# Infiltration combined



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Infiltration combined

**Green Infrastructure:** Infiltration practices can be an important tool for retention and detention of stormwater runoff and treatment of pollutants in stormwater runoff. If the practice utilizes vegetation, additional benefits may include cleaner air, carbon sequestration, improved biological habitat, and aesthetic value.

Photo of a Infiltration trench in Lino Lakes

Infiltration basins, infiltration trenches, dry wells, and underground infiltration systems capture and temporarily store stormwater before allowing it to infiltrate into the soil. As the stormwater penetrates the underlying soil, chemical, biological and physical processes remove pollutants and delay peak stormwater flows.

These four practices are grouped together because design, construction, operation, and maintenance guidelines and specifications are similar. Differences between these practices, where they exist, are highlighted on each of the following pages. For additional information on other infiltration practices, see Stormwater infiltration Best Management Practices and Bioretention terminology.

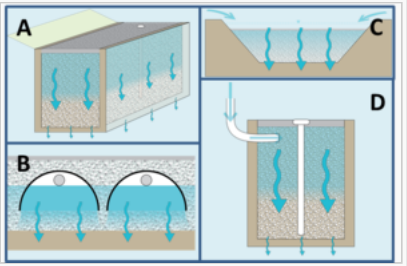
This page combines several articles (pages) on infiltration. To see the individual articles, click on the appropriate link below.

Photo of an infiltration basin. Source: Clark County, Washington, with permission.

- Overview for infiltration
- Types of infiltration
- Design criteria for infiltration
- Construction specifications for infiltration
- Operation and maintenance of stormwater infiltration practices
- Assessing the performance of infiltration
- Calculating credits for infiltration
- Cost-benefit considerations for infiltration
- Case studies for infiltration
- Green Infrastructure benefits of infiltration practices
- Summary of permit requirements for infiltration
- Infiltration photo gallery
- External resources for infiltration
- References for infiltration
- Requirements, recommendations and information for using infiltration basin/underground infiltration BMPs in the MIDS calculator
- Requirements, recommendations and information for using underground infiltration BMPs in the MIDS calculator
- December 15 webinar (powerpoint and link to presentation)
- Infiltration links and interesting websites

## Overview

Stormwater infiltration practices capture and temporarily store stormwater before allowing it to infiltrate into the soil. Infiltration practices are applicable to sites with naturally permeable soils and a suitable distance to the seasonally high groundwater table, bedrock or other impermeable layer. They may be used in residential and other urban settings where elevated runoff volumes, pollutant loads, and runoff temperatures are a concern. Stormwater runoff having high pollutant loads should receive a significant amount of pretreatment to protect the groundwater quality, particularly if soil infiltration rates are high (e.g. HSG A soils). Runoff from potential stormwater hotsposts (PSH) should not be introduced to infiltration areas. Infiltration should be avoided in areas with contaminated soils or groundwater.



Schematic illustrating A)infiltration trench, B) underground infiltration, C) infiltration basin, and D) dry well.

Design variants discussed on this page include the infiltration basin, the infiltration trench, the dry well and the underground infiltration system. To see overviews for other infiltration practices, see the following sections.

- Overview for bioretention
- Overview for permeable pavement
- Overview for trees

For discussions of how these practices differ or are similar to other infiltration practices, see Bioretention terminology and BMPs for stormwater infiltration.

**Green Infrastructure:** infiltration systems are designed to mimic a site's natural hydrology

## Function within stormwater treatment train

The infiltration practices discussed on this page may be located at the end of the treatment train or they can be designed as off-line configurations where the water quality volume is diverted to the infiltration practice. In any case, the practice may be applied as part of a stormwater management system to achieve one or more of the following objectives:

- reduce stormwater pollutants
- increase groundwater recharge
- decrease runoff peak flow rates
- decrease the volume of stormwater runoff
- preserve base flow in streams
- reduce thermal impacts of runoff

## MPCA permit applicability

One of the goals of this Manual is to facilitate understanding of and compliance with the General Stormwater Permit for Construction Activity (MN R100001), commonly called the Construction General Permit (CGP), which includes design and performance standards for permanent stormwater management systems. These standards must be applied in all projects in which at least 1 acre of new impervious area is being created, and the permit stipulates certain standards for various categories of stormwater management practices.

For regulatory purposes, infiltration practices fall under Section 16 (Infiltration systems) in 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 in this section is presented with the assumption that the permit does apply. Also, although it is expected that in many cases infiltration will be used in combination with other practices, standards are described for the case in which it is a stand alone practice.

The following terms are thus used in the text to distinguish various levels of stormwater pond design guidance.

**REQUIRED:** Indicates design standards stipulated by the MPCA Permit (or other consistently applicable regulations).

**HIGHLY RECOMMENDED:** Indicates design guidance that is extremely beneficial or necessary for proper functioning of the infiltration practice, but is not specifically required by the MPCA permit.

**RECOMMENDED:** Indicates design guidance that is helpful for infiltration performance but not critical to the design.

Of course, there are situations, particularly retrofit projects, in which an infiltration facility 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 infiltration facility, depending on where it is situated both jurisdictionally and within the surrounding landscape.

**Information:** There is some concern that underground infiltration systems and dry wells meet the U.S. Environmental Protection Agency (EPA) definition of a Class V injection well. Class V injection wells are defined as any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or an improved sinkhole, or a subsurface fluid distribution system (from U.S. Environmental Protection Agency, June 2003). Please consult EPA with questions on the applicability of Class V injection well rules.

## Retrofit suitability

- **Infiltration trench**: The narrow and versatile shape of infiltration trenches makes them well suited for retrofit projects. For example, infiltration trenches can be situated along the margin or perimeter of a developed site or roadway in many cases. They are particularly desirable as retrofit practices in watersheds or catchments that are targeting volume reduction practices to help minimize channel erosion.
- **Dry well**: Similar to infiltration trenches, the narrow and versatile shape of dry wells makes them well suited for most retrofit projects. However, dry wells are not well suited as retrofits for highway/road applications because of their small size and accessibility concerns.
- **Underground infiltration systems**: In settings where underground infiltration systems can be easily accessed for maintenance, they are ideal for retrofit situations. Another potential concern is fitting these systems, which can require significant space, into land uses where underground utilities are encountered.
- **Infiltration basins**: If adequate space exists, infiltration basins are suitable for retrofit applications. However, space considerations often limit their use in ultra-urban and highway/road settings.

**Warning:** Use of infiltration practices is *PROHIBITED* in the CGP for treatment of runoff from industrial areas with exposed significant materials or from vehicle fueling and maintenance areas.

**Applications for infiltration trenches, dry well, underground infiltration, and infiltration basins**

| | |
|---|---|
| Residential | Yes |
| Commercial | Yes |
| Ultra-urban | Yes except for infiltration basins, which are limited |
| Industrial | Yes[1] |
| Highway/road | [2] |
| Recreational | Yes |

[1] Unless the infiltration practice is located in an industrial area with exposed significant materials or from vehicle fuelling and maintenance areas. Infiltration BMPs are PROHIBITED in these areas; [2] Yes for infiltration trench, limited for underground infiltration and infiltration basin, no for dry well

Generally, infiltration should not be used to treat runoff from manufacturing or industrial sites or other areas with high pollutant concentrations unless correspondingly high levels of pretreatment are provided.

## Special receiving waters suitability

The BMP design restrictions for special watersheds table below provides guidance regarding the use of infiltration practices in areas upstream of special receiving waters. This table is an abbreviated version of a larger table in which other BMP groups are similarly evaluated. The corresponding information about other BMPs is presented in the respective sections of this Manual.

**Infiltration BMP design restrictions for special watersheds. This information applies to all infiltration practices.**
Link to this table

| BMP Group | Receiving water | | | | |
|---|---|---|---|---|---|
| | A Lakes | B Trout Waters | C Drinking Water[1] | 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 |

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

## Cold climate suitability

Infiltration practices should remain effective water quality improvement systems for many years, even during winter conditions, if designed and constructed properly and it has been shown that hydraulic efficiency and infiltration rates can remain at levels used for design sizing. However, in cold climates, some special considerations are HIGHLY RECOMMENDED for surface systems to ensure sustained functionality and limit the damage freezing temperatures and snow and ice removal may cause.

One concern with infiltration in cold weather is the ice that forms both over the top of the practice and within the soil structure, which can completely stop infiltration. To limit the effect of this problem, it is HIGHLY RECOMMENDED that the facility be actively inspected to ensure that it is properly drawing down before it freezes in the late fall. Adequate drawdown can be determined using one of the several field assessment techniques such as those recommended by the University of Minnesota Extension (see section on Assessment). If it is determined that stormwater runoff is not infiltrating prior to hard freeze, the BMP should be placed offline for correction in the spring.

Even if the infiltration properties of an infiltration practice are marginal for snowmelt runoff during the period of deep frost in the winter, the storage available in the facility will provide water quality benefit if it is dry entering the melt season. Routing the first highly-soluble portions of snowmelt (first flush) to an infiltration facility provides the opportunity for soil treatment (such as filtration, adsorption, microbial activity) of these soluble pollutants. Again, however, flow originating in an industrial area, a high traffic area where large amounts of salt are added, or another PSH should be diverted away from infiltration systems if pretreatment features have not been properly designed to handle such an increase in loading. Proprietary, sub-grade infiltration systems provide an alternative to standard surface based systems. Essentially, these systems provide an insulated location for pre-treated snowmelt to be stored and slowly infiltrated, or simply filtered and drained away if groundwater sensitivity is an issue. The insulating value of these systems adds to their appeal as low land consumption alternatives to ponds and surface infiltration basins.

For all BMPs it is HIGHLY RECOMMENDED that snow and ice removal plans including predetermined locations for stockpiling be determined prior to or during the design process. Infiltration features cannot be used for significant snow storage areas as debris build-up, plant damage, and lower infiltration rates are likely to occur. Some snow storage unavoidable when BMPs are adjacent to areas where snow removal is required but it is critical that the property owner and snow and ice removal contractor have identified other areas for large scale snow storage.

Excessive deicing agents have the potential to create a hot spot in some locations that could lead to reduced infiltration rates or concentrations that exceed surface water or groundwater standards. Locations such as busy intersections on slopes, parking garage ramps or on walkways near the entrances of commercial buildings are likely to be heavily treated with deicing agents to avoid slip and falls or vehicle collisions. This should be taken into consideration when siting any infiltration BMP.

For bioinfiltration features, dry swales with check dams, and tree trenches, special considerations regarding snow and ice storage and plant maintenance are required. Plant selection is critical to ensure that the damaging effects of snow and ice removal do not severely impact plantings or seedings. Even a small amount of snow storage can break and uproot plants requiring additional maintenance in the spring. Woody trees and shrubs should be selected that can tolerate some salt spray from plowing operations.

## Water quantity treatment

The amount of stormwater volume infiltrated depends on the design variant selected. Smaller infiltration practices (e.g. infiltration trenches) should either be designed off-line using a flow diversion, or designed to safely pass large storm flows while still protecting the infiltration area. In limited cases (e.g. extremely permeable soils), these smaller infiltration practices can accommodate the channel protection volume, $V_{cp}$, in either an off- or on-line configuration.

In general, supplemental stormwater practices will be necessary to satisfy channel and flood protection requirements when smaller infiltration practices are used. However, these practices can help reduce detention requirements for a site through volume reduction.

Due to their size, the larger infiltration practices (e.g. infiltration basins and underground infiltration systems) have the potential to provide greater water quantity benefits. Surcharge storage above the practice bottom is available for detention. Outlet structures can be sized to partially or fully accommodate larger storm peak discharge control while allowing the volume below the outlet to infiltrate.

## Water quality treatment

Infiltration practices can remove a wide variety of stormwater pollutants through chemical and bacterial degradation, sorption, and filtering. Surface water load reductions are also realized by virtue of the reduction in runoff volume.

There are few data available demonstrating the load reductions or outflow concentrations of larger-scale infiltration practices such as infiltration trenches. Similarly, few sampling programs collect infiltrating water that flows through an infiltration system.

For properly designed, operated, and maintained infiltration systems, all water routed into them should be “removed” from stormwater flow, resulting in 100 percent efficiency relative to volume and pollutant reduction. For this reason, any infiltration BMP performance table should show all 100 percent entries for that portion of stormwater entering the infiltration system. This logic assumes that stormwater is the beneficiary of any infiltration system, but ignores the fact that pollution, if any remains after the internal workings of the infiltration BMP itself (see later discussion in this section), is being transferred into the shallow groundwater system. Good monitoring data on the groundwater impact of infiltrating stormwater are rare, but there are efforts underway today to document this, so future Manual revisions should be able to include some data updates.

Properly designed infiltration systems discussed later in this section will accommodate a design volume based on the required water quality volume. Excess water must be by-passed and diverted to another BMP so that the design infiltration occurs within 48 hours if under state regulation, or generally within 72 hours under certain local and watershed regulations. In no case should the by-passed volume be included in the pollutant removal calculation.

Data that are reported in performance literature for infiltration systems, unless reporting 100 percent effectiveness for surface water or documenting outflow water downward, are not accurately representing behavior, or are representing the excess flow (overflow) from a system. Design specifications in the following sections should prevent putting contaminated runoff and excess water beyond that which will infiltrate within the given time frame. Any runoff containing toxic material or excess volume that cannot infiltrate should be diverted away from the infiltration system and reported as inflow to another treatment device.

### Limitations

The following general limitations should be recognized when considering installation of infiltration practices.

- Limited monitoring data are available and field longevity is not well documented.
- Failure can occur due to improper siting, design, construction and maintenance.
- Systems are susceptible to clogging by sediment and organic debris
- There is a risk of groundwater contamination depending on subsurface conditions, land use and aquifer susceptibility.
- They are not ideal for stormwater runoff from land uses or activities with the potential for high sediment or pollutant loads.
- They are not recommended for areas with steep slopes.

Please note that even though there are potential pollution and physical clogging problems with infiltration, it is one of the most important elements in the stormwater runoff treatment train. Fear of the limitations should not prevent well designed systems from being used.

As noted in various sections, discussion of BMP selection, the benefits associated with infiltration BMPs should only be accrued based on the amount of water actually passing through the BMP. Excess runoff beyond that designed for the BMP should not be routed through the system because of the potential for hydraulic and particulate over-loading, both of which will adversely impact the life and operation of the BMP. For example, an infiltration device designed to treat the first 0.5 inch of runoff from a fully impervious surface will catch about 30 percent of the volume of runoff in the Twin Cities. This means that 70 percent of the runoff volume should be routed around the filtration system and will not be subject to the removals reflected in the above tables. Attributing removal to all runoff just because a BMP is in place in a drainage system is not a legitimate claim.

**Warning:** It is *REQUIRED* that some form of pretreatment, such as a plunge pool, sump pit, filter strip, sedimentation basin, grass channel, or a combination of these practices be installed upstream of the infiltration practice.

## Types of infiltration

**Green Infrastructure:** Infiltration practices can be an important tool for retention and detention of stormwater runoff and treatment of pollutants in stormwater runoff. If the practice utilizes vegetation, additional benefits may include cleaner air, carbon sequestration, improved biological habitat, and aesthetic value.

Best Management Practices that infiltrate stormwater runoff into underlying soil include, but are not limited, to

- infiltration basins,
- infiltration trenches (includes dry wells),
- underground infiltration systems,
- bioinfiltration,
- permeable pavements,

- tree trenches and tree boxes, and
- dry swale with check dams.

These are discussed briefly below. Additional information about these BMPs can be found in the following tables.

- Stormwater infiltration BMPs - overview
- Stormwater infiltration BMPs – selection considerations
- Stormwater infiltration BMPs - treatment properties

## Infiltration basin


Photo of an infiltration basin. Source: Clark County, Washington, with permission.

An infiltration basin is a natural or constructed impoundment that captures, temporarily stores and infiltrates the design volume of water. Drawdown of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. The required drawdown time is 48 hours or less. Water that is stored but not infiltrated must leave the BMP, typically through an outlet, within the required drawdown time. In the case of a constructed basin, the impoundment is created by excavation or embankment. Infiltration basins are commonly used for drainage areas of 5 to 50 acres with land slopes that are less than 20 percent. Typical depths range from 2 to 6 feet, including bounce in the basin. The sizing is to control stormwater volumes at the regional or development scale as opposed to bioretention basins (rain gardens) that are designed at the site scale. Typical dimensions range from 1,000 square feet up to an acre. Infiltration basins are commonly constructed with plant species that can tolerate and thrive in this unique growing environment.

| Applications and treatment capabilities for infiltration basins | | | |
|---|---|---|---|
| **Applications** | | **Treatment capabilities[3, 4, 5]** | |
| Residential | Yes | TSS | High[6] |
| Commercial | Yes | TN | Medium/high |
| Ultra-urban | Limited[1] | TP | Medium/high |
| Industrial | Yes[2] | Chloride | Low |
| Highway/road | Limited | Metals | High |
| Recreational | Yes | Oils and grease | High |
| | | Pathogens | High |

[1] Due to a size restriction; [2] Unless the infiltration practice is located in an industrial area with exposed significant materials or from vehicle fueling and maintenance areas. Infiltration BMPs are PROHIBITED in these areas; [3]Underground infiltration systems may have different (likely lower) pollutant removal capabilities than what is provided in this table. These systems may have a wider application range. [4] This is only for the portion of flow that enters the infiltration basin; by-passed runoff does not receive treatment; [5] Low = < 30%; Medium = 30-65%; High = 65 -100%); [6] Assumes adequate pre-treatment

Sources: Schueler, 1987, 1992; USEPA 1993a, 1993b; Maniquiz et al., 2010; NPRPD, 2007; California Stormwater Manual, 2009; Pennsylvania Stormwater Manual, 2006

For more information, see the following pages in this Manual.

- Overview for infiltration
- Design criteria for infiltration
- Construction specifications for infiltration
- Operation and maintenance of stormwater infiltration practices
- Cost-benefit considerations for infiltration
- Calculating credits for infiltration
- External resources for infiltration
- References for infiltration
- Requirements, recommendations and information for using infiltration basin/underground infiltration BMPs in the MIDS calculator

## Infiltration trench

An infiltration trench is a shallow excavated trench, typically 3 to 6 feet deep, that is backfilled with a coarse stone aggregate allowing for the temporary storage of runoff in the void space of the material. Drawdown of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. Infiltration trenches may be modified to become stormwater tree trenches and boxes where applicable with the addition of growing medium. All water captured by the BMP must be removed within 48 hours through infiltration and/or a drain. Trenches are commonly used for drainage areas less than 5 acres in size.

> **Caution:** To avoid an infiltration trench being classified as a Class V injection well, it is strongly recommended that the length of the trench be at least 2 times greater than the depth of the trench.

For more information, see the following pages in this Manual.

Photo of a Infiltration trench in Lino Lakes

- Overview for infiltration
- Design criteria for infiltration
- Construction specifications for infiltration
- Operation and maintenance of stormwater infiltration practices
- Cost-benefit considerations for infiltration
- Calculating credits for infiltration
- External resources for infiltration
- References for infiltration
- Requirements, recommendations and information for using infiltration basin/underground infiltration BMPs in the MIDS calculator

| Applications and treatment capabilities for infiltration trenches, dry well, underground infiltration | | | |
|---|---|---|---|
| **Applications** | | **Treatment capabilities[3, 4]** | |
| Residential | Yes | TSS[5] | High[5] |
| Commercial | Yes | TN | Medium/high |
| Ultra-urban | Yes | TP | Medium/high |
| Industrial | Yes[1] | Chloride | Low |
| Highway/road | [2] | Metals | High |
| Recreational | Yes | Oils and grease | High |
| | | Pathogens | High |

[1] Unless the infiltration practice is located in an industrial area with exposed significant materials or from vehicle fuelling and maintenance areas. Infiltration BMPs are PROHIBITED in these areas; [2] Yes for infiltration trench, limited for underground infiltration, no for dry well; [3] This is only for the portion of flow that enters the infiltration basin; by-passed runoff does not receive treatment; [4] Low = < 30%; Medium = 30-65%; High = 65 -100%); [5] Assumes adequate pre-treatment

Sources: Schueler, 1987, 1992; USEPA 1993a, 1993b; Maniquiz et al., 2010; NPRPD, 2007; California Stormwater Manual, 2009; Pennsylvania Stormwater Manual, 2006

### Dry wells (a.k.a. infiltration tubes, french drains, soak-away pits or soak holes)

A dry well or soak away pit is a smaller variation of an infiltration trench. It is a subsurface storage facility (a structural chamber or an excavated pit backfilled with a coarse stone aggregate) that receives and temporarily stores stormwater runoff. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. Due to their size, dry wells are typically designed to handle stormwater runoff from smaller drainage areas, less than one acre in size (e.g. roof tops).

For more information, see the following pages in this Manual.

- Overview for infiltration
- Design criteria for infiltration
- Construction specifications for infiltration
- Operation and maintenance of stormwater infiltration practices
- Cost-benefit considerations for infiltration
- Calculating credits for infiltration
- External resources for infiltration
- References for infiltration
- Requirements, recommendations and information for using infiltration basin/underground infiltration BMPs in the MIDS calculator

### Underground infiltration systems

**Information:** The MPCA is working with partners to determine the fate and transport of stormwater pollutants in underground storage systems. Information from these studies should be available in 2018.

Several underground infiltration systems, including pre-manufactured pipes, vaults, and modular structures, have been developed as alternatives to infiltration basins and trenches for space-limited sites and stormwater retrofit applications. Underground infiltration systems are occasionally the only stormwater BMP options on fully developed sites as they can be located under other land uses such as parking lots or play areas. These systems are similar to infiltration basins and trenches in that they are designed to capture, temporarily store and infiltrate the design volume of stormwater over several days. Underground infiltration systems are generally applicable to small development sites (typically less than 10 acres) and should be installed in areas that are easily accessible to routine and non-routine maintenance. These systems should not be located in areas or below structures that cannot be excavated in the event that the system needs to be replaced or invasive maintenance is required to maintain performance.

Underground infiltration systems and dry wells have been installed below parking lots and other impervious surfaces on sites where insufficient space exists for a surface infiltration system. They are designed to temporarily store stormwater runoff before slowly infiltrating the water into the subsurface (Connecticut, 2004). There is limited information on the effectiveness of these systems in removing pollutants.

One concern is that underground infiltration may meet the U.S. Environmental Protection Agency (EPA) definition of a Class V injection well. Class V injection wells are defined as any bored, drilled, or driven shaft, or any dug hole that is deeper than its widest surface dimension. Class V injection wells can also be an improved sinkhole, or a subsurface fluid distribution system (from U.S. EPA, June 2003). The U.S. EPA administers Class V injection well permits in Minnesota. Minimum requirements for installing, permitting, and operating a Class V well is defined by the USEPA.

Underground TrueNorthSteel infiltration system in native sandy soils

A second concern pertains to the overall pollutant removal effectiveness of those underground infiltration systems that do not meet the definition of a Class V injection well. The document released by the Transport Research Synthesis titled "Issues of Concern Related to Underground Infiltration Systems for Stormwater Management and Treatment" provides a good overview of the concerns related to underground infiltration systems (MNDOT, 2009). Issues identified in this report include:

- There is potential that an underground infiltration system meets the criteria of a Class V injection well.
- There is insufficient knowledge of the fate of pollutants in the subgrade below the buried infiltration systems.
- Roadways and parking lots with high volumes of traffic have higher concentrations of certain pollutants, including heavy metals and PAHs.
- Underground systems do not allow for the pollutant removal that is accomplished through biological activity and vegetation uptake.
- The minimum separation requirement of 3 feet between the bottom of the infiltration system and the seasonally high groundwater elevation may be insufficient for adequate pollutant removal. Additional study is recommended.
- Maintenance of underground systems is critical for effective pollutant removal. However, access for maintenance is challenging. There are concerns that the difficult access is preventing owners from properly maintaining these systems.

For more information, see the following pages in this Manual.

- Overview for infiltration
- Design criteria for infiltration
- Construction specifications for infiltration
- Operation and maintenance of stormwater infiltration practices
- Cost-benefit considerations for infiltration
- Calculating credits for infiltration
- External resources for infiltration
- References for infiltration
- Requirements, recommendations and information for using infiltration basin/underground infiltration BMPs in the MIDS calculator

## Bioinfiltration basin

Bioinfiltration basin (Source: CDM Smith)

Bioinfiltration basins, often called rain gardens, use soil (typically engineered media or mixed soil) and native vegetation to capture runoff and remove pollutants. Both the media and underlying soil typically have high infiltration rates that allow captured water to infiltrate within a required drawdown time, usually 48 hours. Bioinfiltration systems, which lack an underdrain and are designed for infiltration, differ from biofiltration systems, which have an underdrain and are designed primarily for filtration. For more information, see the following pages in this Manual.

- Bioretention terminology (including types of bioretention)
- Overview for bioretention
- Design criteria for bioretention
- Construction specifications for bioretention
- Operation and maintenance of bioretention
- Cost-benefit considerations for bioretention
- Calculating credits for bioretention
- Soil amendments to enhance phosphorus sorption
- Summary of permit requirements for bioretention

**Applications and treatment capabilities for bioinfiltration basins**

| Applications | | Treatment capabilities[2, 3] | |
|---|---|---|---|
| Residential | Yes | TSS | High[4] |
| Commercial | Yes | TN | Low/Medium[5] |
| Ultra-urban | Limited[7] | TP | Medium/high[6] |
| Industrial | Yes[1] | Chloride | Low |
| Highway/road | Yes | Metals | High |
| Recreational | Yes | Oils and grease | High |
| | | Pathogens | High |

[1] Unless the infiltration practice is located in an industrial area with exposed significant materials or from vehicle fuelling and maintenance areas. Infiltration BMPs are PROHIBITED in these areas; [2] This is only for the portion of flow that enters the infiltration basin; by-passed runoff does not receive treatment; [3] Low = < 30%; Medium = 30-65%; High = 65 -100%); [4] Assumes adequate pre-treatment; [5] This assumes no underdrain; [6] Certain soil mixes can leach P; [7] Due to a size restriction

- 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

Sources: EPA Factsheet, 1999; Davis et al., 2001, 2003, 2006; Hsieh and Davis, 2005; Hong et al., 2006; Hunt et al., 2006; NPRPD, 2007; Li and Davis, 2009; Diblasi et al., 2009; Passeport et al., 2009; Brown et at., 2011a, b; Komlos et al., 2012; Denich et al., 2013; Li and Davis, 2013; California Stormwater BMP

## Permeable pavement


Permeable pavement (Source: CDM Smith)

Permeable pavements are paving surfaces that allow stormwater runoff to filter through surface voids into an underlying stone reservoir for infiltration and/or storage. They are suitable for driveways, trails, parking lots, and roadways with lighter traffic. The most commonly used permeable pavement surfaces are pervious concrete, porous asphalt, and permeable interlocking concrete pavers (PICP). All permeable pavements have a similar design layering system, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer, optional underdrains for filtration and geotextile over non-compacted soil subgrade. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. The drainage area leading to permeable pavements should not exceed twice the surface area of the final pavement surface.

| Applications and treatment capabilities for permeable pavement | | | |
|---|---|---|---|
| **Applications** | | **Treatment capabilities[2, 3]** | |
| Residential | Yes | TSS | High[4] |
| Commercial | Yes | TN | Medium/High |
| Ultra-urban | Yes | Nitrate | Low/Medium |
| Industrial | Yes[1] | TP | Medium/High |
| Retrofit | Yes | Chloride | Low |
| Highway/road | Yes | Metals | High |
| Recreational | Yes | Oils and grease | High |
| | | Pathogens | [5] |

[1] Unless the infiltration practice is located in an industrial area with exposed significant materials or from vehicle fuelling and maintenance areas. Infiltration BMPs are PROHIBITED in these areas; [2] This is only for the portion of flow that enters the infiltration basin; by-passed runoff does not receive treatment; [3] Low = < 30%; Medium = 30-65%; High = 65 -100%); [4] Assumes adequate pre-treatment; [5] Insufficient information

Source: Schueler, 1987; Pratt et al, 1999; Adams, 2003; Brattebo and Booth, 2003; Adams, 2003; Bean et al, 2007; SEMCOG, 2008; International Stormwater Database, 2012

For more information, see the following pages in this Manual.

- Overview for permeable pavement
- Types of permeable pavement
- Design criteria for permeable pavement
- Construction specifications for permeable pavement
- Assessing the performance of permeable pavement
- Operation and maintenance of permeable pavement
- Calculating credits for permeable pavement
- Additional considerations for permeable pavement
- Links for permeable pavement
- References for permeable pavement
- Requirements, recommendations and information for using permeable pavement BMPs in the MIDS calculator

## Tree box/Tree trench

Tree trenches are a system of trees that are connected by an underground infiltration structure. The system consists of a stormwater tree trench or box lined with geotextile fabric with structural stone, gravel or soil boxes in which the trees are placed. Tree systems consist of an engineered soil or rock layer designed to treat stormwater runoff via filtration through plant and soil/rock media, and through evapotranspiration from trees. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. Tree species are carefully selected to survive both inundation and drought conditions in urban environments where they will be potentially affected by chloride

| Applications and treatment capabilities for tree box/tree trench | | | |
|---|---|---|---|
| **Applications** | | **Treatment capabilities[2, 3]** | |
| Residential | Yes | TSS | High[4] |
| Commercial | Yes | TN | Low/Medium |
| Ultra-urban | Yes | TP | Medium/High[5] |
| Industrial | Yes[1] | Chloride | Low |
| Highway/road | No | Metals | High |
| Recreational | Yes | Oils and grease | High |

Tree box (Source: CDM Smith)

and other traffic concerns. Tree trenches and boxes drainage areas should be less than five acres depending on the size of each trench. Irrigation, whether manual or automated, is strongly encouraged during the tree's establishment period.

| | | | |
|---|---|---|---|
| | | Pathogens | High |

[1] Unless the infiltration practice is located in an industrial area with exposed significant materials or from vehicle fuelling and maintenance areas. Infiltration BMPs are PROHIBITED in these areas; [2] This is only for the portion of flow that enters the infiltration basin; by-passed runoff does not receive treatment; [3] Low = < 30%; Medium = 30-65%; High = 65 -100%); [4] Assumes adequate pre-treatment; [5] Certain soil mixes can leach P.

Source: see [1]

For more information, see the following pages in this Manual.

**Trees - general**

- Overview for trees
- Types of tree BMPs
- Plant lists for trees
- Street sweeping for trees
- References for trees
- Supporting material for trees

**Tree boxes/tree trenches**

- Design guidelines for tree quality and planting - tree trenches and tree boxes
- Design guidelines for soil characteristics - tree trenches and tree boxes
- Construction guidelines for tree trenches and tree boxes
- Protection of existing trees on construction sites
- Operation and maintenance of tree trenches and tree boxes
- Assessing the performance of tree trenches and tree boxes
- Calculating credits for tree trenches and tree boxes
- Case studies for tree trenches and tree boxes
- Soil amendments to enhance phosphorus sorption
- Fact sheet for tree trenches and tree boxes
- Requirements, recommendations and information for using trees as a BMP in the MIDS calculator

## Dry swale with check dams

Dry swale with impermeable concrete check dams. Photo courtesy Limnotech.

Similar to vegetated swales designed for stormwater conveyance, dry swales with check dams are designed as linear, multi-celled stormwater infiltration BMP's. By incorporating earthen or structural check dams, runoff is retained and infiltrated along a series of narrow, shallow basins or cells. Coarse vegetation such as decorative plantings or even turf grass slow runoff movement. This system is designed to move, store, and infiltrate runoff from impervious surfaces such as linear roadways or parking lots. Dry swales are best designed for sites under one acre in size.

For more information see the following sections in the Minnesota Stormwater Manual.

- Terminology for swales (grass channels)
- Overview for dry swale (grass swale)
- Design criteria for dry swale (grass swale)
- Construction specifications for dry swale (grass swale)
- Operation and maintenance of dry swale (grass swale)
- Assessing the performance of dry swale (grass swale)

**Applications and treatment capabilities for dry swale with check dams**

| Applications | | Treatment capabilities[2, 3] | |
|---|---|---|---|
| Residential | Yes | TSS | High[4] |
| Commercial | Yes | TN | Low/Medium |
| Ultra-urban | Limited[6] | TP | Low/Medium[5] |
| Industrial | Yes[1] | Chloride | Low |
| Highway/road | Yes | Metals | High |
| Recreational | Yes | Oils and grease | High |
| | | Pathogens | Medium |

[1] Unless the infiltration practice is located in an industrial area with exposed significant materials or from vehicle fuelling and maintenance areas. Infiltration BMPs are PROHIBITED in these areas; [2] This is only for the portion of flow that enters the infiltration basin; by-passed runoff does not receive treatment; [3] Low = < 30%; Medium = 30-65%; High = 65 -100%); [4] Assumes adequate pre-treatment; [5] Certain soil mixes can leach P; [6] Due to a size restriction.

Source: see [2]

- Calculating credits for dry swale (grass swale)
- Cost considerations for dry swale (grass swale)
- Case studies for dry swale (grass swale)
- Plants for swales
- Check dams for stormwater swales
- External resources for dry swale (grass swale)
- References for dry swale (grass swale)
- Requirements, recommendations and information for using dry swale (grass swale) without an underdrain in the MIDS calculator
- Requirements, recommendations and information for using dry swale (grass swale) with an underdrain in the MIDS calculator
- Requirements, recommendations and information for using swale side slope as a BMP in the MIDS calculator

## High gradient stormwater step-pool swale with check dams


Step pool with impermeable check dam. Courtesy of Limnotech.

