Page Content

Calculating credits for dry swale (grass swale)

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.

Credit (http://stormwater.pca.state.mn.us/index.php/Overview_of_stormwater_credits) refers to the quantity of stormwater or pollutant reduction achieved either by an individual **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 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 Construction permit (https://stormwater.pca.state.mn.us/index.php?title=Construction_stormwater_program); Municipal (MS4) permit (https://stormwater.pca.state.mn.us/index.php?title=Stormwater_Program_for_Municipal_Separate_Storm_Sewer_Systems_(MS4)));
- meeting the MIDS performance goal (http://stormwater.pca.state.mn.us/index.php/Performance_goals_for_new_development,_re-development_and_linear_projects); or
- meeting or complying with water quality objectives, including **total maximum daily load** (https://stormwater.pca.state.mn.us/index.php?title=Total_Maximum_Daily_Loads_(TMDLs)) (TMDL) **wasteload allocations** (WLAs).

This page provides a discussion of how dry swales (https://stormwater.pca.state.mn.us/index.php?title=Dry_swale_(Grass_swale)) can achieve stormwater credits. Swales with and without underdrains are both discussed, with separate sections for each type of system as appropriate.

Contents

Download pdf (https://stormwater.pca.state.mn.us/index.php?title=File:Calculating_credits_for_bioretention_-_Minnesota_Stormwater_Manual.pdf_May_2022.pdf)

Page video summary (https://stormwater.pca.state.mn.us/index.php?title=File:Credit_page_descriptions.mp4)

Recommended pollutant removal efficiencies, in percent, for dry swale BMPs. Sources (http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs#References). NOTE: removal efficiencies are 100 percent for water that is infiltrated.

TSS=total suspended solids; TP=total phosphorus; PP=particulate phosphorus; DP=dissolved phosphorus; TN=total nitrogen

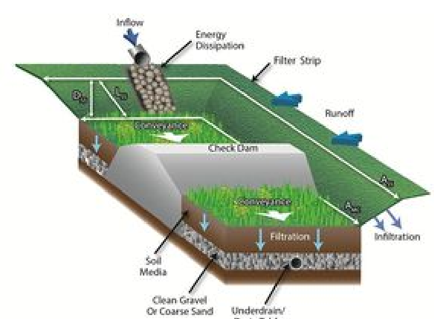
TSS	TP	PP	DP	TN	Metals	Bacteria	Hydrocarbons
68	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	35	80	0	80

Overview

Dry swales (https://stormwater.pca.state.mn.us/index.php?title=Dry_swale_(Grass_swale)), sometimes called grass swales, are similar to **bioretention practices** but are configured as shallow, linear channels. Dry swales function primarily as a conveyance BMP, but provide treatment of stormwater runoff, particularly when used in tandem with **check dams** that temporarily retain water in a series of cells. Dry swales with an **underdrain** and **engineered media** (https://stormwater.pca.state.mn.us/index.php?title=Design_criteria_for_bioretention#Materials_specifications_-_filter_media) are considered a **filtration** (https://stormwater.pca.state.mn.us/index.php?title=Filtration) practice. Dry swales with in-situ soils capable of **infiltration** (https://stormwater.pca.state.mn.us/index.php?title=Stormwater_infiltration_Best_Management_Practices), (A or B soils) are considered infiltration practices. Dry swales are designed to prevent standing water. Dry swales typically have vegetative cover (https://stormwater.pca.state.mn.us/index.php?title=Plants_for_swales) such as turf or native perennial grasses.

Pollutant Removal Mechanisms

Dry swales without check dams or with underdrains primarily remove pollutants through filtration during conveyance of stormwater runoff. Dry swales may also provide some volume reduction benefits through infiltration and **evapotranspiration** during conveyance or below an underdrain. Water quality treatment is also recognized through biological and microbiological uptake, and soil adsorption. Check dams] may be incorporated into dry swale design to enhance infiltration.



Schematic showing characteristics of a dry swale.

