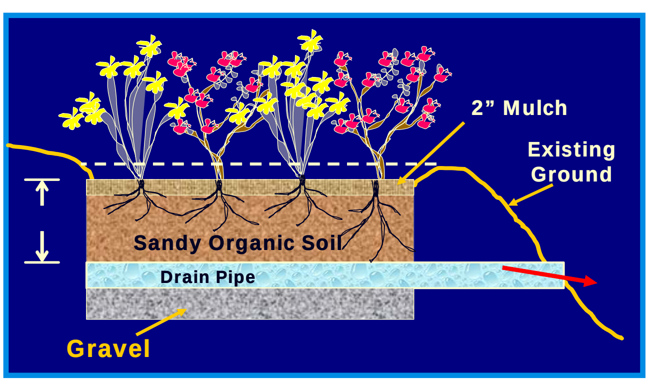
Cost Considerations

There is limited consistent data on the cost of sand filters due to their varied designs. A typical total cost of installation can range between $2.50 and $7.50 per cubic foot of stormwater treated, with an average cost of about $5 per cubic foot. The cost per impervious acre treated varies considerably depending on the region and design used. It is important to note that, although underground and perimeter sand filters can be more expensive than surface sand filters, they consume no surface space, making them a relatively cost-effective practice in ultra-urban areas where land is at a premium.

2.3.2. Biofilters

Description

Biofilters (a.k.a., bioretention areas or rain gardens), are landscaping features adapted to provide on-site treatment of stormwater runoff. They are commonly located in parking lot islands or within small pockets of residential land uses. Surface runoff is directed into shallow, landscaped depressions. These depressions are designed to incorporate many of the pollutant removal mechanisms that operate in forested ecosystems. During storms, runoff ponds above the mulch and soil in the system. Runoff from larger storms is generally diverted past the facility to the storm drain system. The remaining runoff filters through the mulch and prepared soil mix. The filtered runoff can be collected in a perforated underdrain and returned to the storm drain system.



Biofilter

Applicability

Bioretention systems are generally applied to small sites. They are ideally suited to many ultra-urban areas, such as parking lots. While they consume a fairly large amount of space (approximately 5 percent of the area that drains to them), they can be fit into existing parking lot islands or other landscaped areas.

Bioretention areas can be used to treat stormwater hot spots, such as a gas station or convenience store parking lot, as long as an impermeable liner is used at the bottom of the filter bed.

Bioretention can be used as a stormwater retrofit, by modifying existing landscaped areas, or if a parking lot is being resurfaced. In highly urbanized areas, this is one of the few retrofit options that can be employed.

Bioretention is also a good option for discharges directly to streams because water ponds in them for only a short time, decreasing the potential for stream warming. Furthermore, bioretention cells have been shown to decrease the temperature of runoff from certain land uses, such as parking lots.

Siting Criteria

In addition to the broad applicability concerns described above, designers need to consider conditions at the site level. In addition, they need to incorporate design features to improve the longevity and performance of the practice, while minimizing the maintenance burden.

Some considerations for selecting a stormwater management practice are the drainage area the practice will need to treat, the slopes both at the location of the practice and the drainage area, soil and subsurface conditions, and the depth of the seasonably high ground water table. Bioretention can be applied on many sites, with its primary restriction being the need to apply the practice on small sites.

Bioretention areas should usually be used on small sites (i.e., 5 acres or less). When used to treat larger areas, they tend to clog. In addition, it is difficult to convey flow from a large area to a bioretention area.

Bioretention areas are best applied to relatively shallow slopes (usually about 5 percent). However, sufficient slope is needed at the site to ensure that water that enters the bioretention area can be connected with the storm drain system. These stormwater management practices are most often applied to parking lots or residential landscaped areas, which generally have shallow slopes.

Bioretention areas can be applied in almost any soils or topography, since runoff percolates through a man-made soil bed and is returned to the stormwater system.

Bioretention should be separated somewhat from the ground water to ensure that the ground water table never intersects with the bed of the bioretention facility. This design consideration prevents possible ground water contamination.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer. There are some features, however, that should be incorporated into most bioretention area designs.

Pretreatment. Several different mechanisms can be used to provide pretreatment in bioretention facilities. Often, runoff is directed to a grass channel or filter strip to filter out coarse materials before the runoff flows into the filter bed of the bioretention area. Other features may include a pea gravel diaphragm, which acts to spread flow evenly and drop out larger particles.

Treatment. Several basic features should be incorporated into bioretention designs to enhance their pollutant removal. The bioretention system should be sized between 5 and 10 percent of the impervious area draining to it. The practice should be designed with a soil bed that is a sand/soil matrix, with a mulch layer above the soil bed. The bioretention area should be designed to pond a small amount of water (6-9 inches) above the filter bed.

Conveyance. Bioretention practices often are designed with an underdrain system to collect filtered runoff at the bottom of the filter bed and direct it to the storm drain system. An underdrain is a perforated pipe system in a gravel bed, installed on the bottom of the filter bed. Designers should provide an overflow structure to convey flow from storms that are not treated by the bioretention facility to the storm drain.

