Low Impact Development strategies use careful site design and decentralized stormwater management to reduce the environmental footprint of new growth. This approach improves water quality, minimizes the need for expensive pipe-and-pond stormwater systems, and creates more attractive developments.

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FACT SHEET #4

BIORETENTION AREAS

Overview

Bioretention is an important technique that uses soil, plants and microbes to treat stormwater before it is infiltrated or discharged. Bioretention "cells" are shallow depressions filled with sandy soil, topped with a thick layer of mulch, and planted with dense vegetation. Stormwater runoff flows into the cell and slowly percolates through the soil (which acts as a filter) and into the groundwater; some of the water is also taken up by the plants. Bioretention areas are usually designed to allow ponded water 6-8 inches deep, with an overflow outlet to prevent flooding during heavy storms. Where soils are tight or fast drainage is desired, designers may use a perforated underdrain, connected to the storm drain system.

Bioretention areas can provide excellent pollutant removal and recharge for the "first flush" of stormwater runoff. Properly designed cells remove suspended solids, metals, and nutrients, and can infiltrate an inch or more of rainfall. Distributed around a property, vegetated bioretention areas can enhance site aesthetics. In residential developments they are often described as "rain gardens" and marketed as property amenities. Routine maintenance is simple and can be handled by homeowners or conventional landscaping companies, with proper direction.

Applications and Design Principles

Bioretention systems can be applied to a wide range of development in many climatic and geologic situations; they work well on small sites and on large sites divided into multiple small drainages. Common applications for bioretention areas include parking lot islands, median strips, and traffic islands. Bioretention is a feasible "retrofit" that can be accomplished by replacing existing parking lot islands or by re-configuring a parking lot during resurfacing. On residential sites they are commonly used for rooftop and driveway runoff.

Management Objectives

- Provide water quality treatment.
- Remove suspended solids, metals, nutrients.
- Increase groundwater recharge through infiltration.
- Reduce peak discharge rates.
- Reduce total runoff volume.
- Improve site landscaping.

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Above: This bioretention cell at a office park also helps to fulfill site landscaping requirements. *Photo: Low Impact Development Center*

Right: This schematic diagram shows parking lot runoff directed to a bioretention cell, with pretreatment by a grassed filter strip. *Image: Prince George's County (MD) Bioretention Manual*

Cover, top: A rain garden in a Connecticut Subdivision infiltrates rooftop and driveway runoff, and can be marketed as an extra amenity. *Photo: University of Connecticut, Jordan Cove Urban Monitoring Project*

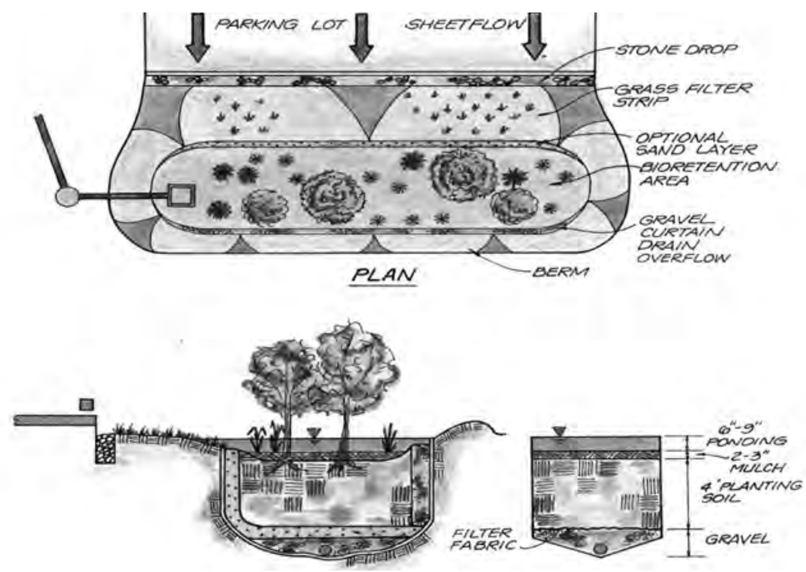
Cover, bottom: A narrow bioretention cell in a parking lot, planted with small trees to reduce the urban heat island effect. *Photo: Low Impact Development Center*

Bioretention cells are usually excavated to a depth of 4 feet, depending on local conditions. Generally, cells should be sized (based on void space and ponding area) to capture and treat the water quality volume (the first 0.5" or 1" of runoff, depending on local requirements.) Some manuals suggest a minimum width of 15', though much narrower bioretention cells have been installed in parking lot islands and are functioning well. Regardless of size, some type of filter should cover the bottom of the excavation. Filter fabric is commonly used but can be prone to clogging; consequently some engineers recommend a filter of coarse gravel, over pea gravel, over sand.