Location in the Treatment Train

Dry swales may be located throughout a **treatment train** (https://stormwater.pca.state.mn.us/index.php?title=Using_the_treatment_train_approach_to_BMP_selection), including the main form of conveyance between or out of BMPs, at the end of a treatment train, or designed as off-line configurations where the **Water Quality Volume** (https://stormwater.pca.state.mn.us/index.php?title=Water_quality_criteria) is diverted to the filtration or 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 (filtration or infiltration practices)
- increase groundwater recharge (infiltration practices)
- decrease runoff peak flow rates (filtration or infiltration practices)
- decrease the volume of stormwater runoff (infiltration practices)
- preserve **baseflow** in streams (infiltration practices)
- reduce thermal impacts of runoff (filtration or infiltration practices)

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 (http://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_swale#Methods_for_calculating_credits).

Dry swale practices generate credits for volume, TSS,and TP. Dry swale practices with an underdrain do not substantially reduce the volume of runoff but may qualify for a partial volume credit as a result of evapotranspiration, infiltration occurring through the sidewalls above the underdrain, and infiltration below the underdrain piping. Dry swale practices are effective at reducing concentrations of other pollutants including metals and **hydrocarbons**. They are generally not effective at removing bacteria. This article does not provide information on calculating credits for pollutants other than TSS and TP, but references are provided that may be useful for calculating credits for other pollutants (http://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_swale#Other_pollutants).

Assumptions and Approach

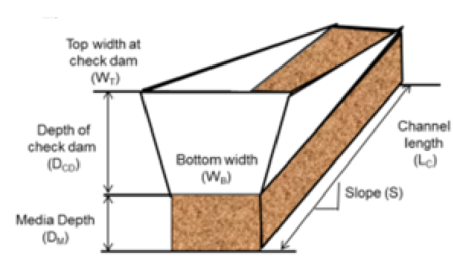
In developing the credit calculations, it is assumed the swale is properly designed, constructed, and maintained in accordance with the Minnesota Stormwater Manual. If any of these assumptions is not valid, the BMP may not qualify for credits or credits should be reduced based on reduced ability of the BMP to achieve volume or pollutant reductions. For guidance on design, construction, and maintenance, see the appropriate article within the Manual (https://stormwater.pca.state.mn.us/index.php?title=Dry_swale_(Grass_swale)).

Warning: Pretreatment is required for all filtration and infiltration practices

Unlike other BMPs such as bioretention and permeable pavement, credits for swales are calculated in two ways. First, if check dams are incorporated into the design, the water quality volume (V_{WQ}) is assumed to be delivered instantaneously to the BMP and stored as water ponded behind the check dam, above the soil or filter media, and below the overflow point of the check dam. V_{WQ} can vary depending on the stormwater management objective(s). For construction stormwater, V_{WQ} is 1 inch times new impervious surface area. For MIDS (https://stormwater.pca.state.mn.us/index.php?title=Minimal_Impact_Design_Standards), the V_{WQ} is 1.1 inches times impervious surface area.

Second, if check dams are not incorporated into the swale, water will infiltrate into the underlying soil or filter media as it is conveyed along the swale. The amount of water captured in this manner is a function of the underlying soil permeability and the length of time flowing water is in contact with the soil, which in turn is affected by the slope of the swale.

Volume credit calculations - check dams and no underdrain



Schematic illustrating terms and dimensions used for volume and pollutant calculations, no underdrain.

Volume credits are typically calculated based on the capacity of the BMP and its ability to permanently remove stormwater runoff from the existing stormwater collection system. When check dams are incorporated into the design, these credits are assumed to be instantaneous values entirely based on the capacity of the BMP for any storm event. Instantaneous volume reduction, or event based volume reduction of a BMP can be converted to annual volume reduction percentages using the MIDS calculator (https://stormwater.pca.state.mn.us/index.php?title=MIDS_calculator) or other appropriate modeling tools.

Credits for dry swales with check dams are dependent on multiple design factors of the swale channel and side slopes, as well as infiltration rates for underlying soils. The water quality volume (V_{wq}) achieved behind each check dam (**instantaneous volume**) is given by

$$V_{wq} = [h^2 * (h * H + B_w)]/(2S)$$

where

- h = check dam height (inches);
- H = horizontal component of the swale side slope (1 vertical : H horizontal)(unitless);
- S = slope (unitless); and
- B_w = channel bottom width (inches).

Convert the volume to cubic feet by dividing by 1728.

Add the V_{wq} for each check dam together to obtain the cumulative water quality volume for the swale.