Maintenance Reduction. In addition to regular maintenance activities needed to maintain the function of stormwater practices, some design features can be incorporated to reduce the required maintenance of a practice. Designers should ensure that the bioretention area is easily accessible for maintenance.

Landscaping. Landscaping is critical to the function and aesthetic value of bioretention areas. It is preferable to plant the area with native vegetation, or plants that provide habitat value, where possible. Another important design feature is to select species that can withstand the hydrologic regime they will experience. At the bottom of the bioretention facility, plants that tolerate both wet and dry conditions are preferable. At the edges, which will remain primarily dry, upland species will be the most resilient. Finally, it is best to select a combination of trees, shrubs, and herbaceous materials.

Partial Exfiltration. One design alternative to the traditional bioretention practice is the use of a "partial exfiltration" system, used to promote ground water recharge. In one design variation of the bioretention system, the underdrain is only installed on part of the bottom of the bioretention system. This design alternative allows for some infiltration, with the underdrain acting as more of an overflow. This system can be applied only when the soils and other characteristics are appropriate for infiltration.

Cold Climate Impacts. In cold climates, bioretention areas can be used as snow storage areas. If used for this purpose, or if used to treat runoff from a parking lot where salt is used as a deicer, the bioretention area should be planted with salt-tolerant, nonwoody plant species.

Limitations

Bioretention areas have a few limitations. Bioretention areas cannot be used to treat a large drainage area, limiting their usefulness for some sites. In addition, although the practice does not consume a large amount of space, incorporating bioretention into a parking lot design may reduce the number of parking spaces available if islands were not previously included in the design.

Maintenance Considerations

Bioretention requires landscaping maintenance, including measures to ensure that the area is functioning properly, as well as maintenance of the landscaping on the practice. In many cases, bioretention areas initially require intense maintenance, but less maintenance is needed over time. In many cases, maintenance tasks can be completed by a landscaping contractor, who may already be hired at the site. Landscaping maintenance requirements can be less resource intensive than with traditional landscaping practices such as elevated landscaped islands in parking areas.

Typical maintenance activities include remulching void areas, treating diseased trees and shrubs and mowing turf areas. Inspection of soil, repair of eroded areas, and removal of litter and debris should be conducted monthly. Dead and diseased vegetation should be removed and replaced twice per year, and mulch should be added and tree stakes and wires replaced annually.

Effectiveness

Flood Control. Bioretention areas are not designed to provide flood control. They can, however, divert initial flow which will aid in maintaining pre-development hydrology.

Channel Protection. Bioretention areas are generally not designed to provide substantial channel protection because at the scale at which they are typically installed they are not able to infiltrate large volumes. Channel protection would be best reached by using bioretention cells in combination with other means, such as ponds or other volume control practices.

Ground Water Recharge. Bioretention areas do not usually recharge the ground water, except in the case of the partial exfiltration design.

Pollutant Removal. Little pollutant removal data have been collected on the pollutant removal effectiveness of bioretention areas. Percent removals rates or ranges from past studies are:

- Copper: 43%-97%
- Lead: 70%-95%
- Zinc: 64%-95%
- Phosphorus: 65%-87%
- Total Kjeldahl Nitrogen (TKN): 52-67%
- Ammonium (NH_4^+): 92%
- Nitrate (NO_3^-): 15%-16%
- Total nitrogen (TN): 49%
- Calcium: 27%

Assuming that bioretention systems behave similarly to swales, their removal rates are relatively high. There is considerable variability in the effectiveness of bioretention areas, and it is believed that properly designing and maintaining these areas may help to improve their performance.

Cost Considerations

Bioretention areas can vary from being relatively inexpensive to expensive. An important consideration when evaluating the costs of bioretention is that this practice replaces an area that most likely would have been landscaped. Furthermore, the use of bioretention areas may reduce the need for other BMPs that require large tracts of contiguous land. Thus, the true cost of the practice is less than the construction cost reported. Similarly, maintenance activities conducted on bioretention areas are not very different from maintenance of a landscaped area; however, bioretention areas may actually lower utility costs by requiring less watering than similarly landscaped areas. The land consumed by bioretention areas is relatively high compared with other practices (about 5 percent of the drainage area). Again, this area should not be considered lost, since the practice may be the same size or only slightly larger than a traditional landscaped area. Finally, bioretention areas can improve upon existing landscaping and are often an aesthetic benefit.

2.4 Vegetative Practices

Vegetative practices such as grass swales and filter strips treat the water quality of small sheet flows from developed areas. They are uniform strips of dense turf or meadow grasses with minimum slope, best suited to accept diffuse flows from roads and highways, roof downspouts, and very small parking lots, usually prior to runoff being collected by ditches or storm drains. They are also an ideal component of stream buffers or as pretreatment to a structural practice.

Grass filter strips are most often located in landscaping areas around building and parking lot perimeters, or in greenbelts or median strips in parking lots and streets. Grass swales are most often located along conservation easements or along the edge of streets.

Their overall effectiveness is highly variable depending on slope, the quality of turf, and flow rates. It is critically important to maintain sheet flow through the filter strip/swale; otherwise the practice provides little to no treatment.