The cell should be filled with a soil mix of sandy loam or loamy sand. The area should be graded to allow a ponding depth of 6-8 inches; depending on site conditions, more or less ponding may be appropriate. The planting plan should include a mix of herbaceous perennials, shrubs, and (if conditions permit) understory trees that can tolerate intermittent ponding, occasionally saline conditions (due to road salt), and extended dry periods. The soil should be covered with 2-3" of fine-shredded hardwood mulch.

In very permeable soils, some bioretention areas can be designed as "off-line" treatment structures (no overflow necessary), but in most situations they will be an "on-line" component of the stormwater management system, connected to downstream treatment structures through an overflow outlet or an overflow drop inlet installed at the ponding depth and routed to the site's stormwater management system. Ideally, overflow outlets should be located as far as possible from runoff inlets to maximize residence time and treatment. In general, bioretention area should be designed to drain within 72 hours. In slowly permeable soils (less than 0.3 inches/hour) a perforated underdrain can be installed at the bottom of the excavation to prevent ponding.

Bioretention areas work best if designed with some pretreatment, either in the form of swales or a narrow filter strip. A stone or pea gravel diaphragm (or, better yet, a concrete level spreader) upstream of a filter strip will enhance sheet flow and better pre-treatment.



Benefits and Effectiveness

- Bioretention areas remove pollutants through filtration, microbes, and uptake by plants; contact with soil and roots provides water quality treatment better than conventional infiltration structures. Studies indicate that bioretention areas can remove 75% of phosphorus and nitrogen; 95% of metals; and 90% of organics,

Above, top: Bioretention cells are designed to allow ponded water six inches deep, which should infiltrate into the ground within 72 hours after a storm.

Above, middle: A large bioretention cell adjacent to a parking lot can reduce or eliminate expenses on storm sewers and detention basins. *Photo: Low Impact Development Center*

Above, bottom: Maintenance of rain gardens can generally be handled by homeowners. *Photo: Low Impact Development Center*

bacteria, and total suspended solids. Bioretention areas qualify as an organic filter according to the Massachusetts Stormwater Policy.

- In most applications, bioretention areas increase groundwater recharge as compared to a conventional "pipe and pond" approach. They can help to reduce stress in watersheds that experience severe low flows due to impervious coverage.
- Low-tech, decentralized bioretention areas are also less costly to design, install, and maintain than conventional stormwater technologies that treat runoff at the end of the pipe. The use of decentralized bioretention cells can also reduce the size of storm drain pipes, a major driver of stormwater treatment costs.
- Bioretention areas enhance the landscape in a variety of ways: they improve the appearance of developed sites, provide wind breaks, absorb noise, provide wildlife habitat, and reduce the urban heat island effect.

Limitations

- Because bioretention areas infiltrate runoff to groundwater, they may be inappropriate for use at stormwater "hotspots" (such as gas stations) with higher potential pollutant loads. On these sites, the design should include adequate pretreatment so that runoff can be infiltrated, or else the filter bed should be built with an impermeable liner, so that all water is carried away by the underdrain to another location for additional treatment prior to discharge.
- Premature failure of bioretention areas is a significant issue that results from lack of regular maintenance. Ensuring long-term maintenance involves sustained public education and deed restrictions or covenants for privately-owned cells.
- Bioretention areas must be used carefully on slopes; terraces may be required for slopes >20%.
- The design should ensure vertical separation of at least 2' from the seasonal high water table.

This parking lot bioretention cell is being constructed with an impermeable liner and a perforated underdrain, to provide retention and treatment of runoff (but not infiltration).