For an example calculation, link here (https://stormwater.pca.state.mn.us/index.php?title=Check_dams_for_stormwater_swales#Sample_calculation).

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.

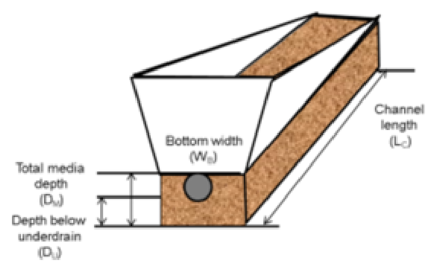
The annual volume captured and infiltrated by the BMP can be determined with appropriate modeling tools, including the MIDS calculator. Example values are shown below for a scenario using the MIDS calculator. For example, a permeable pavement system designed to capture 1 inch of runoff from impervious 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 (https://stormwater.pca.state.mn.us/index.php?title=Water_quality_criteria) Water Quality Volume (https://stormwater.pca.state.mn.us/index.php?title=Water_quality_criteria)**. See footnote[1] for how these were determined.**
Link to this 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.

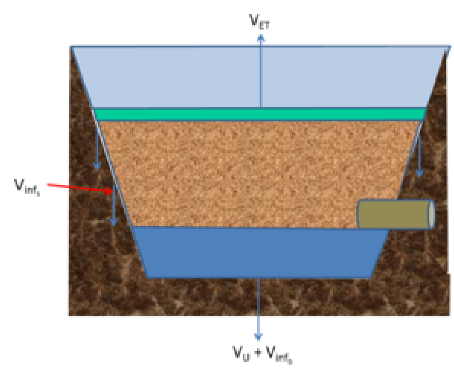
Volume credit calculations - check dams with an underdrain



Schematic illustrating terms and dimensions used for volume and pollutant calculations, with underdrain.

Volume credit for a swale with check dams and an underdrain is the same as for a biofiltration BMP (https://stormwater.pca.state.mn.us/index.php?title=Calculating_credits_for_bioretention#Volume_credit_calculations_-_underdrain), although some of the BMP configurations differ somewhat. Volume credits are available only if the BMP permanently removes a portion of the stormwater runoff via infiltration through sidewalls or beneath the underdrain piping, or through evapotranspiration. These credits are assumed to be instantaneous values based on the design capacity of the BMP for a specific storm event. Instantaneous volume reduction, also termed event based volume reduction, can be converted to annual volume reduction percentages using the MIDS calculator (http://stormwater.pca.state.mn.us/index.php/Performance_curves_for_MIDS_calculator) or other appropriate modeling tools.

Volume credits for a dry swale with check dams and underdrains are calculated by a combination of infiltration through the unlined sides and bottom of the basin (the area below the underdrain), the volume loss through evapotranspiration (ET), and the retention volume below a raised underdrain, if applicable (this is based on the assumption that this stored water will infiltrate into the underlying soil). The main design variables impacting the volume credits include whether the underdrain is elevated above the native soils and if an **impermeable** liner on the sides or bottom of the basin is used. Other design variables include surface area at the check dam overflow, media top surface area, underdrain location, and basin bottom locations, total depth of media, soil **water holding capacity**, soil **porosity (f)**, and **design infiltration rate (https://stormwater.pca.state.mn.us/index.php?title=Design_infiltration_rate_as_a_function_of_soil_texture_for_bioretention_in_Minnesota)** of underlying soils.



Schematic illustrating the different water loss terms for a swale (biofiltration) BMP with a raised underdrain.

Information: For the following equations, units most commonly used in practice are given and unit correction factors are based on those units

The following calculations are for a single check dam. To get the total volume credit add the volumes for each check dam.

The volume credit (V) for a dry swale with a check dam and underdrain, in cubic feet, is given by

$$V = V_{inf_B} + V_{inf_s} + V_{ET} + V_U$$

where:

- V_{inf_b} = volume of infiltration through the bottom of the basin (cubic feet);
- V_{inf_s} = volume of infiltration through the sides of the basin (cubic feet);
- V_{ET} = volume reduction due to evapotranspiration (cubic feet); and
- V_U = volume of water stored beneath the underdrain that will infiltrate into the underlying soil (cubic feet).