Stormwater step pools are defined by its design features that address higher energy flows due to more dramatic slopes than dry or wet swales. Using a series of pools, riffle grade control, native vegetation and a sand seepage filter bed, flow velocities are reduced, treated, and, where applicable, infiltrated. to shallow groundwater. The physical characteristics of the stormwater step pools are similar to Rosgen A or B stream classification types, where "bedform occurs as a step/pool, cascading channel which often stores large amounts of sediment in the pools associated with debris dams" (Rosgen, 1996). These structures feature surface/subsurface runoff storage seams and an energy dissipation design that is aimed at attenuating the flow to a desired level through energy and hydraulic power equivalency principles (Anne Arundel County, 2009). Stormwater step pools are designed with a wide variety of native plant species depending on the hydraulic conditions and expected post-flow soil moisture at any given point within the stormwater step pool.

| Applications and treatment capabilities for step pool with check dams | | | |
|---|---|---|---|
| Applications | | Treatment capabilities[3, 4] | |
| Residential | Yes | TSS | Medium[5] |
| Commercial | Yes | TN | Low |
| Ultra-urban | Limited[1] | TP | Medium[6] |
| Industrial | Yes[2] | Chloride | Low |
| Highway/road | Yes | Metals | Medium |
| Recreational | Yes | Oils and grease | Low |
| | | Pathogens | Low |

[1] Due to size restriction; [2] Unless the infiltration practice is located in an industrial area with exposed significant materials or from vehicle fuelling and maintenance areas. Infiltration BMPs are PROHIBITED in these areas; [3] This is only for the portion of flow that enters the infiltration basin; by-passed runoff does not receive treatment; [4] Low = < 30%; Medium = 30-65%; High = 65 -100%); [5] Assumes adequate pre-treatment; [6] Certain soil mixes can leach P.

Source: see [3]

For more information see the following sections in the Minnesota Stormwater Manual.

- Terminology for high-gradient stormwater step-pool swale
- Overview for high-gradient stormwater step-pool swale
- Design criteria for high-gradient stormwater step-pool swale
- Construction specifications for high-gradient stormwater step-pool swale
- Operation and maintenance of high-gradient stormwater step-pool swale
- Assessing the performance of high-gradient stormwater step-pool swale
- Check dams for stormwater swales
- Plants for swales
- Calculating credits for high-gradient stormwater step-pool swale
- Cost considerations
- External resources for high-gradient stormwater step-pool swale
- References for high-gradient stormwater step-pool swale
- High-gradient stormwater step-pool swale and interesting websites

## Enhanced turf

Infiltration can be enhanced on soils that have been improved or amended. This manual contains limited information on enhanced turf and does not provide guidance for design, construction, maintenance, and assessment of enhanced turf. Information on use of compost in soil and credits associated with improved turf can be found on the Turf page. A discussion of alleviating compaction from construction activities can be found here.

**Warning:** Enhanced turf cannot be used to meet requirements of the Construction Stormwater General permit because infiltrated water does not represent an instantaneous volume.

## Unit processes for different infiltration BMPs

The following table provides a summary of unit processes for the different infiltration BMPs.

**Unit processes of stormwater treatment techniques (Adapted from WEF, 2008)**
Link to this table

| Control | Infiltration basin | Infiltration trench | Bioinfiltration | Permeable pavement | Tree box/tree trench | Enhanced turf |
|---|---|---|---|---|---|---|
| Peak flow attenuation | X | X | X | X | | |
| Runoff volume reduction | X | X | X | X | X | |
| Infiltration | X | X | X | X | X | X |
| Dispersion | | | | | | |
| Evapotranspiration | | | X | | X | |
| Runoff collection and usage | | | X[1] | X[1] | | |
| Sedimentation | X | X | X | | | |
| Flotation | X | | X | | | |
| Laminar separation | | | | | | |
| Swirl concentration | | | | | | |
| Sorption | X | X | X | X | | |
| Precipitation | X | X | X | X | | |
| Coagulation | X | X | X | X | | |
| Filtration | | | X | | | |
| Plant metabolism | | | X | | X | X |
| Nitrification/denitrification | X | X | X | | | |
| Organic compound degradation | X | X | X | X | | |
| Pathogen die off | X | X | | X | | |
| Temperature reduction | X | X | X | X | | |
| Disinfection | X | X | X | X | | |

[1] If underdrain is present

## Information tables

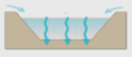
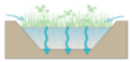
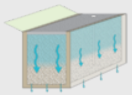
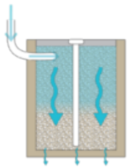
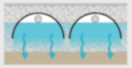
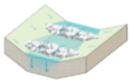
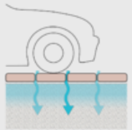
The following tables describe and differentiate different characteristics of stormwater infiltration BMPs.

### Overview table

The following table provides a brief description and schematic of each stormwater infiltration BMP.

**Stormwater infiltration BMPs - overview**

Link to this table

| Stormwater BMP | General Overview | Illustration |
|---|---|---|
| Infiltration Basin | A natural or constructed impoundment that captures, temporarily stores and infiltrates the design volume of water into the surrounding naturally permeable soil over several days. In the case of a constructed basin, the impoundment is created by excavation or embankment. |  |
| Bioinfiltration Basin | Often called rain gardens, bioinfiltration basins use engineered or mixed soils and plantings to capture and infiltrate runoff. Pollutants are removed using highly permeable soils that are able to draw the basin down in less than 48 hours. |  |
| Infiltration Trench Synonym: Infiltration Gallery | A shallow excavated trench that is backfilled with a coarse stone aggregate allowing for the temporary storage of runoff in the void space of the material. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. |  |
| Dry Well Synonym: Infiltration Tube, French Drain, Soak-Away Pits, Soak Holes | A smaller variation of an infiltration trench. It is a subsurface storage facility (a structural chamber or an excavated pit backfilled with a coarse stone aggregate) that receives and temporarily stores stormwater runoff. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. Due to their size, dry wells are typically designed to handle stormwater runoff from smaller drainage areas. |  |
| Underground Infiltration | Several underground infiltration systems, including pre-manufactured pipes, vaults, and modular structures, have been developed as alternatives to infiltration basins and trenches for space-limited sites and stormwater retrofit applications. These systems are similar to infiltration basins and trenches in that they are designed to capture, temporarily store and infiltrate the design volume of stormwater over several days. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. |  |
| Dry Swale with Check Dams | Similar to vegetated swales designed for stormwater conveyance, dry swales with check dams are designed as linear, multi-celled stormwater infiltration BMPs. By incorporating earthen, structural or rock check dams, runoff is retained and infiltrated along a series of narrow, shallow basins or cells. Coarse vegetation such as decorative plantings or even turf grass slow runoff movement. This system is designed to move, store, and infiltrate runoff from impervious surfaces such as linear roadways or parking lots. |  |
| Permeable Pavement | Permeable pavements are paving surfaces that allow stormwater runoff to filter through surface voids into an underlying stone reservoir for infiltration and/or storage. The most commonly used permeable pavement surfaces are pervious concrete, porous asphalt, and permeable interlocking concrete pavers (PICP). All permeable pavements have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer, optional underdrains and geotextile over uncompacted soil subgrade. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. |  |
| Tree Trench/Tree Box | A system of trees that are connected by an underground infiltration structure. The system consists of a trench lined with geotextile fabric with structural stone, gravel or soil boxes in which the trees are placed. Tree systems consist of an engineered soil layer designed to treat stormwater runoff via filtration through plant and soil media, and through evapotranspiration from trees. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. |  |

### Contributing drainage area table

The following table provides a summary of recommended contributing drainage area for each stormwater infiltration BMP.

Contributing area is defined as the total area, including pervious and impervious surfaces, contributing to a BMP. It is assumed that in most cases, with the exception of green roofs and many permeable pavement systems, impervious surfaces will constitute more than 50 percent of the contributing area to the BMP and that most of this impervious is directly connected. The recommended contributing area to a BMP may be modified for the following conditions.

- The recommended contributing area may be increased if pervious surfaces constitute the majority of the contributing area and soils are hydrologic soil group (HSG) A or B
- The recommended contributing area should be decreased if impervious surfaces contribute more than 80 percent of the contributing area or if the entire impervious surface is directly connected and routed to the BMP
- The recommended contributing area should be decreased or may be increased based on pollutant loading (decrease with higher pollutant loads)

Runoff coefficients may be calculated for an area contributing to a BMP. Runoff coefficients greater than about 0.55 are typical of urban areas having 50 percent or more impervious surface. Typical runoff coefficients are shown on these pages ([4], [5]) and discussed here.

#### Stormwater infiltration BMPs - contributing drainage area

Link to this table

| Stormwater BMP | Recommended contributing area | Notes |
|---|---|---|
| Infiltration Basin | 50 acres or less | A natural or constructed impoundment that captures, temporarily stores and infiltrates the design volume of water into the surrounding naturally permeable soil over several days. In the case of a constructed basin, the impoundment is created by excavation or embankment. |
| Bioinfiltration Basin | 5 acres or less | Bioinfiltration basins must meet the required 48 hour drawdown time and must be sized in order to allow for adequate maintenance. It is HIGHLY RECOMMENDED that bioinfiltration basins be designed to prevent high levels of bounce as submerging vegetation may inhibit plant growth. A maximum wet storage depth of 1.5 feet is HIGHLY RECOMMENDED. |
| Infiltration Trench | 5 acres or less | |
| Dry Well Synonym: Infiltration Tube, French Drain, Soak-Away Pits, Soak Holes | 1 acre or less (rooftop only) | |
| Underground Infiltration | 10 acres or less | Though feasible, larger underground infiltration systems may cause groundwater contamination as water is not able to infiltrate through a surface cover. In addition, wind flocculation, UV degradation, and bacterial degradation, which provide additional treatment in surface systems, do not occur in underground systems. Because performance research is lacking for larger features, it is HIGHLY RECOMMENDED that the contributing drainage area to a single device not exceed 10 acres. |
| Dry Swale with Check Dams | 5 acres or less | |
| Permeable Pavement | It is RECOMMENDED that external contributing drainage area not exceed the surface area of the permeable pavement. It is HIGHLY RECOMMENDED that external contributing drainage area not exceed twice the surface area of the permeable pavement | It is RECOMMENDED that external drainage area be as close to 100% impervious as possible. Field experience has shown that drainage area (pervious or impervious) can contribute particulates to the permeable pavement and lead to clogging. Therefore, sediment source control and/or pre-treatment should be used to control sediment run-on to the permeable pavement section. |

| Stormwater BMP | Recommended contributing area | Notes |
|---|---|---|
| Tree Trench/Tree Box | up to 0.25 acres per tree | |

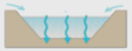
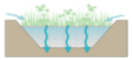
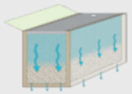
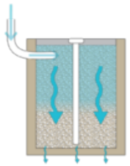
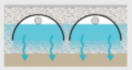
References: Virginia, North Carolina, West Virginia, Maine, Lake Tahoe, Connecticut, Massachusetts, New York, Wisconsin, Vermont, New Hampshire, Ontario, Pennsylvania

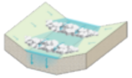
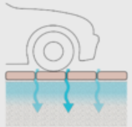
### Treatment properties table

The following table provides information on pollutant removal mechanism(s), location in the stormwater treatment train, general pollutant removal, and potential applications for each of the stormwater BMPs.

**Stormwater infiltration BMPs - treatment properties**

Link to this table

| Stormwater BMP | Illustration | Pollutant Removal Mechanism | Location in Treatment Train | Pollutant Removal [1,2] | Potential Application [1] |
|---|---|---|---|---|---|
| Infiltration Basin |  | Sedimentation / Infiltration | End | TSS: High<br>TN: Medium/High TP: Medium/High Chloride: Low Metals: High Oils and Grease: High<br><br>Pathogens: High | Residential: Yes<br>Commercial: Yes Ultra Urban: Limited Industrial: Limited Retrofit: Yes<br><br>Highway/Road: Limited |
| Bioinfiltration Basin |  | Sedimentation / Infiltration | Beginning | TSS: High<br>TN: Low/Medium TP: Medium/High Chloride: Low Metals: High<br><br>Oils and Grease: High | Residential: Yes<br>Commercial: Yes Ultra Urban: Limited Industrial: Limited Retrofit: Yes<br><br>Highway/Road: Limited |
| Infiltration Trench<br>Synonym: Infiltration Gallery |  | Infiltration | nd | TSS: High<br>TN: Medium/High TP: Medium/High Chloride: Low Metals: High Oils and Grease: High<br><br>Pathogens: High | Residential: Yes<br>Commercial: Yes Ultra Urban: Yes Industrial: Limited Retrofit: Yes<br><br>Highway/Road: Yes |
| Dry Well<br>Synonym: Infiltration Tube, French Drain, Soak-Away Pits, Soak Holes |  | Infiltration | throughout | TSS: High<br>TN: Medium/High TP: Medium/High Chloride: Low Metals: High Oils and Grease: High<br><br>Pathogens: High | Residential: Yes<br>Commercial: Yes Ultra Urban: Yes Industrial: Limited Retrofit: Yes<br><br>Highway/Road: No |
| Underground Infiltration |  | Sedimentation / Infiltration / Flotation/Skimming | End | TSS: High<br>TN: Medium/High TP: Medium/High Chloride: Low Metals: High Oils and Grease: High<br><br>Pathogens: High | Residential: Yes<br>Commercial: Yes Ultra Urban: Yes Industrial: Limited Retrofit: Yes<br><br>Highway/Road: Limited |

| Stormwater BMP | Illustration | Pollutant Removal Mechanism | Location in Treatment Train | Pollutant Removal | Potential Application |
|---|---|---|---|---|---|
| Dry Swale with Check Dams |  | Sedimentation / Infiltration | Throughout | TSS: High<br>TN: Low/Medium TP: Low/Medium Chloride: Low Metals: High Oils and Grease: High<br><br>Pathogens: Medium | Residential: Yes<br>Commercial: Yes Ultra Urban: Limited Industrial: Yes Retrofit: Limited<br><br>Highway/Road: Yes |
| Permeable Pavement |  | Infiltration | Beginning | TSS: High<br>TN: Medium/High TP: Medium/High Chloride: Low Metals: High<br><br>Oils and Grease: High | Residential: Yes<br>Commercial: Yes Ultra Urban: Yes Industrial: Limited Retrofit: Yes<br><br>Highway/Road: Limited |
| Tree Trench/Tree Box |  | Infiltration, Transpiration | Throughout | TSS: High<br>TN: Medium/High TP: Medium/High Chloride: Low Metals: High Oils and Grease: High<br><br>Pathogens: High | Residential: Limited<br>Commercial: Yes Ultra Urban: Yes Industrial: Limited Retrofit: Yes<br><br>Highway/Road: Limited |

[1] Treatment Capabilities and Potential Applications referenced from Manual Section BMP's for stormwater infiltration

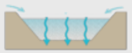
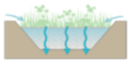
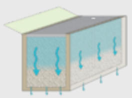
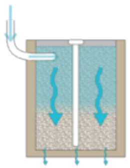
[2] Low = < 30%; Medium = 30-65%; High = 65-100%

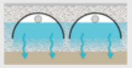
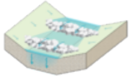
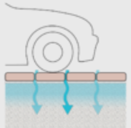
### Selection considerations table

The following table provides information on general cost, maintenance requirements, pretreatment needs, and habitat quality for each of the stormwater infiltration BMPs.

**Stormwater infiltration BMPs – selection considerations**

Link to this table

| Stormwater BMP | Illustration | Cost | Maintenance Requirements [3] | Pre-treatment [4] | Habitat Quality [5] |
|---|---|---|---|---|---|
| Infiltration Basin |  | Low $0.5-$1.3 CF | Simple-Intensive | Needed Oil/Water Separator, Vegetated Filter, Sediment Basin, Water Quality Inlets | Low |
| Bioinfiltration Basin |  | Low $0.5-$1.3 CF | Simple-Intensive | Needed Oil/Water Separator, Vegetated Filter, Sediment Basin, Water Quality Inlets | Medium-High |
| Infiltration Trench Synonym: Infiltration Gallery |  | Low $1-$4 CF | Medium | Needed<br>Oil/Water Separator, Vegetated Filter, Sediment<br><br>Basin, Water Quality Inlets | None |
| Dry Well Synonym: Infiltration Tube, French Drain, Soak-Away Pits, Soak Holes |  | Low $1-$4 CF | Medium | Needed<br>Oil/Water Separator, Vegetated Filter, Water<br><br>Quality Inlets | None |

| Stormwater BMP | Illustration | Cost | Maintenance Requirements | Pre-treatment | Habitat Quality |
|---|---|---|---|---|---|
| Underground Infiltration |  | High 14 CF | Medium | Needed Oil/Water Separator, Water Quality Inlets | None |
| Dry Swale with Check Dams |  | Low $.5-$1.3 CF | Simple-Medium | Needed Vegetated Filter, Water Quality Inlets | Low-Medium |
| Permeable Pavement |  | Medium 3-10 CF | Medium | No Pretreatment Required | None |
| Tree Trench/Tree Box |  | High<br>$1.80 - $12.70 CF based on recommended soil volume<br><br>of 1,414 CF per tree | Intensive | Needed Oil/Water Separator, Water Quality Inlets | Medium |

[1] Maintenance requirements to be addressed and updated in future section

[2] Pretreatment requirements to be revised as per updated section

[3] Habitat quality refers to the possible diversity of plantings commonly installed with each BMP

### See Infiltration Summary Table

To see all information contained in the previous tables in a single table, click on the following link: Infiltration Summary Table

## Related pages for stormwater infiltration

- Overview of stormwater infiltration
- Pre-treatment considerations for stormwater infiltration
- BMPs for stormwater infiltration
- Pollutant fate and transport in stormwater infiltration systems
- Surface water and groundwater quality impacts from stormwater infiltration
- Stormwater infiltration and groundwater mounding
- Stormwater infiltration and setback (separation) distances
- Karst
- Shallow soils and shallow depth to bedrock
- Shallow groundwater
- Soils with low infiltration capacity
- Potential stormwater hotspots
- Stormwater and wellhead protection
- Stormwater infiltrations and contaminated soils and groundwater
- Decision tools for stormwater infiltration
- Stormwater infiltration research needs
- References for stormwater infiltration

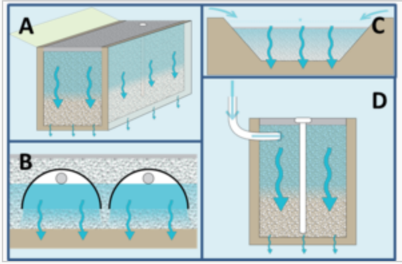
## Related pages for infiltration BMPs

- Infiltration portal

- Overview for infiltration
- Types of infiltration
- Design criteria for infiltration
- Construction specifications for infiltration
- Operation and maintenance of stormwater infiltration practices
- Assessing the performance of infiltration
- Calculating credits for infiltration
- Cost-benefit considerations for infiltration
- Case studies for infiltration
- External resources for infiltration
- References for infiltration
- Requirements, recommendations and information for using infiltration basin/underground infiltration BMPs in the MIDS calculator

- Understanding and interpreting soils and soil boring reports for infiltration BMPs
- Determining soil infiltration rates
- Cold climate considerations for infiltration practices - See [6], [7]

# Design criteria



Schematic illustrating A)infiltration trench, B) underground infiltration, C) infiltration basin, and D) dry well.

This page provides a discussion of design elements and design steps for infiltration practices. These practices include infiltration trench, infiltration basin, dry wells, and underground infiltration practices, although many of the design guidelines can be applied to other infiltration practices.

**Green Infrastructure:** Infiltration practices can be an important tool for retention and detention of stormwater runoff. Depending on design and construction, infiltration practices may provide additional benefits, including cleaner air, carbon sequestration, improved biological habitat, and aesthetic value.

## Terminology

The following terminology is used throughout this design page.

**Warning:** *REQUIRED* - Indicates design standards stipulated by the MPCA Construction General Permit (CGP) or other consistently applicable regulations

*HIGHLY RECOMMENDED* - Indicates design guidance that is extremely beneficial or necessary for proper functioning of the infiltration practice, but not specifically required by the MPCA CGP.

*RECOMMENDED* - Indicates design guidance that is helpful for infiltration practice performance but not critical to the design.

## Details and CADD images

- CADD dwg file for infiltration basin plan and profile
- CADD images

- Infiltration basin plan and profile: File:Infiltration Basin INFILTRATION BASIN PLAN & PROFILE (1).pdf
- Infiltration subsurface layout: File:Infiltration Subsurface Layout2 (1).pdf
- Infiltration trench section: File:INFILTRATION TRENCH INFILTRATION TRENCH SECTION (1).pdf

- Details for underground systems: Underground systems are proprietary devices. Detail varies between each practice. We therefore include links to examples of commonly used devices. We acknowledge there are many more of these devices and reference to any specific commercial product, process, or service by trade name, trademark, service mark, manufacturer, or otherwise does not constitute or imply endorsement, recommendation, or favoring by the Minnesota Pollution Control Agency.
  - ChamberMaxx Retention
  - Terre Arch
  - Triton Stormwater Solutions Chamber System
  - StormTrap Singletrap example project and StormTrap Doubletrap example project
  - Stormtech systems
  - Contech systems

**Caution:** *Reference to any specific commercial product, process, or service by trade name, trademark, service mark, manufacturer, or otherwise does not constitute or imply endorsement, recommendation, or favoring by the Minnesota Pollution Control Agency.*

## Major design elements - Physical feasibility initial check

Before deciding to use an infiltration practice for stormwater management, it is helpful to consider several items that bear on the feasibility of using such a device at a given location. This section describes considerations in making an initial judgment as to whether or not an infiltration practice is the appropriate BMP for the site. The following links provide additional information on specific constraints to infiltration.

- Karst
- Shallow soils and shallow depth to bedrock
- Shallow groundwater
- Soils with low infiltration capacity
- Separation distances
- Potential stormwater hotspots
- Wellhead protection
- Contaminated soils and groundwater
- Procedures for investigating sites with potential constraints

### Contributing drainage area

Contributing area is defined as the total area, including pervious and impervious surfaces, contributing to a BMP. It is assumed that in most cases, with the exception of green roofs and many permeable pavement systems, impervious surfaces will constitute more than 50 percent of the contributing area to the BMP and that most of this impervious is directly connected. The recommended contributing area to a BMP may be modified for the following conditions.

- The recommended contributing area may be increased if pervious surfaces constitute the majority of the contributing area and soils are hydrologic soil group (HSG) A or B
- The recommended contributing area should be decreased if impervious surfaces contribute more than 80 percent of the contributing area or if the entire impervious surface is directly connected and routed to the BMP
- The recommended contributing area should be decreased or may be increased based on pollutant loading (decrease with higher pollutant loads)

Runoff coefficients may be calculated for an area contributing to a BMP. Runoff coefficients greater than about 0.55 are typical of urban areas having 50 percent or more impervious surface. Typical runoff coefficients are shown on these pages ([8], [9]) and discussed here.

It is *HIGHLY RECOMMENDED* that the following infiltration practices be designed with the indicated maximum drainage areas. See the table below for recommended contributing drainage areas for all infiltration BMPs.

- Dry well – 1 acre or less; rooftop only
- Infiltration Trench – 5 acres or less
- Underground Infiltration System – 10 acres or less
- Infiltration Basin – 50 acres or less. Contributing drainage areas should have a maximum 5:1 ratio of impervious area to infiltration area.

Infiltration practices must meet the required 48 hour drawdown time and must be sized in order to allow for adequate maintenance without increasing compaction. Information on recommended contributing drainage areas for all infiltration practices is shown in the following table.

**Stormwater infiltration BMPs - contributing drainage area**

Link to this table

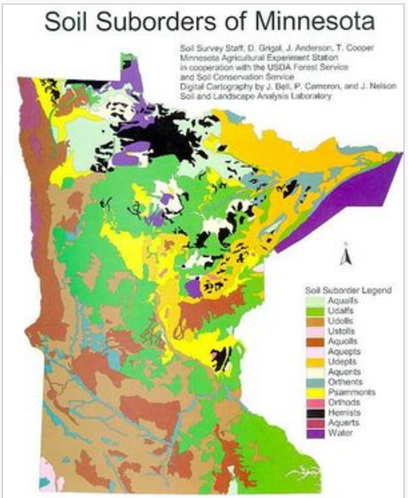
| Stormwater BMP | Recommended contributing area | Notes |
|---|---|---|
| Infiltration Basin | 50 acres or less | A natural or constructed impoundment that captures, temporarily stores and infiltrates the design volume of water into the surrounding naturally permeable soil over several days. In the case of a constructed basin, the impoundment is created by excavation or embankment. |
| Bioinfiltration Basin | 5 acres or less | Bioinfiltration basins must meet the required 48 hour drawdown time and must be sized in order to allow for adequate maintenance. It is HIGHLY RECOMMENDED that bioinfiltration basins be designed to prevent high levels of bounce as submerging vegetation may inhibit plant growth. A maximum wet storage depth of 1.5 feet is HIGHLY RECOMMENDED. |
| Infiltration Trench | 5 acres or less | |
| Dry Well Synonym: Infiltration Tube, French Drain, Soak-Away Pits, Soak Holes | 1 acre or less (rooftop only) | |
| Underground Infiltration | 10 acres or less | Though feasible, larger underground infiltration systems may cause groundwater contamination as water is not able to infiltrate through a surface cover. In addition, wind flocculation, UV degradation, and bacterial degradation, which provide additional treatment in surface systems, do not occur in underground systems. Because performance research is lacking for larger features, it is HIGHLY RECOMMENDED that the contributing drainage area to a single device not exceed 10 acres. |
| Dry Swale with Check Dams | 5 acres or less | |
| Permeable Pavement | It is RECOMMENDED that external contributing drainage area not exceed the surface area of the permeable pavement. It is HIGHLY RECOMMENDED that external contributing drainage area not exceed twice the surface area of the permeable pavement | It is RECOMMENDED that external drainage area be as close to 100% impervious as possible. Field experience has shown that drainage area (pervious or impervious) can contribute particulates to the permeable pavement and lead to clogging. Therefore, sediment source control and/or pre-treatment should be used to control sediment run-on to the permeable pavement section. |
| Tree Trench/Tree Box | up to 0.25 acres per tree | |

References: Virginia, North Carolina, West Virginia, Maine, Lake Tahoe, Connecticut, Massachusetts, New York, Wisconsin, Vermont, New Hampshire, Ontario, Pennsylvania

## Site Topography and Slopes

Unless slope stability calculations demonstrate otherwise (see [10], [11], [12], it is *HIGHLY RECOMMENDED* that infiltration practices be located a minimum horizontal distance of 200 feet from down-gradient slopes greater than 20 percent, and that slopes in contributing drainage areas be limited to 15 percent.

### Soils



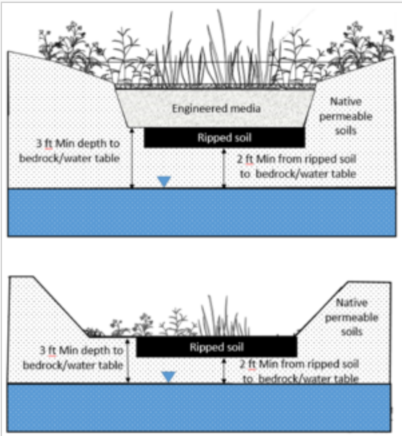

Statewide map of soil suborders. While soil infiltration rates vary widely within a soil order or suborder, infiltration rates tend to be lower on mollisols, histisols and vertisols compared to entisols, inceptisols, spodosols, and alfisols. Source: University of Minnesota

It is *HIGHLY RECOMMENDED* that native soils in proposed infiltration areas have a minimum infiltration rate of 0.2 inches per hour (typically Hydrologic Soil Group A, B and C soils). Initially, soil infiltration rates can be estimated from NRCS soil data, and confirmed with an on-site infiltration evaluation or geotechnical investigation (see Step 5 of the Design procedures section for investigation procedures). It is *HIGHLY RECOMMENDED* that native soils have silt/clay contents less than 40 percent and clay content less than 20 percent, and that infiltration practices not be situated in fill soils.

**Warning:** It is *REQUIRED* that impervious area construction be completed and pervious areas established with dense and healthy vegetation prior to introduction of stormwater into an infiltration practice.

### Depth to groundwater table and bedrock

**Warning:** A separation distance of 3 feet is REQUIRED between the bottom of the infiltration practice and the elevation of the seasonally high water table (saturated soil) or top of bedrock (i.e. there must be a minimum of 3 feet of undisturbed soil beneath the infiltration practice and the seasonally high water table or top of bedrock). See also Step 7 under the Design procedures section.




Schematic illustrating separation distance from bottom of infiltration BMP and soil ripped zones to water table or top of bedrock

Note that if underlying soils are ripped to alleviate compaction, the requirement is a 2 foot minimum between the bottom of the ripped zone and a 3 foot minimum from the bottom of the infiltration practice. If there is only a 3 foot separation distance between the bottom of the infiltration practice and the elevation of the seasonally high water table or bedrock, limit ripping depth to 12 inches. See the alleviating compaction and soil ripping webpages for more detail on compaction prevention.

### Site Location / Minimum Setbacks

The following table summarizes horizontal and vertical setback distances for required and recommended minimum distances from an infiltration practice to an above-ground or underground structure. It will be necessary to consult local ordinances for further guidance on siting infiltration practices.

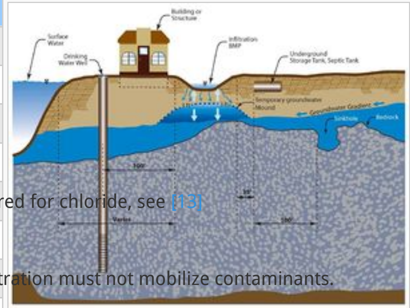
**Warning:** The minimum setback for public water supplies in the table below are *REQUIRED* by the Minnesota Department of Health for the design and location of infiltration practices. It will be necessary to consult local ordinances for further guidance on siting infiltration practices.

**Required and recommended minimum vertical and horizontal separation distances. This represents the minimum distance from the infiltration practice to the structure of concern. If the structure is above-ground, the distance is measured from the edge of the BMP to the structure. If the structure is underground, the vertical separation distance represents the distance from the point of infiltration through the bottom of the system to the structure, while the horizontal separation (often called setback) distance is the shortest distance from the edge of the system to the structure.**
Link to this table

| Structure | | Distance (feet) | Requirement or recommendation | Note(s) |
|---|---|---|---|---|
| Vertical | Saturated soil | 3 | Requirement[1] | |
| | Bedrock | 3 | Requirement[1] | |
| Horizontal | Public supply well | 100 for sensitive wells; 50 for others | Requirement | |
| | Building/structure/property line[2] | 10 | Recommended | |
| | Surface water | none unless local requirements exist | | If nearby stream is impaired for chloride, see [13] |
| | Septic system | 35 | Recommended | |
| | Contaminated soil/groundwater | | | No specific distance. Infiltration must not mobilize contaminants. |
| | Slope | 200 | Recommended | from toe of slope >= 20% |
| | Karst | 1000 up-gradient 100 down-gradient | Requirement[1] | Active karst |

[1] Required under the Construction Stormwater General Permit

[2] Minimum with slopes directed away from the building



Schematic showing some horizontal and vertical separation distances from an infiltration BMP. A separation distance may be required, such as with a drinking water well, or recommended, as with an underground tank. (Source: CDM Smith) Not to scale.

### Karst

It is *HIGHLY RECOMMENDED* that infiltration practices not be used in active karst formations without adequate geotechnical testing.

**Warning:** The Construction Stormwater permit prohibits permittees from constructing infiltration systems in areas within 1,000 feet upgradient or 100 feet downgradient of active karst features

### Wellhead Protection Areas

See stormwater and wellhead protection for guidance and recommendations for determining the appropriateness of infiltrating stormwater in a Drinking Water Supply Management Area (DWSMA). For more information on source water protection see Minnesota Department of Health.

## Major design elements - Practice and site considerations

If physical attributes of a site do not prohibit infiltration, there are several considerations for the infiltration practice and site.

Photo of a Infiltration trench in Lino Lakes. This site illustrates how site

### Conveyance

It is *HIGHLY RECOMMENDED* that a flow splitter or diversion structure be provided to divert the water quality volume ($V_{wq}$) to the infiltration practice and allow larger flows to bypass the practice unless the infiltration practice is sized to retain larger volumes (Channel protection criteria (Vcp), Overbank flood protection criteria (Vp10) or Extreme flood control criteria (Vp100)). Where a flow splitter is not used, it is *HIGHLY RECOMMENDED* that contributing drainage areas be limited to the appropriate size given the BMP and an overflow be provided within the practice to pass part of the $V_{wq}$ to a stabilized watercourse or storm drain. It is also *HIGHLY RECOMMENDED* that overflow associated with the $V_{p10}$ or $V_{p100}$ storm (depending on local drainage criteria) be controlled such that velocities are non-erosive at the outlet point (to prevent downstream slope erosion), and that when discharge flows exceed 3 cubic feet per second, the designer evaluate the potential for erosion to stabilized areas and infiltration facilities.

An infiltration device can be designed to accommodate a concentrated influent flow; however, an energy dissipater and/or level spreader may be needed. See the pretreatment section for more information on pretreatment devices.

aesthetics and landscaping are considered in the BMP design.

### Underdrains

Perforated elevated underdrains are sometimes used to facilitate infiltration. If an infiltration system does not have an underdrain, it should be designed with dewatering provisions in the event of failure. This can be done with underdrain pipe systems that can be pumped out or allowed to gravity drain to the surface.

The following are *RECOMMENDED* for infiltration practices with underdrains.