2.4.1. Grassed Swale

Description

In the context of BMPs to improve water quality, the term swale (a.k.a. grassed channel, dry swale, or wet swale) refers to a vegetated, open-channel management practice designed specifically to treat and attenuate stormwater runoff for a specified water quality volume. As stormwater runoff flows along these channels, it is treated through vegetation slowing the water to allow sedimentation, filtering through a subsoil matrix, and/or infiltration into the underlying soils. Variations of the grassed swale include the grassed channel, dry swale, and wet swale. The specific design features and methods of treatment differ in each of these designs, but all are improvements on the traditional drainage ditch. These designs incorporate modified geometry and other features for use of the swale as a treatment and conveyance practice.

Vegetated swale/filter strip

Applicability

Grassed swales can be applied in most situations with some restrictions. Swales are well suited for treating highway or residential road runoff because they are linear practices. Swales are also useful as one of a series of stormwater BMPs or as part of a treatment train, for instance, conveying water to a detention pond and receiving water from filter strips. Furthermore, swales are highly recommended by the proponents of design approaches such as Low Impact Development and Better Site Design.

Grass swales may not be well suited to ultra-urban areas because they require a relatively large area of pervious surfaces.

With the exception of the dry swale design, hot spot runoff should not be directed toward grassed channels. These practices either infiltrate stormwater or intersect the ground water, making use of the practices for hot spot runoff a threat to ground water quality.

One retrofit opportunity using grassed swales is to modify existing drainage ditches. Ditches have traditionally been designed only to convey stormwater. In some cases, it may be possible to incorporate features to enhance pollutant removal or infiltration such as check dams (i.e., small dams along the ditch that trap sediment, slow runoff, and reduce the effective longitudinal slope).

Grassed channels are a good treatment option within areas that drain to streams because these practices do not pond water for a long period and often induce infiltration. As a result, standing water will not typically be subjected to solar warming.

Siting Criteria

Grass swales are generally considered to be at the downstream end of grass filter strips and are used to transport runoff to stream channels or drainage structures. Designers need to consider site conditions and incorporate design features to improve the longevity and performance of the practice while minimizing the maintenance burden. Designers also need to ensure that this management practice is feasible at the site in question because some site conditions (i.e., steep slopes, highly impermeable soils) might restrict the effectiveness of grassed channels.

Grassed swales should generally treat runoff from small drainage areas (less than 5 acres). If used to treat larger areas, the flows through the swale become too large to produce designs to treat stormwater runoff in addition to conveyance.

Grassed swales should be used on sites with relatively flat slopes of less than 4 percent slope; 1 to 2 percent slope is recommended. When site conditions require installing the swales in areas with larger slopes, check dams can be used to reduce the influence of the slope. Runoff velocities within the channel become too high on steeper slopes. This can cause erosion and does not allow for infiltration or filtering in the swale.

Grassed swales can be used on most soils, with some restrictions on the most impermeable soils. In a dry swale, a fabricated soil bed replaces on-site soils in order to ensure that runoff is filtered as it travels through the soils of the swale.

The required depth to ground water depends on the type of swale used. In the dry swale and grassed channel options, the bottom of the swale should be constructed at least 2 ft above the ground water table to prevent a moist swale bottom or contamination of the ground water. In the wet swale option, treatment is provided by creating a standing or slow flowing wet pool, which is maintained by intersecting the ground water.

Design Considerations

There are some design considerations common to all grassed swales. An overriding similarity is the cross-sectional geometry. Swales often have a trapezoidal or parabolic cross section with relatively flat side slopes (flatter than 3:1), though rectangular and triangular channels can also be used. Designing the channel with flat side slopes increases the wetted perimeter. The wetted perimeter is the length along the edge of the swale cross section where runoff flowing through the swale contacts the vegetated sides and bottom. Increasing the wetted perimeter slows runoff velocities and provides more contact with vegetation to encourage sorption, filtering, and infiltration. Another advantage to flat side slopes is that runoff entering the grassed swale from the side receives some pretreatment along the side slope.

Pretreatment. In all design options, a small forebay should be used at the front of the swale to trap incoming sediments. A pea gravel diaphragm, a small trench filled with river-run gravel, should be constructed along the length of the swale and used as pretreatment for runoff entering the sides of the swale.

Treatment. Features designed to enhance the performance of grassed swales are a flat longitudinal slope (generally between 1 percent and 2 percent) and a dense vegetative cover in the channel. The flat slope helps to reduce the flow velocity within the channel. The dense vegetation also helps reduce velocities, protects the channel from erosion, and acts as a filter to treat stormwater runoff. During construction, it is important to stabilize the channel while the vegetation is becoming established, either with a temporary grass cover or with natural or synthetic erosion control products. In addition to treating runoff for water quality, grassed swales must convey runoff from larger storms safely. Typical designs allow the runoff from the 2-year storm to flow through the swale without causing erosion. Swales should also have the capacity to pass larger storms (typically a 10-year storm) safely.