Volume credits for infiltration through the bottom of the basin (V_{inf_b}) are accounted for only if the bottom of the basin is not lined. As long as water continues to draw down, some infiltration will occur through the bottom of the BMP. However, it is assumed that when an underdrain is included in the installation, the majority of water will be filtered through the media and exit through the underdrain. Because of this, the drawdown time is likely to be short. Volume credit for infiltration through the bottom of the basin is given by

$$V_{inf_B} = A_B\ DDT\ I_R/12/2$$

where

- I_R = design infiltration rate of underlying soil (inches per hour);
- A_B = surface area at the bottom of the basin (square feet); and
- DDT = drawdown time for ponded water (hours).

Because of the slope in a swale and the resulting unequal pool depth behind a check dam, a correction factor of 2 is included in the above equation.

Information: The MIDS calculator assigns a default value of 0.06 inches per hour, equivalent to a D soil, to I_R. This is based on the assumption that most water will drain to the underdrain, but that some loss to underlying soil will occur. A conservative approach assuming a D soil was thus chosen.

The **drawdown time** is typically a maximum of 48 hours, which is designed to be protective of plants grown in the media. The Construction Stormwater permit (https://stormwater.pca.state.mn.us/index.php?title=Construction_stormwater_program) requires drawdown within 48 hours and recommends 24 hours when discharges are to a trout stream. With a properly functioning underdrain, the drawdown time is likely to be considerably less than 48 hours.

Volume credit for infiltration through the sides of the basin is accounted for only if the sides of the basin are not lined with an impermeable liner. Volume credit for infiltration through the sides of the basin is given by

$$V_{inf_s} = (A_O - A_U)\ DDT\ I_R/12$$

where

- A_O = the surface area at the overflow (square feet); and
- A_U = the surface area at the underdrain (square feet).

Information: The MIDS calculator assigns a default value of 0.06 inches per hour, equivalent to a D soil, to I_R. This is based on the assumption that most water will drain to the underdrain, but that some loss to underlying soil will occur. A conservative approach assuming a D soil was thus chosen.

This equation assumes water will infiltrate through the entire sideslope area during the period when water is being drawn down. This is not the case, however, since the water level will decline in the BMP. The MIDS calculator assumes a linear drop in water level and thus divides the right hand term in the above equation by 2.

Volume credit for media storage capacity below the underdrain (V_U) is accounted for only if the underdrain is elevated above the native soils. Volume credit for media storage capacity below the underdrain is given by

$$V_U = (n - FC)\ D_U\ (A_U + A_B)/2$$

where

- A_B = surface area at the bottom of the media (square feet);
- n = media porosity (cubic feet per cubic foot);
- FC is the field capacity of the soil, in cubic feet per cubic foot; and
- D_U = the depth of media below the underdrain (feet).

This is an instantaneous volume. This will somewhat overestimate actual storage when the majority of water is being captured by the underdrains. This equation assumes water between the soil porosity and field capacity (http://stormwater.pca.state.mn.us/index.php/Soil_water_storage_properties) will infiltrate into the underlying soil.

The volume of water lost through ET is assumed to be the smaller of two calculated values: potential ET and measured ET. Potential ET (ET_{pot}) is equal to the amount of water stored in the basin between **field capacity** and the **wilting point**. Measured ET (ET_{mea}) is the amount of water lost to ET as measured using available data and is assumed to be 0.2 inches/day. ET_{mea} is converted to ET by multiplying by a factor of 0.5. ET is considered to occur over a period equal to the drawdown time of the basin. Volume credit for evapotranspiration is given by the lesser of

$$ET_{mea} = (0.2/12)\ A\ 0.5\ t\ ET_{pot} = D\ A\ C_S$$

where

- t = time over which ET is occurring (days);
- D = depth being considered (feet);
- A = area being considered (square feet); and
- C_S = soil water available for ET, generally assumed to be the water between field capacity and wilting point.

ET is likely to be greater if one or more trees is planted in the swale. The MIDS calculator increases the above ET credit by a factor of 3 when a tree is planted in the swale, but this credit is not available for swales. See Plants for swales for information about trees that might be acceptable in swales.