- The minimum pipe diameter is 4 inches.
- Install 2 or more underdrains for each infiltration system in case one clogs. At a minimum provide one underdrain for every 1,000 square feet of surface area.
- Include at least 2 observation /cleanouts for each underdrain, one at the upstream end and one at the downstream end. Cleanouts should be at least 4 inches diameter vertical non-perforated schedule 40 PVC pipe, and extend to the surface. Cap cleanouts with a watertight removable cap.
- Construct underdrains with Schedule 40 or SDR 35 smooth wall PVC pipe.
- Install underdrains with a minimum slope of 0.5 percent, particularly in HSG D soils (Note: to utilize Manning's equation the slope must be greater than 0).
- Include a utility trace wire for all buried piping.
- For underdrains that daylight on grade, include a marking stake and animal guard;
- For each underdrain have an accessible knife gate valve on its outlet to allow the option of operating the system as either an infiltration system, filtration system, or both. The valve should enable the ability to make adjustments to the discharge flow so the sum of the infiltration rate plus the under-drain discharge rate equal a 48 hour draw-down time.
- Perforations should be 3/8 inches. Use solid sections of non-perforated PVC piping and watertight joints wherever the underdrain system passes below berms, down steep slopes, makes a connection to a drainage structure, or daylights on grade.
- Spacing of collection laterals should be less than 25 feet.
- Underdrain pipes should have a minimum of 3 inches of washed #57 stone above and on each side of the pipe (stone is not required below the pipe). Above the stone, two inches of choking stone is needed to protect the underdrain from blockage.
- Avoid filter fabric.
- Pipe socks may be needed for underdrains imbedded in sand. If pipe socks are used, then use circular knit fabric.

The procedure to size underdrains is typically determined by the project engineer. An example for sizing underdrains is found in Section 5.7 of the North Carolina Department of Environment and Natural Resources Stormwater BMP Manual. Underdrain spacing can be calculated using the following spreadsheet, which utilizes the vanSchilfgaarde Equation. The spradsheet includes an example calculation. File:Underdrain spacing calculation.xlsx

### Pretreatment

**Warning:** It is *REQUIRED* that some form of pretreatment, such as a plunge pool, sump pit, filter strip, sedimentation basin, grass channel, or a combination of these practices be installed upstream of the infiltration practice.

It is *HIGHLY RECOMMENDED* that the following pretreatment sizing guidelines be followed:

- Before entering an infiltration practice, stormwater should first enter a pretreatment practice sized to treat a minimum volume of 25 percent of the $V_{wq}$.
- If the infiltration rate of the native soils exceeds 2 inches per hour a pretreatment practice capable of treating a minimum volume of 50 percent of the $V_{wq}$ should be installed.
- If the infiltration rate of the native soils exceeds 5 inches per hour a pretreatment practice capable of treating a minimum volume of 100 percent of the $V_{wq}$ should be installed.

It is *HIGHLY RECOMMENDED* that pretreatment practices be designed such that exit velocities from the pretreatment systems are non-erosive (less than 3 feet per second) and flows are evenly distributed across the width of the practice (e.g., by using a level spreader).

**Caution:** - Use low-impact earth moving equipment - DO NOT Overexcavate

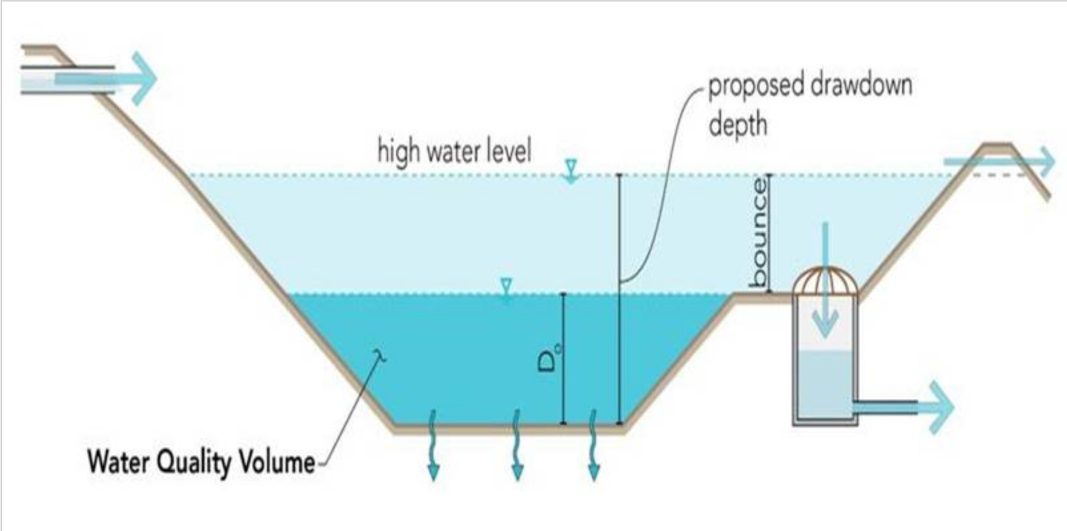
For additional information, see the pretreatment section in the manual.

### Treatment

#### Drawdown time and bounce

For information on assessing the performance of a BMP and determining if it meets the required drawdown time, click here.

**Warning:** The Construction Stormwater permit states: "The Permittee(s) must design the infiltration/filtration system to discharge the water quality volume routed to the system through the soil surface or filter media within 48 hours or less. Additional flows that cannot be infiltrated or filtered within 48 hours must be routed to bypass the system through a stabilized discharge point. The Permittee(s) must design the infiltration system to provide a means to visually verify that the system is discharging through the soil surface or filter media within 48 hours or less."




This schematic defines and demonstrates the concept of bounce and drawdown within an infiltration practice. This figure conceptualizes the water quality volume, the high water level, the proposed drawdown depth, and bounce as they relate to an infiltration practice.

#### Space occupied

Space varies depending on the depth of the practice. Typically, infiltration trenches are 3 to 12 feet deep with a width less than 25 feet. A dry well is essentially a smaller version of an infiltration trench, consistent with the fact that the drainage area to an infiltration trench is typically five times greater (or larger) than that of a dry well. Underground infiltration systems are larger practices that range in depth from approximately 2 to 12 feet. Permeable Pavement systems have an average depth of 2 to 5 feet depending on the pavement and media thickness. The surface area of all infiltration practices is a function of MPCA's 48-hour drawdown requirement and the infiltration capacity of the underlying soils.

The maximum storage volume statically stored within the infiltration practice must completely drawdown within 48 hours. An emergency spillway and/or backup underdrain should be constructed if the infiltration device is unable to dewater within 48 hours.

**Warning:** The Construction Stormwater permit states: "The Permittee(s) must design the infiltration/filtration system to discharge the water quality volume routed to the system through the soil surface or filter media within 48 hours or less. Additional flows that cannot be infiltrated or filtered within 48 hours must be routed to bypass the system through a stabilized discharge point. The Permittee(s) must design the infiltration system to provide a means to visually verify that the system is discharging through the soil surface or filter media within 48 hours or less."

#### Slope of the infiltration practice

It is *RECOMMENDED* that the bottom of all infiltration practices be flat, in order to enable even distribution and infiltration of stormwater. It is *RECOMMENDED* that the longitudinal slope range only from the ideal 0 percent up to 1 percent, and that lateral slopes be held at 0 percent.

#### Side slopes

It is *HIGHLY RECOMMENDED* that the maximum side slope for an infiltration practice is 3:1 (h:v).

#### Depth


Schematic showing the effective infiltration area for side slopes less than 3H:1V.

The depth of an infiltration practice is a function of the maximum drawdown time and the design infiltration rate. When the drawdown time for an infiltration system is 48 hours, the total drawdown depth is 78.2 inches for GW and GP Hydrologic Soil Group (HSG) A soils, 38.4 inches for GM and SW (HSG A) soils; 21.6 inches for SM (HSG B) soils; 14.4 inches for loam, silt loam and MH (HSG B) soils; and 9.6 inches for HSG C soils. If field tested rates for any soil exceeds the rate for A soils in the manual (1.63 inches per hour), the total drawdown depth (water quality volume depth + bounce) must not exceed 6.5 feet. When the drawdown time is 24 hours, the above water quality volume depths are reduced by a factor of 2. Any captured depth (bounce) beyond the water quality volume needs to be removed from the BMP within 48 hours via an emergency spillway designed to overflow at the top of the storage volume and/or a control structure used to limit peak discharge rates.

**Warning:** The REQUIRED drawdown time for infiltration practices is 48 hours or less, and so the depth of the practice should be determined accordingly.

**Warning:Groundwater Protection**: It is *REQUIRED* that runoff from potential stormwater hotspots (PSHs) not be infiltrated unless adequate pretreatment has been provided. Infiltration of runoff from confirmed hotspot areas, industrial areas with exposed significant materials, or vehicle fueling and maintenance areas is *PROHIBITED*.

#### Aesthetics

Infiltration basins can be effectively integrated into the site planning process, and aesthetically designed as attractive green spaces planted with native vegetation. If vegetation is used, the infiltration practice becomes a bioinfiltration practice. See the Design Criteria for bioinfiltration practices webpage for more information. Infiltration trenches are less conducive to site aesthetics, but the surface of trenches can be designed with turf cover crops if desired.

Concerning infiltration practices with exposed filter media, keep adjacent vegetation from forming an overhead canopy above infiltration practices, in order to keep leaf litter, fruits, and other vegetative materials from clogging the filter media.

### Landscaping

**Warning:** It is *REQUIRED* that impervious area construction is completed and pervious areas established with dense and healthy vegetation prior to introduction of stormwater into a vegetated infiltration practice.

Landscaping is critical to the performance and function of vegetated areas of infiltration practices. Therefore, a landscaping plan is *HIGHLY RECOMMENDED* for vegetated infiltration practices. *RECOMMENDED* planting guidelines for vegetated practices are as follows:

- Vegetation should be selected based on a specified zone of hydric tolerance. *Plants for Stormwater Design - Species selection for the Upper Midwest* is a good resource.
- Native plant species should be specified over non-native species. Hardy native species that thrive in our ecosystem without chemical fertilizers and pesticides are the best choices.
- Many vegetated practices feature wild flowers and grasses as well as shrubs and some trees.
- If woody vegetation is placed near inflow locations, it should be kept out of pretreatment devices and be far enough away to not hamper maintenance of pretreatment devices.
- Trees should not be planted directly overtop of under-drains and may be best located along the perimeter of the practice.
- Salt resistant vegetation should be used in locations with probable adjacent salt application, i.e. roadside, parking lot, etc.
- Plugs, bare root plants or potted plants are RECOMMENDED over seed for herbaceous plants, shrubs, and trees. Erosion control mats pre-vegetated with herbaceous plants are also acceptable. For turf, sod is recommended over seed. (NOTE: Fluctuating water levels following seeding (prior to germination) can cause seed to float and be transported, resulting in bare areas that are more prone to erosion and weed invasion than vegetated areas. Seed is also difficult to establish through mulch, a common surface component of vegetated practices. It may take more than two growing seasons to establish the function and desired aesthetic of mature vegetation via seeding.)
- Vegetated practices should be operated off-line for 1 year or, within the first year, until vegetation is established.
- Example target plant coverage includes

- at least 50 percent of specified vegetation cover at end of the first growing season;
- at least 90 percent of specified vegetation cover at end of the third growing season;
- supplement plantings to meet project specifications if cover targets are not met; and
- tailoring percent coverage targets to project goals and vegetation. For example, percent cover required for turf after 1 growing season would likely be 100 percent, whereas it would likely be lower for other vegetation types.

- Vegetated areas should be integrated into the site planning process, and aesthetic considerations should be taken into account in their siting and design.

Operation and maintenance of vegetated practices is critical to meeting these landscape recommendations and targets. For more information on operation and maintenance, see the section on operation and maintenance of stormwater infiltration practices.

### Safety

Dry wells, infiltration trenches and subsurface infiltration systems do not pose any major safety hazards. Infiltration basins should have similar side slope considerations as ponds and wetlands.

**Warning:** If a dry well or infiltration trench is greater than five feet deep, it is *REQUIRED* that OSHA health and safety guidelines be followed for safe construction practices.

Additional information on safety for construction sites is available from OSHA.

### Maximum flow path

Flow path length is important only if high flows are not bypassed. Below are recommendations from other states or localities.

- North Carolina: The geometry of the cell shall be such that width, length, or radius are not less than 10 feet. This is to provide sufficient space for plants.
- Virginia: Length of shortest flow path to overall length is 0.3 for Level 1 Design and 0.8 for Level 2 Design
- Dakota County Soil and Water Conservation District: Where off-line designs are not achievable, bioretention practices shall be designed to route high flows on the shortest flow path across the cell to provide the least disturbance and displacement of the Water Quality Volume to be treated. Energy dissipation to avoid high flow velocity turbulence is required.

### Use of multiple cells

In comparison to multiple cells, one large bioretention or infiltration cell will often perform just as well as multiple smaller cells if sized and designed appropriately. One large cell is generally less costly than multiple smaller cells. This is due to the simpler geometry and grading requirements of one large cell, as well as a reduction in piping and outlet structures. Multiple smaller cells do however provide greater redundancy, i.e. if one large cell fails, more function is lost than if just one of multiple cells fail. Multiple cells are also more feasible than one large cell in steep terrain (slopes greater than 5 percent), where they can be terraced to match the existing grade. Provided access is maintained to each cell, multiple cells typically results in less and easier maintenance.

### Snow considerations

Considering management of snow, the following are recommended.

- Plan a plow path during design phase and tell snowplow operators where to push the snow. Plan trees around (not in) plow path, with a 16 foot minimum between trees.
- Plan for snow storage (both temporary during construction and permanent). Don’t plow into raingardens routinely. Raingardens should be a last resort for snow storage (i.e. only for very large snow events as “emergency overflow”.
- Snow storage could be, for example, a pretreatment moat around a raingarden, i.e. a forebay for snow melt.

For more information and example photos, see the section on snow and ice management.

## Materials specifications

Specifications for infiltration basin, infiltration trench, dry well, and underground infiltration practices are provided below. The table below shows a comparison of different material specifications for infiltration practices. To view this information in an Excel file, link here.

### Observation well

- Vertical 4- to 6-inch Schedule 40 PVC perforated pipe according to MNDOT Manual Section 3248 with a lockable cap and anchor plate within gravel portion of bed
- Install one per 50 feet of length of infiltration practice
- Bottom of the cap shall rest on the bottom of the infiltration practice

### Emergency overflow structure

**Infiltration trench and infiltration basin**

- All infiltration beds should be designed with overflow spillway for extreme storm events
- Properly designed vegetated filters are required from the overflow of all infiltration systems

**Dry well**

- A surcharge pipe should be constructed as an emergency overflow device for Dry Wells which receive runoff directly from a roof leader

### High flow bypass structure

**Infiltration trench and infiltration basin**

- A high flow bypass or diversion structure should be included to safely convey high flows from large storm events
- Control in beds is usually provided as an outlet control structure
- Modified inlet box with internal concrete weir (or weir plate) and low-flow orifice is common
- High flows must be bypassed within 48 hours and allow the infiltration practice to meet the 48 hour drawdown requirement

**Underground infiltration**

- A flow bypass structure should be located upgradient of the infiltration structure to convey high flows around the structure
- High flows must be bypassed within 48 hours and allow the infiltration practice to meet the 48 hour drawdown requirement

### Buffer vegetation

**Infiltration basin, underground infiltration, dry well**

- Keep adjacent vegetation from forming overhead canopy above infiltration practices. This keeps leaf litter, fruits, and other vegetative material from clogging stone
- For infiltration basins, trees may be planted along side slopes but must be 15 ft away from pipes and 25 ft away from risers.

**Infiltration trench**

- Grass strip or other vegetated buffer at least 20 feet wide should be maintained around trenches accepting surface runoff as sheet flow
- Slope of filter strip should be approximately 1% along entire length and 0% across width

### Surface cover

**Infiltration basin**

- For stone cover: apply a two inch layer of pea gravel or river stone

#### Infiltration trench

- 3-inch layer of river stone or pea gravel with filter fabric and additional aggregate on top

#### Underground infiltration

- Permeable topsoil and planted with grass
- Deep-rooted plants, such as prairie grass, should be used to increase infiltration capacity
- Bottom and side slopes of basin should be planted with dense water-tolerant grass (such as fescues)
- Soil cover (12 - 18 inches) should be maintained above infiltration bed to allow for a healthy vegetative cover
- Overly infiltration bed with native grasses, meadow mix, or other low-growing, dense vegetation
- In place of turf, use basin liner of 6 to 12 inches of fill material (coarse sand)

#### Dry well

- Covered by a minimum of 12 inches of topsoil

### Filter bed (stone)

#### Infiltration basin

- 1 to 3-foot thick layer of double-washed, uniform (uniformity coefficient of 2 or smaller with a void ratio of 0.40) aggregate between 1.5 and 3.0 inch diameter
- MNDOT Coarse Aggregate Bedding (Section 3149 G.2) ranging 1-2 inch in gradation

#### Infiltration trench

- 1 to 4-foot thick layer of double-washed, uniform (uniformity coefficient of 2 or smaller with a void ratio of 0.40) aggregate between 1.5 and 3.0 inch diameter
- MNDOT Coarse Aggregate Bedding (Section 3149 G.2) ranging 1-2 inch in gradation

#### Underground infiltration

- 1 to 4-foot thick layer of double-washed, uniform (uniformity coefficient of 2 or smaller with a void ratio of 0.40) aggregate between 1.5 and 3.0 inch diameter
- MNDOT Coarse Aggregate Bedding (Section 3149 G.2) ranging 1-2 inch in gradation

#### Dry well

- Double-washed, uniform (uniformity coefficient of 2 or smaller with a void ratio of 0.40) aggregate between 1.5 and 3.0 inch diameter
- MNDOT Coarse Aggregate Bedding (Section 3149 G.2) ranging 1-2 inch in gradation

### Filter fabric

#### Infiltration basin

- Top of geotextile should be 6-12 inches below upper surface of drainage media with 12" overlap of fabric seams
- Fabric should be placed between side walls and between stone and gravel layers but not on the basin bottom
- Geotextile must meet MNDOT Type I Non-woven geotextile
- Examples: Mirafi 140N, Amoco 4547, and Geotex 451

#### Infiltration trench

- Surround fill on sides with filter fabric with 12" overlap of fabric seams. A separate piece should be used for the top layer to act as a failure plane
- Fabric should be placed between side walls and between stone and gravel layers but not on the trench bottom
- Geotextile must meet MNDOT Type I non-woven geotextile
- Examples: Mirafi 140N, Amoco 4547, and Geotex 451

#### Underground infiltration

- Surround fill on sides with filter fabric with 12" overlap of fabric seams
- Geotextile must meet MNDOT Type I non-woven geotextile
- Examples: Mirafi 140N, Amoco 4547, and Geotex 451

**Dry well**

- Geotextile on trench sides and top keyed into drywell
- Geotextile must meet MNDOT Type I non-woven geotextile
- Examples: Mirafi 140N, Amoco 4547, and Geotex 451

### Bottom

**Infiltration basin, infiltration trench, underground infiltration, dry well**
Any of the following can be used on the bottom:

- 6 to 8 inch clean sand (1-2 percent fines or less)
- 3/8 inch pea gravel
- 6-12 inch layer of MNDOT Fine Filter Aggregate (Section 3149 J.2)
- 12" of gravel or sand (good for cold climates)

### In-situ soils

**Infiltration basin, infiltration trench, underground infiltration, dry well**
NRCS Type A and B soils are the most efficient soils for proper infiltration. Type C soils are acceptable of the infiltration practice meets the required 48 hour drawdown period

### Miscellaneous considerations

- All material must be placed such that compaction is avoided. See the Construction Specifications webpage for more details
- For infiltration trench and underground infiltration, plastic, aluminum, or concrete gallery frames can be inserted to increase the runoff capture storage volume.

## Infiltration material specifications

Link to this table. To open this table in Excel format, link here.

| Component | Infiltration basin | Bioinfiltration basin | Infiltration trench | Underground infiltration | Dry well | Dry swale with check dams | Permeable pavement | Tree trench/box/planter |
|---|---|---|---|---|---|---|---|---|

| Component | Infiltration basin | Bioinfiltration basin | Infiltration trench | Underground infiltration | Dry well | Dry swale with check dams | Permeable pavement | Tree trench/box/planter |
|---|---|---|---|---|---|---|---|---|
| Observation well | • Vertical 4- to 6-inch Schedule 40 PVC perforated pipe according to MNDOT Manual Section 3248 with a lockable cap and anchor plate within gravel portion of bed<br>• Install one per 50 ft. of length of infiltration practice<br>• Cap should be flush with or above the surface of the infiltration practice | | | | | | • Vertical 4- to 6-inch Schedule 40 PVC perforated pipe according to MNDOT Manual Section 3248 with a lockable cap and anchor plate within gravel portion of bed<br>• Install one per 50 ft. of length of infiltration practice<br>• Install at downstream end of all permeable pavement systems >10,000 $ft^2$ contributing drainage area | • Vertical 4- to 6-inch Schedule 40 PVC perforated pipe according to MNDOT Manual Section 3248 with a lockable cap and anchor plate within gravel portion of bed<br>• Install one per 50 ft. of length of infiltration practice<br>• Cap should be flush with or above the surface of the infiltration practice |
| Emergency overflow structure | • All infiltration beds should be designed with overflow spillway for extreme storm events<br>• Properly designed vegetated filters are required from the overflow of all infiltration systems<br>• See detail | | | NA | A surcharge pipe should be constructed as an emergency overflow device for Dry Wells which receive runoff directly from a roof leader. [14] | NA | See Design criteria for permeable pavement | Tree box filters should be designed with an emergency overflow pipe |

| Component | Infiltration basin | Bioinfiltration basin | Infiltration trench | Underground infiltration | Dry well | Dry swale with check dams | Permeable pavement | Tree trench/box/planter |
|---|---|---|---|---|---|---|---|---|
| High flow bypass structure | • A high flow bypass or diversion structure should be included to safely convey high flows from large storm events<br>• Control in beds is usually provided as an outlet control structure<br>• Modified inlet box with internal concrete weir (or weir plate) and low-flow orifice is common<br>• High flows must be bypassed within 48 hours and allow the infiltration practice to meet the 48 hour drawdown requirement | | | • A flow bypass structure should be located upgradient of the infiltration structure to convey high flows around the structure<br>• High flows must be bypassed within 48 hours and allow the infiltration practice to meet the 48 hour drawdown requirement | NA | NA | NA | NA |

| Component | Infiltration basin | Bioinfiltration basin | Infiltration trench | Underground infiltration | Dry well | Dry swale with check dams | Permeable pavement | Tree trench/box/planter |
|---|---|---|---|---|---|---|---|---|
| Buffer vegetation | • Keep adjacent vegetation from forming an overhead canopy above infiltration practices. This keeps leaf litter, fruits, and other vegetative material from clogging stone.<br>• Trees may be planted along side slopes but must be 15 ft away from pipes and 25 ft away from risers | | • Grass strip or other vegetated buffer at least 20 feet wide should be maintained around trenches accepting surface runoff as sheet flow<br>• Slope of filter strip should be approximately 1% along entire length and 0% across width | Keep adjacent vegetation from forming an overhead canopy above infiltration practices. This keeps leaf litter, fruits, and other vegetative material from clogging stone. | | • Planted with turf grass, tall meadow grasses, decorative herbaceous cover, or trees<br>• See MNDOT Standards and Specs Section 3876 for Seed Requirements for Dry Swales<br>• If receiving runoff from an impervious area, construct an adjacent grass filter strip, gravel diaphragm, or gravel flow spreader to provide pretreatment | NA | • Although deep rooted, native species are preferred, noninvasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities<br>• See MNDOT Standards and Specifications for Native Species<br>• Energy dissipator Stones placed over the mulch layer may be used as a pretreatment to reduce velocity of inflow |
| Surface cover | For stone cover: apply a two inch layer of pea gravel or river stone | • Establish dense vegetation on basin side slopes and floor:<br>◦ Dry- and mesic-prairie species for side slopes<br>◦ Wet meadow species for lower portions<br>• Mulch (2-3 inch layer) must be free of weeds and consist of aged, double-shredded | 3-inch layer of river stone or pea gravel with filter fabric and additional aggregate on top | • Permeable topsoil and planted with grass.<br>• Deep-rooted plants, such as prairie grass, should be used to increase infiltation capacity<br>• Bottom and side slopes of basin should be planted with dense water-tolerant grass (such as fescues) | Covered by a minimum of 12 inches of topsoil | • 3" layer of mulch on surface to enhance plant survival<br>• See MNDOT Standards and Specs Section 3882 for Mulch Requirements<br>• Erosion control matting can be used in lieu of mulch where flow velocities may wash mulch away | • Porous Asphalt Course: 3 to 7 inch thick layer with 15% to 20% void content<br>• Pervious Concrete Course: 5 to 8 inch thick layer with 15% to 25% void content[1]<br>• Plastic Grid Pavers: depends on fill material<br>• Concrete Grid Pavers: 3.5 inch thick layer with 20% to 50% void content<br>• Concrete Interlocking Pavers: 3 inch thick | • 3" layer of mulch on surface to enhance plant survival<br>• See MNDOT Standards and Specs Section 3882 for Mulch Requirements |

| Component | Infiltration basin | Bioinfiltration basin | Infiltration trench | Underground infiltration | Dry well | Dry swale with check dams | Permeable pavement | Tree trench/box/planter |
|---|---|---|---|---|---|---|---|---|
| | | hardwood bark mulch or shredded leaf mulch<br>• Sand, if used, must comply with MNDOT Sand Cover in Section 3149 K<br>• Deep-rooted, native species for vegetative cover<br>• If sod is used, grow over permeable soils | | • Soil cover (12 - 18 inches) should be maintained above infiltration bed to allow for a healthy vegetative cover<br>• Overly infiltration bed with native grasses, meadow mix, or other low-growing, dense vegetation<br>• In place of turf, use basin liner of 6 to 12 inches of fill material (coarse sand) | | | layer with 5% to 15% void content[1]<br>• Min Thickness (NAPA, 2008)<br>◦ Parking: 2.5 in<br>◦ Residential Trucks: 4.0 in<br>◦ Heavy Truck: 6.0 in | |
| Intermediate layer | NA | NA | NA | NA | NA | NA | Choker Layer: A 2 to 8 inch bedding coarse of Medium Filter Aggregate (MNDOT Section 3149 J.1) is usually placed over the top of the base material to help stabilize the irregular surface | NA |

| Component | Infiltration basin | Bioinfiltration basin | Infiltration trench | Underground infiltration | Dry well | Dry swale with check dams | Permeable pavement | Tree trench/box/planter |
|---|---|---|---|---|---|---|---|---|
| Filter bed (stone) | • 1 to 3-foot thick layer of double-washed, uniform (uniformity coefficient of 2 or smaller with a void ratio of 0.40) aggregate between 1.5 and 3.0 inch diameter<br>• MNDOT Coarse Aggregate Bedding (Section 3149 G.2) ranging 1-2 inch in gradation | Bioinfiltration engineered soil mix | • 1 to 4-foot thick layer of double-washed, uniform (uniformity coefficient of 2 or smaller with a void ratio of 0.40) aggregate between 1.5 and 3.0 inch diameter<br>• MNDOT Coarse Aggregate Bedding (Section 3149 G.2) ranging 1-2 inch in gradation | | • Double-washed, uniform (uniformity coefficient of 2 or smaller with a void ratio of 0.40) aggregate between 1.5 and 3.0 inch diameter<br>• MNDOT Coarse Aggregate Bedding (Section 3149 G.2) ranging 1-2 inch in gradation | 20-30 inch layer of permeable manufactured soil mixture meeting the bioinfiltration soil mix | • Reservoir Layer: 1 to 4-foot deep bed of double-washed, uniform (uniformity coefficient of 2 or smaller with a void ratio of 0.40) aggregate between 1.5 and 3.0 inch diameter<br>• MNDOT Coarse Aggregate Bedding (Section 3149 G.2) ranging 1-2 inch in gradation | 3' of bioinfiltration Soil Media |
| Filter fabric | • Top of geotextile should be 6-12 inches below upper surface of drainage media with 12" overlap of fabric seams<br>• Fabric should be placed between side walls and between stone and gravel layers but not on the basin bottom<br>• Geotextile must meet MNDOT Type I Non-woven geotextile<br>• Examples: Mirafi 140N, Amoco 4547, and Geotex 451. | • Geotextile or a pea gravel filter separating stone and soil media<br>• Geotextile must meet MNDOT Type I non-woven geotextile<br>• Examples: Mirafi 140N, Amoco 4547, and Geotex 451 | • Surround fill on sides with filter fabric with 12" overlap of fabric seams. A separate piece should be used for the top layer to act as a failure plane. Fabric should be placed between side walls and between stone and gravel layers but not on the trench bottom.<br>• Geotextile must meet MNDOT Type I non-woven geotextile<br>• Examples: Mirafi 140N, Amoco 4547, and Geotex 451 | • Surround fill on sides with filter fabric with 12" overlap of fabric seams<br>• Geotextile must meet MNDOT Type I non-woven geotextile<br>• Examples: Mirafi 140N, Amoco 4547, and Geotex 451 | • Geotextile on trench sides and top keyed into drywell<br>• Geotextile must meet MNDOT Type I non-woven geotextile<br>• Examples: Mirafi 140N, Amoco 4547, and Geotex 451 | • A pea gravel choking layer (3 to 4 inches thick) should be placed below the filter media and above the bottom aggregate<br>• If a geotextile is used in lieu of the pea gravel layer, it must meet MNDOT Type I non-woven geotextile<br>• Examples: Mirafi 140N, Amoco 4547, and Geotex 451 | • Filter Blanket could include any of the following:<br>  ∘ 8 inch layer of sand or filter fabric (Fine Aggregate)<br>  ∘ 3" thick of 3/8" pea gravel<br>  ∘ MNDOT Type I non-woven geotextile<br>• Examples: Mirafi 140N, Amoco 4547, and Geotex 451 (K)<br>• Geotextile should be placed on filter bed sides between filter media and in-situ soils | • Geotextile lining engineered media on sides<br>• Geotextile must meet MNDOT Type I non-woven geotextile<br>• Examples: Mirafi 140N, Amoco 4547, and Geotex 451. |

| Component | Infiltration basin | Bioinfiltration basin | Infiltration trench | Underground infiltration | Dry well | Dry swale with check dams | Permeable pavement | Tree trench/box/planter |
|---|---|---|---|---|---|---|---|---|
| Bottom | • Any of the following can be used on the bottom:<br>◦ 6 to 8 inch clean sand (1-2% fines or less)<br>◦ 3/8" pea gravel<br>◦ 6-12" layer of MNDOT Fine Filter Aggregate (Section 3149 J.2)<br>◦ 12" of gravel or sand (good for cold climates) | • Any of the following can be used on the bottom:<br>◦ Uniformly graded, crushed, clean-washed stone. (less than 0.5% wash loss, by mass, per AASHTO T-11 wash loss test<br>◦ Grass turf that can be inundated for +72 hrs<br>◦ MNDOT Coarse Aggregate Bedding (Section 3149 G.2)<br>◦ Coarse organic material (composted mulch or erosion control mix) tilled into soil, soaked and allowed to dry | • Any of the following can be used on the bottom:<br>◦ 6 to 8 inch clean sand (1-2% fines or less)<br>◦ 3/8" pea gravel<br>◦ 6-12" layer of MNDOT Fine Filter Aggregate (Section 3149 J.2)<br>◦ 12" of gravel or sand (good for cold climates) | | | • Double-washed, uniform (uniformity coefficient of 2 or smaller with a void ratio of 0.40) aggregate between 1.5 and 3.0 inch diameter<br>• MNDOT Coarse Aggregate Bedding (Section 3149 G.2) ranging 1-2 inch in gradation. | Bottom Layer: 4" min depth of .75" crushed stone MNDOT Coarse Aggregate Bedding (Section 3149 G.2) | 2' layer of clean, washed angular gravel 0.75 to 1.5 inch diameter |
| in-situ soils | NRCS Type A and B soils are the most efficient soils for proper infiltration. Type C soils are acceptable of the infiltration practice meets the required 48 hour drawdown period | | | | | | | |

| Component | Infiltration basin | Bioinfiltration basin | Infiltration trench | Underground infiltration | Dry well | Dry swale with check dams | Permeable pavement | Tree trench/box/planter |
|---|---|---|---|---|---|---|---|---|
| Miscellaneous | All material must be placed such that compaction is avoided. See the Construction Specifications webpage for more details | | To increase the runoff capture storage volume of trenches, plastic, aluminum or concrete gallery frames can be inserted All material must be placed such that compaction is avoided. See the Construction Specifications webpage for more details | | | • Non-erosive material such as wood, gabions, riprap, or concrete<br>• Underlay with geotextile and include 1/2 inch weep holes<br>• Construct check dams 6 to 12 inches high<br>• 9" min diameter rock on outside edges, 12-18" diameter larger rocks at core. Gaps filled with 4-6" diameter smaller rock<br>• Designed so pond behind dam will drawdown within 12 hours | | |

[1]Thickness will vary depending on traffic conditions.Typically, thicker configurations are needed for heavier traffic loads.

## Materials specifications - filter media

Infiltration practices do not typically use engineered filter media. If engineered media is used, all media should meet the specifications listed in the design criteria for bioretention basin webpage. Links are provided below.

- Filter media depth
- Performance specifications
- Guidance for bioretention media composition
  - Mix A
  - Mix B
  - Mix C
  - Mix D

- Mix E
- Mix F
- Other media

## Design procedure - design steps

The following steps outline a recommended design procedure for infiltration practices in compliance with the MPCA Permit for new construction. Design recommendations beyond those specifically required by the permit are also included and marked accordingly.