Maintenance

- Bioretention requires careful attention while plants are being established and seasonal landscaping maintenance thereafter.
- In many cases, maintenance tasks can be completed by a landscaping contractor working elsewhere on the site.
- Inspect pretreatment devices and bioretention cells regularly for sediment build-up, structural damage, and standing water.
- Inspect soil and repair eroded areas monthly. Re-mulch void areas as needed. Remove litter and debris monthly.
- Treat diseased vegetation as needed. Remove and replace dead vegetation twice per year (spring and fall.)
- Proper selection of plant species and support during establishment of vegetation should minimize—if not eliminate—the need for fertilizers and pesticides.
- Remove invasive species as needed to prevent these species from spreading into the bioretention area.
- Replace mulch every two years, in the early spring.
- Upon failure, excavate bioretention area, scarify bottom and sides, replace filter fabric and soil, replant, and mulch.

Cost

Bioretention areas require careful design and construction, the price of which will depend on site conditions and design objective. Generally, the cost of bioretention areas is less than or equal to that of a catch basin and underground chambers intended to treat the same area. Additionally, bioretention areas treat and recharge stormwater thereby reducing the amount/size of piping needed and the size of downstream basins and treatment structures.

Design Details

- Where bioretention areas are adjacent to parking areas, allow 3" of freeboard above ponding depth to prevent flooding.
- Determine the infiltrative capacity of the underlying native soil through an infiltration test using a double-ring infiltrometer. Do not use a standard septic system percolation test to determine soil permeability.
- Soil mix should be sandy loam or loamy sand with clay content less than 15%. Soil pH should generally be between 5.5-6.5, which is optimal for microbial activity and adsorption of nitrogen, phosphorus, and other pollutants. Planting soils should be 1.5-3% organic content and maximum 500ppm soluble salts.
- Planting soils should be placed in 1'-2' lifts, compacted with minimal pressure, until desired elevation is achieved. Some engineers suggest flooding the cell between each lift placement in lieu of compaction.
- Planting plan should generally include one tree or shrub per 50 s.f. of bioretention area, and at least 3 species each of herbaceous perennials, shrubs, and (if applicable) trees to avoid a monoculture.
- The bioretention landscaping plan should meet the requirements of any applicable local landscaping requirements.
- During construction, avoid excessive compaction of soils around the bioretention areas and accumulation of silt around the drainfield.
- In order to minimize sediment loading in the treatment area, only runoff from stabilized drainage areas should be directed to bioretention areas; construction runoff should be diverted elsewhere.

Additional References

Design Manual for Use of Bioretiention in Stormwater Management; Department of Environmental Resources, Prince George's County, MD; 1993.

Bioretention as a Water Quality Best Management Practice, Article 110 from Watershed Protection Techniques; Center for Watershed Protection; 2000 http://www.cwp.org/Downloads/ELC_PWP110.pdf

Storm Water Technology Fact Sheet, Bioretention, United States Environmental Protection Agency, Office of Water; 1999 http://www.lowimpactdevelopment.org/epa03/biospec. htm

Bioretention Fact Sheet, Federal Highway Administration www.fhwa.dot.gov/ environment/ultraurb/3fs3.html

This publication is one component of the Massachusetts Low Impact Development Toolkit, a production of the Metropolitan Area Planning Council, in coordination with the I-495 MetroWest Corridor Partnership, with financial support from US EPA. The Massachusetts Low Impact Development Interagency Working Group also provided valuable input and feedback on the LID Toolkit.

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FACT SHEET #5

VEGETATED SWALES

Overview

Vegetated swales are an important Low Impact Development technique used to convey stormwater runoff. These open, shallow channels slow runoff, filter it, and promote infiltration into the ground; as a result, runoff volumes are smaller, peak discharge rates are lower, and runoff is cleaner. This approach contrasts with conventional stormwater strategies that rely on gutters and pipes that increase the velocity of runoff and do nothing for water quality.

Swales are not just ditches under another name—they must be carefully designed and maintained to function properly. The vegetation in swales, usually thick grass, helps to trap pollutants (suspended solids and trace metals), and reduce the velocity of stormwater runoff; stormwater also percolates through the natural substrate.