Provided **soil water (moisture) content** is greater than the wilting point, ET will continually occur during the non-frozen period. However, because the above volume calculations are event based, t will be equal to the time between rain events. In the MIDS calculator, a value of 3 days is used because this is the average number of days between precipitation events. ET will occur over the entire media depth. D may therefore be set equal to the media depth (D_M). In this case, the value for A would be the average area through the entire depth of the media. The MIDS calculator limits ET to the area above the underdrain. If infiltration is being computed through the bottom and sidewalls of the basin, then C_S would be field capacity minus the wilting point of soils (cubic feet per cubic foot) since water above the field capacity would infiltrate (or go to an underdrain).

The volume of water passing through underdrains can be determined by subtracting the volume loss (V) from the volume of water instantaneously captured by the BMP. No volume reduction credit is given for filtered stormwater that exits through the underdrain, but the volume of filtered water can be used in the calculation of pollutant removal credits through filtration.

The volume reduction credit (V) can be converted to an annual volume if desired. This conversion can be generated using the MIDS calculator or other appropriate modeling techniques. The MIDS calculator obtains the percentage annual volume reduction through performance curves (http://stormwater.pca.state.mn.us/index.php/Performance_curves_for_MIDS_calculator) developed from multiple modeling scenarios using the volume reduction capacity for swales, the infiltration rate of the underlying soils, and the contributing watershed size and imperviousness.

Volume credit calculations - no check dam

When a check dam is not incorporated into the design, water will infiltrate into the soil or media as it is conveyed along the swale. Volume credits for swales without check dams can be calculated using an appropriate model, such as the MIDS calculator or soil infiltration models (e.g. Green and Ampt (https://www.hydrology.bee.cornell.edu/BEE3710Handouts/GreenAmpt.pdf)).

Water quality credit calculations

Water quality credits applied to dry swales can be calculated by rainfall event or annual rainfall. This value is obtained from the infiltration and filtration volume capacity of the BMP (calculated above).

Total suspended solids

TSS reduction credits correspond with volume reduction through infiltration and filtration of water captured by the swale and are given by

$$M_{TSS} = M_{TSS_i} + M_{TSS_f}$$

where

M_{TSS} = TSS removal (pounds);
M_{TSS_i} = TSS removal from infiltrated water (pounds); and
M_{TSS_f} = TSS removal from filtered water (pounds).

Pollutant removal for infiltrated water is assumed to be 100 percent. The event-based mass of pollutant removed through infiltration, in pounds, is given by

- filtration (underdrain) - $M_{TSS_i} = 0.0000624\ (V_{inf_b} + V_{inf_s} + V_U)\ EMC_{TSS}$
- infiltration - $M_{TSS_i} = 0.0000624\ V_{WQ}\ EMC_{TSS}$

where

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, link here (http://stormwater.pca.state.mn.us/index.php/Total_Suspended_Solids_%28TSS%29_in_stormwater) or here (https://stormwater.pca.state.mn.us/index.php?title=Event_mean_concentrations_by_land_use).

Removal for the filtered portion is less than 100 percent. The event-based mass of pollutant removed through filtration, in pounds, is given by

$$M_{TSS_f} = 0.0000624\ (V_{total} - (V_{inf_b} + V_{inf_s} + V_U))\ EMC_{TSS}\ R_{TSS}$$

where

V_{total} is the total volume of water captured by the BMP (cubic feet); and
R_{TSS} is the TSS pollutant removal percentage for filtered runoff.

The Stormwater Manual (https://stormwater.pca.state.mn.us/index.php?title=Information_on_pollutant_removal_by_BMPs) provides a recommended value for R_{TSS} of 0.68 (68 percent) removal for filtered water. Alternate justified percentages for TSS removal can be used if proven to be applicable to the BMP design.

The above calculations may be applied on an event or annual basis and are given by

$$M_{TSS_f} = 2.72\ F\ V_{F_{annual}}\ EMC_{TSS}\ R_{TSS}$$

where

F is the fraction of annual volume filtered through the BMP; and
V_{annual} is the annual volume treated by the BMP, in acre-feet.

Total phosphorus

Total phosphorus (TP) reduction credits correspond with volume reduction through infiltration and filtration of water captured by the swale and are given by

$$M_{TP} = M_{TP_i} + M_{TP_f}$$

where

- M_{TP} = TP removal (pounds);
- M_{TP_i} = TP removal from infiltrated water (pounds); and
- M_{TP_f} = TP removal from filtered water (pounds).