When riser pipe outlets are used in infiltration basins, it is *HIGHLY RECOMMENDED* that they be constructed with manholes that either have locks or are sufficiently heavy to prevent easy removal.

Fencing of dry wells and infiltration trenches is neither necessary nor desirable. Infiltration basins may warrant fencing in some situations.

### Step 1. Make a preliminary judgment

Make a preliminary judgment as to whether site conditions are appropriate for the use of an infiltration practice, and identify the function of the practice in the overall treatment system.

A. Consider basic issues for initial suitability screening, including:

- site drainage area (See the **Summary of infiltration practices for given drainage areas** table below);
- site topography and slopes;
- soil infiltration capacity;
- regional or local depth to groundwater and bedrock;
- site location/ minimum setbacks; and
- presence of active karst.

B. Determine how the infiltration practice will fit into the overall stormwater treatment system.

- Decide whether the infiltration practice is the only BMP to be employed, or if are there other BMPs addressing some of the treatment requirements.
- Decide where on the site the infiltration practice is most likely to be located.

**Stormwater infiltration BMPs - contributing drainage area**
Link to this table

| Stormwater BMP | Recommended contributing area | Notes |
|---|---|---|
| Infiltration Basin | 50 acres or less | A natural or constructed impoundment that captures, temporarily stores and infiltrates the design volume of water into the surrounding naturally permeable soil over several days. In the case of a constructed basin, the impoundment is created by excavation or embankment. |
| Bioinfiltration Basin | 5 acres or less | Bioinfiltration basins must meet the required 48 hour drawdown time and must be sized in order to allow for adequate maintenance. It is HIGHLY RECOMMENDED that bioinfiltration basins be designed to prevent high levels of bounce as submerging vegetation may inhibit plant growth. A maximum wet storage depth of 1.5 feet is HIGHLY RECOMMENDED. |
| Infiltration Trench | 5 acres or less | |

| Stormwater BMP | Recommended contributing area | Notes |
|---|---|---|
| Dry Well Synonym: Infiltration Tube, French Drain, Soak-Away Pits, Soak Holes | 1 acre or less (rooftop only) | |
| Underground Infiltration | 10 acres or less | Though feasible, larger underground infiltration systems may cause groundwater contamination as water is not able to infiltrate through a surface cover. In addition, wind flocculation, UV degradation, and bacterial degradation, which provide additional treatment in surface systems, do not occur in underground systems. Because performance research is lacking for larger features, it is HIGHLY RECOMMENDED that the contributing drainage area to a single device not exceed 10 acres. |
| Dry Swale with Check Dams | 5 acres or less | |
| Permeable Pavement | It is RECOMMENDED that external contributing drainage area not exceed the surface area of the permeable pavement. It is HIGHLY RECOMMENDED that external contributing drainage area not exceed twice the surface area of the permeable pavement | It is RECOMMENDED that external drainage area be as close to 100% impervious as possible. Field experience has shown that drainage area (pervious or impervious) can contribute particulates to the permeable pavement and lead to clogging. Therefore, sediment source control and/or pre-treatment should be used to control sediment run-on to the permeable pavement section. |
| Tree Trench/Tree Box | up to 0.25 acres per tree | |

References: Virginia, North Carolina, West Virginia, Maine, Lake Tahoe, Connecticut, Massachusetts, New York, Wisconsin, Vermont, New Hampshire, Ontario, Pennsylvania

### Step 2. Confirm design criteria and applicability

Determine whether the infiltration practice must comply with the MPCA Construction Stormwater General (CSW) Permit. Check with local officials, Watershed management Organizations (WMOs), and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

**Warning:** If the infiltration practice must comply with the CSW permit, the following prohibitions apply:

- areas that receive discharges from vehicle fueling and maintenance;
- areas with less than three (3) feet of separation distance from the bottom of the infiltration system to the elevation of the seasonally saturated soils or the top of bedrock;
- areas that receive discharges from industrial facilities which are not authorized to infiltrate industrial stormwater under an NPDES/SDS Industrial Stormwater Permit issued by the MPCA;
- areas where high levels of contaminants in soil or groundwater will be mobilized by the infiltrating stormwater;
- areas of predominately Hydrologic Soil Group D (clay) soils;
- areas within 1,000 feet up-gradient, or 100 feet down-gradient of active karst features;
- areas within a Drinking Water Supply Management Area (DWSMA) as defined in Minn. R. 4720.5100, subp. 13., if the system will be located:
  - in an Emergency Response Area (ERA) within a DWSMA classified as having high or very high vulnerability as defined by the Minnesota Department of Health; or
  - in an ERA within a DWSMA classified as moderate vulnerability unless a regulated MS4 Permittee performed or approved a higher level of engineering review sufficient to provide a functioning treatment system and to prevent adverse impacts to groundwater; or
  - outside of an ERA within a DWSMA classified as having high or very high vulnerability, unless a regulated MS4 Permittee performed or approved a higher level of engineering review sufficient to provide a functioning treatment system and to prevent adverse impacts to groundwater; and
- areas where soil infiltration rates are more than 8.3 inches per hour unless soils are amended to slow the infiltration rate below 8.3 inches per hour.

### Step 3. Perform field verification of site suitability

**Warning:** The Construction Stormwater permit includes the following requirements.
16.10. Permittees must provide at least one soil boring, test pit or infiltrometer test in the location of the infiltration practice for determining infiltration rates.

16.11. For design purposes, permittees must divide field measured infiltration rates by 2 as a safety factor or permittees can use soil-boring results with the infiltration rate chart in the Minnesota Stormwater Manual to determine design infiltration rates. When soil borings indicate type A soils, permittees should perform field measurements to verify the rate is not above 8.3 inches per hour. This permit prohibits infiltration if the field measured infiltration rate is above 8.3 inches per hour.

Designers should evaluate soil properties during preliminary site layout with the intent of installing infiltration practices on soils with the highest infiltration rates (HSG A and B). Preliminary planning for the location of an infiltration device may be completed using a county soil survey or the NRCS Web Soil Survey. These publications provide HSG information for soils across Minnesota. To ensure long-term performance, however, field soil measurements are desired to provide site-specific data.

If the initial evaluation indicates that an infiltration practice would be a good BMP for the site, it is *RECOMMENDED* that soil borings or pits be dug within the proposed boundary of the infiltration practice to verify soil types and infiltration capacity characteristics and to determine the depth to groundwater and bedrock. Soil borings for building structural analysis are not acceptable. In all design scenarios, a minimum of one soil boring (two are recommended) shall be completed to a depth 5 feet below the bottom of the proposed infiltration Stormwater Control Measure (SCM or BMP) (Dakota County Soil and Water Conservation District, 2012) per ASTM D1586 (ASTM, 2011). For infiltration SCMs with surface area between 1000 and 5000 square feet, two borings shall be made. Between 5000 and 10000 square feet, three borings are needed, and for systems with greater than 10000 square feet in surface area, 4 or more borings are needed. For each additional 2500 square feet beyond 12,500 square feet, an additional soil boring should be made. Soil borings must be undertaken during the design phase (i.e. prior to the commencement of construction) to determine how extensive the soil testing will be during construction. Borings should be completed using continuous split spoon sampling, with blow counts being recorded to determine the level of compaction of the soil. Soil borings are needed to understand soil types, seasonally high groundwater table elevation, depth to karst, and bedrock elevations.

**Recommended number of soil borings, pits or permeameter tests for bioretention design. Designers select one of these methods.**
Link to this table

| Surface area of stormwater control measure (BMP)($ft^2$) | Borings | Pits | Permeameter tests |
|---|---|---|---|
| < 1000 | 1 | 1 | 5 |
| 1000 to 5000 | 2 | 2 | 10 |
| 5000 to 10000 | 3 | 3 | 15 |
| >10000 | 4[1] | 4[1] | 20[2] |

[1]an additional soil boring or pit should be completed for each additional 2,500 $ft^2$ above 12,500 $ft^2$

[2]an additional five permeameter tests should be completed for each additional 5,000 $ft^2$ above 15,000 $ft^2$

It is *HIGHLY RECOMMENDED* that soil profile descriptions be recorded and include the following information for each soil horizon or layer (Source: *Site Evaluation for Stormwater Infiltration*, Wisconsin Department of Natural Resources Conservation Practice Standards 2004):

- thickness, in inches or decimal feet;
- Munsell soil color notation;
- soil mottle or redoximorphic feature color, abundance, size and contrast;
- USDA soil textural class with rock fragment modifiers;
- soil structure, grade size and shape;
- soil consistence, root abundance and size;
- soil boundary; and
- occurrence of saturated soil, impermeable layers/lenses, ground water, bedrock or disturbed soil.

It is RECOMMENDED that a standard soil boring form be used. A good example is File:Boring Pit Log form.docx. The NRCS Field Book for Describing and Sampling Soils provide detailed information for identifying soil characteristics. Munsell color charts can be found at [15].

**Warning:** A separation distance of 3 feet is REQUIRED between the bottom of the infiltration practice and the elevation of the seasonally high water table (saturated soil) or top of bedrock (i.e. there must be a minimum of 3 feet of undisturbed soil beneath the infiltration practice and the seasonally high water table or top of bedrock).

It is HIGHLY RECOMMENDED that the field verification be conducted by a qualified geotechnical professional.

### Step 4. Compute runoff control volumes

**Warning:** If the infiltration practice is being designed to meet the requirements of the MPCA Permit, the *REQUIRED* treatment volume is the water quality volume ($V_{wq}$) of 1 inch of runoff from the new impervious surfaces created from the project. If part of the overall $V_{wq}$ is to be treated by other BMPs, subtract that portion from the $V_{wq}$ to determine the part of the $V_{wq}$ to be treated by the infiltration practice.

The design techniques in this section are meant to maximize the volume of stormwater being infiltrated. If the site layout and underlying soil conditions permit, a portion of the Channel Protection Volume ($V_{cp}$), Overbank Flood Protection Volume ($V_{p10}$), and the Extreme Flood Volume ($V_{p100}$) may also be managed in the infiltration practice.

### Step 5. Determine infiltration type and size practice

Once the physical suitability evaluation is complete (Step 3), it is *HIGHLY RECOMMENDED* that the designer apply the better site design principles in sizing and locating the infiltration practice(s) on the development site.

**Select design variant**

After following the steps outlined above, the designer will presumably know the location of naturally occurring permeable soils, the depth to the water table, bedrock or other impermeable layer, and the contributing drainage area. Given the steps performed in the physical suitability evaluation (Step 3), identify the most suitable location for the infiltration practice. Given the water quality volume and the drainage area, select the appropriate infiltration practice for the first iteration of the design process. See the section on BMPs for stormwater infiltration for more information.

Note: Information collected during the site suitability evaluation (see Steps 1 and 3) should be used to explore the potential for multiple infiltration practices versus relying on a single infiltration facility. The use of smaller infiltration practices dispersed around a development is usually more sustainable than a single regional facility that is more likely to have maintenance and groundwater mounding problems (Source: Site Evaluation for Stormwater Infiltration, Wisconsin Department of Natural Resources Conservation Practice Standards, 2004). See Using the treatment train approach to BMP selection for more information on selecting multiple BMPs at a site.

**Warning:** Infiltration practices shall discharge through the soil or filter media in 48 hours or less. Additional flows that cannot be infiltrated or filtered in 48 hours should be routed to bypass the system through a stabilized discharge point.

Experience has demonstrated that, although the drawdown period is 48 hours, there is often some residual water pooled in the infiltration practice after 48 hours. This residual water may be associated with reduced head, water gathered in depressions within the practice, water trapped by vegetation, and so on. The drawdown period is therefore defined as the time from the high water level in the practice to 1 to 2 inches above the bottom of the facility. This criterion was established to provide the following: wet-dry cycling between rainfall events; unsuitable mosquito breeding habitat; suitable habitat for vegetation; aerobic conditions; and storage for back-to-back precipitation events. This time period has also been called the period of inundation.

**Caution:** It is *HIGHLY RECOMMENDED* that the drawdown time for infiltration practices is 24 hours or less from the peak water level in the practice when discharges are to a trout stream.

**Determine site infiltration rates (for facilities with infiltration and/or recharge)**

For design purposes, there are two ways of determining the soil infiltration rate. The first, and preferred method, is to field-test the soil infiltration rate using appropriate methods described below. The other method uses the typical infiltration rate of the most restrictive underlying soil (determined during soil borings).

If infiltration rate measurements are made, a minimum of one infiltration test in a soil pit must be completed at the elevation from which exfiltration would occur (i.e. interface of gravel drainage layer and in situ soil). When the SCM surface area is between 1000 and 5000 square feet, two soil pit measurements are needed. Between 5000 and 10000 square feet of surface area, a total of three soil pit infiltration measurements should be made. Each additional 5000 square feet of surface area triggers an additional soil pit.

**Recommended number of soil borings, pits or permeameter tests for bioretention design. Designers select one of these methods.**
Link to this table

| Surface area of stormwater control measure (BMP)($ft^2$) | Borings | Pits | Permeameter tests |
|---|---|---|---|
| < 1000 | 1 | 1 | 5 |
| 1000 to 5000 | 2 | 2 | 10 |
| 5000 to 10000 | 3 | 3 | 15 |
| >10000 | 4[1] | 4[1] | 20[2] |

[1]an additional soil boring or pit should be completed for each additional 2,500 $ft^2$ above 12,500 $ft^2$

[2]an additional five permeameter tests should be completed for each additional 5,000 $ft^2$ above 15,000 $ft^2$

The median measured infiltration rate should be utilized for design. Soil pits should be dug during the design phase and should be a minimum of two feet in diameter for measurement of infiltration rate. Infiltration testing in the soil pit can be completed with a double-ring infiltrometer or by filling the pit with water and measuring stage versus time. If the infiltration rate in the first pit is greater than 2 inches per hour, no additional pits shall be needed.

Alternatively, a Modified Philip-Dunne permeameter can be used to field test infiltration rate. Modified Philip-Dunne permeameter tests may be made in conjunction with soil borings or may be completed using a handheld soil auger. Borings should be lined with a plastic sleeve to prevent infiltration from the sides of the borehole (i.e. restrict flow to vertical infiltration). Soil borings should be filled with water. The time for the borehole to drain should be recorded and divided by the initial ponding depth in the borehole to provide an infiltration rate measurement. The design infiltration rate should be the lower of the median soil pit infiltration rate or the median borehole method infiltration rate. For information on conducting soil borings see Understanding and interpreting soils and soil boring reports for infiltration BMPs.

NOTE: In the table above, the recommended number of permeameter tests increases by 5 tests per each additional 5000 square feet of surface area. For larger sites, this can result in a very large number of samples. There may be situations where fewer permeameter tests may be used (5 is the minimum) . For example, in situations where the variability in saturated hydraulic conductivity between measurements is not great, fewer samples may be taken. One method for determining the number of samples is to plot standard deviation versus number of samples. Measurements may be halted when the standard deviation becomes relatively constant from one sample to the next. In the example to the right the standard deviation flattens at about 7 to 10 samples. Therefore, 7 to 10 samples would be an appropriate number of samples for this situation.

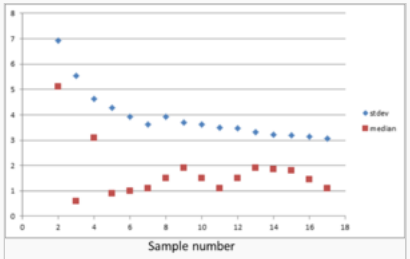


Illustration of how to determine the appropriate number of permeameter samples. When the standard deviation for all measurements flattens out with successive measurements, collection of additional permeameter tests may be halted, provided a minimum of 5 samples have been collected.

For information on conducting soil infiltration rate measurements, see Determining soil infiltration rates.

If the infiltration rate is not measured, use the table below to estimate an infiltration rate for the design of infiltration practices. These infiltration rates represent the long-term infiltration capacity of a practice and are not meant to exhibit the capacity of the soils in the natural state.

**Caution:** Select the design infiltration rate from the table based on the least permeable soil horizon within the first 5 feet below the bottom elevation of the proposed infiltration practice

**Caution:** The table for design infiltration rates has been modified. Field testing is recommended for gravelly soils (HSG A; GW and GP soils;

gravel and sandy gravel soils). If field-measured soil infiltration rates exceed 8.3 inches per hour, the Construction Stormwater permit requires the soils be amended. Guidance on amending these soils can be found here.

**Design infiltration rates, in inches per hour, for A, B, C, and D soil groups. Corresponding USDA soil classification and Unified soil Classifications are included. Note that A and B soils have two infiltration rates that are a function of soil texture.***
**The values shown in this table are for uncompacted soils. This table can be used as a guide to determine if a soil is compacted. For information on alleviating compacted soils, link here. If a soil is compacted, reduce the soil infiltration rate by one level (e.g. for a compacted B(SM) use the infiltration rate for a B(MH) soil).**
Link to this table

| Hydrologic soil group | Infiltration rate (inches/hour) | Infiltration rate (centimeters/hour) | Soil textures | Corresponding Unified Soil Classification |
|---|---|---|---|---|
| A | Although a value of 1.63 inches per hour (4.14 centimeters per hour) may be used, it is ***Highly recommended*** that you conduct field infiltration tests or amend soils.[b] See Guidance for amending soils with rapid or high infiltration rates and Determining soil infiltration rates. | | gravel<br>sandy gravel | GW - well-graded gravels, sandy gravels<br>GP - gap-graded or uniform gravels, sandy gravels |
| | 1.63[a] | 4.14 | silty gravels<br>gravelly sands<br>sand | GM - silty gravels, silty sandy gravels<br>SW - well-graded gravelly sands<br>SW - uniformly graded sands |
| | 0.8 | 2.03 | sand<br>loamy sand<br>sandy loam | SP - gap-graded or poorly graded sands |
| B | 0.45 | 1.14 | | SM - silty sands, silty gravelly sands |
| | 0.3 | 0.76 | loam, silt loam | MH - micaceous silts, diatomaceous silts, volcanic ash |
| C | 0.2 | 0.51 | Sandy clay loam | ML - silts, very fine sands, silty or clayey fine sands |

| Hydrologic soil group | Infiltration rate (inches/hour) | Infiltration rate (centimeters/hour) | Soil textures | Corresponding Unified Soil Classification |
|---|---|---|---|---|
| D | 0.06 | 0.15 | clay loam<br>silty clay loam<br>sandy clay<br>silty clay<br>clay | GC - clayey gravels, clayey sandy gravels<br>SC - clayey sands, clayey gravelly sands<br>CL - low plasticity clays, sandy or silty clays<br>OL - organic silts and clays of low plasticity<br>CH - highly plastic clays and sandy clays<br>OH - organic silts and clays of high plasticity |

*NOTE that this table has been updated from Version 2.X of the Minnesota Stormwater Manual. The higher infiltration rate for B soils was decreased from 0.6 inches per hour to 0.45 inches per hour and a value of 0.06 is used for D soils (instead of < 0.2 in/hr).

Source: Thirty guidance manuals and many other stormwater references were reviewed to compile recommended infiltration rates. All of these sources use the following studies as the basis for their recommended infiltration rates: (1) Rawls, Brakensiek and Saxton (1982); (2) Rawls, Gimenez and Grossman (1998); (3) Bouwer and Rice (1984); and (4) Urban Hydrology for Small Watersheds (NRCS). SWWD, 2005, provides field documented data that supports the proposed infiltration rates. (view reference list)

[a]This rate is consistent with the infiltration rate provided for the lower end of the Hydrologic Soil Group A soils in the Wisconsin Department of Natural Resources Conservation Practice Standard: Site Evaluation for Stormwater Infiltration.

[b]The infiltration rates in this table are recommended values for sizing stormwater practices based on information collected from soil borings or pits. A group of technical experts developed the table for the original Minnesota Stormwater Manual in 2005. Additional technical review resulted in an update to the table in 2011. Over the past 5 to 7 years, several government agencies revised or developed guidance for designing infiltration practices. Several states now require or strongly recommend field infiltration tests. Examples include North Carolina, New York, Georgia, and the City of Philadelphia. The states of Washington and Maine strongly recommend field testing for infiltration rates, but both states allow grain size analyses in the determination of infiltration rates. The Minnesota Stormwater Manual strongly recommends field testing for infiltration rate, but allows information from soil borings or pits to be used in determining infiltration rate. A literature review suggests the values in the design infiltration rate table are not appropriate for soils with very high infiltration rates. This includes gravels, sandy gravels, and uniformly graded sands. Infiltration rates for these geologic materials are higher than indicated in the table.

References: Clapp, R. B., and George M. Hornberger. 1978. Empirical equations for some soil hydraulic properties. Water Resources Research. 14:4:601–604; Moynihan, K., and Vasconcelos, J. 2014. SWMM Modeling of a Rural Watershed in the Lower Coastal Plains of the United States. Journal of Water Management Modeling. C372; Rawls, W.J., D. Gimenez, and R. Grossman. 1998. Use of soil texture, bulk density and slope of the water retention curve to predict saturated hydraulic conductivity Transactions of the ASAE. VOL. 41(4): 983-988; Saxton, K.E., and W. J. Rawls. 2005. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Science Society of America Journal. 70:5:1569-1578.

The infiltration capacity and existing hydrologic regime of natural basins are inherently different than constructed practices and may not meet MPCA Permit requirements for constructed practices. In the event that a natural depression is being proposed to be used as an infiltration system, the design engineer must demonstrate the following information:

- infiltration capacity of the system under existing conditions (inches per hour)
- existing drawdown time for the high water level (HWL) and a natural overflow elevation.

The design engineer should also demonstrate that operation of the natural depression under post-development conditions mimics the hydrology of the system under pre-development conditions.

If the infiltration rates are measured, the tests shall be conducted at the proposed bottom elevation of the infiltration practice. If the infiltration rate is measured with a double-ring infiltrometer the requirements of ASTM D3385 (Standard test method for infiltration rate of soils in field using double-ring infiltrometer) should be used for the field test.

**Warning:** The measured infiltration rate shall be divided by a safety factor of 2.

The safety factor of 2 adjusts the measured infiltration rates for the occurrence of less permeable soil horizons below the surface and the potential variability in the subsurface soil horizons throughout the infiltration site. This safety factor also accounts for the long-term infiltration capacity of the stormwater management facility.

**Size infiltration practice**

To meet requirements of the Stormwater General Permit (CSW permit), the surface area ($A_s$, in square feet) of an infiltration practice is given by

<math>A_s = V_w / D_o</math>

Where:
$V_w$ = the water treatment volume of the area contributing runoff to the practice; and
$D_o$ = the storage depth of ponded water in the practice.

The water treatment volume is given by

<math>V_w = 0.0833 A_c</math>

Where
0.0833 = one inch of infiltration, as required by the permit; and
$A_c$ = the impervious surface area contributing to the practice.

The entire water quality treatment volume is assumed to be instantaneously ponded in the infiltration practice.

For a BMP with sloped sides, the surface area ($A_s$) of an infiltration practice is the average area of the BMP, given by

<math> A_s = (A_o + A_M)/2 </math>

Where
$A_o$ is the surface area at the overflow; and
$A_M$ is the surface area at the top of the infiltration practice

The water treatment volume must drain with 48 hours (24 hours is RECOMMENDED if discharges from the practice are to a trout stream). The ponding depth can therefore be calculated knowing the infiltration rate of the soils underlying the practice.

Given the assumed infiltration rate for the practice, determine the maximum depth using the following equation

<math>D = I_R DDT_{calc}</math>

where

D = maximum depth of practice (inches);
$I_R$ = infiltration rate (inches/hour); and
$DDT_{calc}$ = maximum drawdown time (48 hours).

Field-measured infiltration rates are preferred. If the infiltration rate has not been measured, use the table below to determine the infiltration rate of the underlying soils. Note the numbers in the table are intentionally conservative based on experience gained from Minnesota infiltration sites. Two example calculations are provided below.

**Sizing example 1**

Assume a 5 acre watershed is 20 percent impervious. Runoff from this watershed will be routed to an infiltration practice that has an underlying loam soil.

- The treatment volume = 5 acres * 0.20 * 43560 square feet per acre * 0.0833 inches = 3630 cubic feet
- The ponded depth = 48 hours * 0.30 inches per hour = 14.4 inches = 1.2 feet
- The surface area of the practice = 3025 square feet

The dimensions of the infiltration practice can be determined to accommodate this area. For example, a square practice will be 55 feet wide by 55 feet long.

**Sizing example 2**

Assume a 7 acre watershed is 15 percent impervious. Runoff from this watershed will be routed to an infiltration practice where the underlying soil has a field-measured infiltration rate of 2 inches per hour.

Note:

- The infiltration rate must be divided by a safety factor of 2 since a field-measure rate is being used. This gives an infiltration rate of 1 inch per hour.
- The ponded depth = 48 hours * 1 inch per hour = 48 inches = 4 feet.
- The treatment volume = 7 acres * 0.15 * 43560 square feet per acre * 0.0833 inches = 3811 cubic feet
- The surface area of the practice = 3811$ft^3$ / 4.0 ft = 953 square feet

The dimensions of the infiltration practice can be determined to accommodate this volume. For example, a square practice will be 30.9 feet wide by 30.9 feet long.

If the infiltration practice does not require meeting the Construction Stormwater General Permit, methods other than the instantaneous volume method may be used. For example, as an infiltration basin fills during a rain event, water infiltrates the media. The infiltration area could be sized as follows

<math>A_s = V_{wq} / (D_o + (I_R * t))</math>

Where:
$I_R$ = infiltration rate of underlying soils (feet per day);and
t = time during which the infiltration basin continues to capture runoff.

The time during which runoff continues to be delivered to the BMP varies with each event. As an example, for a 1 hour event on a B (SM) soil with an infiltration rate of 0.45 inches per hour, 1 acre of contributing impervious area, and a 1.5 foot ponding depth, $A_s$ is 2361 square feet, compared to 2420 square feet considering only an instantaneous volume, or a decrease of 2.4 percent in the size of the basin. On an A soil with and infiltration rate of 1.6 inches per hour, $A_s$ is 2222 square feet, or a decrease of 8.2 percent in the needed size of the basin. The area of the basin can also be decreased by increasing the ponded depth.

Infiltration practices may also be sized using different treatment goals. For example, the performance goal for Minimal Impact Design Standards (MIDS) is 1.1 inches, compared to 1 inch for the CSW permit. The MIDS performance goal was also based on initial modeling that included infiltration during the rain event.

**Warning:** 48 hours is the *REQUIRED* maximum $t_f$ for infiltration under the CGP

**Caution:** The table for design infiltration rates has been modified. Field testing is recommended for gravelly soils (HSG A; GW and GP soils; gravel and sandy gravel soils). If field-measured soil infiltration rates exceed 8.3 inches per hour, the Construction Stormwater permit requires the soils be amended. Guidance on amending these soils can be found here.

**Design infiltration rates, in inches per hour, for A, B, C, and D soil groups. Corresponding USDA soil classification and Unified soil Classifications are included. Note that A and B soils have two infiltration rates that are a function of soil texture.***
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| | 0.8 | 2.03 | sand<br>loamy sand<br>sandy loam | SP - gap-graded or poorly graded sands |
| B | 0.45 | 1.14 | | SM - silty sands, silty gravelly sands |
| | 0.3 | 0.76 | loam, silt loam | MH - micaceous silts, diatomaceous silts, volcanic ash |
| C | 0.2 | 0.51 | Sandy clay loam | ML - silts, very fine sands, silty or clayey fine sands |
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Source: Thirty guidance manuals and many other stormwater references were reviewed to compile recommended infiltration rates. All of these sources use the following studies as the basis for their recommended infiltration rates: (1) Rawls, Brakensiek and Saxton (1982); (2) Rawls, Gimenez and Grossman (1998); (3) Bouwer and Rice (1984); and (4) Urban Hydrology for Small Watersheds (NRCS). SWWD, 2005, provides field documented data that supports the proposed infiltration rates. (view reference list)

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States. Journal of Water Management Modeling. C372; Rawls, W.J., D. Gimenez, and R. Grossman. 1998. Use of soil texture, bulk density and slope of the water retention curve to predict saturated hydraulic conductivity Transactions of the ASAE. VOL. 41(4): 983-988; Saxton, K.E., and W. J. Rawls. 2005. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Science Society of America Journal. 70:5:1569-1578.

### Step 6. Size outlet structure and/or flow diversion structure, if needed

It is *HIGHLY RECOMMENDED* that the outlet for the infiltration practice shall safely convey stormwater using all of the following mechanisms (Infiltration Basin, Wisconsin Department of Natural Resources Conservation Practice Standard, 10/04).

**Drawdown valve**: infiltration systems may be designed with a drawdown valve for the removal of standing water for maintenance and winter diversion.
**Emergency spillway**:

**Warning:** A means to release discharge in excess of the infiltration volume safely into the downstream stormwater conveyance system is *REQUIRED.*

**Freeboard**: It is *HIGHLY RECOMMENDED* that two feet of freeboard be provided from the 100-year flood elevation of the infiltration practice to the lowest basement floor elevation of residential, commercial, industrial and institutional buildings located adjacent to the BMP, unless local requirements recommend otherwise.
**Drop Structure**: Infiltration trenches or subsurface infiltration systems may be designed with a drop structure sized to handle the overflow. This additional volume of stormwater may be directed into the existing stormwater system or it may be diverted to a downstream BMP.

### Step 7. Perform ground-water mounding analysis

Groundwater mounding, the process by which a mound of water forms on the water table as a result of recharge at the surface, can be a limiting factor in the design and performance of infiltration practices. A groundwater mounding analysis is RECOMMENDED to verify separation distances required for infiltration practices. For more information on groundwater mounding, see the following sections in this manual.

- Stormwater infiltration and groundwater mounding
- When should a mounding analysis be conducted?
- How to predict the extent of a mound
- Example mound calculations

### Step 8. Determine pretreatment volume and design pretreatment measures

See the section on pretreatment for specific pretreatment design guidance

### Step 9. Check volume, peak discharge rates and drawdown time against State, local and watershed organization requirements

Follow the design procedures identified in the unified sizing criteria section of the Manual to determine the volume control and peak discharge requirements for water quality, recharge, channel protection, overbank flood and extreme storm.

Perform hand calculations or model the proposed development scenario using a surface water model appropriate for the hydrologic and hydraulic design considerations specific to the site (see also the section on stormwater modeling). This includes defining the parameters of the infiltration practice defined above: elevation and area (defines the storage volume), infiltration rate and method of application (effective infiltration area), and outlet structure and/or flow diversion information. The results of this analysis can be used to determine whether or not the proposed design meets the applicable requirements. If not, the design will have to be re-evaluated (back to Step 5).

The following items are specifically *REQUIRED* by the MPCA Permit

**Warning:**

- *Volume* - Infiltration or filtration systems shall be sufficient to infiltrate or filter a water quality volume of 1 inch of runoff from the new impervious surfaces created by the project. If this criterion is not met, increase the storage volume of the bioretention practice or treat excess water quality volume (Vwq) in an upstream or downstream BMP (see Step 5). Retrofit and supplemental systems do not need to meet this requirement, provided new impervious surfaces are not created.
- *Peak Discharge Rates* - Since most infiltration systems are not designed for quantity control they generally do not have peak discharge limits. However outflow must be limited such that erosion does not occur down gradient.
- *Drawdown* - Infiltration practices shall discharge through the soil or filter media in 48 hours or less. Additional flows that cannot be infiltrated or filtered in 48 hours should be routed to bypass the system through a stabilized discharge point.

Experience has demonstrated that, although the drawdown period is 48 hours, there is often some residual water pooled in the infiltration practice after 48 hours. This residual water may be associated with reduced head, water gathered in depressions within the practice, water trapped by vegetation, and so on. The drawdown period is therefore defined as the time from the high water level in the practice to 1 to 2 inches above the bottom of the facility. This criterion was established to provide the following: wet-dry cycling between rainfall events; unsuitable mosquito breeding habitat; suitable habitat for vegetation; aerobic conditions; and storage for back-to-back precipitation events. This time period has also been called the period of inundation.

Other design requirements may apply to a particular site. The applicant should confirm local design criteria and applicability (see Step 2).

### Step 10. Prepare Vegetation and Landscaping Plan

A landscaping plan for an infiltration trench should be prepared to indicate how the enhanced swale system will be stabilized and established with vegetation. Landscape design should specify proper grass species and wetland plants based on specific site, soils and hydric conditions present along the channel. Further information on plant selection and use occurs in the Minnesota plant lists section.

### Step 11. Prepare Operation and Maintenance (O&M) Plan

See Operation and Maintenance section for guidance on preparing an O&M plan.

### Step 12. Prepare Cost Estimate

See Cost Considerations section for guidance on preparing a cost estimate that includes both construction and maintenance costs.

# Construction specifications

**Green Infrastructure:** Infiltration practices can be an important tool for retention and detention of stormwater runoff and treatment of pollutants in stormwater runoff. If the practice utilizes vegetation, additional benefits may include cleaner air, carbon sequestration, improved biological habitat, and aesthetic value.

This page provides a discussion of construction specifications for infiltration basins, trenches, and underground infiltration, including a construction sequence.

## Access agreements

An easement is a legally binding agreement between two parties, and is defined as "a non-possessory right to use and/or enter onto the real property of another without possessing it." An easement is required for one party to access, construct, or maintain any feature or infrastructure on the property of another. Easements can be temporary or permanent. For example, temporary easements can be used if limits needed for construction are larger than the permanent easement footprint of constructed features. Having an easement provides a mechanism for enforcement of maintenance agreements to help ensure infiltration practices are maintained and functioning. See an example access agreement.

