Overview for bioretention

Bioretention is a terrestrial-based (up-land as opposed to wetland) water quality and water quantity control process. Bioretention employs a simplistic, site-integrated design that provides opportunity for runoff **infiltration** (https://stormwater.pca.state.mn.us/index.php?title=Stormwater_infiltration_Best_Management_Practices), **filtration** (https://stormwater.pca.state.mn.us/index.php?title=Filtration), storage, and water uptake by vegetation.

A rain garden in a residential development. Photo courtesy of Katherine Sullivan.

Bioretention areas are suitable stormwater treatment practices for all land uses, as long as the **contributing drainage area (https://stormwater.pca.state.mn.us/index.php?title=Contributing_drainage_area_to_stormwater_BMPs)** is appropriate for the size of the facility. Common bioretention opportunities include landscaping islands, cul-de-sacs, parking lot margins, commercial setbacks, open space, rooftop drainage and street-scapes (i.e., between the curb and sidewalk). Bioretention, when designed with an **underdrain** and liner (https://stormwater.pca.state.mn.us/index.php?title=Liners_for_stormwater_management), is also a good design option for treating potential **stormwater hotspots (https://stormwater.pca.state.mn.us/index.php?title=Potential_stormwater_hotspots)** (PSHs). Bioretention is extremely versatile because of its ability to be incorporated into landscaped areas. The versatility of the practice also allows for bioretention areas to be frequently employed as stormwater retrofits.

Contents

Function within stormwater treatment train

Unlike end-of-pipe BMPs, bioretention facilities are typically shallow depressions located in upland areas of a **treatment train** (https://stormwater.pca.state.mn.us/index.php?title=Using_the_treatment_train_approach_to_BMP_selection). The strategic, uniform distribution of bioretention facilities across a development site results in smaller, more manageable subwatersheds, and thus, will help in controlling runoff close to the source where it is generated (Prince George's County Bioretention Manual (https://www.slideshare.net/Sotirakou964/md-prince-georges-county-bioretention-manual), 2002). Bioretention facilities are designed to function by essentially mimicking certain physical, chemical, and biological processes that occur in the natural environment. Depending upon the design of a facility, different processes can be maximized or minimized depending on the type of pollutant loading expected (Prince George's County, 2002).

Green Infrastructure: bioretention facilities are designed to mimic a site's natural hydrology

MPCA permit applicability

One of the goals of this Manual is to facilitate understanding of and compliance with the MPCA Construction General Permit (https://stormwater.pca.state.mn.us/index.php?title=Construction_stormwater_program) (CGP), which includes design and performance standards for **permanent stormwater management** systems. Standards for various categories of stormwater management practices must be applied in all projects in which at least one acre of new impervious area is being created.

For regulatory purposes, bioinfiltration practices fall under *Infiltration systems* described in the CGP. Biofiltration practices fall under *Filtration systems* of the permit. If used in combination with other practices, credit for combined stormwater treatment can be given. Due to the statewide prevalence of the MPCA permit, design guidance is presented with the assumption that the permit does apply. Also, although it is expected that in many cases the bioretention practice will be used in combination with other practices, standards are described for the case in which it is a stand-alone practice.

There are situations, particularly retrofit projects, in which a bioretention practice is constructed without being subject to the conditions of the MPCA permit. While compliance with the permit is not required in these cases, the standards it establishes can provide valuable design guidance to the user. It is also important to note that additional and potentially more stringent design requirements may apply for a particular bioretention practice, depending on where it is situated both jurisdictionally and within the surrounding landscape.

Retrofit suitability

The ability to use bioretention as a retrofit often depends on the age of development within a subwatershed. Subwatersheds that have been developed over the last few decades often present many bioretention opportunities because of open spaces created by modern setback, screening and landscaping requirements in local zoning and building codes. However, not every open area will be a good candidate for bioretention due to limitations associated with existing **inverts** of the storm drain system and the need to tie the **underdrain** from the bioretention area (for practices requiring an underdrain) into the storm drain system. In general, 4 to 6 feet of elevation above this invert or use of an upturned elbow (http://chesapeakestormwater.net/wp-content/uploads/downloads/2014/03/Internal-Water-Storage-for-Bioretention-2009.pdf) is needed to drive stormwater through the proposed bioretention area.

Special receiving waters suitability

The table below provides guidance regarding the use of bioretention practices in areas upstream of **special receiving waters** (https://stormwater.pca.state.mn.us/index.php?title=Special_Waters_and_Impaired_Waters). Note that the suitability of a bioretention practice depends on whether the practice has an underdrain (i.e. filtration vs. infiltration practice).