Pollutant removal for infiltrated water is assumed to be 100 percent. The mass of pollutant removed through infiltration, in pounds, is given by

- filtration (underdrain) - $M_{TP_i} = 0.0000624\ (V_{inf_b} + V_{inf_s} + V_U)\ EMC_{TP}$
- infiltration - $M_{TP_i} = 0.0000624\ V_{WQ}\ EMC_{TP}$

where

- EMC_{TP} is the event mean TP concentration in runoff water entering the BMP (milligrams per liter).

The EMC_{TP} (https://stormwater.pca.state.mn.us/index.php?title=Event_mean_concentrations_by_land_use) entering the BMP is a function of the contributing land use and treatment by upstream tributary BMPs.

The filtration credit for TP (https://stormwater.pca.state.mn.us/index.php?title=Information_on_pollutant_removal_by_BMPs) in a swale with underdrains assumes removal rates based on the soil media mix (http://stormwater.pca.state.mn.us/index.php/Design_criteria_for_bioretention#Materials_specifications_-_filter_media) used and the presence or absence of amendments (http://stormwater.pca.state.mn.us/index.php/Soil_amendments_to_enhance_phosphorus_sorption). Soil mixes with more than 30 mg/kg phosphorus (P) content are likely to leach phosphorus and do not qualify for a water quality credit. If the soil phosphorus concentration is less than 30 mg/kg, the mass of phosphorus removed through filtration, in pounds, is given by

$$M_{TP_f} = 0.0000624\ (V_{total} - (V_{inf_b} + V_{inf_s} + V_U))\ EMC_{TP}\ R_{TP}$$

Information: Soil mixes C and D are assumed to contain less than 30 mg/kg of phosphorus and therefore do not require testing

Again, assuming the phosphorus content in the media is less than 30 milligrams per kilogram, the removal efficiency (R_{TP}) provided in the Stormwater Manual (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain) is a function of the fraction of phosphorus that is in particulate or dissolved form, the depth of the media, and the presence or absence of soil amendments. For the purpose of calculating credits it can be assumed that TP in storm water runoff consists of 55 percent particulate phosphorus (PP) and 45 percent dissolved phosphorus (DP). The removal efficiency for particulate phosphorus is 68 percent. The removal efficiency for dissolved phosphorus is 20 percent if the media depth is 2 feet or greater. The efficiency decreases by 1 percent for each 0.1 foot decrease in media thickness below 2 feet. If a soil amendment is added to the BMP design, an additional 40 percent credit is applied to dissolved phosphorus. Thus, the overall removal efficiency, (R_{TP}), expressed as a percent removal of total phosphorus, is given by

$$R_{TP} = (0.68 * 0.55) + (0.45 * ((0.2 * (D_{MU_{max=2}})/2) + 0.40_{ifamendmentisused})) * 100$$

where

- the first term on the right side of the equation represents the removal of particulate phosphorus;
- the second term on the right side of the equation represents the removal of dissolved phosphorus; and
- $D_{MU_{max=2}}$ = the media depth above the underdrain, up to a maximum of 2 feet.

The assumption of 55 percent particulate phosphorus and 45 percent dissolved phosphorus is likely inaccurate for certain land uses, such as industrial, transportation, and some commercial areas. Studies indicate particulate phosphorus comprises a greater percent of total phosphorus in these land uses. It may therefore be appropriate to modify the above equation with locally derived ratios for particulate and dissolved phosphorus. For more information on fractionation of phosphorus in stormwater runoff, link here (https://stormwater.pca.state.mn.us/index.php?title=Event_mean_concentrations_of_total_and_dissolved_phosphorus_in_stormwater_runoff#Ratios_of_particulate_to_dissolved_phosphorus).

Methods for calculating credits

This section provides specific information on generating and calculating credits from swale BMPS for volume, Total Suspended Solids (TSS) and Total Phosphorus (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 models (https://stormwater.pca.state.mn.us/index.php?title=Available_stormwater_models_and_selecting_a_model)
- The Simple Method (https://stormwater.pca.state.mn.us/index.php?title=The_Simple_Method_for_estimating_phosphorus_export) and MPCA Estimator (https://stormwater.pca.state.mn.us/index.php?title=Guidance_and_examples_for_using_the_MPCA_Estimator)
- MIDS Calculator (https://stormwater.pca.state.mn.us/index.php?title=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 dry swales. 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.