## Construction specifications for infiltration practices


Installation of underground infiltration pipes.

Construction of infiltration practices incorporates techniques and steps that may be considered nonstandard. It is recommended that construction specifications include project pretreatment devices, construction sequencing, temporary and permanent erosion control measures, excavation and fill, grading, soil decompaction, material specifications, and final stabilization. All of these topics are addressed in further detail below.

Additional specifications for items applicable to infiltration practices can be found in the Minnesota Department of Transportation's (MnDOT) Specifications for Construction. The current version of this resource was completed in 2016. Below is a list of MnDOT sections that may be helpful when writing project specifications for infiltration practices.

- 1717 Air, land and water pollution
- 2101 Clearing and grubbing
- 2105 Excavation and embankment
- 2511 Riprap
- 2571 Plant installation and establishment
- 2572 Protection and restoration of vegetation
- 2573 Storm water management
- 2574 Soil preparation
- 2575 Establishing turf and controlling erosion
- 3149 Granular material
- 3877 Topsoil material
- 3878 Sod
- 3882 Mulch material
- 3884 Hydraulic erosion control products
- 3885 Rolled erosion control products
- 3897 Sediment control log

### Pre-construction meeting

A pre-construction meeting is recommended and should include a walkthrough of the site with the builder/contractor/subcontractor to identify important features of the work and to review and discuss the plans. This is the best time to identify potential issues related to construction methods and sequencing that will affect site protection, erosion and sediment control, and proper installation of the work.

### Site protection

**Pretreatment**

Pretreatment is a required part of infiltration and filtration practices. Pretreatment is needed to protect BMPs from the build-up of trash, gross solids, and particulate matter. When the velocity of stormwater decreases, sediment and solids drop out. If pretreatment is not provided, this process will occur in the BMP, resulting in long-term clogging and poor aesthetics.

**Warning:** The Construction Stormwater general permit states: To prevent clogging of the infiltration or filtration system, the Permittee(s) must use a pretreatment device such as a vegetated filter strip, small sedimentation basin, or water quality inlet (e.g., grit chamber) to settle particulates before the stormwater discharges into the infiltration or filtration system.

**Temporary erosion and sediment control**

During construction, it is critical to keep sediment out of the infiltration device as much as practicable. Utilizing sediment and erosion control measures will help to keep infiltration areas from clogging. As soon as grading is complete, stabilize slopes to reduce erosion of native soils. Protect temporary soil stockpiles from run-on and run-off from adjacent areas and from erosion by wind. Sweep as often as required if sediment is on paved surfaces to prevent transport offsite by tracking and airborne dust. All sediment and erosion control measures must be properly installed and maintained. When sediment build up reaches 1/3 the height of the device, action is required, such as removing the accumulated sediment or installing additional sediment controls downgradient of the original device. Link here for more information.

**Warning:**

- It is REQUIRED that future infiltration locations not be used as temporary sedimentation basins unless 3 feet of cover is left in place during construction.
- If the infiltration area is excavated to final grade (or within 3 feet of) it is REQUIRED that rigorous erosion prevention and sediment controls (e.g., diversion berms) are used to keep sediment and runoff infiltration away from the infiltration area.

Pretreatment inlet structure to dry swale with check dam contains sump and skimmer (top), dry swale with check dam inlet pipe, downstream of inlet structure (bottom). Photos courtesy of Barr Engineering.

**Compaction prevention**

Preventing and alleviating compaction are crucial during construction of infiltration practices, as compaction can reduce infiltration rates by increasing bulk density of the soil. The infiltration area should be marked with paint and/or stakes to keep construction traffic from traveling in the area.

### Inspection and documentation

Inspections before, during, and after construction are needed to ensure infiltration practices are built in accordance with the plans and specifications. It is recommended that onsite inspectors are familiar with project plans and specifications to ensure the contractor's interpretation of the plans are consistent with the designer's intent. The inspectors should take frequent photos and notes of construction activities and features as work progresses and at all critical points (such as immediately prior to backfilling). They should check dimensions and depths of all installed materials. All materials and products should be verified or tested for conformance with the specifications.

**Construction checklists**

- Infiltration trench
- Infiltration basin

## Construction sequence

### Step 1 – Site examination and preparation

It is the responsibility of the contractor to:

- Examine the areas for performing earthwork and determine that conditions are satisfactory to proceed, or to correct all unsatisfactory conditions prior to starting work.
- Arrange to locate, mark, and protect all existing utilities and underground facilities in the areas of work.
- Remove all existing features marked for removal and required earthwork

### Step 2 – Excavation

Sub-cut the infiltration area as shown on the plans. Where possible, excavation should be performed with a backhoe and work should be done from the sides and outside the footprint of the infiltration area to avoid soil compaction. If it is necessary to work in the infiltration area, only low ground pressure tracked equipment should be allowed to complete the work. Rubber tire equipment should be strictly prohibited within the infiltration area, unless working from pavement outside of the basin or trench. The contractor should start the work at the far side of the trench or basin and work their way out.

Contractor is to ensure all laws and regulations are followed regarding stability of excavations. This may require shoring, bracing, sloping, or benching. Materials should not be stockpiled near the edge of the excavation. Drainage and control of water in the excavation must also be considered.

**Warning:** It is REQUIRED that infiltration systems not be excavated to final grade until the contributing drainage area has been constructed and fully stabilized.

Example of subsoiling and incorporation of compost and sand. Note the equipment is kept out of the practice.


Partial excavation for retaining wall, infiltration basin is not excavated (top), retaining wall constructed, infiltration basin is fully excavated and has infiltration media in place (bottom). Photo courtesy of Barr Engineering.

### Step 3 – Decompaction

Subsoil decompaction is required in all infiltration areas. Decompact subsoil with a backhoe ripper attachment or other approved method to a depth of at least 18 inches below subgrade in all locations indicated on the drawings. Also known as soil loosening or soil ripping, this technique has been shown to increase infiltration and reduce compaction from construction activities. For more information on alleviating compaction, link here.

### Step 4 – Subsoil Infiltration Testing

Subsoil infiltration testing is recommended prior to the placement of any infiltration media. After the subsoil is decompacted, test the infiltration area to verify the assumed infiltration rate and that the infiltration area will drain dry within 48 hours. This can be accomplished by performing double ring infiltrometer tests (ASTM D3385) in the bottom of the basin, or by filling the infiltration basin and timing how long it takes to drain from maximum water depth to dry bottom. The measured infiltration rate should equate to double the designed infiltration rate. If the basin is filled with water to perform this check, be sure sediments are not being washed into the basin during filling. If sediments are washed into the basin, they need to be removed prior to placing infiltration media.

If the basin does not drain dry within 48 hours, 24 hours for special waters, or the infiltration rate is slower than twice what was assumed in the design, additional soil loosening or modification may be necessary.

Information on soil testing can be found here.

### Step 5 – Installation of materials - infiltration media


Infiltration media being placed in infiltration area with tracked backhoe. Photo courtesy of Barr Engineering.

Soil test results should be provided to the designer a minimum of two weeks prior to delivery of planting soil to the site. Submitted test results should include gradation and USDA soil texture classification or certification that the soil mix meets MnDOT specifications or other requirements. Samples of the mixed product should be also provided to the designer two weeks prior to delivery of media to the site. The designer should review the materials as soon as possible to avoid any potential delays in the procurement and review of another media source should the initial submittal not meet specifications.

All accumulated sediment and silt from the bottom of the infiltration area should be removed prior to the placement of infiltration media. The contractor should make every effort possible to place the infiltration media in a way to minimize compaction of the subgrade and the infiltration media itself. No construction vehicles are allowed in the infiltration area after the media is placed unless approved by designer. Decompaction should occur if the subgrade has been compacted by construction equipment or supplies. Loose placement of infiltration media shall be accomplished by dumping from the edges and spreading with the bucket of a backhoe, which is outside of the infiltration area, or some other acceptable means determined by the designer. If spreading with a backhoe is not possible for the entire area of the infiltration area, only tracked skid steers or other low ground pressure equipment should be permitted in the basin to spread the infiltration media. This method should be minimized as much as possible. Travel over placed infiltration media should be strictly prohibited. The contractor should overfill the infiltration media areas approximately 20 percent to account for consolidation of the loose soil once wetting occurs. Any small irregularities at the designed finished grade should be worked out with hand tools. The contractor should contact the designer upon final placement of media for a final inspection prior to planting and mulching. At this inspection, the designer should check thickness and grades after soil wetting occurs and notify the contractor of areas that do not meet the tolerances specified. Tolerances in final grade are commonly vertically +/- 0.1 foot and horizontally +/- 0.5 foot.

If time goes by between the initial placement of infiltration media and planting, the contractor should be required to remove or mix in accumulated silt. This work is also a chance to perform any final subgrade grading adjustments required to obtain the finished grades as shown on the drawing.

### Step 6 – Restoration and plantings

After final placement of infiltration media has been approved, planting or seeding should happen as soon as possible to avoid erosion, sedimentation, and the establishment of weeds. The contractor should notify the designer at least four days in advance of when planting or seeding will occur in advance of delivery of materials to the site to allow for scheduling of site inspections. At least two weeks prior to the planting or seeding dates, any existing weeds should be thoroughly eradicated mechanically or with herbicide within the project area.

Infiltration practice complete with trees

> **Warning:** It is REQUIRED that the planting or seeding contractor have proven successful experience installing and maintaining projects of similar scope and scale and provide a superintendent that will be onsite during the entire seeding or planting process.

All seed and plants should be shipped and stored with protection from weather or other conditions that would damage the product. All plants and seeds will be inspected by the designer and items that have become wet, moldy, or otherwise damaged in transit or in storage should be rejected. Plants and seed should arrive within 24 hours of delivery. Plants and seed needs to be protected against drying and damage prior to planting.

It is typical for the plant or seeding contractor to guarantee the work for some length of time. The common minimum for herbaceous plantings or sod is 60 days during the growing season. The growing season in central Minnesota is defined as May 1st through October 31st. A one-year guarantee on containerized plants can help to ensure good establishment and decrease weed infestations while maintaining infiltration rates over time through the growth of healthy root systems. Any watering required to keep the plants healthy should be covered under the cost of the warranty period. It is appropriate to require that the contractor provide some form of surety, such as a letter of credit or other security, to the permitting entity for 150 percent of the estimated costs and quantities of all herbaceous plants or seeding for the duration of the 1-year warranty period. Planting and seeding establishment should meet the requirements within MnDOT Section 2571 (page 478).

> **Warning:** Seeding maintenance requires specialized knowledge and experience in plant and weed identification. Ensure a thorough maintenance plan is established prior to construction and that budget has been allocated for at least three full growing seasons and preferable longer. Native seedings can be more difficult than containerized plantings to establish.

Applying mulch is an important tool for preventing weed establishment and retaining moisture for the plants or seed. Twice-shredded hardwood mulch is readily available and appropriate for use in plantings that use contained plant stock. Straw or native grass cuttings are very effective on sites that have been seeded.

### Step 7 – Final stabilization and Closeout

As defined in the NPDES/SDS Construction Stormwater permit, final site stabilization is achieved when all soil disturbing activity is completed and the exposed soils have been stabilized with a vegetative cover with a uniform density of at least 70 percent over the entire site or by equivalent means to prevent soil failure. Simply seeding and mulching is not considered acceptable cover for final stabilization. Final stabilization must consist of an established permanent cover, such as a perennial vegetative cover, concrete, riprap, gravel, rooftops, asphalt, etc

The NPDES permit requires all stormwater treatment systems to meet all permit requirements and be operating as designed prior to submitting the NPDES notice of termination. This can be accomplished by infiltration rate testing or by observation that all water in the stormwater practice draws down in 48 hours or less. It is highly recommended that all infiltration areas are tested prior to project close out, even if an NPDES permit is not required.

MnDOT projects requires at least five tests per acre of infiltration area and a minimum of five tests per infiltration area. Infiltration rates shall meet or exceed double the design rate assumed. The test results from a MnDOT project must be submitted to MnDOT.

When a final construction inspection has been completed, log the GPS coordinates for each facility and submit them for entry into the local BMP maintenance tracking database, if available.

Additional information on construction of infiltration practices can be found on the Construction Specifications for Permeable Pavement page.

## Minnesota Department of Transportation example construction protocols

### Preliminary analysis and selection

**Recommended number of soil borings, pits or permeameter tests for bioretention design. Designers select one of these methods.**
Link to this table

| Surface area of stormwater control measure (BMP)($ft^2$) | Borings | Pits | Permeameter tests |
|---|---|---|---|
| < 1000 | 1 | 1 | 5 |
| 1000 to 5000 | 2 | 2 | 10 |
| 5000 to 10000 | 3 | 3 | 15 |
| >10000 | 4[1] | 4[1] | 20[2] |

[1]an additional soil boring or pit should be completed for each additional 2,500 $ft^2$ above 12,500 $ft^2$

[2]an additional five permeameter tests should be completed for each additional 5,000 $ft^2$ above 15,000 $ft^2$

### Field verification testing prior to pond construction

- Soil hydraulic group represent what is stated in SWPPP (Stormwater Pollution Prevention Plan)
- Seasonally high water table not discovered within 3 feet of the excavated pond base within a test pit
- Commonly will test bottom of proposed pond for soil compaction (subsequent subsoil ripping) prior to media placement
- Commonly will test bottom of proposed pond for insitu infiltration rate by test pit or water filled barrel placed on pond base surface

### Filter media and material testing

- Existing soil (option 1 below) or Washed sand (option 2 below), and compost certification
- Washed course aggregate choker certification
- Other treatment material certification of iron filings, activated charcoal, pH buffers, minerals, etc.
- Geotextile separation fabric certification
- Drain-tile certification (if filtration is specified)
- Seed source certification
- Barrel test verification of infiltration rate using 2.5 feet of imported 3877 Type G media

### Field verification testing/inspection/verification during construction

- Water drains away in 48 hours
- Infiltration drainage rate does not exceed 8.3 inches per hour
- No tracking/equipment in pond bottom
- No sediment deposits from ongoing construction activity, media perimeter controls kept functional
- Forebay is trapping settleable solids, floating materials, and oil/grease
- Area staked off

### Notice of Termination (NOT) verification

- **Option 1. Amending existing HSG soils with compost or other treatment material.** Test the infiltration rate of each infiltration basin using a double ring infiltrometer prior to completion of the basin. Conduct the test at the finished grade of the basin bottom, prior to blending the compost with the in-situ soils or sand. Ensure infiltration rates meet or exceed greater of two times the

designed infiltration rate or 2 inches per hour. Conduct a minimum of five tests per representative acre of basin area and a minimum of five tests per basin. Conduct double ring infiltrometer tests in accordance with ASTM standards. Thoroughly wet test areas prior to conducting infiltrometer tests.
- **Option 2. Importing 3877 Type G Filter Topsoil Borrow (may be amended with other treatment material)**. Ensure infiltration rates meet or exceed greater of two times the designed infiltration rate or 2 inches per hour, or rate specified in the plan. Conduct a minimum of five tests per representative acre of basin area and a minimum of five tests per basin. Conduct double ring infiltrometer tests in accordance with ASTM standards. Thoroughly wet test areas prior to conducting infiltrometer tests. Amend soils with additional washed sand if rates less than specified in the contract, or compost if rates exceed 8.3 inches per hour.

The permanent stormwater management system must meet all requirements in sections 15, 16, and 17 of the CSW permit and must operate as designed. Temporary or permanent sedimentation basins that are to be used as permanent water quality management basins have been cleaned of any accumulated sediment. All sediment has been removed from conveyance systems and ditches are stabilized with permanent cover.

### CADD images

CADD based details for pond systems are contained in the section on drawings. The following details, with specifications, have been created for infiltration systems:

- infiltration basin
- infiltration trench
- subsurface infiltration system
- inlet/outlet structures

### Useful links

- Chesapeake Stormwater Network TECHNICAL BULLETIN No. 10. Bioretention Illustrated: A Visual Guide for Constructing, Inspecting, Maintaining and Verifying the Bioretention Practice

## Operation and maintenance

**Green Infrastructure:** Bioretention practices can be an important tool for retention and detention of stormwater runoff. Because they utilize vegetation, bioretention practices provide additional benefits, including cleaner air, carbon sequestration, improved biological habitat, and aesthetic value.

**Information:** Due to the similarities of the majority of inspection and maintenance tasks required for both bioretention practices and infiltration practices, the Operations and Maintenance sections for both bioretention and infiltration practices have been combined into a single wiki page.

The Chesapeake Stormwater Network has developed materials that illustrate inspection and maintenance of BMP practices. These include information on visual inspections and two videos. Visit their maintenance page. **NOTE: These materials provide**

The most frequently cited maintenance concern for infiltration practices is surface clogging caused by organic matter, fine silts, hydrocarbons, and algal matter. Common operational problems include

- standing water;
- clogged filter surface; and
- inlet, outlet or under-drains clogged.

Recommendations described below are aimed at preventing these common problems.

### Design phase maintenance considerations

Implicit in the design guidance is the fact that many design elements of infiltration systems can minimize the maintenance burden and maintain pollutant removal efficiency. Key examples include

**useful guidance but should not be used for compliance with Minnesota permits.**

- limiting drainage area;
- providing easy site access (*REQUIRED*);
- providing pretreatment (*REQUIRED*); and
- utilizing native plantings (see Plants for Stormwater Design).

For more information on design information for individual infiltration practices, link here.

## Construction phase maintenance

Proper construction methods and sequencing play a significant role in reducing problems with operation and maintenance (O&M). In particular, with construction of these practices, the most important action for preventing operation and maintenance difficulties is to ensure that the contributing drainage area has been fully stabilized prior to bringing the practice on line.

**Warning:** It is required that the contributing drainage area has been fully stabilized prior to bringing the practice on line

Inspections during construction are needed to ensure that the infiltration practice is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor's interpretation of the plan is acceptable to the professional designer. An example construction phase inspection checklist is provided below.

**Infiltration practices construction inspection checklist**.
Link to this table
To access an Excel version of form (for field use), click here.

| | | |
|---|---|---|
| Project: | | |
| Location: | | |
| Site Status: | | |
| Date: | | |
| Time: | | |
| Inspector: | | |
| **Construction Sequence** | **Satisfactory / Unsatisfactory** | **Comments** |
| **1. Pre-Construction** | | |
| Pre-construction meeting | | |
| Runoff diverted (Note type of bypass) | | |
| Facility area cleared | | |
| Soil tested for permeability | | |
| Soil tested for phosphorus content (include test method) | | |
| Verify site was not overdug | | |
| Project benchmark near site | | |
| Facility location staked out | | |
| Temporary erosion and sediment protection properly installed | | |

| | | |
|---|---|---|
| **2. Excavation** | | |
| Lateral slopes completely level | | |
| Soils not compacted during excavation | | |
| Longitudinal slopes within design range | | |
| Stockpile location not adjacent to excavation area and stabilized with vegetation and/ or silt fence | | |
| Verify stockpile is not causing compaction and that it is not eroding | | |
| Was underlying soil ripped or loosened | | |
| **3. Structural Components** | | |
| Stone diaphragm installed per plans | | |
| Outlets installed pre plans | | |
| Underdrain installed to grade | | |
| Pretreatment devices installed per plans | | |
| Soil bed composition and texture conforms to specifications | | |
| **4. Vegetation** | | |
| Complies with planting specs | | |
| Topsoil complies with specs in composition and placement | | |
| Soil properly stabilized for permanent erosion control | | |
| **5. Final Inspection** | | |
| Dimensions per plans | | |
| Pre-treatment operational | | |
| Inlet/outlet operational | | |
| Soil/ filter bed permeability verified | | |
| Effective stand of vegetation stabilized | | |
| Construction generated sediments removed | | |
| Contributing watershed stabilized before flow is diverted to the practice | | |
| Comments: | | |
| Actions to be taken: | | |

## Post-construction operation and maintenance

**Warning:** A maintenance plan clarifying maintenance responsibility is *REQUIRED*. Effective long-term operation of infiltration practices necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Proper maintenance will not only increase the expected lifespan of the facility but will improve aesthetics and property value.

### Inspection and maintenance planning


Example of a failing bioinfiltration system. Failure was due to clogging of the media surface by incoming sediment.

A maintenance plan clarifying maintenance responsibilities is REQUIRED. Effective long-term operation of bioretention and infiltration practices necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Proper maintenance will not only increase the expected lifespan of the facility but will improve aesthetics and property value.

Some important post-construction considerations are provided below along with RECOMMENDED maintenance standards.

- A site-specific O&M plan that includes the following considerations should be prepared by the designer prior to putting the stormwater practice into operation.
  - Inspection checklists
  - Routine maintenance checklists
  - Operating instructions for outlet component
  - Vegetation maintenance schedule
- A legally binding and enforceable maintenance agreement should be executed between the practice owner and the local review authority.
- Adequate access must be provided for inspection, maintenance and landscaping upkeep, including appropriate equipment and vehicles.
- Maintenance activities should be careful not to cause compaction. No vehicles will be allowed within the footprint of the filtration or infiltration area. Foot traffic and stockpiling should be kept to a minimum.
- The surface of the ponding area may become clogged with fine sediment over time. Core aeration or cultivating of non-vegetated areas may be required to ensure adequate filtration.
- BMP areas generally should not be used as dedicated snow storage areas, but can be with the following considerations.
  - Snow storage should not occur in areas designated as potential stormwater hotspots for road salt.
  - Areas designed for infiltration should be protected from excessive snow storage where sand and salt is applied.
  - Specific snow storage areas should be assigned that will provide some filtration before the stormwater reaches the BMP areas.**NOTE: Chloride will not be attenuated in filtration BMPs.**
  - When used for snow storage, or if used to treat parking lot runoff, the BMP area should be planted with salt tolerant and non-woody plant species.
  - Practices should always be inspected for sand build-up on the surface following the spring melt event.
- General maintenance activities and schedule are provided below.

### Summary of typical maintenance regime


Maintenance of vegetated infiltration practices is critical during the establishment period. Although some plants look healthy in this photo, maintenance is needed to remove sediment from the filter strip and inflow area, remove weeds from the basin, re-

The list below highlights the assumed maintenance regime for an infiltration or bioinfiltration basin or trench, tree trench, or dry swale with check dams. Note that some items pertain only to vegetated systems.

- First year after planting
  - Adequate water is crucial to plant survival and temporary irrigation will be needed unless rainfall is adequate until plants mature
- As needed
  - Prune and weed to maintain appearance
  - Stabilize or replace mulch when erosion is evident
  - Remove trash and debris
  - Mow filter strip
  - Renew mulch to replace that which has decomposed
  - Replace vegetation whenever percent cover of acceptable vegetation falls below 90 percent or project specific performance requirements are not met. If vegetation suffers for no apparent reason, consult with horticulturist and/or test soil as needed
- Semi-annually
  - Inspect inflow and pretreatment systems for clogging (off-line systems) and remove any sediment
  - Inspect filter strip/grass channel for erosion or gullying. Sod as necessary
  - Herbaceous vegetation, trees and shrubs should be inspected to evaluate their health and replanted as appropriate to meet project goals
  - Remove any dead or severely diseased vegetation

- Annually in fall
  - Inspect and remove any sediment and debris build-up in pretreatment areas
  - Inspect inflow points and infiltration surface for buildup of road sand associated with spring melt period, remove as necessary, and replant areas that have been impacted by sand/salt build up
- Annually in spring
  - Cut back and remove previous year's plant material and remove accumulated leaves if needed (or controlled burn where appropriate)

vegetate some ares, and add mulch to some areas.

## Estimated hours to perform maintenance activities

All estimated hours listed below would be to perform maintenance on a commercially sized bioinfiltration or bioretention basin approximately 1,000 square feet in size that has adequate pretreatment, has been planted with containerized plants, and mulched appropriately.

- **Plant Establishment Period (First two years)**
  - Bi-monthly weeding – 4 visits at 3 hours per visit
  - Plant replacement – 1 replacement planting in the Fall, 4 hours (assuming 10 percent plant loss)
  - Spring cleanup (cut back of previous years vegetation) –2 hours
  - Erosion, sediment, and pretreatment cleanout – 1 hour (assuming vacuum truck clean-out of sump catch basin or sediment fore bay)
- **Regular Maintenance (After first two years)**
  - Bi-monthly weeding – 4 visits at 2 hours per visit
  - Plant replacement – 1 replacement planting in the Fall, 2 hours (assuming 5 percent plant loss)
  - Spring cleanup (cut back of previous years vegetation) – 4 hours
  - Tree and shrub pruning – 2 hours (every third year)
  - Erosion, sediment, and pretreatment clean-out – 4 Hours (assuming vacuum truck clean-out of sump catch basin or sediment forebay once per year and at least one bi-yearly sediment removal from the bottom of the basin)

## Erosion protection and sediment monitoring, removal, and disposal – protecting your investment

Regular inspection of not only the BMP but also the immediate surrounding catchment area is necessary to ensure a long lifespan of the water quality improvement feature. Erosion should be identified as soon as possible to avoid the contribution of significant sediment to the BMP.

Pretreatment devices need to be maintained for long-term functionality of the entire BMP. Accumulated sediment in forebays, filter strips, water quality sump catch basins, or any pretreatment features will need to be inspected yearly. Timing of cleaning of these features is dependent on their design and sediment storage capabilities. In watersheds with erosion or high sediment loadings, the frequency of clean out will likely be increased. A vacuum truck is typically used for sediment removal. It is possible that any sediment removed from pretreatment devices or from the bottom of a basin may contain high levels of pollutants. All sediments, similar to those retrieved from a stormwater pond during dredging, may be subjected to the MPCA's guidance for reuse and disposal.

If a grassed filter strip or swale is used as pretreatment, they should be mowed as frequently as a typical lawn. Depending on the contributing watershed, grassed BMPs may also need to be swept before mowing. All grassed BMPs should be swept annually with a stiff bristle broom or equal to remove thatch and winter sand. The University of Minnesota's Sustainable Urban Landscape Series website provides guidance for turf maintenance, including mowing heights.

Sediment loading can potentially lead to a drop in infiltration or filtration rates. It is recommended that infiltration performance evaluations follow the four level assessment systems in Stormwater Treatment: Assessment and Maintenance (Gulliver et al., 2010).

## Seeding, planting, and landscaping maintenance – keeping it looking good

Plant selection during the design process is essential to limit the amount of maintenance required. It is also critical to identify who will be maintaining the BMP in perpetuity and to design the plantings or seedings accordingly. The decision to install containerized plants or to seed will dictate the appearance of the BMP for years to come. If the BMP is designed to be seeded with an appropriate native plant based seed mix, it is essential the owner have trained staff or the ability to hire specialized management professionals. Seedings can provide plant diversity and dense coverage that helps maintain drawdown rates, but landscape management professionals that have not been trained to identify and appropriately manage weeds within the seeding may inadvertently allow the BMP to become infested and the designed plant diversity be lost. The following are minimum requirements for seed establishment and plant coverage.

- At least 50 percent of specified vegetation cover at end of the first growing season, not including REQUIRED cover crop
- At least 90 percent of specified vegetation cover at end of the third growing season
- Supplement plantings to meet project specifications if cover requirements are not met
- Tailor percent coverage requirements to project goals and vegetation. For example, percent cover required for turf after one growing season would likely be 100 percent, whereas it would be lower for other vegetation types.

For information on plant selection, link here.


This bioretention basin utilizes several native species.

For proper nutrient control, bioretention BMP's must not be fertilized unless a soil test from a certified lab indicates nutrient deficiency. An exception is a one-time fertilizer application during planting of the cell, which will help with plant establishment. Irrigation is also typically needed during establishment.

Weeding is especially important during the plant establishment period, when vegetation cover is not 100 percent yet. Some weeding will always be needed. It is also important to budget for some plant replacement (at least 5 to 10 percent of the original plantings or seedings) during the first few years in case some of the plants or seed that were originally installed don't become vigorous. It is highly recommended that the install contractor be responsible for a plant warranty period. Typically, plant warranty periods can be 60 days or up to one year from preliminary acceptance through final inspections. If budget allows, installing larger plants (#1 Cont. vs 4" Pot) during construction can decrease replacement rates if properly cared for during the establishment period.

Weeding in years after initial establishment should be targeted and thorough. Total eradication of aggressive weeds at each maintenance visit will ultimately reduce the overall effort required to keep the BMP weed free. Mulch is highly effective at preventing weeds from establishing while helping retain moisture for plant health. Mulch renewal will be needed two or three times after establishment (first five years). After that, the plants are typically dense enough to require less mulching, and the breakdown of plant material will provide enough organic matter to the infiltration/filtration practice.

Rubbish and trash removal will likely be needed more frequently than in the adjacent landscape. Trash removal is important for prevention of mosquitoes and for the overall appearance of the BMP.

## Sustainable service life for infiltration and bioretention BMPs

The service life of infiltration practices depends upon the pollutant of concern.

### Infiltration rate service life before clogging

Infiltration rate appears to drop immediately after installation and then level off at a sustainable level (Jenkins et al., 2010; Barrett et al., 2013). Planted bioretention columns even showed a slight increase in infiltration rate after the initial drop (Barrett et al., 2013). Plant roots are essential in macropore formation, which help to maintain the infiltration rate. If proper pretreatment is present, service life for infiltration should be unlimited. However, if construction site runoff is not kept from entering the infiltration cell, clogging will occur, limiting or eliminating the infiltration function of the system, thus requiring restorative maintenance or repair (Brown and Hunt, 2012).

### Nitrogen reduction

An important mechanism of nitrogen removal in vegetated infiltration systems is plant uptake since nitrogen is essential for plant growth. If the BMP has an internal water storage zone, soluble nitrogen is also removed through denitrification, a microbially-mediated process that only occurs under anoxic conditions. Denitrification requires organic matter as a carbon source, which is supplied by decaying root matter and mulch. Particulate bound nitrogen in stormwater runoff will typically be removed through sedimentation. All of these processes are self-sustaining, and the service life of an infiltration system designed for nitrogen reduction should be very long. In oxygenated systems where denitrification is not an important process, leaching of nitrate is likely. In systems having soils with a high organic matter content, organic nitrogen can be converted to nitrate, resulting in additional loss of nitrogen through leaching (Liging and Davis, 2014).

### Phosphorus reduction

With design optimized for phosphorus reduction, service life can be more than three decades (Lucas and Greenway, 2011c). Sediment bound phosphorus is removed through sedimentation, while removal of soluble phosphorus in bioretention depends on the type of media used. If the media is already saturated with P (i.e. its P binding sites are full), it will not be able to retain additional dissolved

P and the P in stormwater will tend to leach from the media as it passes through the biofilter (Hunt et al., 2006). It is highly recommended that the P-index of the media at installation be below 30, which equates to less than 36 milligrams per kilogram P, to ensure P removal capacity. Laboratory research has suggested an oxalate extractable P concentration of 20 to 40 milligrams per liter will provide consistent removal of P (O'Neill and Davis, 2012). After an effective loading of the equivalent of more than three decades of P into bioretention mecocosms optimized for P reduction, researchers in Australia showed that excellent P retention was still occurring. Keys to maximize P reduction in these systems included P sorptive soils or soil amendments (e.g. aluminum water treatment residuals [WTR] or Krasnozem soils [K40], a highly aggregated clay), use of coir peat (a source of organic matter low in phosphorus), and healthy vegetation. The systems with aluminum water treatment residuals still retained up to 99 percent of applied PO4-P in storm water after the equivalent of 32 years of treatment. After 110 weeks of effluent loading at typical stormwater concentrations, the equivalent of 48 years of bioretention loads, phosphate retention from storm water by the K40 soils treatment was 85 percent. "Comparison with the K40 treatments over the loading and dosing regimes suggest that the WTR treatments will perform at least as well as the K40 treatment under similar exposure of 48 years" (Lucas and Greenway, 2011).

### Heavy metals retention

Metals are typically retained in infiltration systems through sedimentation and adsorption processes. Since there are a finite amount of sorption sites for metals in a particular soil, there will be a finite service life for the removal of dissolved metals. Morgan et al. (2011) investigated cadmium, copper, and zinc removal and retention with batch and column experiments. Using synthetic stormwater at typical stormwater concentrations, they found that 6 inches of filter media composed of 30 percent compost and 70 percent sand will last 95 years until breakthrough (i.e. when the effluent concentration is 10 percent of the influent concentration). They also found that increasing compost from 0 percent to 10 percent more than doubles the expected lifespan for 10 percent breakthrough in 6 inches of filter media for retainage of cadmium and zinc. Using accelerated dosing laboratory experiments, Hatt et al. (2011) found that breakthrough of Zn was observed after 2000 pore volumes, but did not observe breakthrough for Cd, Cu, and Pb after 15 years of synthetic stormwater passed through the media. However, concentrations of Cd, Cu, and Pb on soil media particles exceeded human and/or ecological health levels, which could have an impact on disposal if the media needed replacement. Since the majority of metals retainage occurs in the upper 2 to 4 inches of the soil media (Li and Davis, 2008), long-term metals capture may only require rejuvenation of the upper portion of the media.

### Polycyclic aromatic hydrocarbons (PAHs) reduction

Accumulation of polycyclic aromatic hydrocarbons (PAHs) in sediments has been found to be so high in some stormwater retention ponds that disposal costs for the dredging spoils were prohibitively high. Research has shown that rain gardens, on the other hand, are "a viable solution for sustainable petroleum hydrocarbon removal from stormwater, and that vegetation can enhance overall performance and stimulate biodegradation." (Lefevre, 2012b).

## Typical maintenance problems and activities for infiltration practices

The following table summarizes common maintenance concerns, suggested actions, and recommended maintenance schedule.