Grassed Channel. Of the three grassed swale designs, grassed channels are the most similar to a conventional drainage ditch, with the major differences being flatter side slopes and longitudinal slopes, and a slower design velocity for water quality treatment of small storm events. Of all of the options, grassed channels are the least expensive but also provide the least reliable pollutant removal. An excellent application of a grassed channel is as pretreatment to other structural stormwater practices. A major difference between the grassed channel and many other structural practices is the method used to size the practice. Most stormwater management water quality practices are sized by volume. This method sets the volume available in the practice equal to the water quality volume, or the volume of water to be treated in the practice. The grassed channel, is a flow-rate-based design. The channel should be designed so that runoff takes, on average, 10 minutes to flow from the top to the bottom of the channel.

Dry Swales. Dry swales are similar in design to bioretention areas. These designs incorporate a fabricated soil bed into their design. The native soil is replaced with a sand/soil mix that meets minimum permeability requirements. An underdrain system is installed at the bottom of the soil bed. This underdrain is a gravel layer that encases a perforated pipe. Stormwater treated in the soil bed flows into the underdrain, which routes this treated stormwater to the storm drain system or receiving waters. Dry swales are a relatively new design, but studies of swales with a native soil similar to the man-made soil bed of dry swales suggest high pollutant removal.

Wet Swales. Wet swales intersect the ground water and behave similarly to a linear wetland cell. This design variation incorporates a shallow permanent pool and wetland vegetation to provide stormwater treatment. This design also has potentially high pollutant removal. Wet swales are not commonly used in residential or commercial settings because the shallow standing water may be a potential mosquito breeding area.

Cold Climate Impacts. In cold or snowy climates, swales may serve a dual purpose by acting as both a snow storage/treatment and a stormwater management practice. This dual purpose is particularly relevant when swales are used to treat road runoff. If used for this purpose, swales should incorporate salt-tolerant vegetation, such as creeping bentgrass.

Limitations

Grassed swales have some limitations, including the following:

- Grassed swales cannot treat a very large drainage area.
- Wet swales may become a nuisance due to mosquito breeding.
- If designed improperly (e.g., if proper slope is not achieved), grassed channels will have very little pollutant removal.

Maintenance Considerations

Maintenance of grassed swales mostly involves litter control and maintaining the grass or wetland plant cover. Only a minimum amount of maintenance should be necessary to ensure continued functioning of grass swales. The most significant concern is gully formation from unexpected concentrated flows. If rills and gullies occur, they must be repaired and stabilized with seed or sod. Measures must be taken to eliminate concentrated flow. Grass swales should be inspected annually to assure that the level spreader is not clogged and to remove built-up sediment.

Effectiveness

Few studies are available regarding the effectiveness of grassed channels. Limited data suggests relatively high removal rates for some pollutants, negative removals for some bacteria, and fair performance for phosphorous. Documented percent removals rates or ranges are:

- Total Suspended Solids: 81%
- Total Phosphorous: 29%
- Nitrate Nitrogen: 38%
- Metals: 14% to 55%
- Bacteria: -50%

While it is difficult to distinguish between different designs based on the small amount of available data, grassed channels generally have poorer removal rates than wet and dry swales.

Cost Considerations

Costs to construct swales should be taken in context. With most development designs, some conveyance structure must be constructed as part of the development. The construction of grass swales is less expensive than concrete ditches or sewers. Hence, the use of grass swales is often a less expensive alternative than traditional design approaches. A realistic estimate would be a total cost of approximately \$0.50 per ft^2, which compares favorably with other stormwater management practices.

2.4.2. Vegetated Filter Strip

Description

Vegetated filter strips (grassed filter strips, filter strips, and grassed filters) are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and by providing some infiltration into underlying soils. Filter strips were originally used as an agricultural treatment practice, and have more recently evolved into an urban practice. With proper design and maintenance, filter strips can provide relatively high pollutant removal. One challenge associated with filter strips, however, is that it is difficult to maintain sheet flow, so the practice may be "short circuited" by concentrated flows, receiving little or no treatment.

Applicability

Filter strips are restricted in some situations because they consume a large amount of space relative to other practices. Filter strips are best suited to treating runoff from roads and highways, roof downspouts, very small parking lots, and pervious surfaces. They are also ideal components of the "outer zone" of a stream buffer or as pretreatment to a structural practice.

Filter strips are impractical in ultra-urban areas because they consume a large amount of space. They also should not receive hot spot runoff, such as drainage from a gas station, because the practice encourages infiltration. In addition, it is questionable whether this practice can reliably remove pollutants, so it should definitely not be used as the sole treatment of hot spot runoff. Filter strips are generally a poor retrofit option because they consume a relatively large amount of space and cannot treat large drainage areas.

While some treatment practices, such as wet ponds can warm stormwater substantially, filter strips do not warm pond water on the surface for long periods of time and are not expected to increase stormwater temperatures. Thus, these practices are good for protection of cold-water streams.

Siting Criteria

Grass filter strips are used as close as possible to the source of the runoff. They are integrated throughout a development site such as along the edges of parking lots.