Use of models or calculators for the purpose of computing pollutant removal credits should be supported by detailed documentation, including:

1. Model name and version
2. Date of analysis
3. Person or organization conducting analysis
4. Detailed summary of input data
5. Calibration and verification information
6. 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 constructed basin BMPs. In using this table to identify models appropriate for constructed ponds and wetlands, use the sort arrow on the table and sort by *Constructed Basin BMPs*. Models identified with an *X* may be appropriate for using with constructed basins.

Comparison of stormwater models and calculators. Additional information and descriptions for some of the models listed in this table can be found at this link (http://stormwater.pca.state.mn.us/index.php/Available_stormwater_models_and_selecting_a_model). Note that the Construction Stormwater General Permit (https://stormwater.pca.state.mn.us/index.php?title=Construction_stormwater_program) 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 table

Access this table as a Microsoft Word document: File:Stormwater Model and Calculator Comparisons table.docx.

Model name	BMP Category						Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices				
Center for Neighborhood Technology Green Values National Stormwater Management Calculator (https://cnt.org/tools/green-values-calculator)	X	X	X		X		No	No	Yes	Does not compute volume reduction for some BMPs, including cisterns and tree trenches.

Model name	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices	Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
	BMP Category									
CivilStorm (http://www.bentley.com/en-US/Products/CivilStorm/)							Yes	Yes	Yes	CivilStorm has an engineering library with many different types of BMPs to choose from. This list changes as new information becomes available.
EPA National Stormwater Calculator (http://www.epa.gov/nrmrl/wswrd/wq/models/swc/)	X		X		X		No	No	Yes	Primary purpose is to assess reductions in stormwater volume.
EPA SWMM (https://www.epa.gov/water-research/storm-water-management-model-swmm)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
HydroCAD (http://www.hydrocad.net/)	X		X	X			No	No	Yes	Will assess hydraulics, volumes, and pollutant loading, but not pollutant reduction.
infoSWMM (http://www.innovyze.com/products/infoswmm/)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
infoWorks ICM (http://www.innovyze.com/products/infoworks_icm/)	X	X	X	X			Yes	Yes	Yes	
i-Tree-Hydro (http://www.itreetools.org/hydro/index.php)			X				No	No	Yes	Includes simple calculator for rain gardens.
i-Tree-Streets (http://www.itreetools.org/streets/index.php)							No	No	Yes	Computes volume reduction for trees, only.

Model name	BMP Category: Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices	Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
LSPC (https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NERL&dirEntryId=75860&CFID=22884508&CFTOKEN=98267566)	X		X	X			Yes	Yes	Yes	Though developed for HSPF, the USEPA BMP Web Toolkit can be used with LSPC to model structural BMPs such as detention basins, or infiltration BMPs that represent source control facilities, which capture runoff from small impervious areas (e.g., parking lots or rooftops).
MapShed (https://wikiwatershed.org/help/model-help/mapshed/)	X	X	X	X			Yes	Yes	Yes	Region-specific input data not available for Minnesota but user can create this data for any region.
MCWD/MWMO Stormwater Reuse Calculator (http://minnehahacreek.org/sites/minnehahacreek.org/files/Stormwater%20Harvesting%20and%20Reuse%20Model_v2.0.xlsx)					X		Yes	No	Yes	Computes storage volume for stormwater reuse systems
Metropolitan Council Stormwater Reuse Guide Excel Spreadsheet (http://www.metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning.aspx)					X		No	No	Yes	Computes storage volume for stormwater reuse systems. Uses 30-year precipitation data specific to Twin Cites region of Minnesota.
MIDS Calculator (http://stormwater.pca.state.mn.us/index.php/MIDS_calculator)	X	X	X	X	X	X	Yes	Yes	Yes	Includes user-defined feature that can be used for manufactured devices and other BMPs.