**Typical maintenance problems and activities for infiltration practices**
Link to this table

| Inspection Focus | Common Maintenance Problems | Maintenance Activity | Recommended Maintenance Schedule | Applicable Infiltration Practices[1] |
|---|---|---|---|---|
| **Drainage Area and Drawdown Time** | Clogging, sediment deposition | Ensure that contributing catchment areas to practice, and inlets are clear of debris | Monthly | 1,2,3,4,5,6,7 |
| | Erosion of catchment area contributing significant amount of sediment | In case of severely reduced drawdown time, scrape bottom of basin and remove sediment. Disc or otherwise aerate/scarify basin bottom. De-thatch if basin bottom is turf grass. Restore original design cross section or revise section to increase infiltration rate and restore with vegetation as necessary. | Upon identification of drawdown times longer than 48 hours or upon complete failure | 1,2,3,4,5,6 |
| **Pretreatment** | Pretreatment screens or sumps reach capacity | Remove sediment and oil/grease from pretreatment devices/structures. | Minimum yearly or as per manufacturer's recommendations | 1,2,3,4,5 |
| | Vegetative filter strip failure | Reduce height of vegetative filter strip that may be limiting in-flow. Re-establish vegetation to prevent erosion. Leave practice off-line until full reestablishment. | Mow grass filter strips monthly. Restore as necessary | 1,2,4,6 |

| Inspection Focus | Common Maintenance Problems | Maintenance Activity | Recommended Maintenance Schedule | Applicable Infiltration Practices |
|---|---|---|---|---|
| **Site Erosion** | Scouring at inlets | Correct earthwork to promote non-erosive flows that are evenly distributed | As necessary | 1,2,3,6 |
| | Unexpected flow paths into practice | Correct earthwork to eliminate unexpected drainage or created additional stable inlets as necessary | As necessary | 1,2,3,6 |
| **Vegetation** | Reduced drawdown time damaging plants | Correct drainage issues as described above | Replace with appropriate plants after correction of drainage issues | 2,6,8 |
| | Severe weed establishment | Limit the ability for noxious weed establishment by properly mowing, mulching or timely herbicide or hand weeding. Refer to the MDA Noxious Weed List | Bi-monthly April through October | 2,6,8 |

[1]1=Infiltration Basin; 2=Bioinfiltration Basin; 3=Infiltration Trench; 4=Dry Well; 5=Underground Infiltration; 6=Dry Swale with Check Dams; 7=Permeable Pavement; 8=Tree Trench/Tree Box

## Maintenance agreements

A Maintenance Agreement is a legally binding agreement between two parties, and is defined as "a nonpossessory right to use and/or enter onto the real property of another without possessing it." Maintenance Agreements are often required for the issuance of a permit for construction of a stormwater management feature and are written and approved by legal counsel. Maintenance Agreements are often similar to Construction Easements. A Maintenance Agreement is required for one party to define and enforce maintenance by another party. The Agreement also defines site access and maintenance of any features or infrastructure if the property owner fails to perform the required maintenance.

Maintenance Agreements are commonly established for a defined period such as five years for a residential site or 10 to 20 years for a commercial/governmental site after construction of the infiltration practice. Maintenance agreements often define the types of inspection and maintenance that would be required for that infiltration practice and what the timing and duration of the inspections and maintenance may be. Essential inspection and maintenance activities include but are not limited to drawdown time, sediment removal, erosion monitoring and correction, and vegetative maintenance and weeding. If maintenance is required to be performed due to failure of the site owner to properly maintain the infiltration practices, payment or reimbursement terms of the maintenance work are defined in the Agreement. Below is an example list of maintenance standards from an actual Maintenance Agreement.

1. Plants shall be watered daily for two weeks after the garden installation is complete.
2. In the first year, rainwater gardens require vigilant weeding and should be weeded monthly. The need for weeding will decrease as plants become established.
3. Dead plant material and garbage or other debris shall be removed from the rain garden.
4. Areas devoid of mulch shall be re-mulched on an annual basis.
5. The rainwater garden shall be inspected annually for sediment trapped in the pretreatment area and in the garden itself. If possible, accumulated sediment should be removed.
6. Shrubs shall be pruned as necessary to keep a neat appearance.
7. Plants that do not survive shall be removed and replanted.
8. Side slopes must be inspected for erosion and the formation of rills or gullies at least annually and erosion problems must be corrected immediately.
9. If gardens are properly planned and designed (protected from sediment and compaction and incorporating a sufficient turf pretreatment area), a rainwater basin is likely to retain its effectiveness for well over 20 years. After that time, inspection will reveal whether sedimentation warrants scraping out the basin and replanting it (possibly with salvaged plants).

In some project areas, a drainage easement may be required. Having an easement provides a mechanism for enforcement of maintenance agreements to help ensure infiltration practices are maintained and functioning. Drainage Easements also require that the land use not be altered in the future. Drainage Easements exist in perpetuity and are required property deed amendment to be passed down to all future property owners.

As defined by the Maintenance Agreement, the landowner should agree to provide notification immediately upon any change of the legal status or ownership of the property. Copies of all duly executed property transfer documents should be submitted as soon as a property transfer is made final.

- Example Maintenance Agreement 1
- Example Maintenance Agreement 2
- Example Maintenance Agreement 3

## Maintenance inspection reports

- Maintenance inspection report for infiltration basins
  - upload MS Word version File:Maintenance inspection report for infiltration basins.docx
- Maintenance inspection report for bioinfiltration basins
  - upload MS Word version File:Maintenance inspection report for bioinfiltration basins.docx
- Maintenance inspection report for infiltration trench
  - upload MS Word version File:Maintenance inspection report for infiltration trench.docx
- Maintenance inspection report for dry well
  - upload MS Word version File:Maintenance inspection report for dry well.docx
- Maintenance inspection report for underground infiltration facilities
  - upload MS Word version File:Maintenance inspection report for underground infiltration facilities.docx
- Maintenance inspection report for dry swale with check dams
  - upload MS Word version File:Maintenance inspection report for dry swale with check dams.docx
- Maintenance inspection report for permeable pavement
  - upload MS Word version File:Maintenance inspection report for permeable pavement.docx
- Maintenance inspection report for tree trench/tree box
  - upload MS Word version File:Maintenance inspection report for tree trench-tree box.docx

Link to Chesapeake Stormwater visual indicators form.

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### Useful links

- Chesapeake Stormwater Network TECHNICAL BULLETIN No. 10. Bioretention Illustrated: A Visual Guide for Constructing, Inspecting, Maintaining and Verifying the Bioretention Practice
- Archived webcast from Chesapeake Stormwater Network - TRUST BUT VERIFY: Urban BMP Verification in the Chesapeake Bay

## Assessing performance

**Green Infrastructure:** Infiltration practices can be an important tool for retention and detention of stormwater runoff and treatment of pollutants in stormwater runoff. If the practice utilizes vegetation, additional benefits may include cleaner air, carbon sequestration, improved biological habitat, and aesthetic value.

Infiltration trenches and basins are designed to infiltrate runoff and remove pollutants from the surface water stream through attenuation in soil or media or transport into underlying groundwater at concentrations below drinking water standards. It is difficult to assess the performance of these BMPs, although considering only potential impacts to surface waters, a properly functioning infiltration system is considered to be highly performing.

Performance of an infiltration BMP is determined by the length of time needed for captured water to infiltrate. This time is called the drawdown time or period of inundation. The drawdown time is typically 48 hours, meaning water captured by an infiltration BMP should completely infiltrate into the underlying soil or media within 48 hours.

Note: experience has demonstrated that, although the drawdown period is 48 hours, there is often some residual water pooled in the infiltration practice after 48 hours. This residual water may be associated with reduced head, water gathered in depressions within the practice, water trapped by vegetation, and so on. The drawdown period is therefore defined as the time from the high water level in the practice to 1 to 2 inches above the bottom of the facility. This criterion was established to provide the following: wet-dry cycling between rainfall events; unsuitable mosquito breeding habitat; suitable habitat for vegetation; aerobic conditions; and storage for back-to-back precipitation events. This time period has also been called the period of inundation.

An online manual for assessing BMP treatment performance was developed in 2010 by Andrew Erickson, Peter Weiss, and John Gulliver from the University of Minnesota and St. Anthony Falls Hydraulic Laboratory. The manual advises on a four-level process to assess the performance of a Best Management Practice.

- Level 1: Visual Inspection. This includes assessments for infiltration practices and for filtration practices. The website includes links to a downloadable checklist.
- Level 2: Capacity Testing. Level 2 testing can be applied to both infiltration and filtration practices.
- Level 3: Synthetic Runoff Testing for infiltration and filtration practices. Synthetic runoff test results can be used to develop an accurate characterization of pollutant retention or removal, but can be limited by the need for an available water volume and discharge.
- Level 4: Monitoring for infiltration or filtration practices

Level 1 activities do not produce numerical performance data that could be used to obtain a stormwater management credit. BMP owners and operators who are interested in using data obtained from Levels 2 and 3 should consult with the MPCA or other regulatory agency to determine if the results are appropriate for credit calculations. Level 4, Monitoring, is the method most frequently used for assessment of the performance of a BMP.

Use these links to obtain detailed information on the following topics related to BMP performance monitoring:

- Developing an Assessment Program
- Water Budget Measurement
- Sampling Methods

- Analysis of Water and Soils
- Data Analysis for Monitoring

Additional information on designing a monitoring network and performing field monitoring are found at this link.

# Cost-benefit considerations

The section on integrated stormwater management outlines a cost estimation method which site planners could use to compare the relative construction and maintenance costs for structural best management practices. These curves are excellent for purposes of comparison; however, it is recommended that construction and maintenance budgets should be based on site specific information. Utilizing the cost estimation worksheet below will allow designers to avoid over or under estimation of fixed costs.

**Infiltration trench and infiltration basin cost estimate worksheet.**
Link to this table

| | | | | |
|---|---|---|---|---|
| Project Title | | | | |
| Owner | | | | |
| Location | | | | |
| Project Number | | | | |
| Date | | | | |
| **Description** | **Units** | **Quantity** | **Unit Cost** | **Total Estimated Price** |
| **Site Preparation** | | | | |
| Tree removal - up to 12" diameter | each | | $350.00 | $0.00 |
| Clear and grub brush | square yard | | $1.50 | $0.00 |
| Tree protection - temp. fence | lineal foot | | $3.00 | $0.00 |
| Infiltration area protection - silt fence | lineal foot | | $2.00 | $0.00 |
| Topsoil - 6" depth, salvage on site | square yard | | $4.50 | $0.00 |
| **Site Formation** | | | | |
| Excavation - 6' depth | square yard | | $8.00 | $0.00 |
| Grading | square yard | | $1.50 | $0.00 |
| Hauling off-site - 6' depth | square yard | | $10.00 | $0.00 |
| **Structural Components** | | | | |
| Inlet structure | each | | $1,500.00 | $0.00 |
| Multi-stage outlet structure | each | | $2,500.00 | $0.00 |
| **Site Restoration** | | | | |
| Sod filter strip | lineal foot | | $1.50 | $0.00 |
| Soil preparation | square yard | | $5.00 | $0.00 |
| Seeding - above outlet elevation | square yard | | $0.50 | $0.00 |
| Planting - below outlet elevation | square yard | | $30.00 | $0.00 |

| | | | | |
|---|---|---|---|---|
| Mulch | square yard | | $2.00 | $0.00 |
| Subtotal | | | | $0.00 |
| 10% Contingencies | | | | $0.00 |
| Subtotal | | | | $0.00 |
| Apply MN Location Factor | | | | $0.00 |
| TAL CONSTRUCTION COST | | | | $0.00 |
| **Annual Operation and Maintenance** | | | | |
| Replace planting media | square yard | | $12.00 | $0.00 |
| Debris removal | per visit | | $50.00 | $0.00 |
| Mow filter strips | per visit | | $50.00 | $0.00 |
| Sediment removal | per year | | $500.00 | $0.00 |
| Replace plants | per plant | | $5.00 | $0.00 |
| Erosion repair | square yard | | $75.00 | $0.00 |
| Gate / valve operation | per visit | | $125.00 | $0.00 |
| Inspection | per visit | | $125.00 | $0.00 |
| Subtotal | | | | $0.00 |
| Apply MN Location Factor | | | | $0.00 |
| TOTAL ANNUAL O&M COST | | | | $0.00 |
| **Minnesota Location Factors** | | | | |
| Bemidji | | 0.963 | | |
| Brainerd | | 1.003 | | |
| Detroit Lakes | | 0.962 | | |
| Duluth | | 0.991 | | |
| Mankato | | 0.990 | | |
| Bemidji | | 0.963 | | |
| Minneapolis | | 1.035 | | |
| Rochester | | 0.983 | | |
| St. Paul | | 1.000 | | |
| St. Cloud | | 1.002 | | |
| Thief River Falls | | 1.042 | | |
| Willmar | | 0.961 | | |
| Windom | | 0.935 | | |

Note: Suggested unit costs are based on RS Means prices for Spring, 2005, then factored into an area basis based on typical design features for Constructed Wetlands BMPs. To be used for preliminary cost estimation

The table below lists the specific site components that are specific to infiltration practices. Not included in this table are those cost items that are common to all construction projects, such as mobilization, traffic control, erosion and sediment control, permitting, etc.

**Summary of infiltration practices cost components**.
Link to this table

| Implementation Stage | Primary Cost Components | Basic Cost Estimate | Other Considerations |
|---|---|---|---|
| Site Preparation | Tree & plant protection | Protection Cost ($/acre) * Affected Area (acre) | Removal of existing structures, topsoil removal and stockpiling |
| | Infiltration area protection | Silt fence cost ($/'foot) * Perimeter of infiltration area | |
| | Clearing & grubbing | Clearing Cost ($/acre) * Affected Area (acre) | |
| | Topsoil salvage | Salvage Cost ($/acre) * Affected Area | |
| Site Formation | Excavation / grading | X-ft Depth Excavation Cost ($/acre) * Area (acre) | Soil & rock fill material, tunneling |
| | Hauling material offsite | Excavation Cost * (% of Material to be hauled away) | |
| Structural Components | Vault structure (for underground infiltration) | ($/structure) | Pipes, catchbasins, manholes, valves, vaults |
| | Media (for infiltration trenches) | Media cost ($/cubic yard) * filter volume (cubic yard) | |
| | Geotextile | Geotextile cost ($/cy) * area of trench, including walls | |
| | inlet structure | ($/structure) | |
| | Overflow structure | ($/structure) | |
| | Observation well | ($/structure) | |
| Site Restoration | Soil preparation | Topsoil or amendment cost ($/acre) * Area (acre) | Tree protection, soil amendments, seed bed preparation, trails |
| | Seeding | Seeding Cost ($/acre) * Seeded Area (acre) | |
| | Filter strip | Sod cost ($/square foot) * filter strip area | |
| | Planting / transplanting | Planting Cost ($/acre) * Planted Area (acre) | |
| Annual Operation, Maintenance, and Inspection | Sediment removal | Removal Cost ($/acre) * Area (acre) * Frequency (1 time per 5 years) | Vegetation maintenance, cleaning of structures |
| | Debris removal | Removal Cost ($/acre) * Area (acre) * Frequency (2 time per year) | |
| | Inspection | Inspection Cost ($) * Inspection Frequency (6 times per year) | |
| | Mowing (for some vegetative filters) | Mowing Cost ($) * Mowing Frequency (6 times per year) | |

=Calculating credits=

'''Warning:''' Models are often selected to calculate credits. The model selected depends on your objectives. For compliance with the Construction Stormwater permit, the model must be based on the assumption that an instantaneous volume is captured by the BMP.

{| class="wikitable" style="float:right; margin-left: 10px; width:100px;" |- | colspan="8" style="text-align: center;" | '''Recommended pollutant removal efficiencies, in percent, for infiltration BMPs. [http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs#References Sources].

TSS=total suspended solids; TP=total phosphorus; PP=particulate phosphorus; DP=dissolved phosphorus; TN=total nitrogen''' |- | '''TSS''' | '''TP''' | '''PP''' | '''DP''' | '''TN''' | '''Metals''' | '''Bacteria''' |'''Hydrocarbons''' |- | colspan="8" style="text-align: center;" |Pollutant removal is 100 percent for the volume that is captured and infiltrated |}

'''Green Infrastructure:''' Infiltration practices can be an important tool for retention and detention of stormwater runoff and treatment of pollutants in stormwater runoff. If the practice utilizes vegetation, additional benefits may include cleaner air, carbon sequestration, improved biological habitat, and aesthetic value.

[http://stormwater.pca.state.mn.us/index.php/Overview_of_stormwater_credits Credit] refers to the quantity of stormwater or pollutant reduction achieved either by an individual [[Glossary#B|Best Management Practice]] (BMP) or cumulatively with multiple BMPs. Stormwater credits are a tool for local stormwater authorities who are interested in *providing incentives to site developers to encourage the [[Credits for Better Site design|preservation of natural areas and the reduction of the volume of stormwater]] runoff being conveyed to a best management practice (BMP); *complying with permit requirements, including antidegradation (see [http://stormwater.pca.state.mn.us/index.php/Construction_stormwater_permit]; [http://stormwater.pca.state.mn.us/index.php/MS4_General_Permit]); *meeting the [http://stormwater.pca.state.mn.us/index.php/Performance_goals_for_new_development,_re-development_and_linear_projects MIDS performance goal]; or *meeting or complying with water quality objectives, including [[Total Maximum Daily Loads (TMDLs)|Total Maximum Daily Load]] (TMDL) Wasteload Allocations (WLAs). This page provides a discussion of how infiltration practices can achieve stormwater credits. Infiltration practices include infiltration basins, infiltration trenches (including dry wells), and underground infiltration systems. The discussion does not include [[Bioretention|bioinfiltration]] and [[Permeable pavement|permeable pavement]] systems, unless specifically mentioned. To view the credit articles for other BMPs, see the [[Calculating credits for infiltration basin#Related articles|Related pages]] section. ==Overview== [[File:Infiltration basin schematic..jpg|thumb|300px|alt=Infiltration Basin Detailed Cross Section|Schematic showing an infiltration basin. Note that inflow into the practice has undergone pretreatment. Once the infiltration basin is filled, water bypasses rather than enters the practice.]] Infiltration practices are designed to capture, store, and infiltrate stormwater runoff. They rely on naturally permeable soils to fully infiltrate the designed [[Glossary#W|water quality volume]] ($V_{WQ}$). These are typically off-line practices utilizing an emergency spillway or outlet structure to capture the volume of stormwater runoff for which the practice is designed. Volumes that exceed the rate or volume of the infiltration practice are allowed to bypass the BMP. ===Pollutant removal mechanisms=== Infiltration practices reduce stormwater volume and pollutant loads through infiltration of the stormwater runoff into the native soil. Infiltration practices also can remove a wide variety of stormwater pollutants through secondary removal mechanisms including filtration, biological uptake, and soil adsorption through plantings and soil media (WEF Design of Urban Stormwater Controls, 2012). See [[#Other Pollutants|Other Pollutants]], for a complete list of other pollutants addressed by infiltration practices. ===Location in the treatment train=== Stormwater [[Using the treatment train approach to BMP selection|Treatment Trains]] are comprised of multiple Best Management Practices that work together to minimize the volume of stormwater runoff, remove pollutants, and reduce the rate of stormwater runoff being discharged to Minnesota wetlands, lakes and streams. Because infiltration practices are designed to be off-line, they may either be located at the end of the treatment train, or used as off-line configurations to divert the [[Glossary#W|water quality volume]] from the on-line system. ==Methodology for calculating credits== This section describes the basic concepts and equations used to calculate credits for volume, Total Suspended Solids (TSS) and Total Phosphorus (TP). Specific methods for calculating credits are discussed later in this article. Infiltration practices are also effective at reducing concentrations of other pollutants including nitrogen, metals, bacteria, and hydrocarbons. This article does not provide information on calculating credits for pollutants other than TSS and TP, but [[Calculating credits for infiltration basin#Other pollutants|references]] are provided that may be useful for calculating credits for other pollutants. ===Assumptions and approach === In developing the credit calculations, it is assumed the infiltration practice is properly designed, constructed, and maintained in accordance with the Minnesota Stormwater Manual. If any of these assumptions is not valid, the BMP may not qualify for credits or credits should be reduced based on reduced ability of the BMP to achieve volume or pollutant reductions. For guidance on design, construction, and maintenance, see the appropriate article within the [[Infiltration basin|infiltration basin]] or [[Infiltration trench|infiltration trench]] sections of the Manual. Because of their high susceptibility of failure due to clogging, pretreatment is REQUIRED in all infiltration designs.

'''Warning:''' Pretreatment is required for all infiltration practices

In the following discussion, the water quality volume ($V_{WQ}$) is delivered instantaneously to the BMP. $V_{WQ}$ is stored as water ponded above the soil or engineered media and below the overflow elevation. $V_{WQ}$ can vary depending on the stormwater management objective(s). For construction stormwater, $V_{WQ}$ is 1 inch off new impervious surface. For MIDS, $V_{WQ}$ is 1.1 inches. In reality, some water will infiltrate through the bottom and sidewalls of the BMP as a rain event proceeds. The instantaneous volume method therefore may underestimate actual volume and pollutant losses. The approach in the following sections is based on the following general design considerations: *Credit calculations presented in this article are for both event and annual volume and pollutant load removals. *Stormwater volume credit equates to the volume of runoff that will ultimately be infiltrated into the soil subgrade. *TSS and TP credits are achieved for the volume of runoff that is infiltrated. ===Volume Credit Calculations=== [[File:Infiltration basin schematic..jpg|thumb|300px|alt=Infiltration Basin Detailed Cross Section|Schematic showing terms used in calculating volume credits for an infiltration basin.]] Volume credits are calculated based on the capacity of the BMP and its ability to permanently remove stormwater runoff via infiltration into the underlying soil from the existing stormwater collection system. These credits are assumed to be instantaneous values entirely based on the capacity of the BMP to capture, store, and transmit water in any storm event. Because the volume is calculated as an instantaneous volume, the water quality volume ($V_{WQ}$) is assumed to pond below the overflow elevation and above the bioretention media. This entire volume is assumed to infiltrate through the bottom of the BMP. The volume credit ($V_{inf_b}$) for infiltration through the bottom of the BMP into the underlying soil, in cubic feet, is given by <math> V_{inf_b} = D_o\ (A_O + A_M)\ / 2 </math> where :$A_O$ is the overflow surface area of the bioretention system, in square feet; :$A_M$ is the area at the surface of the media, in square feet; and :$D_o$ is the ponded depth with the BMP, in feet. If native soils are used rather than engineered media, the term $A_M$ may be substituted by $A_B$, as shown in the above schematic and in the schematics for the [[MIDS calculator]]. To comply with the [http://stormwater.pca.state.mn.us/index.php/Construction_stormwater_permit Construction Stormwater General Permit], $V_{WQ}$ must infiltrate within 48 hours (24 hours is recommended if discharges are to a trout stream). Some of the $V_{WQ}$ will be lost to evapotranspiration rather than all being lost to infiltration. In terms of a water quantity credit, this differentiation is unimportant, but it may be important if attempting to calculate actual infiltration into the underlying soil. The annual volume captured and infiltrated by the BMP can be determined with appropriate modeling tools, including the [[MIDS calculator]]. Example values are shown below for a scenario using the MIDS calculator. For example, a permeable pavement system designed to capture 1 inch of runoff from impervious surfaces will capture 89 percent of annual runoff from a site with B (SM) soils. '''Annual volume, expressed as a percent of annual runoff, treated by a BMP as a function of soil and [[Glossary#W|water quality volume]]. See footnote[1] for how these were determined.'''

Link to this [[Annual volume treated as a function of soil and water quality volume|table]]

| Soil | Water quality volume ($V_{WQ}$) (inches) | | | | |
|---|---|---|---|---|---|
| | **0.5** | **0.75** | **1.00** | **1.25** | **1.50** |
| A (GW) | 84 | 92 | 96 | 98 | 99 |
| A (SP) | 75 | 86 | 92 | 95 | 97 |
| B (SM) | 68 | 81 | 89 | 93 | 95 |
| B (MH) | 65 | 78 | 86 | 91 | 94 |
| C | 63 | 76 | 85 | 90 | 93 |

[1]Values were determined using the [[MIDS calculator]]. BMPs were sized to exactly meet the water quality volume for a 2 acre site with 1 acre of impervious, 1 acre of forested land, and annual rainfall of 31.9 inches. ===Total suspended solid (TSS) calculations=== Pollutant removal for infiltrated water is assumed to be 100 percent. The mass of pollutant removed through infiltration, $M_{TSS_i}$ in pounds, is given by <math> M_{TSS_i} = 0.0000624\ V_{inf_b}\ EMC_{TSS} </math> where *$V_{inf_b}$ is the volume of water infiltrated, in cubic feet; and *$EMC_{TSS}$ is the event mean TSS concentration in runoff water entering the BMP (milligrams per liter). The $EMC_{TSS}$ entering the BMP is a function of the contributing land use and treatment by upstream tributary BMPs. For more information on EMC values for TSS, [http://stormwater.pca.state.mn.us/index.php/Total_Suspended_Solids_%28TSS%29_in_stormwater link here]. The above calculation may be applied on an annual basis and is given by <math> M_{TSS_f} = 2.72\ F\ V_{annual}\ EMC_{TSS} </math> where :$V_{annual}$ is the annual volume treated by the BMP, in acre-feet. The annual volume captured and infiltrated by the BMP can be determined with appropriate modeling tools, including the [[MIDS calculator]]. ===Total phosphorus credit calculations=== Pollutant removal for infiltrated water is assumed to be 100 percent. The mass of pollutant removed through infiltration, in pounds, is given by <math> M_{TP_i} = 0.0000624\ V_{inf_b}\ EMC_{TP} </math> where :$EMC_{TP}$ is the event mean TP concentration in runoff water entering the BMP (milligrams per liter). The $EMC_{TP}$ entering the BMP is a function of the contributing land use and treatment by upstream tributary BMPs. The above calculation may be applied on an annual basis and is given by <math> M_{TP_f} = 2.72\ V_{annual}\ EMC_{TP} </math> where :$V_{annual}$ is the annual volume treated by the BMP, in acre-feet. ==Methods for calculating credits== This section provides specific information on generating and calculating credits from infiltration practices for volume, TSS and TP. Stormwater runoff volume and pollution reductions ("credits") may be calculated using one of the following methods: #Quantifying volume and pollution reductions based on accepted hydrologic/hydraulic models #The Simple Method and MPCA Estimator #[[Overview of Minimal Impact Design Standards (MIDS)|MIDS Calculator]] #Quantifying volume and pollution reductions based on values reported in literature #Quantifying volume and pollution reductions based on field monitoring ===Credits based on models===

'''Warning:''' The model selected depends on your objectives. For compliance with the Construction Stormwater permit, the model must be based on the assumption that an instantaneous volume is captured by the BMP.

Users may opt to use a water quality model or calculator to compute volume, TSS and/or TP pollutant removal for the purpose of determining credits for infiltration practices. The available models described in the following sections are commonly used by water resource professionals, but are not explicitly endorsed or required by the Minnesota Pollution Control Agency. Furthermore, many of the models listed below cannot be used to determine compliance with the [http://stormwater.pca.state.mn.us/index.php/Construction_stormwater_permit Construction Stormwater General permit] since the permit requires the water quality volume to be calculated as an instantaneous volume. Use of models or calculators for the purpose of computing pollutant removal credits should be supported by detailed documentation, including: #Model name and version #Date of analysis #Person or organization conducting analysis #Detailed summary of input data #Calibration and verification information #Detailed summary of output data The following table lists water quantity and water quality models that are commonly used by water resource professionals to predict the hydrologic, hydraulic, and/or pollutant removal capabilities of a single or multiple stormwater BMPs. The table can be used to guide a user in selecting the most appropriate model for computing volume, TSS, and/or TP removal for biofiltration BMPs. Sort the table by ''Infiltrator BMPs'' to identify BMPs that may include infiltration practices. '''Comparison of stormwater models and calculators. Additional information and descriptions for some of the models listed in this table can be found at this [http://stormwater.pca.state.mn.us/index.php/Available_stormwater_models_and_selecting_a_model link]. Note that the [http://stormwater.pca.state.mn.us/index.php/III._STORMWATER_DISCHARGE_DESIGN_REQUIREMENTS#III.D._PERMANENT_STORMWATER_MANAGEMENT_SYSTEM Construction Stormwater General Permit] requires the water quality volume to be calculated as an instantaneous volume, meaning several of these models cannot be used to determine compliance with the permit.'''

Link to this [[Stormwater model and calculator comparisons|table]]
Access this table as a Microsoft Word document: [[File:Stormwater Model and Calculator Comparisons table.docx]].

| Model name | BMP Category | | | | | | Assess TP removal? | As TS re |
|---|---|---|---|---|---|---|---|---|
| | Constructed basin BMPs | Filter BMPs | Infiltrator BMPs | Swale or strip BMPs | Reuse | Manu-factured devices | | |
| [http://greenvalues.cnt.org/national/calculator.php Center for Neighborhood Technology Green Values National Stormwater Management Calculator] | X | X | X | | X | | No | No |
| [http://www.bentley.com/en-US/Products/CivilStorm/ CivilStorm] | | | | | | | Yes | Ye |
| [http://www.epa.gov/nrmrl/wswrd/wq/models/swc/ EPA National Stormwater Calculator] | X | | X | | X | | No | No |
| [http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/ EPA SWMM] | X | | X | | X | | Yes | Ye |
| [http://www.hydrocad.net/ HydroCAD] | X | | X | X | | | No | No |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| [http://www.innovyze.com/products/infoswmm/ infoSWMM] | X | | X | | X | | Yes | Ye |
| [http://www.innovyze.com/products/infoworks_icm/ infoWorks ICM] | X | X | X | X | | | Yes | Ye |
| [http://www.itreetools.org/hydro/index.php i-Tree-Hydro] | | | X | | | | No | No |
| [http://www.itreetools.org/streets/index.php i-Tree-Streets] | | | | | | | No | No |
| [http://www.epa.gov/athens/wwqtsc/html/lspc.html LSPC] | X | | X | X | | | Yes | Ye |
| [http://www.mapshed.psu.edu/overview.htm MapShed] | X | X | X | X | | | Yes | Ye |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| [http://minnehahacreek.org/sites/minnehahacreek.org/files/Stormwater%20Harvesting%20and%20Reuse%20Model_v2.0.xlsx MCWD/MWMO Stormwater Reuse Calculator] | | | | | X | | Yes | N |
| [http://www.metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning.aspx Metropolitan Council Stormwater Reuse Guide Excel Spreadsheet] | | | | | X | | No | N |
| [http://stormwater.pca.state.mn.us/index.php/MIDS_calculator MIDS Calculator] | X | X | X | X | X | X | Yes | Ye |
| [http://www.mikebydhi.com/Products/Cities/MIKEURBAN.aspx MIKE URBAN (SWMM or MOUSE)] | X | | X | | X | | Yes | Ye |
| [http://wwwalker.net/p8/ P8] | X | | X | X | | X | Yes | Ye |
| [http://www.chiwater.com/Software/PCSWMM/ PCSWMM] | X | | X | | X | | Yes | Ye |
| [http://water.epa.gov/scitech/datait/models/basins/framework.cfm#models PLOAD] | X | X | X | X | | X | Yes | Ye |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| [http://wwwalker.net/ PondNet] | X | | | | | | Yes | No |
| [http://www.bentley.com/en-US/Products/PondPack PondPack] | X | | [ | | | | No | No |
| [http://dnr.wi.gov/topic/stormwater/standards/recarga.html RECARGA] | | | X | | | | No | No |
| [http://www.werf.org/i/c/Tools/SELECT.aspx SELECT] | X | X | X | X | | X | Yes | Ye |
| [https://www.barr.com/WhatsNew/SHSAM/SHSAMapp.asp SHSAM] | | | | | | X | No | Ye |
| [http://www.epa.gov/nrmrl/wswrd/wq/models/sustain/ SUSTAIN] | X | X | X | X | X | | Yes | Ye |
| [http://swat.tamu.edu/ SWAT] | X | X | X | | | | Yes | Ye |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| [http://www.vwrrc.vt.edu/swc/Virginia%20Runoff%20Reduction%20Method.html Virginia Runoff Reduction Method] | X | X | X | X | X | X | Yes | No |
| [http://www.epa.gov/athens/wwqtsc/html/warmf.html WARMF] | X | X | | | | | Yes | Ye |
| [http://www.aquaterra.com/resources/hspfsupport/index.php WinHSPF] | X | | X | X | | | Yes | Ye |
| [http://winslamm.com/ WinSLAMM] | X | X | X | X | | | Yes | Ye |
| [http://www.xpsolutions.com/software/xpswmm/ XPSWMM] | X | | X | | X | | Yes | Ye |

===The Simple Method and MPCA Estimator=== The Simple Method is a technique used for estimating storm pollutant export delivered from urban development sites. Pollutant loads are estimated as the product of mean pollutant concentrations and runoff depths over specified periods of time (usually annual or seasonal). The method was developed to provide an easy yet reasonably accurate means of predicting the change in pollutant loadings in response to development. [http://www.stormwatercenter.net/Library/Practice/13.pdf Ohrel] (2000) states: "In general, the Simple Method is most appropriate for small watersheds (<640 acres) and when quick and reasonable stormwater pollutant load estimates are required". Rainfall data, land use (runoff coefficients), land area, and pollutant concentration are needed to use the Simple Method. For more information on the Simple Method, see [http://www.stormwatercenter.net/monitoring%20and%20assessment/simple%20meth/simple.htm The Simple method to Calculate Urban Stormwater Loads] or [[The Simple Method for estimating phosphorus export]]. Some simple stormwater calculators utilize the Simple Method ([http://it.tetratech-ffx.com/steplweb/models$docs.htm STEPL], Watershed Treatment Model). The MPCA developed a simple calculator for estimating load reductions for TSS, total phosphorus, and bacteria. Called the **MPCA Estimator**, this tool was developed specifically for complying with the MS4 General Permit TMDL annual reporting requirement. The MPCA Estimator provides default values for pollutant concentration, runoff coefficients for different land uses, and precipitation, although the user can modify these and is encouraged to do so when local data exist. The user is required to enter area for different land uses and area treated by BMPs within each of the land uses. BMPs include infiltrators (e.g. bioinfiltration, infiltration basin/trench, tree trench, permeable pavement, etc.), filters (biofiltration, sand filter, green roof), constructed ponds and wetlands, and swales/filters. The MPCA Estimator includes standard removal efficiencies for these BMPs, but the user can modify those values if better data are available. Output from the calculator is given as a load reduction (percent, mass, or number of bacteria) from the original estimated load.