Typically, filter strips are used to treat very small drainage areas. The limiting design factor, however, is not the drainage area the practice treats but the length of flow leading to it. As stormwater runoff flows over the ground's surface, it changes from sheet flow to concentrated flow. Rather than moving uniformly over the surface, the concentrated flow forms rivulets which are slightly deeper and cover less area than the sheet flow. When flow concentrates, it moves too rapidly to be effectively treated by a grassed filter strip. Furthermore, this concentrated flow can lead to scouring. As a rule, flow concentrates within a maximum of 75 feet for impervious surfaces, and 150 feet for pervious surfaces. Using this rule, a filter strip can treat one acre of impervious surface per 580-foot length.

Filter strips should be designed on slopes between 2 and 6 percent. Greater slopes than this would encourage the formation of concentrated flow. Except in the case of very sandy or gravelly soil, runoff would pond on the surface on slopes flatter than 2 percent, creating potential mosquito breeding habitat.

Filter strips should not be used on soils with a high clay content, because they require some infiltration for proper treatment. Very poor soils that cannot sustain a grass cover crop are also a limiting factor.

Filter strips should be separated from the ground water by between 2 and 4 ft to prevent contamination and to ensure that the filter strip does not remain wet between storms.

Design Considerations

Filter strips appear to be a minimal design practice because they are basically no more than a grassed slope. However, some design features are critical to ensure that the filter strip provides some minimum amount of water quality treatment.

- A pea gravel diaphragm should be used at the top of the slope. The pea gravel diaphragm (a small trench running along the top of the filter strip) serves two purposes. First, it acts as a pretreatment device, settling out sediment particles before they reach the practice. Second, it acts as a level spreader, maintaining sheet flow as runoff flows over the filter strip.
- The filter strip should be designed with a pervious berm of sand and gravel at the toe of the slope. This feature provides an area for shallow ponding at the bottom of the filter strip. Runoff ponds behind the berm and gradually flows through outlet pipes in the berm. The volume ponded behind the berm should be equal to the water quality volume. The water quality volume is the amount of runoff that will be treated for pollutant removal in the practice. Typical water quality volumes are the runoff from a 1-inch storm or ½-inch of runoff over the entire drainage area to the practice.
- The filter strip should be at least 25 feet long to provide water quality treatment.
- Designers should choose a grass that can withstand relatively high velocity flows and both wet and dry periods.
- Both the top and toe of the slope should be as flat as possible to encourage sheet flow and prevent erosion.

Cold Climate Impacts. In cold climates, filter strips provide a convenient area for snow storage and treatment. If used for this purpose, vegetation in the filter strip should be salt-tolerant, such as creeping bentgrass, and a maintenance schedule should include the removal of sand built up at the bottom of the slope.

Limitations

Filter strips have several limitations related to their performance and space consumption:

- The practice has not been shown to achieve high pollutant removal.
- Filter strips require a large amount of space, typically equal to the impervious area they treat, making them often infeasible in urban environments where land prices are high.
- If improperly designed, filter strips can allow mosquitos to breed.
- Proper design requires a great deal of finesse, and slight problems in the design, such as improper grading, can render the practice ineffective in terms of pollutant removal.

Maintenance Considerations

Filter strips require similar maintenance to other vegetative practices such as grassed swales. Maintenance is very important for filter strips, particularly in terms of ensuring that flow does not short circuit the practice. Only a minimum amount of maintenance should be necessary to ensure continued functioning of grass filter strips. The most significant concern is gully formation from unexpected concentrated flows. If rills and gullies occur, they must be repaired and stabilized with seed or sod. Measures must be taken to eliminate concentrated flow. Filter strips should be inspected annually to assure that the level spreader is not clogged and to remove built-up sediment. Grass within the filter strip should be maintained as lawn. Grass height should be about 3 to 4 inches. Vegetation must be kept healthy.

Effectiveness

Filter strips do not have the capacity to detain the peak flows of relatively large storm events (at least 1- to 2-year storms for channel protection and at least 10- to 50-year storms for flood control). These events, but can be designed with a bypass system that routes these flows around the practice entirely.

Filter strips can provide a small amount of ground water recharge as runoff flows over the vegetated surface and ponds at the toe of the slope. In addition, it is believed that filter strips can provide modest pollutant removal. Studies from agricultural settings suggest that a 15-foot-wide grass buffer can achieve a 50 percent removal rate of nitrogen, phosphorus, and sediment, and that a 100-foot buffer can reach closer to 70 percent removal of these constituents. It is unclear how these results can be translated to the urban environment, however.

Cost Considerations

Little data are available on the actual construction costs of filter strips. One rough estimate can be the cost of seed or sod, which is approximately 30¢ per ft^2 for seed or 70¢ per ft^2 for sod. This amounts to between $13,000 and $30,000 per acre for a filter strip, or the same amount per impervious acre treated. This cost is relatively high compared with other treatment practices. However, the grassed area used as a filter strip may have been seeded or sodded even if it were not used for treatment. In these cases, the only additional costs are the design, which is minimal, and the installation of a berm and gravel diaphragm. Typical maintenance costs are about $350/acre/year. This cost is relatively inexpensive and, again, might overlap with regular landscape maintenance costs.

The true cost of filter strips is the land they consume, which is higher than for any other treatment practice. In some situations this land is available as wasted space beyond back yards or adjacent to roadsides, but this practice is cost-prohibitive when land prices are high and land could be used for other purposes.