Vegetated swales can replace curb and gutter systems as well as storm sewers that convey runoff. Swales require more room than curb and gutter systems but they require less expensive hardscaping; furthermore, the reduction in discharge rate and volume means that downstream treatment facilities can be smaller. Swales also double as landscaping features, increasing the value and attractiveness of the site, as well as its appeal to neighbors and regulatory boards.

Applications and Design Principles

Water quality swales are widely applicable on residential, commercial, industrial, and institutional sites. The amount of impervious cover in the contributing area to each swale should be no more than a few acres, and swales should not be used in areas where pollutant spills are likely. Grassed swales can be used in parking lots to break up areas of impervious cover. Roadside swales can be used in place of curb and gutter systems, except where there are numerous driveways requiring culverts. Where sidewalk and road are parallel, swale should be between the sidewalk and the road.

Management Objectives

- Provide water quality treatment; remove suspended solids, heavy metals, trash.
- Reduce peak discharge rate.
- Reduce total runoff volume.
- Infiltrate water into the ground.
- Provide a location for snow storage.
- Improve site landscaping.

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Vegetated swales may be parabolic or trapezoidal in cross section. Longitudinal slopes should be as low as possible, and never more than 4%; swales should follow natural topography and drainage patterns to the extent possible. Swales work best in sandy loams that facilitate infiltration; very sandy soils may be prone to erosion under high runoff velocities. Check dams placed along the length of the swale can help to slow the runoff even more and promote greater infiltration and pollutant removal. Careful hydrologic design is necessary to ensure adequate pretreatment of the water quality volume and nonerosive conveyance of large storms.

In some applications, swales are designed with a 2- to 3-foot deep soil bed of loamy sand to promote greater infiltration; on denser sites, this bed may include a perforated underdrain to ensure rapid drainage of the swale if groundwater infiltration is slow. In such applications, the runoff would end up (via the underdrain or swale termination) in the conventional stormwater system, but the swale would still provide considerable quality, quantity, and rate benefits.