**Caution:** The MPCA Estimator should not be used for modeling a stormwater system or selecting BMPs.

Because the MPCA Estimator does not consider BMPs in series, makes simplifying assumptions about runoff and pollutant removal processes, and uses generalized default information, it should only be used for estimating pollutant reductions from an estimated load. It is not intended as a decision-making tool.

**Download MPCA Estimator here: File:MPCA Estimator.xlsx**

A quick guide for the estimator is available Quick Guide: MPCA Estimator tab.

### MIDS Calculator

The Minimal Impact Design Standards (MIDS) best management practice (BMP) calculator is a tool used to determine stormwater runoff volume and pollutant reduction capabilities of various low impact development (LID) BMPs. The MIDS calculator estimates the stormwater runoff volume reductions for various BMPs and annual pollutant load reductions for total phosphorus (including a breakdown between particulate and dissolved phosphorus) and total suspended solids (TSS). The calculator was intended for use on individual development sites, though capable modelers could modify its use for larger applications.

Minimal Impact Design Standards
for enhancing stormwater management in Minnesota

Download the MIDS Calculator

The MIDS calculator is designed in Microsoft Excel with a graphical user interface (GUI), packaged as a windows application, used to organize input parameters. The Excel spreadsheet conducts the calculations and stores parameters, while the GUI provides a platform that allows the user to enter data and presents results in a user-friendly manner.

Detailed guidance has been developed for all BMPs in the calculator, including infiltration practices. An overview of individual input parameters and workflows is presented in the MIDS Calculator User Documentation.

### Credits Based on Reported Literature Values

A simplified approach to computing a credit would be to apply a reduction value found in literature to the pollutant mass load or concentration (EMC) of the pond or wetland device. A more detailed explanation of the differences between mass load reductions and concentration (EMC) reductions can be found on the pollutant removal page here. Designers may use the pollutant reduction values or may research values from other databases and published literature. Designers who opt for this approach should

- select the median value from pollutant reduction databases that report a range of reductions, such as from the International BMP Database;

- select a pollutant removal reduction from literature that studied a bioretention device with site characteristics and climate similar to the device being considered for credits;
- review the article to determine that the design principles of the studied bioretention are close to the design recommendations for Minnesota, as described in this manual and/or by a local permitting agency; and
- give preference to literature that has been published in a peer-reviewed publication.

The following references summarize pollutant reduction values from multiple studies or sources that could be used to determine credits. Users should note that there is a wide range of monitored pollutant removal effectiveness in the literature. Before selecting a literature value, users should compare the characteristics of the monitored site in the literature against the characteristics of the proposed stormwater pond, considering such conditions as watershed characteristics, pond sizing, and climate factors.

- International Stormwater Best Management Practices (BMP) Database Pollutant Category Summary Statistical Addendum: TSS, Bacteria, Nutrients, and Metals.
  - Compilation of BMP performance studies published through 2011.
  - Provides values for TSS, Bacteria, Nutrients, and Metals
  - Applicable to grass strips, bioretention, bioswales, detention basins, green roofs, manufactured devices, media filters, porous pavements, wetland basins, and wetland channels.
- Effectiveness Evaluation of Best Management Practices for Stormwater Management in Portland, Oregon.
  - Appendix M contains Excel spreadsheet of structural and non-structural BMP performance evaluations.
  - Provides values for sediment, nutrients, pathogens, metals, quantity, air purification, carbon sequestration, flood storage, avian habitat, aquatics habitat and aesthetics.
  - Applicable to Filters, Wet Ponds, Porous Pavements, Soakage Trenches, Flow through Stormwater Planters, Infiltration Stormwater Planters, Vegetated Infiltration Basins, Swales, and Treatment Wetlands.
- The Illinois Green Infrastructure Study.
  - Figure ES-1 summarizes BMP effectiveness
  - Provides values for TN, TSS, peak flows / runoff volumes
  - Applicable to Permeable Pavements, Constructed Wetlands, Infiltration, Detention, Filtration, and Green Roofs
- New Hampshire Stormwater Manual.
  - Volume 2, Appendix B summarizes BMP effectiveness
  - Provides values for TSS, TN, and TP removal
  - Applicable to basins and wetlands, stormwater wetlands, infiltration practices, filtering practices, treatment swales, vegetated buffers, and pre-treatment practices
- BMP Performance Analysis. Prepared for US EPA Region 1, Boston MA.
  - Appendix B provides pollutant removal performance curves
  - Provides values for TP, TSS, and Zn.
  - Pollutant removal broken down according to land use.
  - Applicable to Infiltration Trench, Infiltration Basin, Bioretention, Grass Swale, Wet Pond, and Porous Pavement.

### Credits based on field monitoring

Field monitoring may be used to calculate stormwater credits in lieu of desktop calculations or models/calculators as described. Careful planning is HIGHLY RECOMMENDED before commencing a program to monitor the performance of a BMP. The general steps involved in planning and implementing BMP monitoring include the following.

1. Establish the objectives and goals of the monitoring.
   a. Which pollutants will be measured?
   b. Will the monitoring study the performance of a single BMP or multiple BMPs?
   c. Are there any variables that will affect the BMP performance? Variables could include design approaches, maintenance activities, rainfall events, rainfall intensity, etc.
   d. Will the results be compared to other BMP performance studies?
   e. What should be the duration of the monitoring period? Is there a need to look at the annual performance vs the performance during a single rain event? Is there a need to assess the seasonal variation of BMP performance?
2. Plan the field activities. Field considerations include:
   a. Equipment selection and placement
   b. Sampling protocols including selection, storage, delivery to the laboratory
   c. Laboratory services

    d. Health and Safety plans for field personnel
    e. Record keeping protocols and forms
    f. Quality control and quality assurance protocols

3. Execute the field monitoring
4. Analyze the results

The following guidance manuals have been developed to assist BMP owners and operators on how to plan and implement BMP performance monitoring.

**Urban Stormwater BMP Performance Monitoring**

Geosyntec Consultants and Wright Water Engineers prepared this guide in 2009 with support from the USEPA, Water Environment Research Foundation, Federal Highway Administration, and the Environment and Water Resource Institute of the American Society of Civil Engineers. This guide was developed to improve and standardize the protocols for all BMP monitoring and to provide additional guidance for Low Impact Development (LID) BMP monitoring. Highlighted chapters in this manual include:

- Chapter 2: Designing the Program
- Chapters 3 & 4: Methods and Equipment
- Chapters 5 & 6: Implementation, Data Management, Evaluation and Reporting
- Chapter 7: BMP Performance Analysis
- Chapters 8, 9, & 10: LID Monitoring

**Evaluation of Best Management Practices for Highway Runoff Control (NCHRP Report 565)**

AASHTO (American Association of State Highway and Transportation Officials) and the FHWA (Federal Highway Administration) sponsored this 2006 research report, which was authored by Oregon State University, Geosyntec Consultants, the University of Florida, and the Low Impact Development Center. The primary purpose of this report is to advise on the selection and design of BMPs that are best suited for highway runoff. The document includes the following chapters on performance monitoring that may be a useful reference for BMP performance monitoring, especially for the performance assessment of a highway BMP:

- Chapter 4: Stormwater Characterization
    - 4.2: General Characteristics and Pollutant Sources
    - 4.3: Sources of Stormwater Quality data
- Chapter 8: Performance Evaluation
    - 8.1: Methodology Options
    - 8.5: Evaluation of Quality Performance for Individual BMPs
    - 8.6: Overall Hydrologic and Water Quality Performance Evaluation
- Chapter 10: Hydrologic Evaluation
    - 10.5: Performance Verification and Design Optimization

**Investigation into the Feasibility of a National Testing and Evaluation Program for Stormwater Products and Practices**.

In 2014 the Water Environment Federation released this White Paper that investigates the feasibility of a national program for the testing of stormwater products and practices. The information contained in this White Paper would be of use to those considering the monitoring of a manufactured BMP. The report does not include any specific guidance on the monitoring of a BMP, but it does include a summary of the existing technical evaluation programs that could be consulted for testing results for specific products (see Table 1 on page 8).

**Caltrans Stormwater Monitoring Guidance Manual (Document No. CTSW-OT-13-999.43.01**)

The most current version of this manual was released by the State of California, Department of Transportation in November 2013. As with the other monitoring manuals described, this manual does include guidance on planning a stormwater monitoring program. However, this manual is among the most thorough for field activities. Relevant chapters include:

- Chapter 4: Monitoring Methods and Equipment
- Chapter 5: Analytical Methods and Laboratory Selection
- Chapter 6: Monitoring Site Selection

- Chapter 8: Equipment Installation and Maintenance
- Chapter 10: Pre-Storm Preparation
- Chapter 11: Sample Collection and Handling
- Chapter 12: Quality Assurance / Quality Control
- Chapter 13: Laboratory Reports and Data Review
- Chapter 15: Gross Solids Monitoring

**Optimizing Stormwater Treatment Practices: A Handbook of Assessment and Maintenance**

This online manual was developed in 2010 by Andrew Erickson, Peter Weiss, and John Gulliver from the University of Minnesota and St. Anthony Falls Hydraulic Laboratory with funding provided by the Minnesota Pollution Control Agency. The manual advises on a four-level process to assess the performance of a Best Management Practice, involving:

- Level 1: Visual Inspection
- Level 2: Capacity Testing
- Level 3: Synthetic Runoff Testing
- Level 4: Monitoring
- Level 1 activities do not produce numerical performance data that could be used to obtain a stormwater management credit. BMP owners and operators who are interested in using data obtained from Levels 2 and 3 should consult with the MPCA or other regulatory agency to determine if the results are appropriate for credit calculations. Level 4, Monitoring, is the method most frequently used for assessment of the performance of a BMP.

Use these links to obtain detailed information on the following topics related to BMP performance monitoring:

- Water Budget Measurement
- Sampling Methods
- Analysis of Water and Soils
- Data Analysis for Monitoring

## Other Pollutants

In addition to TSS and phosphorus, infiltration practices can reduce loading of other pollutants. According to the International Stormwater Database, studies have shown that infiltration practices are effective at reducing concentration of pollutants, including nutrients, metals, bacteria, cyanide, oils and grease, Volatile Organic Compounds (VOC), and Biological Oxygen Demand (BOD). A compilation of the pollutant removal capabilities from a review of literature are summarized below.

### Relative pollutant reduction from bioretention systems for metals, nitrogen, bacteria, and organics.

Link to this table

| Pollutant Category | Constituent | Treatment Capabilities (Low = < 30%; Medium = 30-65%; High = 65 -100%) |
|---|---|---|
| Metals[1] | Cr, Cu, Zn | High[2] |
| | Ni, Pb | |
| Nutrients | Total Nitrogen, TKN | Medium/High |
| Bacteria | Fecal Coliform, E. coli | High |
| Organics | | High |

[1] Results are for total metals only

[2] Treatment capabilities are based mainly on information from sources that referenced only metals as a category and did not provide individual efficiency for specific metals

### References and suggested reading


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## Case studies

**Green Infrastructure:** Infiltration practices can be an important tool for retention and detention of stormwater runoff and treatment of pollutants in stormwater runoff. If the practice utilizes vegetation, additional benefits may include cleaner air, carbon sequestration, improved biological habitat, and aesthetic value.

Case studies of stormwater infiltration systems, including one underground system, are presented below.

**Information:** *Reference to any specific commercial product, process, or service by trade name, trademark, service mark, manufacturer, or otherwise does not constitute or imply endorsement, recommendation, or favoring by the Minnesota Pollution Control Agency.*

### Upper Villa Park Infiltration and Reuse, Capitol Region Watershed District, SRF Consulting Group, Inc., City of Roseville

Plan layout of infiltration and reuse systems. Click on mage to enlarge.

TrueNorthSteel infiltration system in native sandy soils

In fall of 2015, Capitol Region Watershed District (CRWD), in partnership with the City of Roseville and through two State of Minnesota grants, constructed a 60,000 cubic foot (450,000 gallon) underground stormwater infiltration system at Upper Villa Park in Roseville, Minnesota. The underground system was combined with a 13,000 cubic foot (100,000 gallon) modular concrete cistern to harvest and use stormwater for irrigation of a high-use softball field. The underground infiltration system was comprised of a TrueNorthSteel CMP (Corrugated Metal Pipe) Detention System. The construction project will protect water quality within Lake McCarrons, a high quality recreational lake within the urban core of the Twin Cities, and the Villa Park Wetland System by capturing stormwater runoff and filtering pollutants associated with urban stormwater, such as total phosphorus (TP), total suspended solids (TSS), heavy metals, and petroleum products.

Pretreatment to the underground infiltration basin is provided by a baffled sump catch basin. The Preserver by Momentum Environmental provides settlement of suspended sediments and the capture of debris up stream of the infiltration system. Perforated baffles prevent resuspension and loss of fine sediments into the infiltration system. Pretreatment is consistent with the Minnesota Stormwater Manual guidance.

StormTrap underground storage vault for water stormwater reuse as irrigation.

In addition to removing approximately 45 pounds of TP annually, the system will save up to 1.3 million gallons of drinking water by capturing and using rainwater to irrigate the softball field in the park.

In order to determine the effectiveness of infiltration practice pollutant removal, three custom-built pan-lysimeter wells were installed. Samples will be extracted from the wells and tested for a suite of pollutants and bacteria to determine the fate of these constituents once they leave the infiltration system on their way to groundwater resources.

CRWD has operated an automated ISCO sampler at the outflow of this 250-acre subwatershed since 2014. CRWD will continue to assess the effectiveness of the system by monitoring inflow, bypass, and levels within both the cistern and pipe gallery, and will sample upstream and downstream of the system in 2016.

The goal of this project is to protect water quality within Lake McCarrons and the Villa Park Wetland System by reducing stormwater volumes and annually removing 45 pounds of phosphorus. Secondary goals are to reduce drinking water as an irrigation source, determine the pollutant removal and groundwater protection capacity of infiltrating into native sands, and to optimize volume reduction by utilizing real time controls based on weather forecasts.

Estimates for total annual volume reduction (1,330,000 cubic feet, 10 million gallons), TP removal (45 pounds) and potable water use reduction (174,000 cubic feet, 1.3 million gallons) will be verified with monitoring data.

For more information, visit CRWD's project site page.

**Location:** Roseville, MN
**Owners:** City of Roseville and Capitol Region Watershed District
**Designer:** SRF Consulting Group Inc.
**Year of Completion:** 2015
**Design Features:** underground stormwater infiltration system, modular concrete cistern for water reuse as irrigation
**Total Drainage Area:** 250 Acres
**Total Construction Cost:** $861,500
**Pretreatment:** The Preserver (Momentum Environmental) baffled sump catch basin
**Documented Maintenance Practices:** Inspection, sediment depth measurements, sediment removal and disposal

**Pollutant Removal:** 45 lb/yr total phosphorus removed
**Is the Site Publicly Accessible:** Yes

## Riverside Stormwater Park, City of Minneapolis

Schematic for the Riverside Stormwater Park. Click on image to enlarge.

The City of Minneapolis hired Barr Engineering to design stormwater best management practices (BMPs) along Riverside Avenue in conjunction with a street reconstruction project, which added bike lanes, parking, designated turn lanes, and center medians. Design and construction took place between 2011 and 2013.

Infiltration soil being carefully placed to avoid compaction

The 8th Street infiltration basin was constructed at the intersection of Riverside Avenue and 8th Street where Riverside crossed at an angle, resulting in an awkward intersection and an unbuildable triangular piece of property. The intersection was redesigned to align 8th Street through the unused triangular property to create a standard perpendicular intersection. Bisecting the property allowed for the creation of two BMPs on either side of 8th Street. On one side there is a stormwater infiltration basin with a curved concrete retaining wall and railing. Trees and grasses were planted at the bottom while shrubs on the side slopes frame the basin. On the opposite side of 8th Street there is a plaza with permeable pavers over a stormwater tree trench system (modified Swedish tree trenches) consisting of layers of crushed stone and soil to provide stormwater storage and growing media for the trees. BMPs on both sides of 8th Street are connected with an equalizer pipe. A stone sitting bench completes the pedestrian-friendly plaza. The 8th Street BMPs are expected to capture and treat 0.5 inches of runoff from 2.2 acres of tributary area.

Finished basin with simple groupings of shrubs grasses and trees

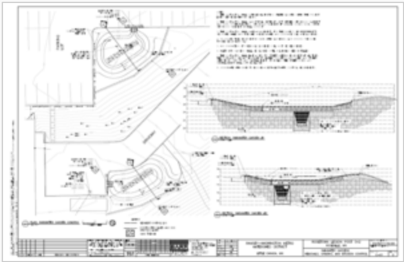
The goals of this green infrastructure project are:

- treating stormwater runoff to remove sediments and other pollutants;
- infiltrating significant portions of the contributing drainage area runoff;
- increasing the amount of pervious surface in the right of way;
- providing a non-irrigated water source to the proposed trees and plantings; and
- enhancing beauty and functionality of public space.

**Location:** Minneapolis, MN
**Owners**: City of Minneapolis
**Designer:** Barr Engineering Company
**Year of Completion:** 2013
**Design Features:** Tree planter boxes, permeable pavers, surface and underground storage, raingardens, depressed boulevards
**Pretreatment Features:** Water quality catch basin with sumps for sediment capture meeting current Stormwater Manual guidance
**Total Drainage Area:** 2.2 Acres
**Total Construction Cost:** $153,000
**Documented Maintenance Practices:** Inspection, herbicide/pesticide treatments, weeding, trimming, plant and tree replacement
**Pollutant Removal:** 1.0 lb/yr Dissolved Phosphorus removed, 407 lb/yr TSS removed.
**Is the Site Publicly Accessible**: Yes.

## Rosetown American Legion Post 542 Infiltration Basin

As part of a watershed properties study of commercial parcels begun in 2014, Ramsey-Washington Metro Watershed District identified green space adjacent to the parking lot of the Rosetown American Legion Post 542 in Roseville, Minnesota. An unused turf area was targeted for a commercially sized infiltration basin. Collaborating with the American Legion leadership, the project was constructed in 2015 as part of a series of BMPs identified during the initial watershed properties study.



Plan and section view of the infiltration basin. Click on image to enlarge.

For preconstruction investigations, an 18 foot soil boring was used to identify sandy gravel soils. There was no confining layer of less permeable subsoils identified. The basin was sized to collect the 1.1 inch storm event off the parking lot and surrounding sidewalks. The basin was graded to store water no deeper than 12 inches below the gutter flow line. The curb cut was positioned at the lowest possible downstream side of the curb. Surrounding slopes within the basin were designed to be no greater than 4:1.

Modular Block Sediment Trap for pretreatment.

Pretreatment for the infiltration basin is provided by a curb cut with a modular block step-down structure. Stormwater flows down the block steps and into a shallow sump feature akin to a small forebay. The energy of the stormwater is dissipated to prevent scouring or erosion while sediments are allowed to drop out for easy collection later. The pretreatment sump is not sized per current Stormwater Manual recommendations that the forebay be approximately 10 percent the size of the infiltration basin.

The infiltration basin was designed to have ornamental grasses, including ‘Heavy Metal’ Switchgrass (Panicum virgatum ‘Heavy Metal’), low shrubs including low bush honeysuckle (Diervilla Lonicera) , natives sedges such as tussock sedge (Carex stricta) and native forbs such as Joe Pye Weed (Eutrochium purpurem).

Infiltration basin with rough grading complete

The infiltration basin cost $47,000, treats 1,100 cubic feet of stormwater and is estimated to remove 262 pounds of TSS and 0.57 pounds of dissolved P per year.

The Rosetown American Legion Post 542 infiltration basin has been included as one of several projects being maintained as part of the Ramsey-Washington Metro Watershed District BMP Maintenance Program. As part of the maintenance program, the site is inspected monthly during the growing season by a contractor. The site is assessed for any erosion, trash, weeds and sediment depths in the modular block splash block assemblies. The required time for crews to remove and dispose of materials is recorded and time and expenses are paid for. Contractor crews also look for any plant damage or soil conditions that would indicate slow drainage. Budgets for maintenance of the site are adjusted yearly.

Infiltration basin before planting

In the spring, all the previous year’s vegetation from the perennials, sedges and grasses is removed and disposed of. The shrubs are pruned for proper form and to remove any dead branches. As mulch decomposes, its depth is refreshed to maintain approximately 3 inches of shredded hardwood mulch throughout the basin.

**Location:** Roseville, MN
**Owners:** Ramsey-Washington Metro Watershed District
**Designer:** Barr Engineering Company
**Year of Completion:** 2015
**Design Features:** Bioinfiltration basin
**Total Drainage Area:** 0.85 Acres
**Total Construction Cost**: $47,000
**Documented Maintenance Practices:** Inspection, herbicide/pesticide treatments, weeding, trimming, removal of sediment from sump step down structure
**Pollutant Removal**: 0.57 lb/yr Dissolved Phosphorus removed, 262 lb/yr TSS removed.
**Is the Site Publicly Accessible**: Yes but on private property

## Green Infrastructure benefits of infiltration practices

Green Infrastructure benefits of infiltration practice

## Summary of permit requirements for infiltration

The following are requirements of the Construction Stormwater General Permit.

**Infiltration systems (including bioinfiltration)**

- Permittees must design infiltration systems such that pre-existing hydrologic conditions of wetlands in the vicinity are not impacted (e.g., inundation or breaching a perched water table supporting a wetland).
- Permittees must not excavate infiltration systems to final grade, or within three (3) feet of final grade, until the contributing drainage area has been constructed and fully stabilized unless they provide rigorous erosion prevention and sediment controls (e.g., diversion berms) to keep sediment and runoff completely away from the infiltration area.
- When excavating an infiltration system to within three (3) feet of final grade, permittees must stake off and mark the area so heavy construction vehicles or equipment do not compact the soil in the infiltration area.
- Permittees must use a pretreatment device such as a vegetated filter strip, forebay, or water quality inlet (e.g., grit chamber) to remove solids, floating materials, and oil and grease from the runoff, to the maximum extent practicable, before the system routes stormwater to the infiltration system.
- Permittees must design infiltration systems to provide a water quality volume (calculated as an instantaneous volume) of one (1) inch of runoff, or one (1) inch minus the volume of stormwater treated by another system on the site, from the net increase of impervious surfaces created by the project.
- Permittees must design the infiltration system to discharge all stormwater (including stormwater in excess of the water quality volume) routed to the system through the uppermost soil surface or engineered media surface within 48 hours. Permittees must route additional flows that cannot infiltrate within 48 hours to bypass the system through a stabilized discharge point.
- Permittees must provide a means to visually verify the infiltration system is discharging through the soil surface or filter media surface within 48 hours or less.
- Permittees must provide at least one soil boring, test pit or infiltrometer test in the location of the infiltration practice for determining infiltration rates.
- For design purposes, permittees must divide field measured infiltration rates by 2 as a safety factor or permittees can use soil-boring results with the infiltration rate chart in the Minnesota Stormwater Manual to determine design infiltration rates. When soil borings indicate type A soils, permittees should perform field measurements to verify the rate is not above 8.3 inches per hour. This permit prohibits infiltration if the field measured infiltration rate is above 8.3 inches per hour.
- Permittees must employ appropriate on-site testing ensure a minimum of three (3) feet of separation from the seasonally saturated soils (or from bedrock) and the bottom of the proposed infiltration system.
- Permittees must design a maintenance access, typically eight (8) feet wide, for the infiltration system.
- This permit prohibits permittees from constructing infiltration systems that receive runoff from vehicle fueling and maintenance areas including construction of infiltration systems not required by this permit.
- This permit prohibits permittees from constructing infiltration systems where infiltrating stormwater may mobilize high levels of contaminants in soil or groundwater. Permittees must either complete the MPCA's contamination screening checklist or conduct their own assessment to determine the suitability for infiltration. Permittees must retain the checklist or assessment with the SWPPP.

For more information and to access the MPCA's "contamination screening checklist" see the Minnesota Stormwater Manual.

- This permit prohibits permittees from constructing infiltration systems in areas where soil infiltration rates (including amended soils) are field measured at more than 8.3 inches per hour unless they amend soils to slow the infiltration rate below 8.3 inches per hour.
- This permit prohibits permittees from constructing infiltration systems in areas with less than three (3) feet of separation distance from the bottom of the infiltration system to the elevation of the seasonally saturated soils or the top of bedrock.
- This permit prohibits permittees from constructing infiltration systems in areas of predominately Hydrologic Soil Group type D soils (clay).
- This permit prohibits permittees from constructing infiltration systems within a Drinking Water Supply Management Area (DWSMA) as defined in Minn. R. 4720.5100, subp. 13, if the system will be located:

  a. in an Emergency Response Area (ERA) within a DWSMA classified as having high or very high vulnerability as defined by the Minnesota Department of Health; or
  b. in an ERA within a DWSMA classified as moderate vulnerability unless a regulated MS4 Permittee performed or approved a higher level of engineering review sufficient to provide a functioning treatment system and to prevent adverse impacts to groundwater; or
  c. outside of an ERA within a DWSMA classified as having high or very high vulnerability, unless a regulated MS4 Permittee performed or approved a higher level of engineering review sufficient to provide a functioning treatment system and to prevent adverse impacts to groundwater.

See "higher level of engineering review" in the Minnesota Stormwater Manual for more information.

- This permit prohibits permittees from constructing infiltration systems in areas within 1,000 feet upgradient or 100 feet downgradient of active karst features.
- This permit prohibits permittees from constructing infiltration systems in areas that receive runoff from the following industrial facilities not authorized to infiltrate stormwater under the NPDES stormwater permit for industrial activities: automobile salvage yards; scrap recycling and waste recycling facilities; hazardous waste treatment, storage, or disposal facilities; or air transportation facilities that conduct deicing activities.

# Infiltration photo gallery

**Click on an image for enlarged view.**

TrueNorthSteel infiltration system

StormTrap underground storage vault

Infiltration basin with rough grading complete

Infiltration basin before planting

### Related pages

- Bioretention photo gallery

# External resources

### Links to other manuals and guidance

# References

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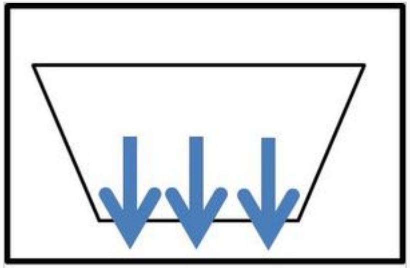
# Requirements, recommendations and information for using infiltration basin/underground infiltration BMPs in the MIDS calculator

**Information:** Note this BMP name has been changed in the MIDS calculator to Infiltration trench/Infiltration basin (aboveground). A new BMP called Underground infiltration was created for Version 3 of the calculator (See Requirements, recommendations and information for using underground infiltration BMPs in the MIDS calculator). The information on the page below remains accurate for aboveground infiltration BMPs.



MIDS calculator symbol for infiltration basin.

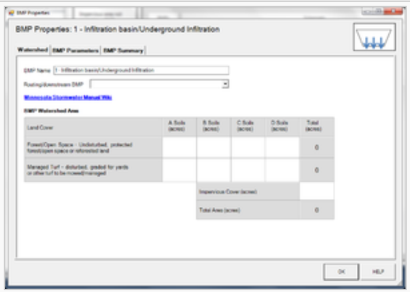
For an infiltration basin system, all stormwater captured by the BMP is infiltrated into the underlying soil between rain events. All pollutants in the infiltrated water are credited as being reduced. Pollutants in the stormwater that bypasses the BMP are not reduced.

## MIDS calculator user inputs for infiltration

For infiltration basin systems, the user must input the following parameters to calculate the volume and pollutant load reductions associated with the BMP.

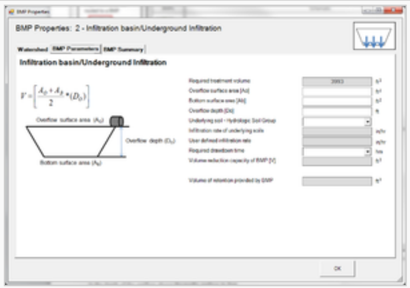
- **Watershed tab**
  - BMP Name: this cell is auto-filled but can be changed by the user.
  - Routing/downstream BMP: if this BMP is part of a treatment train and water is being routed from this BMP to another BMP, the user selects the name of the BMP from the dropdown box to which water is being routed. All water must be routed to a single downstream BMP. The User must include the BMP receiving the routed water in the Schematic or the BMP will not appear in the dropdown box.

- BMP Watershed Area: BMP watershed areas are the areas draining directly to the BMP. Values can be added for four soil types (Hydrologic Soil Groups (HSG) A, B, C, D) and for three Land Cover types (Forest/Open Space, Managed Turf and impervious). The surface area of the BMP should be included as a managed turf land cover under the hydrologic soils group of the native soils located under the BMP. Units are in acres.



Screen shot of the watershed tab for the MIDS calculator. The user must input a zip code and impervious acres. Other entries are optional.

- **BMP Parameters tab**
  - Overflow surface area ($A_o$): This is the surface area of the BMP at the lowest outlet point from the BMP. The user inputs this value in square feet.
  - Media surface area ($A_M$): This is the surface area at the bottom of the ponded water within the BMP. Therefore, this is the area at the surface of the media. The user inputs this value in square feet. **NOTE: Native soils may exist at the bottom of the ponded water. In this case, the MIDS calculator term $A_B$ (Bottom surface area) would be the correct term.**
  - Overflow depth ($D_O$): This is the maximum depth of ponded water within the BMP (i.e., distance from the overflow elevation to the top of the media). The user inputs this value in feet.
  - Underlying soil - Hydrologic Soil Group: The user selects the most restrictive soil (lowest hydraulic conductivity) within 5 feet of the soil/media interface in the infiltration basin. There are 14 soil options that fall into 4 different Hydrologic Soil Groups (Hydrologic Soil Group (HSG) A, B, C, or D) for the user. Once a soil type is selected, the corresponding infiltration rate will populate in the *Infiltration rate of underlying soils* field. The user may also select *User Defined*. This selection will activate the *User Defined Infiltration Rate* cell allowing the user to enter a different value from the values in the predefined selection list. The maximum allowable infiltration rate is 1.63 inches per hour.
  - Required drawdown time (hrs): This is the time in which the stormwater captured by the BMP must drain into the underlying soil/media. The user selects from predefined values of 48 or 24 hours. The MPCA Construction Stormwater General Permit requires drawdown within 48 hours, but 24 hours is Highly Recommended when discharges are to a trout stream. The calculator uses the underlying soil infiltration rate and the overflow depth to check if the BMP is meeting the drawdown time requirement. The user will encounter an error and be required to enter a new *Overflow depth* if the stormwwater stored in the BMP cannot drawdown in the required time.



Screen shot of user inputs needed for the MIDS calculator for infiltration basin.

- **BMP Summary Tab**: The BMP Summary tab summarizes the volume and pollutant reductions provided by the specific BMP. It details the performance goal volume reductions and annual average volume, dissolved P, particulate P, and TSS load reductions. Included in the summary are the total volume and pollutant loads received by the BMP from its direct watershed, from upstream BMPs and a combined value of the two. Also included in the summary, are the volume and pollutant load reductions provided by the BMP, in addition to the volume and pollutant loads that exit the BMP through the outflow. This outflow load and volume is what is routed to the downstream BMP if one is defined in the Watershed tab. Finally, percent reductions are provided for the percent of the performance goal achieved, percent annual runoff volume retained, total percent annual particulate phosphorus reduction, total percent annual dissolved phosphorus reduction, total percent annual TP reduction, and total percent annual TSS reduction.

## Model input requirements and recommendations

The following are requirements or recommendations for inputs into the MIDS calculator. If the following are not met, an error message will inform the user to change the input to meet the requirement.

- The basin must meet the drawdown time requirement specified. The drawdown time requirement is checked by comparing the user defined drawdown time with the calculated drawdown time ($DDT_{calc}$), which is given by

<math>DDT_{calc} = D_O / (I_R / 12)</math>

Where

$D_O$ is the overflow depth (ft); and
$I_R$ is the infiltration rate of the native soils (inches/hr).

If the $DDT_{calc}$ is greater than the user defined required drawdown time then the user will be prompted to enter a new overflow depth or infiltration rate.

- Infiltration rates of the underlying soils are restricted to being below 1.63 inches per hour.
- The *Media surface area* must be equal to or smaller than the *Overflow surface area*.
- The *Overflow depth* is recommended to be 4 feet or less, but the User may enter a larger value if the ponded volume can infiltrate within the drawdown time.

## Methodology

### Required Treatment Volume

*Required treatment volume*, or the volume of stormwater runoff delivered to the BMP, equals the performance goal (1.1 inches or user-specified performance goal) times the impervious area draining to the BMP plus any water routed to the BMP from an upstream BMP. This stormwater is delivered to the BMP instantaneously.