2.5 Runoff Pretreatment Devices

Description

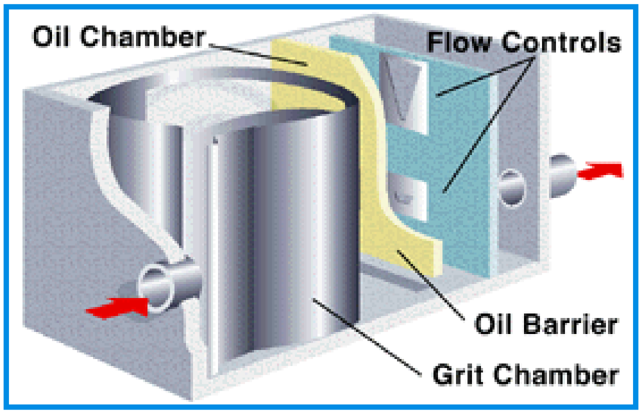
Runoff pretreatment devices provide water quality treatment of sheet flow runoff from developed areas. They are generally used to treat runoff from areas of less than 5 acres with highly impervious surfaces such as parking lots, parking decks, and roadways before eventually discharging to storm sewers or stream channels.

These devices are approved by ODOT for transportation projects but are generally not accepted by Ohio EPA on new development since they do not provide hydrologic control and are not designed to capture AND detain runoff. However, use of in-line storage with these devices can provide capture of runoff from some storm events. Ohio EPA does permit use of pretreatment devices on small sites (< 5 acres) or redevelopment sites of any size if site constraints prohibit use of standard BMPs.

2.5.1. Manufactured Products

Description

A variety of products called swirl separators or hydrodynamic structures have been widely applied to stormwater inlets in recent years. Swirl separators are modifications of traditional oil-grit separators. They contain an internal component that creates a swirling motion as stormwater flows through a cylindrical chamber. The concept behind these designs is that sediments settle out as stormwater moves in this swirling path, and additional compartments or chambers are sometimes present to trap oil and other floatables. There are several different types of proprietary separators, each incorporating slightly different design variations, such as off-line application.



Manufactured product

Applicability

Swirl separators and other manufactured products are ideal for ultra-urban locations where available land area precludes the use of other, more land intensive BMPs. They have a very small footprint and can be placed in most locations. Because little data are available on their performance (independently conducted studies suggest marginal pollutant removal), swirl separators should not be used as a stand-alone practice for new development. The best application for these products is as pretreatment to another stormwater device or, when space is limited, as a retrofit. In-line storage can be provided up- or downstream of these devices to detain storm water runoff, reduce peak discharges to the storm water collection system and provide flood control.

Planning Considerations

Runoff pretreatment devices can be designed to treat a number of pollutants. They can be designed to remove grit/sediment, oil/grease, floatables or all of the above. The structures are generally located near or under the source of the runoff. For large drainage areas, they can be integrated throughout the development site such as along the edges of parking lots. If developments are located along receiving streams, the discharge from the pretreatment devices should be directed to grass filter strips, swales or buffer strips to diffuse high flows and provide additional treatment.

Design Considerations

The design of swirl concentrators is specified in the manufacturer's product literature. For the most part, swirl concentrators are a rate-based designs. That is, their size is based on the peak flow of a specific storm event. This design contrasts with most other stormwater management practices, which are sized based on the capture, storage or treatment of a specific volume. Sizing based on flow rate allows the practice to provide treatment within a much smaller area than other stormwater management practices.

Maintenance Considerations

Periodic inspection is required for all runoff pretreatment devices. Inspection is highly recommended after large storm events. Structures generally need to be cleaned out at least twice per year. Facilities designed with filter (s) to remove oil/grease may need to be addressed more frequently. Maintenance is performed using a vactor truck, as is used for catch basins. Due to hazardous waste, pretreatment, or groundwater regulations, sediments may sometimes be barred from landfills, from land applications, and from introduction into sanitary sewer systems.

Effectiveness

While manufacturers' literature typically reports removal rates for swirl separators, there is little independent data to evaluate the effectiveness of these products. Recent studies have reported moderate pollutant removal, but while the product outperforms oil/grit separators, the removal rates are not substantially different from the standard catch basin. One long-term advantage of these products over catch basins is that if they incorporate an off-line design, trapped sediment will not become resuspended.

Cost Considerations

A typical swirl separator costs between $5,000 and $10,000 per impervious acre. This cost is within the range of some sand filters, which also treat highly urbanized runoff. Swirl separators consume very little land, making them attractive in highly urbanized areas.

The maintenance of these practices is relatively expensive if existing equipment is not available. Swirl concentrators typically require quarterly maintenance. The most common method of cleaning these practices is a vactor truck, which costs over $100,000. Depending on the materials capture, disposal costs of the sediment captured in swirl separators may be significant.

2.5.2. In-line Storage

Description

In-line storage is not a “treatment” device (although it does provide detention time for particles to settle out) as much as it provides storage volume for manufactured products or other treatment devices.