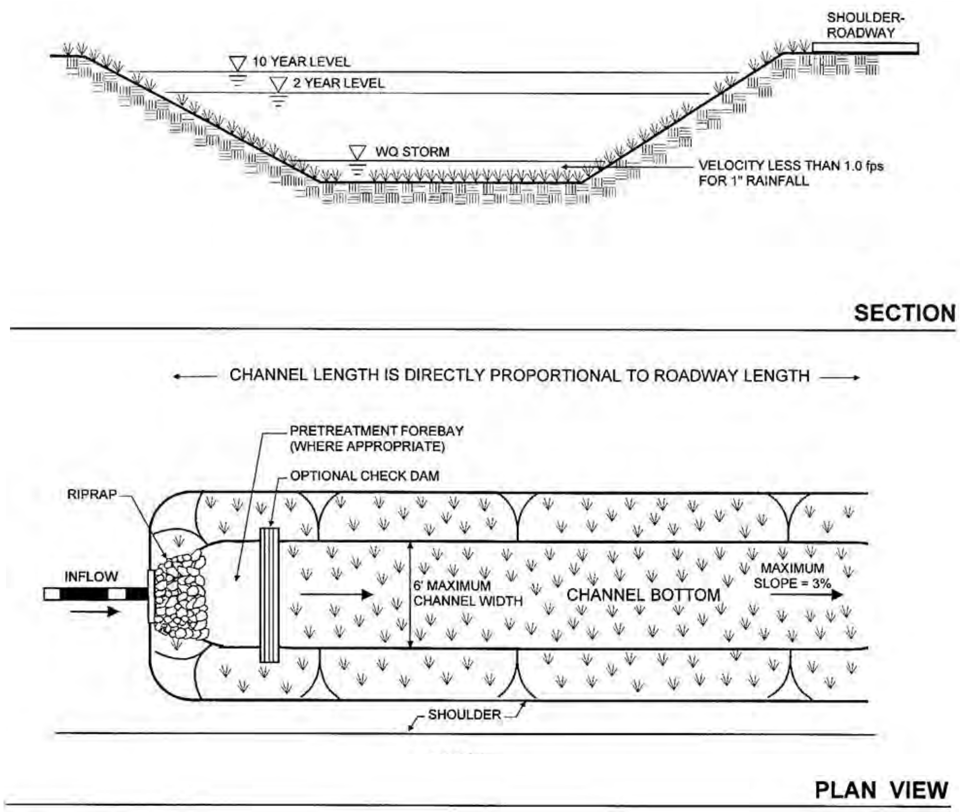
Benefits and Effectiveness

- Swales help to control peak discharges by reducing runoff velocity, lengthening flow paths, and increasing time of concentration.
- Infiltration through the natural substrate helps to reduce total stormwater runoff volume.
- Swales provide effective pretreatment for downstream BMPs by trapping, filtering and infiltrating particulates and associated pollutants. The design rate for TSS removal is 70%.
- Swales accent the landscape and may help to satisfy landscaping and greenspace requirements.
- Swales can provide a location for snow storage during winter months.
- Roadside swales effectively keep stormwater flows away from street surfaces.
- Construction may cost less than conventional curb and gutter systems.

Cover, top: Stone check dams in this roadside swale serve to slow run-off, promote settling, and increase infiltration. *Photo: Virginia Stormwater Management Handbook*

Cover, bottom: This swale in a residential neighborhood fits in with the landscaping. *Photo: University of Connecticut, Jordan Cove Urban Monitoring Project*

Below: A meandering grassed swale filters runoff and helps to improve site landscaping. *Photo: Low Impact Development Center.*



Above: This roadside swale can provide a convenient location for snow storage. As the snow melts, sand is filtered by the vegetation and some of the runoff will infiltrate. *Photo: University of Connecticut, Jordan Cove Urban Monitoring Project.*

Limitations

- Each grassed swale can treat a relatively small drainage area of a few acres, depending on land use and soil type. Large areas should be divided and treated using multiple swales.
- Swales are impractical in areas with steep topography.
- A thick vegetative cover is needed for these practices to function properly. Grass must not be mowed too short.
- Swales should be used carefully on industrial sites or areas of higher pollutant concentrations. If used, they should be part of a "treatment train" that includes other treatment BMPs.
- Swales can be subject to channelization, if erosive velocity is exceeded.
- Soil compaction can reduce infiltration capacity.
- Swales are not effective at reducing soluble nutrients such as phosphorous.
- In some places, the use of swales is restricted by law; many local municipalities may require curb and gutter systems in residential areas.

Maintenance

- Permits for water quality swales should specify schedules and responsibility for inspection and maintenance. Since swales may be located on private residential property, it is important for developers to clearly outline the maintenance requirements to property purchasers.
- Inspect on a semi-annual basis; additional inspections should be scheduled during the first few months to make sure that the vegetation in the swales becomes adequately established. Inspections should assess slope integrity, soil moisture, vegetative health, soil stability, compaction, erosion, ponding, and sedimentation.
- Mow at least once per year, but do not cut grass shorter than the design flow

Above: Swales can be used on commercial sites to convey runoff around the site and to help slow peak discharge rates. *Photo: Lower Columbia River Estuary Partnership*

depth because the effectiveness of the vegetation in reducing flow velocity and pollutant removal may be reduced. Grass cuttings should be removed from the swale and composted.

- Remove accumulated sediment when it is 3" deep or higher than the turf, to minimize potential concentrated flows and sediment resuspension.
- Irrigate only as necessary to prevent vegetation from dying.
- The application of fertilizers and pesticides should be minimal.
- Reseed periodically to maintain dense turf.
- Remove trash or obstructions that cause standing water.
- Prevent off-street parking or other activities that can cause rutting or soil compaction.

Cost

Vegetated swales typically cost less to construct than curbs and gutters or underground stormwater conveyance pipes. The cost of construction will depend on local conditions and management objectives. As with any stormwater management structure, property owners should provide a budget for ongoing maintenance, such as regular mowing and repairs as necessary.