Infiltration and filtration bmp[1] design restrictions for special waters and watersheds.
Link to this table

BMP Group	receiving water				
	A Lakes	B Trout Waters	C Drinking Water[2]	D Wetlands	E Impaired Waters
Infiltration	RECOMMENDED	RECOMMENDED	NOT RECOMMENDED if potential stormwater pollution sources evident	RECOMMENDED	RECOMMENDED unless target TMDL pollutant is a soluble nutrient or chloride
Filtration	Some variations NOT RECOMMENDED due to poor phosphorus removal, combined with other treatments	RECOMMENDED	RECOMMENDED	ACCEPTABLE	RECOMMENDED for non-nutrient impairments

[1]Filtration practices include green roofs, bmps with an underdrain, or other practices that do not infiltrate water and rely primarily on filtration for treatment.

[2] Applies to groundwater drinking water source areas only; use the lakes category to define BMP design restrictions for surface water drinking supplies

It is *Highly Recommended* that bioretention practices be designed **offline**. Offline facilities are defined by the **flow path** through the facility. Any facility that utilizes the same entrance and exit flow path upon reaching pooling capacity is considered an offline facility.

Cold climate suitability

Studies conducted since the 2008 version of this manual indicate the difference between summer and winter performance of bioretention systems is not substantial, even on sites with severe winters (Shanstrom (https://www.deeproot.com/blog/blog-entries/does-bioretention-still-work-when-the-ground-freezes-maximizing-bioretention-cold-climate-performance/), 2012; Davidson, et al., 2008; Dietz and Clausen, 2006; Kahn et al., 2012; LeFevre et al., 2009; Roseen et al. (https://www.researchgate.net/publication/253847256_Seasonal_Performance_Variations_for_StormWater_Management_Systems_in_Cold_Climate_Conditions), 2009; Toronto and Region Conservation (TRCA), 2008). Davidson et al. (https://www.yumpu.com/en/document/view/32101879/recommendations-to-optimize-hydrologic-bioretention-performance) (2008) provide several recommendations for bioretention systems in cold climates. These recommendations are consistent with design recommendations in the Minnesota Stormwater Manual.

Water quantity treatment

High-flow **bypass** systems are utilized to safely discharge stormwater when bioretention cells fill and reach their maximum ponding depth. This will occur during storms exceeding the **Water Quality Volume** (https://stormwater.pca.state.mn.us/index.php?title=Water_quality_criteria) design storm. There are typically three types of high-flow bypass systems which are split into two categories: offline and online. Whenever possible, offline designs are preferable, as they reduce the potential for internal erosion in the bioretention cell. Offline facilities are defined by the flow path through the bioretention cell. Any facility that utilizes the same entrance and exit point upon reaching maximum ponding depth is considered an offline system. This is typically achieved with a curb cut set at the intended elevation of maximum ponding or through the use of some other upstream diversion, which results in flow bypass down the gutter when the cell has filled. This type of bypass is often simple to utilize in retrofit situations (commercial and transportation applications) where existing drainage infrastructure is present.

Where offline designs are not achievable, it is *Highly Recommended* that bioretention practices be designed to route high flows on the shortest flow path across the cell to avoid scour in the bioretention practice. The overflow location should be placed as close as practicable to the inlet(s). No matter the bypass design, energy dissipation should always be provided at the inlet(s) to avoid high flow velocity and associated turbulence that can re-suspended particulates and cause erosion in the bioretention cell.

Two types of online bypass systems may be used. The first option is to utilize an internal drainage inlet. Concrete box drop structures may be used to provide an overflow for bioretention cells; however, they should be located away from the inlet(s) to provide an elongated flow path and prevent **short-circuiting**. These internal drainage structures may be tied into the existing drainage infrastructure, which is an attractive benefit in commercial applications. When using these high-flow bypass devices, it is critical to set the brink-of-overflow elevation properly, otherwise the cell will not function properly when construction is complete. In a tree-shrub-mulch cell, the internal drainage inlets should have a system of screens to prevent loss of mulch. These overflow devices should be designed to safely pass the design discharge.

A second option is to use a broad crested or compound **weir** in the **berm** of the bioretention cell to convey overflow. This will typically be the best option in residential, institutional, and rural bioretention applications, where the overflow can tie in to an existing surface conveyance (**swale** (https://stormwater.pca.state.mn.us/index.php?title=Dry_swale_(Grass_swale)) or ditch). Weir structures may be constructed of pressure-treated lumber, cast-in-place concrete, or precast concrete. The invert of the weir should be set at the intended brink-of-overflow elevation. This type of bypass structure should be designed to non-erosively bypass the design discharge.

In limited cases, a bioretention practice may be able to accommodate the channel protection volume (https://stormwater.pca.state.mn.us/index.php?title=Unified_sizing_criteria), V_{cp}, in either an offline or online configuration, and in general they do provide some (albeit limited) storage volume. Bioretention can help reduce detention requirements for a site by providing elongated flow paths, longer times of concentration, and volumetric losses from infiltration and **evapotranspiration**. Experience and modeling analysis have shown that bioretention can be used for stormwater management quantity control when facilities are distributed throughout a site to reduce runoff and maintain the pre-existing time of concentration. This effort can be incorporated into the site hydrologic analysis. Generally, however, it is *Highly Recommended* that in order to meet site water quantity or peak discharge criteria, another structural control (e.g. detention) be used in conjunction with a bioretention area.