Applicability

In-line storage is ideal for ultra-urban locations where available land area precludes the use of other, more land intensive BMPs. In-line storage can be provided up- or downstream of manufactured products and other treatment devices to detain storm water runoff, reduce peak discharges to the storm water collection system and provide flood control. In-line storage is generally provided underground and can be located under parking lots or roadways in ultra-urban areas. Tank storage is provided on small areas because underground storage for a large drainage area would generally be costly. Because the drainage area contributing to tank storage is typically small, the outlet diameter needed to reduce the flow from very small storms would very small. A very small outlet diameter, along with the underground location of the tanks, creates the potential for debris being caught in the outlet and resulting maintenance problems. Since it is necessary to control small runoff events (such as the runoff from a 1-inch storm) to improve water quality, it is generally infeasible to use tank storage for water quality and generally impractical to use it to protect stream channels.

Planning Considerations

In-line storage is generally located underground near the source of the runoff. For developments located along receiving streams, the discharge from the pretreatment devices should be directed to grass filter strips or swales to diffuse high flows and provide additional treatment.

Design Considerations

In-line storage devices are sized based on the specific volume of flow to be captured, and are usually based on a design storm event.

Maintenance Considerations

Structures generally need to be cleaned out at least twice per year. Maintenance is performed using a vactor truck, as is used for catch basins. Due to hazardous waste, pretreatment, or groundwater regulations, sediments may sometimes be barred from landfills, from land applications, and from introduction into sanitary sewer systems.

Effectiveness

Removal rates are likely not substantially different from the standard catch basin. One long-term advantage of these products over catch basins is that if they incorporate an off-line design, trapped sediment will not become resuspended.

Cost Considerations

Costs vary due to pipe size and storage device.

2.5.3. Catch Basin Inserts

Description

Catch basins, also known as storm drain inlets and curb inlets, are inlets to the storm drain system. They typically include a grate or curb inlet and a sump to capture sediment, debris, and pollutants. Catch basins are used in combined sewer overflow (CSO) watersheds to capture floatables and settle some solids, and they act as pretreatment for other treatment practices by capturing large sediments. The effectiveness of catch basins, their ability to remove sediments and other pollutants, depends on its design and on maintenance procedures to regularly remove accumulated sediments from its sump.

Inserts designed to remove oil and grease, trash, debris, and sediment can improve the efficiency of catch basins. Some inserts are designed to drop directly into existing catch basins, while others may require retrofit construction.

In general, catch basin inserts are allowed on private sites within the City but are not to be used on public projects.

Catch basin insert

Applicability

Catch basins are ideally used as pretreatment to another stormwater management practice. Retrofitting existing catch basins may substantially improve their performance. A simple retrofit option is to ensure that all catch basins have a hooded outlet to prevent floatable materials, such as trash and debris, from entering the storm drain system. Catch basin inserts for both new development and retrofits at existing sites may be preferred when available land is limited, as in urbanized areas.

Limitations

Catch basin inserts have three major limitations:

- Catch basin inserts cannot remove pollutants as well as structural stormwater management practices, such as wet ponds, sand filters, and stormwater wetlands.
- Unless frequently maintained, pollutants captured by catch basin inserts can become dislodged during additional events and provide limited removal of suspended solids.
- Catch basin inserts cannot effectively remove soluble pollutants or fine particles.

Design Considerations

Several varieties of catch basin inserts exist for filtering runoff. There are two basic catch basin insert varieties. One insert option consists of a series of trays, with the top tray serving as an initial sediment trap, and the underlying trays composed of media filters. Another option uses filter fabric to remove pollutants from stormwater runoff. Yet another option is a plastic box that fits directly into the catch basin. The box construction is the filtering medium. Hydrocarbons are removed as the stormwater passes through the box while trash, rubbish, and sediment remain in the box itself as stormwater exits. These devices have a very small volume, compared to the volume of the catch basin sump, and would typically require very frequent sediment removal. Bench test studies found that a variety of options showed little removal of total suspended solids.

Maintenance Considerations

Typical maintenance of catch basin inserts includes frequent trash removal. Operators need to be properly trained in catch basin maintenance.

Maintenance should include keeping a log of the amount of sediment collected and the date of removal. Frequent clean-out can retain the volume in the catch basin insert available for treatment of future stormwater flows.

Catch basin inserts should be inspected after every storm event and cleaned when required. Past studies suggest that increasing the frequency of maintenance can improve performance.

Cost Considerations

Retrofit catch basin inserts range from as little as $400 for a "drop-in" type to as much as $10,000 or more for more elaborate designs.

SECTION 3

Non-Structural BMPs

Structural practices treat runoff *after* construction, but additional considerations are needed to effectively prevent and minimize impacts. Therefore additional non-structural management practices are strongly encouraged. Practices such as stream setbacks or reduction of impervious areas influence the layout and design of a development site so that important hydrologic areas are maintained and impervious surfaces are limited. The management practices listed below are encouraged by the City of Akron, but while each of the management practices is beneficial, there may be some limitations for a particular practice.