Design Details

- The topography of the site should generally allow for a longitudinal slope of no more than 4% and no less than 0.5%. Flatter slopes can result in ponding, while steeper slopes may result in erosion (depending on soil type, vegetation, and velocity.) Use natural topographic low points and drainageways to minimize excavation.
- Underlying soils should be a sandy loam or a similar soil type with no more than 20% clay. Soil augmentation may be necessary.
- Side slopes should be 3:1 or flatter for maintenance and to prevent side slope erosion. Swale bottoms should generally be between 2 and 8 feet in width.
- Use pea gravel diaphragms for lateral inflows.
- Check dams can be utilized to establish multiple cells. Check dams at 50-foot intervals (<2' drop) help to maximize retention time, increase infiltration, promote particulate settling, and decrease flow velocities. Check dams are not necessary with very low longitudinal slopes. Provide for scour protection below check dam.
- Outlet protection must be used at any discharge point from swales to prevent scour.
- Select grass species that produce fine, uniform, and dense cover and that can withstand prevailing moisture conditions.
- Temporary erosion and sediment controls should be utilized during construction.
- Keep heavy equipment out of the channel during construction to minimize compaction. Even a bobcat grader can compact soils and reduce potential infiltration. Use excavator with a swing arm and work from the side of the swale.
- Mulch anchoring should be done immediately after seeding.

Additional References

- *Massachusetts Stormwater Management Policy: Volume Two: Stormwater Technical Handbook*; Massachusetts Department of Environmental Protection and Massachusetts Coastal Zone Management; 1997
- *Grassed Swales*; from The Wisconsin Stormwater Manual, University of Wisconsin-Extension Service; 2000

This publication is one component of the Massachusetts Low Impact Development Toolkit, a production of the Metropolitan Area Planning Council, in coordination with the I-495 MetroWest Corridor Partnership, with financial support from US EPA. The Massachusetts Low Impact Development Interagency Working Group also provided valuable input and feedback on the LID Toolkit.

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FACT SHEET #6

GRASS FILTER STRIPS

Overview

Grass filter strips are low-angle vegetated slopes designed to treat sheet flow runoff from adjacent impervious areas. Filter strips (also known as vegetated filter strips and grassed filters) function by slowing runoff velocities, filtering out sediment and other pollutants, and providing some infiltration into underlying soils. Because they use sheet flow and not channelized flow, filter strips are often more effective than swales at removing suspended solids and trash from runoff. They provide good "pretreatment" of stormwater that will then be routed to another technique such as a bioretention area.

Filter strips were originally used as an agricultural treatment practice, but have recently been used in more urban and suburban locations. They differ slightly from buffer strips, which are natural vegetated areas alongside streams and lakes; buffer strips are left undisturbed for habitat protection and visual screening, while filter strips are altered areas designed primarily for stormwater management. Like many other LID techniques, vegetated filter strips can add aesthetic value to development. They cost significantly less than "hardscaped" stormwater infrastructure and also provide a convenient and effective area for snow storage and treatment.

Applications and Design Principles

Filter strips are appropriate for roadside applications and along the edge of small- to medium-sized parking lots, so long as the tributary area extends no more than 60 feet uphill from the buffer strip. They can also be used to treat roof runoff that is discharged over a level spreader. Filter strips are ideal components of the outer zone of a stream buffer, or as pretreatment to another stormwater treatment practice. They are generally require too much land area for applications in urban areas. The contributing drainage area should generally be less than five acres.

Management Objectives

- Remove suspended solids, heavy metals, trash, oil and grease.
- Reduce peak discharge rate and total runoff volume.
- Provide modest infiltration and recharge.
- Provide snow storage areas.
- Improve site landscaping.

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Filter strips work best when they are at least 20 feet long (downhill axis), though shorter strips will still provide some treatment. They should have slopes between 1% and 15%, preferably in the lower end of that range. It is critical for filter strips to be planar or convex, since any undulation in the surface or obstructions can cause concentrated flow that leads to erosion, channelization, and loss of water quality benefits.

The design should seek to keep runoff velocity in the low to moderate range (less than 2 feet per second) in order to maximize water quality benefits. This can be done by limiting the size of the contributing impervious surface. Both the top and toe of the slope should be as flat as possible to encourage sheet flow. A pea gravel or cement level spreader (with a lip) at the top of the filter strip will improve sheet flow and will capture some sediment.

Some filter strips are designed with a pervious berm at the downhill end of the filter strip, to detain water temporarily, increasing infiltration and reducing peak discharge rates. This berm can significantly enhance water quality benefits if it is designed to impound the water quality volume.