### Volume Reduction

The volume reduction achieved by a BMP compares the capacity of the BMP to the required treatment volume. The *Volume reduction capacity of BMP* is calculated using BMP inputs provided by the user. For this BMP, the *Volume reduction capacity* is equal to the amount of stormwater that can be instantaneously captured above the media and below the overflow point. The captured volume (V) is given by

<math>V= [(A_O+A_M)/2*(D_O)]</math>

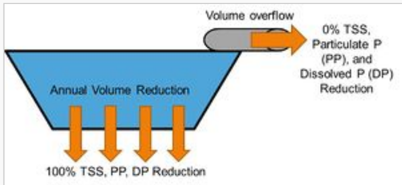
Where:

$A_O$ is the overflow surface area (ft);
$A_M$ Is the media surface area (ft); and
$D_O$ is the overflow depth (ft).

The *Volume of retention provided by BMP* is the amount of volume credit the BMP provides toward the performance goal. This value is equal to the lesser of the *Volume reduction capacity of BMP* calculated using the above method or the *Required treatment volume*. This check makes sure that the BMP is not getting more credit than the amount of water it receives. For example, if the BMP is oversized the user will only receive credit for the *Required treatment volume* routed to the BMP, which corresponds with meeting the performance goal for the site.

### Pollutant Reduction

Pollutant load reductions are calculated on an annual basis. Therefore, the first step in calculating annual pollutant load reductions is converting the *Volume reduction capacity of BMP*, which is an instantaneous volume reduction, to an annual volume reduction percentage. This is accomplished through the use of performance curves developed from multiple modeling scenarios. The performance curves use the *Volume reduction capacity of BMP*, the infiltration rate of the underlying soils, the contributing watershed percent impervious area, and the size of the contributing watershed to calculate a percent annual volume reduction. While oversizing a BMP above the *Required treatment volume* will not provide additional credit towards the performance goal volume, it may provide additional pollutant reduction on an average annual basis.




Schematic illustrating how the MIDS calculator estimates pollutant load reductions. All TSS and phosphorus that infiltrates into the underlying soil is reduced. There is no reduction for water not captured by the BMP.

A 100 percent removal is credited for all pollutants associated with the reduced volume of stormwater since these pollutants are either attenuated within the media or pass into the underlying soil with infiltrating water . Pollutants in the stormwater that bypasses the BMP through overflow are not reduced. A schematic of the removal rates can be seen in the sidebar.

NOTE: The user can modify event mean concentrations (EMCs) on the Site Information tab in the calculator. Default concentrations are 54.5 milligrams per liter for total suspended solids (TSS) and 0.3 milligrams per liter for total phosphorus (particulate plus dissolved). The calculator will notify the user if the default is changed. Changing the default EMC will result in changes to the total pounds of pollutant reduced.

## Routing

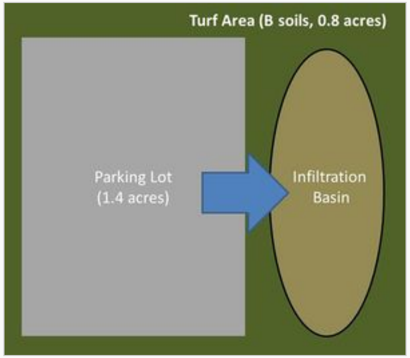
An infiltration basin can be routed to any other BMP, except for a green roof and a swale side slope or any BMP that would cause stormwater to be rerouted back to the infiltration basin already in the stormwater runoff treatment sequence. All BMPs can be routed to an infiltration basin, except for a swale side slope.

### Assumptions

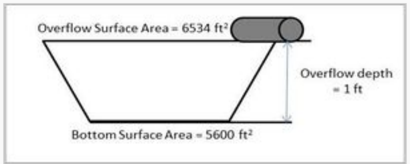
The following general assumptions apply in calculating the credit for an infiltration basin. If these assumptions are not followed, the volume and pollutant reduction credits cannot be applied.

- The infiltration basin has been properly designed, constructed and will be properly maintained.
- Stormwater runoff entering the bioretention basin has undergone pretreatment.
- Stormwater captured by the BMP enters the BMP instantaneously and is initially ponded within the BMP. This will underestimate actual infiltration since some water will enter the soil/media during a rain event, thus creating more volume for storage in the BMP.

### Infiltration Basin/Underground Infiltration (Calculator Version 2)

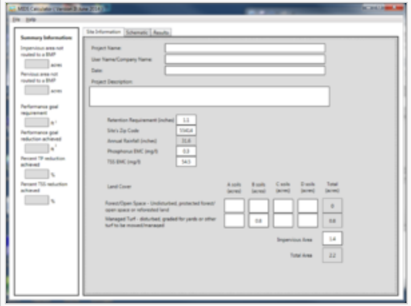


Schematic used for the infiltration basin example for the MIDS calculator. Impervious area is 1.4 acres and pervious area, which includes turf and the infiltration BMP, is 0.8 acres. See Step 1.



Schematic used for the MIDS calculator example for infiltration basin. See Step 1.

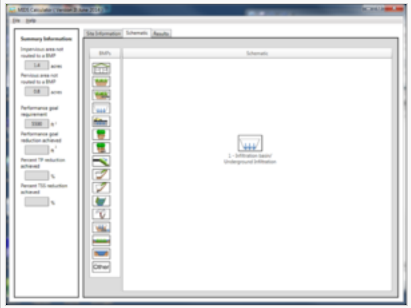
An infiltration basin is to be constructed in a watershed that contains a 1.4 acre parking lot surrounded by 0.8 acres of pervious area (turf area and the infiltration BMP area). All of the runoff from the watershed will be treated by the infiltration basin. The soils across the area have a unified soils classification of SM (HSG type B soil). The infiltration basin is designed to have 1 foot of ponding depth below the overflow point (e.g. surface outlet or invert of a pipe). The surface area of the infiltration basin at the overflow point will be 6534 square feet. The surface area will be 5600 square feet at the soil/media surface (Media surface area ($A_M$)). Following the MPCA Construction Stormwater General Permit requirement, the infiltration basin needs to drawdown in a 48 hour time period. The following steps detail how this system would be set up in the MIDS calculator.


Screen shot of the Site information tab for the MIDS calculator example for infiltration basin. See Step 2.

**Step 1**: Determine the watershed characteristics of your entire site. For this example we have a 2.2 acre site with 1.4 acres of impervious area and 0.8 acres of pervious area in type B soils. The pervious area includes the turf area and the area of the infiltration basin.

**Step 2**: Fill in the site specific information into the *Site Information* tab. This includes entering a Zip Code (55414 for this example) and the watershed information from Step 1. The Managed Turf area includes the turf area and the area of the infiltration basin. Zip code and impervious area must be filled in or an error message will be generated. Other fields on this screen are optional.

**Step 3**: Go to the Schematic tab and drag and drop the *Infiltration basin/Underground Infiltration* icon into the *Schematic Window*.

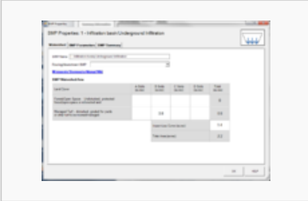

Screen shot of the Schematic tab for the infiltration basin example for the MIDS calculator. See Step 3.

**Step 4**: Open the BMP properties for the infiltration basin by right clicking on the *Infiltration basin/Underground infiltration* icon and selecting *Edit BMP properties*, or by double clicking on the *Infiltration basin/Underground Infiltration* icon.

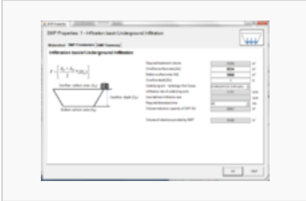
**Step 5**: If help is needed, click on the *Minnesota Stormwater Manual Wiki* link or the *Help* button to review input parameter specifications and calculation specific to the *Infiltration basin/Underground infiltration* BMP.

**Step 6**: Determine the watershed characteristics for the infiltration basin. For this example the entire site is draining to the infiltration basin. The watershed parameters therefore include a 2.2 acre site with 1.4 acres of impervious area and 0.8 acres of pervious turf area in type B soils. There is no routing for this BMP. Fill in the BMP specific watershed information (1.4 acres on impervious cover and 0.8 acres of Managed turf in B soils).

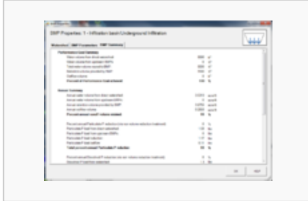
**MIDS calculator screen shots for inputs for infiltration basin/underground infiltration. Click on an image for enlarged view.**



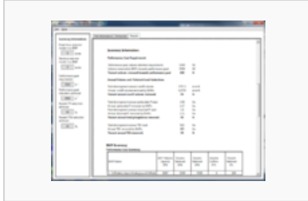
Schematic showing watershed tab for an infiltration. See Step 6.



Schematic showing BMP Parameters tab for an infiltration basin. See Step7.



Screen shot of the BMP Summary tab for an infiltration basin. See Step 8.



Screen shot for the example of an infiltration basin. See Step 10.

**Step 7**: Enter in the BMP design parameters into the *BMP parameters* tab. Infiltration basin/Underground Infiltration requires the following entries.

- Overflow surface area which is 6534 square feet;
- Media surface area which is 5600 square feet;
- Overflow depth which is 1 foot;
- Underlying soil – Hydrologic Soil Group which is 6 SM (HSG B, 0.45 in/hr); and
- Required drawdown time which is 48 hours.

**Step 8**: Click on *BMP Summary* tab to view results for this BMP.

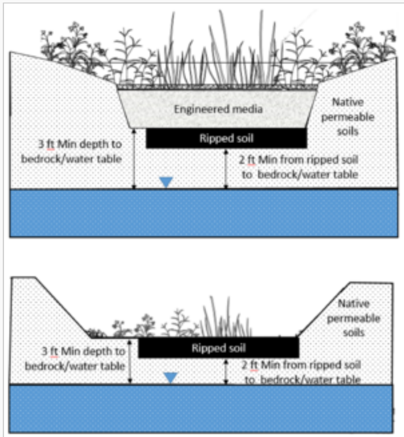
**Step 9**: Click on the *OK* button to exit the BMP properties screen.

**Step 10**: Click on *Results* tab to see overall results for the site.

## Requirements

**Warning:** The following are requirements of the Minnesota Construction Stormwater General Permit

- Use the most restrictive infiltration rate within 5 feet of the bottom of the BMP
- For measured infiltration rates, apply a safety factor of 2
- Pretreatment for infiltration systems
- Infiltration is prohibited when the infiltration system will be constructed in:
  - Areas that receive discharges from vehicle fueling and maintenance.
  - Areas with less than three (3) feet of separation distance from the bottom of the infiltration system to the elevation of the seasonal high water table or the top of bedrock.
  - Areas that receive discharges from industrial facilities which are not authorized to infiltrate industrial stormwater under an NPDES/SDS Industrial Stormwater Permit issued by the MPCA.
  - Areas where high levels of contaminants in soil or groundwater will be mobilized by the infiltrating stormwater.
  - Areas of predominately Hydrologic Soil Group D (clay) soils.
  - Areas within 1,000 feet up-gradient, or 100 feet down-gradient of active karst.
  - areas within a Drinking Water Supply Management Area (DWSMA) as defined in Minn. R. 4720.5100, subp. 13., if the system will be located:
    - in an Emergency Response Area (ERA) within a DWSMA classified as having high or very high vulnerability as defined by the Minnesota Department of Health; or
    - in an ERA within a DWSMA classified as moderate vulnerability unless a regulated MS4 Permittee performed or approved a higher level of engineering review sufficient to provide a functioning treatment system and to prevent adverse impacts to groundwater; or
    - outside of an ERA within a DWSMA classified as having high or very high vulnerability, unless a regulated MS4 Permittee performed or approved a higher level of engineering review sufficient to provide a functioning treatment system and to prevent adverse impacts to groundwatert.




Measurement of depth from the bottom of the infiltration BMP to the seasonally high water table or bedrock. Note that there must be a minimum of 2 feet separation when soils beneath the BMP are ripped, with a total separation distance of 3 feet or more. Infiltration

- Areas where soil infiltration rates are more than 8.3 inches per hour unless soils are amended to slow the infiltration rate below 8.3 inches per hour.

BMPs include any BMP that allows water to infiltrate into the underlying soil.

### Recommendations

**Caution:** The following are recommendations for inputs into the MIDS calculator

- Drawdown time of 24 hours when the discharge is to trout streams
- Field tested infiltration rates rather than table values

### Information

**Information:** The following information may be useful in determining inputs for the MIDS calculator

- Guidance on determining infiltration rates
- Information on site constraints (shallow soil, karst, etc.)
- Guidance on pretreatment
- Construction specifications for infiltration BMPs
- Information on operation and maintenance of infiltration BMPs.

### Links to MIDS pages

- Overview of Minimal Impact Design Standards (MIDS)
- Performance goals for new development, re-development and linear projects
- Design Sequence Flowchart-Flexible treatment options
- Community Assistance Package
- MIDS calculator
- Performance curves for MIDS calculator
- Training and workshop materials and modules
- Technical documents

## Requirements, recommendations and information for using underground infiltration BMPs in the MIDS calculator

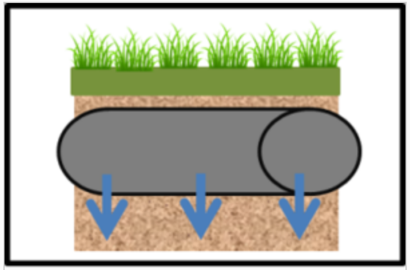
For an underground infiltration system, all stormwater captured below the outflow pipe in the underground pipe/storage device or in the underlying engineered media by the BMP is infiltrated into the underlying soil between rain events. All pollutants in the infiltrated water are credited as being reduced. Pollutants in the stormwater that bypasses the best management practice (BMP), including pollutants in water discharged through the outflow pipe, are not reduced.

### MIDS calculator user inputs for underground infiltration

For underground infiltration systems, the user must input the following parameters to calculate the volume and pollutant load reductions associated with the BMP.

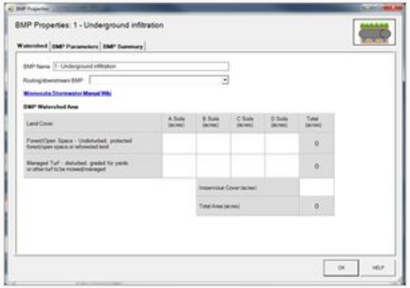
- **Watershed tab**

- **BMP Name:** this cell is auto-filled but can be changed by the user.
- **Routing/downstream BMP:** if this BMP is part of a treatment train and water is being routed from this BMP to another BMP, the user selects the name of the BMP from the dropdown box to which water is being routed. All water must be routed to a single downstream BMP. The User must include the BMP receiving the routed water in the Schematic or the BMP will not appear in the dropdown box.
- **BMP Watershed Area:** BMP watershed areas are the areas draining directly to the BMP. Values can be added for four soil types (Hydrologic Soil Groups (HSG) A, B, C, D) and for three Land Cover types (Forest/Open Space, Managed Turf and impervious). The surface area of the BMP should be included as a managed turf land cover under the hydrologic soils group of the native soils located under the BMP. Units are in acres

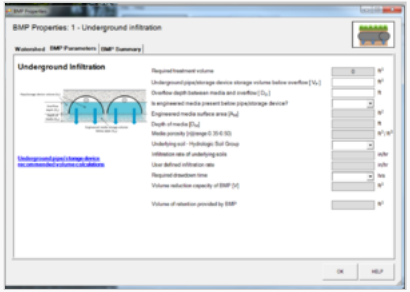


Symbol for underground infiltration in MIDS calculator

- **BMP Parameters tab**
  - **Underground pipe/storage device storage volume below overflow ($V_P$):** The total storage volume in the pipe or storage device that is below the overflow. The storage device needs to be perforated to allow infiltration into the underlying soils. Methods for calculating the storage volume depend on the type of storage device used. A spreadsheet was developed to perform this calculation for different types of underground practices. The spreadsheet includes example calculations. The user enters this value in cubic feet.
  - **Overflow depth between media and overflow ($D_O$):** The total depth between the outflow from the storage device to the underlying media. This value is used to calculate the drawdown time of the device to make sure it meets drawdown time requirements. The user enters this value in feet.
  - **Is engineered soil present below pipe/storage device?:** The user enters 'Yes' if engineered soils designed to add storage capacity to increase infiltration are present below the storage device.
  - **Engineered media surface area ($A_M$):** The average surface area of the engineered media below the storage device, typically equal to the width of the underground storage system times the length of the system. This value is used to calculate the volume of water that is stored in the engineered media. The user enters this value in square feet.
  - **Depth of media ($D_M$):** The depth of the engineered media below the storage device. This value is used to calculate the volume of water stored in the engineered soils. The user enters this value in feet.
  - **Media porosity (n):** This is the ratio of pore space in the engineered media to the total volume of the engineered media. Units are volume/volume (e.g., cubic centimeters per cubic centimeter). If various types of media are used in the BMP, this value should be an average of the media installed between the underdrain and the native soils. Values for porosity based on soil type can be found here. Typical values range between 0.35 and 0.5 cubic feet per cubic foot.
  - **Underlying soil - Hydrologic Soil Group:** The user selects the most restrictive soil (lowest hydraulic conductivity) within 3 feet of the soil/media interface in the infiltration basin. There are 14 soil options that fall into 4 different Hydrologic Soil Groups (Hydrologic Soil Group (HSG) A, B, C, or D) for the user. These correspond with soils and infiltration rates contained in this Manual. Once a soil type is selected, the corresponding infiltration rate will populate in the "Infiltration rate of underlying soils" field. The user may also select "User Defined." This selection will activate the "User Defined Infiltration Rate" cell allowing the user to enter a different value from the values in the predefined selection list. The maximum allowable infiltration rate is 1.63 inches per hour.
  - **Required drawdown time (hours):** This is the time in which the stormwater captured by the BMP must drain into the underlying soil/media. The user selects from predefined values of 48 or 24 hours. The MPCA Construction Stormwater General Permit requires drawdown within 48 hours, but 24 hours is Highly Recommended when discharges are to a trout stream. The calculator uses the underlying soil infiltration rate and the overflow depth to check if the BMP is meeting the drawdown time requirement. The user will encounter an error and be required to enter a new "Overflow depth" if the stormwwater stored in the BMP cannot drawdown in the required time.



Screenshot of Watershed tab, called "BMP Properties 1 - Underground infiltration"



Screenshot from MIDS calculator showing user inputs needed for underground infiltration. The link located below the image is to a page that allows the user to make necessary calculations for $V_P$ and $A_M$.

- **BMP Summary Tab:** The BMP Summary tab summarizes the volume and pollutant reductions provided by the specific BMP. It details the performance goal volume reductions and annual average volume, dissolved P, particulate P, and TSS load reductions. Included in the summary are the total volume and pollutant loads received by the BMP from its direct watershed, from upstream BMPs and a combined value of the two. Also included in the summary, are the volume and pollutant load reductions provided by the BMP, in addition to the volume and pollutant loads that exit the BMP through the outflow. This outflow load and volume is what is routed to the downstream BMP if one is defined in the Watershed tab. Finally, percent reductions are provided for the percent of the performance goal achieved, percent annual runoff volume retained, total percent annual particulate phosphorus reduction, total percent annual dissolved phosphorus reduction, total percent annual TP reduction, and total percent annual TSS reduction.

## Model input requirements and recommendations

The following are requirements or recommendations for inputs into the MIDS calculator. If the following are not met, an error message will inform the user to change the input to meet the requirement.

- The water underneath the underdrain and in the engineered media must meet the drawdown time requirement specified. The drawdown time requirement is checked by comparing the user defined drawdown time with the calculated drawdown time ($DDT_{calc}$), which is given by

<math> DDT_{calc}=(D_O+D_M)/(I_R/ 12) </math>

Where

$D_O$ is the depth between the underdrain and the engineered media(ft);
$D_M$ is the depth of the engineered media if present; and
$I_R$ is the infiltration rate of the native soils (inches/hr).

- Infiltration rates of the underlying soils are restricted to being below 1.63 inches per hour.

## Methodology

### Required treatment volume

"Required treatment volume," or the volume of stormwater runoff delivered to the BMP, equals the performance goal (1.1 inches or user-specified performance goal) times the impervious area draining to the BMP, plus any water routed to the BMP from an upstream BMP. This stormwater is delivered to the BMP instantaneously.

### Volume reduction capacity of BMP (V) and comparison with performance goal

The volume reduction achieved by a BMP compares the capacity of the BMP to the required treatment volume. The "Volume reduction capacity of BMP" is calculated using BMP inputs provided by the user. For this BMP the volume reduction credit is equal to the amount of water that can be instantaneously captured by the BMP in the storage device and in the engineered media below the outflow. The capture volume (V) is therefore equal to the following

<math> V= V_P+[A_M*n*D_M ] </math>

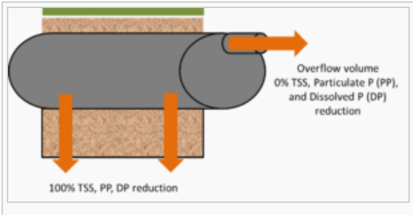
Where:

$V_P$ Is the storage volume in the underground pipe/storage device below the overflow pipe in cubic feet. This includes water stored in the pipe9s) and in the media adjacent to the pipe(s). Methods and examples for calculating the volume based on type of storage device can be found here.
$A_M$ Is the surface area of the engineered soils below the storage device (if engineered media is present) in ft2
n is the media porosity of the soils
$D_M$ is the depth of the engineered media in ft

The "Volume of retention provided by BMP" is the amount of volume credit the BMP provides toward the performance goal. This value is equal to the lesser of the "Volume reduction capacity of BMP" calculated using the above method or the "Required treatment volume". This check makes sure that the BMP is not getting more credit than necessary to meet the performance goal. For example, if the BMP is oversized the user will only receive credit for the "Required treatment volume" routed to the BMP, which corresponds with meeting the performance goal for the site .

### Pollutant Reduction

Pollutant load reductions are calculated on an annual basis. Therefore, the first step in calculating annual pollutant load reductions is converting the "Volume reduction capacity of BMP," which is an instantaneous volume reduction, to an annual volume reduction percentage. This is accomplished through the use of performance curves developed from multiple modeling scenarios. The performance curves use the "Volume reduction capacity of BMP", the infiltration rate of the underlying soils, the contributing watershed percent impervious area, and the size of the contributing watershed to calculate a percent annual volume reduction. While oversizing a BMP above the "Required treatment volume" will not provide additional credit towards the performance goal volume, it may provide additional pollutant reduction.



A 100 percent removal is credited for all pollutants associated with the reduced volume of stormwater since these pollutants are either attenuated within the media or pass into the underlying soil with infiltrating water. Pollutants in the stormwater that bypasses the BMP through overflow are not reduced. A schematic of the removal rates can be seen in the sidebar.

Schematic shows pollutant load reduction for infiltrated and overflow water

NOTE: The user can modify event mean concentrations (EMCs) on the *Site Information* tab in the calculator. Default concentrations are 54.5 milligrams per liter for total suspended solids (TSS) and 0.3 milligrams per liter for total phosphorus (particulate plus dissolved). The calculator will notify the user if the default is changed. Changing the default EMC will result in changes to the total pounds of pollutant reduced.

### Routing

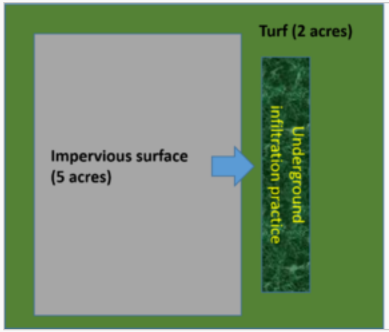
An underground infiltration BMP can be routed to any other BMP, except for a green roof, stormwater disconnection (impervious disconnection), and a swale side slope or any BMP that would cause stormwater to be rerouted back to the infiltration basin already in the stormwater runoff treatment sequence. All BMPs can be routed to the underground infiltration, except for a swale side slope.

### Assumptions

The following general assumptions apply in calculating the credit for a underground infiltration system. If these assumptions are not followed, the volume and pollutant reduction credits cannot be applied.

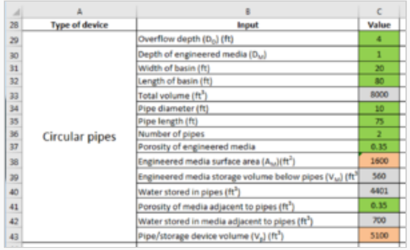
- The underground infiltration is properly designed (link).
- The underground infiltration was properly constructed (link), consistent with the design criteria (link).
- The underground infiltration is properly maintained (link). The performance of the underground infiltration should be regularly assessed (link).

## Underground infiltration example (Version 3)




Schematic used for the MIDS Calculator example for underground infiltration BMP. This example has 1.4 acres of impervious parking lot draining to an underground practice. Total pervious surface is 0.8 acres and includes the Turf Area and the area above the practice. See Step 1.

An underground infiltration practice is to be constructed in a watershed that contains a 1.4 acre parking lot surrounded by 0.8 acres of pervious area (the latter includes turf area and the area above the underground practice). All of the runoff from the watershed will be treated by the underground practice. The soils across the entire area have a unified soils classification of classification of GW (HSG type A soil). The underground practice utilizes two 75-foot long, 10-foot diameter circular pipes (half-pipes in practice) with 1.0 foot of engineered media below the pipes. The depth from the overflow pipe to the engineered media is 4 feet. The *Engineered media surface area ($A_M$)* and the *Pipe/storage device volume ($V_P$)* are needed to calculate the volume retention. These values can be calculated using an Excel spreadsheet developed for this application. A screen shot of that spreadsheet is shown to the right for this example. The media porosity for this example is assumed to be 0.35 cubic feet per cubic foot. Following the MPCA Construction Stormwater General Permit requirement, water in the practice must drawdown in a 48 hour time period. The following steps detail how this system would be set up in the MIDS Calculator.



| | A | B | C |
|---|---|---|---|
| 28 | Type of device | Input | Value |
| 29 | Circular pipes | Overflow depth ($D_O$) (ft) | 4 |
| 30 | | Depth of engineered media ($D_M$) | 1 |
| 31 | | Width of basin (ft) | 20 |
| 32 | | Length of basin (ft) | 80 |
| 33 | | Total volume ($ft^3$) | 8000 |
| 34 | | Pipe diameter (ft) | 10 |
| 35 | | Pipe length (ft) | 75 |
| 36 | | Number of pipes | 2 |
| 37 | | Porosity of engineered media | 0.35 |
| 38 | | Engineered media surface area ($A_M$)($ft^2$) | 1600 |
| 39 | | Engineered media storage volume below pipes ($V_M$) ($ft^3$) | 560 |
| 40 | | Water stored in pipes ($ft^3$) | 4401 |
| 41 | | Porosity of media adjacent to pipes ($ft^3$) | 0.35 |
| 42 | | Water stored in media adjacent to pipes ($ft^3$) | 700 |
| 43 | | Pipe/storage device volume ($V_P$) ($ft^3$) | 5100 |

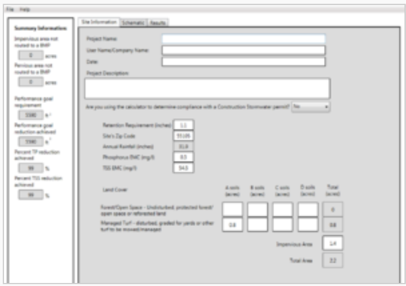
Screenshot from Excel spreadsheet used to calculate values needed as inputs for the calculator. The two values needed are shown in orange and include the Engineered media surface area ($A_M$) and the Pipe/storage device volume ($V_P$). Click on image to enlarge.

Step 1: Determine the watershed characteristics of your entire site. For this example, we have a 2.2 acre site that includes 1.4 acres of impervious area and 0.8 acres of pervious area in type A soils. The pervious area includes the turf area and the area above the underground practice. The entire site drains into the underground practice.

Step 2: Fill in the site specific information into the Site Information tab. This includes entering a ZIP Code (55105 for this example) and the watershed information from Step 1. The Managed Turf area includes the turf area plus the area above the underground practice. ZIP code and impervious area must be filled in or an error message will be generated. The user must also indicate whether the calculator is being used for permit compliance. Other fields on this screen are optional.

Step 3: Go to the Schematic tab and drag and drop the Underground infiltration icon into the Schematic window.

Step 4: Open the BMP properties for underground infiltration by right clicking on the Underground infiltration icon and selecting Edit BMP Properties, or by double clicking on the Underground infiltration icon.



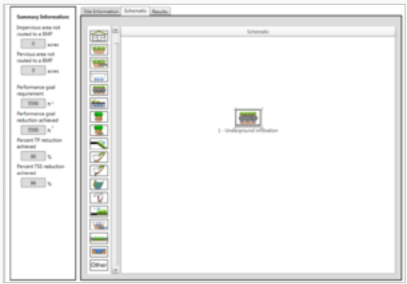
Screen shot of the Site Information tab for underground infiltration. In this example, the user has entered a ZIP code and acres of pervious and impervious surfaces. Note also the user must indicate whether or not the calculator is being used to determine compliance with the Construction Stormwater permit. See Step 2.

Step 5: If help is needed, click on the Minnesota Stormwater Manual Wiki link or the Help button to review input parameter specifications and calculations pertinent to Underground infiltration.

Step 6: Determine the watershed characteristics for the underground infiltration practice. For this example the entire site is draining to the practice. The watershed parameters therefore include a 2.2 acre site with 1.4 acres of impervious area and 0.8 acres of pervious turf area in type A soils. There is no routing/downstream BMP for this BMP. Fill in this BMP-specific watershed information in the Watershed tab (1.4 acres of Impervious Cover and 0.8 acres of Managed Turf in A soils).

Step 7: Click on the BMP Parameters tab and enter the BMP design parameters. This Underground infiltration example requires the following entries:

- Underground pipe/storage device storage volume below overflow [$V_P$]: 5100 cubic feet;
- Overflow depth between media and overflow [$D_O$]: 4 feet;
- Is engineered media present below pipe/storage device?: Yes (selected from dropdown box);
- Engineered media surface area [$A_M$]; 1600 square feet;
- Depth of media [$D_M$]: 1.0 foot;
- Media porosity [n](range 0.35-0.50): 0.35 cubic feet per cubic foot;
- Underlying soil – Hydrologic Soil Group: GW (HSG A; 1.63 in/hr) (selected in dropdown box); and
- Required drawdown time: 48 hrs (selected in dropdown box).



Screenshot of the Watershed tab for underground infiltration. The user has dragged the Underground infiltration icon onto the Schematic screen. See Step 3.

**MIDS Calculator screen shots for inputs for Underground infiltration. Click on an image for enlarged view.**

Screen shot showing Watershed tab for Underground infiltration. See Step 6.

Screen shot showing BMP Parameters tab for Underground infiltration. See Step 7.

Screen shot of the BMP Summary tab for Underground infiltration. See Step 8.

Screen shot of the Results tab for Underground infiltration. See Step 10.

**Step 8**: Click on *BMP Summary* tab to view results for this BMP.

**Step 9**: Click on the *OK* button to exit the *BMP Properties* screen.

**Step 10**: Click on *Results* tab to see overall results for the site.

## Requirements

**Warning:** The following are requirements of the Minnesota Construction Stormwater General Permit

- At least a 3 foot separation from the bottom of an infiltration system to the seasonal high water table
- If soils below the bottom of the infiltration system are ripped to promote infiltration, at least 2 feet of separation from the bottom of the ripped zone to the seasonal high water table
- Use the most restrictive infiltration rate within 5 feet of the bottom of the BMP
- For measured infiltration rates, apply a safety factor of 2

- Pretreatment for infiltration systems

### Recommendations

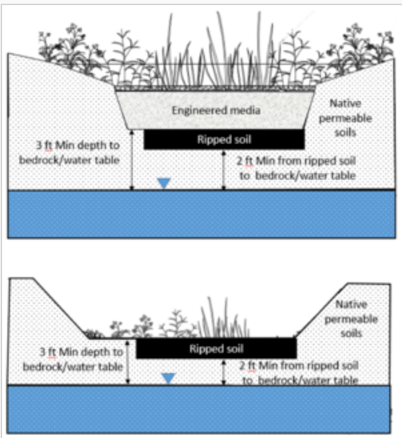
**Caution:** The following are recommendations for inputs into the MIDS Calculator

- Drawdown time of 24 hours when the discharge is to trout streams
- Use of field tested infiltration rates rather than table values

### Information

**Information:** The following information may be useful in determining inputs for the MIDS Calculator

- Guidance on determining infiltration rates
- Information on site constraints (shallow soil, karst, etc.)
- Guidance on pretreatment
- Information on soil mixes
- Construction specifications for bioretention BMPs
- Information on operation and maintenance of bioretention BMPs.



Measurement of depth from the bottom of the infiltration BMP to the seasonally high water table or bedrock. Note that there must be a minimum of 2 feet separation when soils beneath the BMP are ripped, with a total separation distance of 3 feet or more. Infiltration BMPs include any BMP that allows water to infiltrate into the underlying soil.

### Links to MIDS pages

- Overview of Minimal Impact Design Standards (MIDS)
- Performance goals for new development, re-development and linear projects
- Design Sequence Flowchart-Flexible treatment options
- Community Assistance Package
- MIDS calculator
- Performance curves for MIDS calculator
- Training and workshop materials and modules
- Technical documents

## Links and interesting websites

This page contains links to information on stormwater infiltration practices and links to interesting websites.

- St. Anthony Regional Stormwater Treatment and Research System

Category: Table

MINNESOTA POLLUTION CONTROL AGENCY