Buffer Zones

A riparian or forested buffer is an area along a shoreline, wetland or stream where development is restricted or prohibited. The primary function of aquatic buffers is to physically protect and separate a stream, lake, or wetland from future disturbance or encroachment. If properly designed, a buffer can provide stormwater management, and can act as a right-of-way during floods, sustaining the integrity of stream ecosystems and habitats. As conservation areas, aquatic buffers are part aquatic ecosystem and part urban forest.

The City has existing riparian setback requirements, but additional setbacks above and beyond those required are encouraged.

Open Space Design

Open space design, also known as conservation development or cluster development, is a better site design technique that concentrates dwelling units in a compact area in one portion of the development site in exchange for providing open space and natural areas elsewhere on the site. The minimum lot sizes, setbacks and frontage distances for the residential zone are relaxed in order to create the open space at the site. Open space designs have many benefits in comparison to the conventional subdivisions that they replace: they can reduce impervious cover, stormwater pollutants, construction costs, grading, and the loss of natural areas.

The City has an existing ordinance that addresses open space development, but this ordinance might need to be revised to achieve greater water quality and environmental benefits.

Conservation Easements

Conservation easements are voluntary agreements that allow individuals or groups to limit the type or amount of development on their property. A conservation easement can cover all or just a portion of a property, and it can either be permanent or temporary. Easements typically describe the resource they are designed to protect (e.g., agricultural, forest, historic, or open space easements), and they explain and mandate the restrictions on the uses of the particular property.

Easements can relieve property owners of the burden of managing these areas. They do so by shifting responsibility to a private organization (land trust) or government agency better equipped to handle maintenance and monitoring issues. Furthermore, in some cases, tax benefits might be realized by property owners who place conservation easements on some or all of their property.

Conservation easements may indirectly contribute to water quality protection. Land set aside in a permanent conservation easement has a prescribed set of uses or activities that generally restrict future development.

The location of the land held in a conservation easement may be evaluated to determine its ability to provide water quality benefits. Property along stream corridors and shorelines can act as a vegetated buffer that filters-out pollutants from stormwater runoff. The ability of a conservation easement to function as a stream buffer depends on the width of the easement and in what vegetated state the easement is maintained.

Narrower Residential Streets

This better site design practice promotes the narrowing of streets to reduce the amount of impervious cover created by new residential development. By doing so, stormwater runoff and associated pollutant loads may also be reduced.

The City has existing standards on residential street rights-of-way but is considering revisions to current standards. Private roads can be narrower than standard roads if emergency access, on-street parking, or vehicular and pedestrian safety are not compromised.

Eliminating Curb and Gutters

This practice promotes grass swales as an alternative to curbs and gutters along residential streets. Curbs and gutters are designed to quickly convey runoff from the street to the stormdrain and, ultimately, to a local receiving water. Consequently, they provide little or no removal of stormwater pollutants. Indeed, curbs often act as traps where deposited pollutants remain until the next storm washes them away.

The City of Akron has some existing streets without curb and gutters, but it generally requires curbs and gutters as standard elements of road sections. Revisions to current road and drainage regulations are being considered to promote greater use of grass swales and new roads without curbs and gutters may be permitted on a case-by-case basis.

BMP Inspection and Maintenance

The effectiveness of post-construction stormwater control best management practices (BMPs) depends upon regular inspections of the control measures. Generally, BMP inspection and maintenance falls into two categories: expected routine maintenance and non-routine (repair) maintenance. Routine maintenance is performed regularly to maintain both the aesthetics of the BMPs and their good working order. Routine inspection and maintenance helps prevent potential nuisances (odors, mosquitoes, weeds, etc.), reduces the need for repair maintenance, and reduces the chance of polluting stormwater runoff by finding and fixing problems before the next rain.

In addition to maintaining the effectiveness of stormwater BMPs and reducing the incidence of pests, proper inspection and maintenance is essential to avoid the health and safety threats inherent in BMP neglect. The failure of structural stormwater BMPs can lead to downstream flooding, which can cause property damage, injury, and even death.

The City has recently developed Post-Construction Inspection Forms for several different BMPs and a Guidance Manual for Post-Construction Maintenance that describes elements of a maintenance program, routine maintenance needs, and general maintenance costs.

Ordinances for Post-Construction Runoff

A vital step in controlling the harmful effects of development on urban water-quality is managing post-construction stormwater runoff. Land development creates roads, sidewalks, parking lots, rooftops and other impervious surfaces that can have detrimental effects on aquatic systems. Impervious cover has been linked with stream warming and the loss of aquatic biodiversity in urban areas.

Stormwater runoff from impervious areas can contain sediment, nutrients, road salts, heavy metals, bacteria, petroleum hydrocarbons, and other pollutants detrimental to water quality.

An ordinance promotes the public welfare by guiding, regulating, and controlling the design, construction, use, and maintenance of any development or other activity that disturbs or breaks the topsoil or results in the movement of earth on land. The goal of a stormwater management ordinance for post-construction runoff is to limit surface runoff volumes and reduce water runoff pollutant loadings.

The City recently enacted a Sediment Control and Post-Construction Storm Water Quality Ordinance, Ordinance No. 50.80, that addresses the control of runoff from construction sites and the requirements for continued maintenance of post-construction BMPs.

SECTION 4

References

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