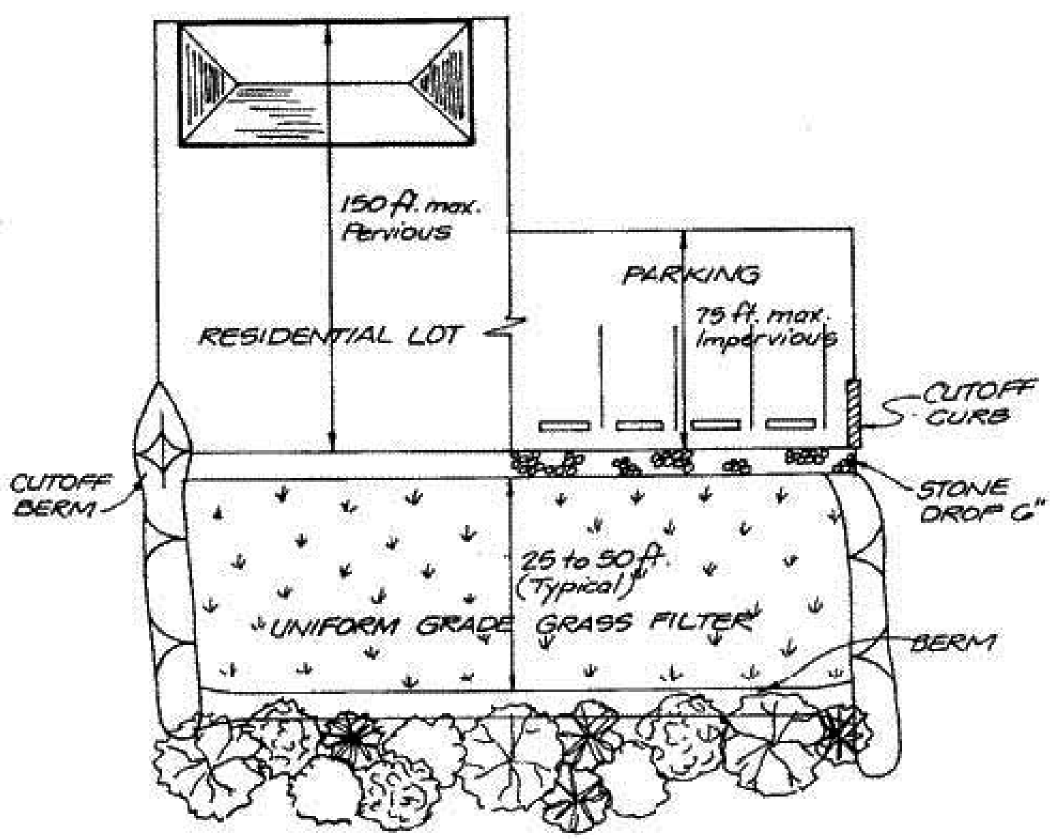
Cover, top: This 40-foot wide filter strip provides water quality pretreatment of runoff from the adjacent highway. *Photo: California Stormwater Quality Association.*

Cover, bottom: A filter strip adjacent to this filling station provides room for snow storage and can remove sediment and organics from runoff. *Photo: Steve Haubner, Atlanta Regional Commission*

Below right: A plan view of filter strips in residential and commercial settings. *Image: Center for Watershed Protection*

Benefits and Effectiveness

- Filter strips provide runoff pretreatment by trapping, filtering and infiltrating particulates and associated pollutants. TSS removal rates range from 40%-90%. Effectiveness depends largely on the quantity of water treated, the slope and length of the filter strip, the type of vegetation, and the soil infiltration rate.
- Vegetated filter strips also reduce runoff velocities and increase the time of concentration as compared to channelized flow, resulting in a reduction of peak discharge rates.
- Filter strips may provide groundwater recharge as runoff infiltrates into soil; recharge may be considerable if design incorporates a ponding area at the toe of the slope.



Above: Here a filter strip is being used as pretreatment for parking lot runoff directed to an infiltration basin. Note concrete level spreader (at right) to facilitate sheetflow across filter strip. *Photo: California Stormwater Quality Association*

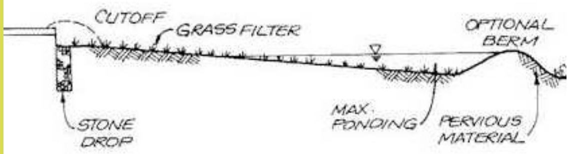
- Filter strips can serve as a location for snow storage during winter months and will also help to trap and treat the salt and sand in snow when it melts.
- Filter strips are inexpensive to construct, especially when compared to conventional curb-and-gutter systems.
- Vegetated filter strips help to accent the natural landscape by providing green space adjacent to parking lots and roadways.