No matter the type of overflow device used, it is important that the designer provide non-erosive flow velocities at the outlet point to reduce downstream erosion. During the 10-year or 25-year storm (depending on local drainage criteria), discharge velocity should be kept below 4 feet per second for grassed channels. Erosion control matting or rock should be specified if higher velocities are expected.

Water quality treatment

Bioretention can be designed as an effective infiltration / recharge practice, particularly when parent soils have high permeability (> ~ 0.5 inches per hour). Where soils are not favorable, a rock infiltration gallery can be used to promote slow infiltration / recharge of stored water.

Bioretention is an excellent stormwater treatment practice due to the variety of pollutant removal mechanisms including vegetative filtering, settling, evaporation, infiltration, transpiration, biological and microbiological uptake, and soil adsorption. Pollutant removal and effluent concentration data for select parameters are provided in the two tables below.

Median pollutant removal percentages for several stormwater BMPs. Sources (http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs#References). More detailed information and ranges of values can be found in other locations in this manual, as indicated in the table.
Link to this table

Practice	TSS	TP	PP	DP	TN	Metals[1]	Bacteria	Hydrocarbons
Infiltration (https://stormwater.pca.state.mn.us/index.php?title=Stormwater_infiltration_Best_Management_Practices)[2]	3	3	3	3	3	3	3	3
Biofiltration and Tree trench/tree box with underdrain	80	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	50	35	95	80
Sand filter	85	50	85	0	35	50	80	80
Iron enhanced sand filter (http://stormwater.pca.state.mn.us/index.php/Iron_enhanced_sand_filter_%28Minnesota_Filter%29)	85	74	85	60[6]	35	50	80	80

Practice	TSS	TP	PP	DP	TN	Metals[1]	Bacteria	Hydrocarbons
Dry swale	68	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	35	0	80	80
Wet swale	35	0	0	0			0	
Constructed wet ponds[4, 5]	84	46	84	0	30	70	60	80
Constructed wetlands	73	38	69	0	30	70	60	80
Permeable pavement	74	41	82	0				
Green roofs	85	0	0	0				

TSS=Total suspended solids, TP=Total phosphorus, PP=Particulate phosphorus, DP=Dissolved phosphorus, TN=Total nitrogen

[1]Data for metals is based on the average of data for zinc and copper

[2]BMPs designed to infiltrate stormwater runoff, such as infiltration basin/trench, bioinfiltration, permeable pavement with no underdrain, tree trenches with no underdrain, and BMPs with raised underdrains.

[3]Pollutant removal is 100 percent for the volume infiltrated, 0 for water bypassing the BMP. For filtered water, see values for other BMPs in the table.

[4]Dry ponds do not receive credit for volume or pollutant removal

[5]Removal is for Design Level 2 (https://stormwater.pca.state.mn.us/index.php?title=Requirements,_recommendations_and_information_for_using_stormwater_pond_as_a_BMP_in_the_MIDS_calculator#Pollutant_Reduction)

[6]Removal is for Tier 2 iron enhanced sand filter. Tier 1 removal is 40 percent, resulting in a TP removal of 65%

Typical pollutant effluent concentrations, in milligrams per liter, for stormwater BMPs. Source (Winer (https://www.stormwatercenter.net/Library/STP-Pollutant-Removal-Database.pdf), 2000)..
Link to this table

Practice	TSS	TP	TN	Cu	Zn
Bioretention	11	0.3	1.1[1]	0.007	0.040

[1] Assumed values based on filtering practices

Early bioretention facilities were designed to provide water quality benefits by controlling the “first flush” event. Using highly permeable planting soils and an underdrain creates a high-rate biofilter, which can treat 90 to 95 percent (or higher) of the total annual volume of rainfall/runoff, depending on the design.

Limitations

Bioretention practices have been widely utilized for the past decade. Data suggests that these practices, when properly designed, constructed and maintained, perform well over long periods of time. However, design, construction and maintenance of these practices can be complex. In particular, maintenance personnel may need additional instruction on routine Operation and Maintenance requirements.

References

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Related pages

- Bioretention terminology (including types of bioretention)
- Overview for bioretention
- Design criteria for bioretention
- Construction specifications for bioretention
- Operation and maintenance of bioretention
- Assessing the performance of bioretention
- Cost-benefit considerations for bioretention
- Calculating credits for bioretention
- Soil amendments to enhance phosphorus sorption
- Summary of permit requirements for bioretention
- Supporting material for bioretention
- External resources for bioretention
- References for bioretention
- Requirements, recommendations and information for using bioretention with no underdrain BMPs in the MIDS calculator
- Requirements, recommendations and information for using bioretention with an underdrain BMPs in the MIDS calculator