Limitations

- Because filter strips infiltrate runoff to groundwater, they could be inappropriate at stormwater "hotspots" (such as gas stations) with higher potential pollutant loads. They should be combined with other BMPs to ensure adequate treatment of polluted runoff prior to discharge.
- Channelization and premature failure may result from poor design, imprecise construction, or lack of maintenance. Proper design requires a great deal of finesse, and slight problems in the construction, such as improper grading, can render the practice less effective in terms of pollutant removal.
- Filter strips have low removal rates for nutrients, so they must be used in conjunction with other best management practices.
- Filter strips often require lots of space, making them often infeasible in urban environments where land prices are high.

Maintenance

- Inspect level spreader monthly and remove built-up sediment.
- Inspect vegetation monthly for rills and gullies and correct. Fill any depressions or channels. Seed or sod bare areas.
- In the year following construction, inspect the filter strip regularly to ensure that grass has established. If not, replace with an alternative species. Allow natural succession by native grasses and shrubs if it occurs.



This diagram shows a filter strip designed with a berm to impound water, resulting in improved water quality treatment and increased infiltration. *Image: Center for Watershed Protection*

- Mow grass, as rarely as 2-3 times per year, to maintain 4" to 6" of dense grass cover. Grass clippings should be collected and composted elsewhere. Provide a minimum of fertilizer only when necessary. Mow when the soil is dry and firm to prevent rutting.
- Semi-annually, remove sediment that has accumulated to prevent berms or channels.

Cost

Filter strips cost considerably less to construct than many hardscaped stormwater management structures such as curbs, storm sewers, and ponds. The primary direct expenses are clearing, grading, and seed or sod. Additional expenses may include construction of a level spreader at the top of the strip or a berm at the toe of the slope.

The most significant cost of filter strips may be an indirect expense, which is the cost of the land, which may be very valuable in dense urban settings. In many cases, however, open spaces and buffers are required by municipal landscaping or zoning regulations, and filter strips may be used to satisfy these requirements. Established vegetated buffers may also add value a property.

Design Details

- The limiting design factor for filter strips is not total drainage area but rather the length of flow contributing to it. Because sheetflow runoff becomes concentrated flow as distance increases, the contributing area to a vegetated buffer should be no more than 60 feet for impervious surfaces, and 100 feet for pervious surfaces.
- Slopes should be between 1% and 15%, though slopes less than 5% are preferred. The top and toe of the slope should be as flat as possible.
- The filter strip should be at least 20' long (downhill length) to provide water quality treatment. Minimum width is 8' or 0.2 X length of flow over the impervious surface upstream of the filter strip.
- Depth of sheetflow should be less than 0.5" for the design storm. Depending on the pollutant removal required, residence time should be at least 5 minutes, preferably 9 minutes or more.
- Use Manning's equation to calculate velocity, assuming hydraulic radius equals depth, with n values of 0.20 for mowed grass slope and 0.24 for infrequently mowed grass slope. Normal velocity should be <1.0 feet/second for design flow, with maximum permissible velocity of 3.0 feet/second for peak discharge during 10-year storm.
- Use a cement level spreader or pea gravel diaphragm at the top of the slope.
- Filter strips can 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.
- Designers should choose a grass that can withstand calculated flow velocities, and both wet and dry periods. Also consider depth to groundwater and choose facultative wetland species if appropriate.
- If filter strip will be used for snow storage, use salt tolerant vegetation (e.g., creeping bentgrass.)
- During construction, divert runoff from unstabilized areas away from filter strips.
- Protect the underlying soil from compaction to the extent possible: work from outside the boundaries of the filter strip or use oversized tires and lightweight equipment.

Additional Resources

Mass Highway Department Stormwater Handbook
(www.mhd.state.ma.us/mhd/environ/publications.htm)
www.stormwatercenter.net

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