Model name	BMP Category						Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices				
MIKE URBAN (SWMM or MOUSE) (http://www.mikebydhi.com/Products/Cities/MIKEURBAN.aspx)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
P8 (http://wwwalker.net/p8/)	X		X	X		X	Yes	Yes	Yes	
PCSWMM (http://www.chiwater.com/Software/PCSWMM/)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
PLOAD (http://water.epa.gov/scitech/datait/models/basins/framework.cfm#models)	X	X	X	X		X	Yes	Yes	No	User-defined practices with user-specified removal percentages.
PondNet (http://wwwalker.net/)	X						Yes	No	Yes	Flow and phosphorus routing in pond networks.
PondPack (http://www.bentley.com/en-US/Products/PondPack)	X		[				No	No	Yes	PondPack can calculate first-flush volume, but does not model pollutants. It can be used to calculate pond infiltration.
RECARGA (http://dnr.wi.gov/topic/stormwater/standards/recarga.html)			X				No	No	Yes	
SHSAM (https://shsam.barr.com/)						X	No	Yes	No	Several flow-through structures including standard sumps, and proprietary systems such as CDS, Stormceptors, and Vortechs systems
SUSTAIN (https://www.epa.gov/water-research/system-urban-stormwater-treatment-and-analysis-integration-sustain)	X	X	X	X	X		Yes	Yes	Yes	Categorizes BMPs into Point BMPs, Linear BMPs, and Area BMPs

Model name	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices	Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
	BMP Category									
SWAT (http://swat.tamu.edu/)	X	X	X				Yes	Yes	Yes	Model offers many agricultural BMPs and practices, but limited urban BMPs at this time.
Virginia Runoff Reduction Method (https://swbmp.vwrrc.vt.edu/vrrm/)	X	X	X	X	X	X	Yes	No	Yes	Users input Event Mean Concentration (EMC) pollutant removal percentages for manufactured devices.
WARMF (https://www.epri.com/research/products/3002011868)	X	X					Yes	Yes	Yes	Includes agriculture BMP assessment tools. Compatible with USEPA Basins
WinHSPF (https://www.researchgate.net/figure/The-WinHSPF-interface-available-through-BASINS_fig1_274344576)	X		X	X			Yes	Yes	Yes	USEPA BMP Web Toolkit available to assist with implementing structural BMPs such as detention basins, or infiltration BMPs that represent source control facilities, which capture runoff from small impervious areas (e.g., parking lots or rooftops).
WinSLAMM (http://www.winslamm.com/default.html)	X	X	X	X			Yes	Yes	Yes	
XPSWMM (https://www.innovyze.com/en-us/products/xpswmm)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.

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 **event mean concentration** 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. Ohrel (http://www.stormwatercenter.net/Library/Practice/13.pdf) (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 The Simple method to Calculate Urban Stormwater Loads (http://www.stormwatercenter.net/monitoring%20and%20assessment/simple%20meth/simple.htm) or The Simple Method for estimating phosphorus export.

Some simple stormwater calculators utilize the Simple Method (EPA STEPL (https://www.epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl), Watershed Treatment Model (https://www.stormwatercenter.net/monitoring%20and%20assessment/watershed_treatment_model.htm)). The MPCA developed a simple calculator for estimating load reductions for TSS, total phosphorus, and bacteria. Called the **MPCA Estimator** (http://stormwater.pca.state.mn.us/index.php/Guidance_and_examples_for_using_the_MPCA_Estimator), this tool was developed specifically for complying with the MS4 General Permit TMDL annual reporting requirement (https://stormwater.pca.state.mn.us/index.php?title=Forms,_guidance,_and_resources_for_completing_the_TMDL_annual_report_form). The MPCA Estimator provides default values for pollutant concentration, **runoff coefficients** (https://stormwater.pca.state.mn.us/index.php?title=Runoff_coefficients_for_5_to_10_year_storms) 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, 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. Default TSS removal fractions are 0.84 for wet basins and 0.73 for constructed wetlands. Default removal fractions for TP are 0.50 for wet basins and 0.38 for constructed wetlands.

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 (https://stormwater.pca.state.mn.us/index.php?title=File:MPCA_simple_estimator_version_3.0_March_5_2021.xlsx)

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 swales (https://stormwater.pca.state.mn.us/index.php?title=Links_to_Manual_pages_that_address_the_MIDS_calculator). An overview of individual input parameters and workflows is presented in the MIDS Calculator User Documentation (http://stormwater.pca.state.mn.us/index.php/User%E2%80%99s_Guide).

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 event mean concentration (EMC) of the dry swale. A more detailed explanation of the differences between mass load reductions and EMC reductions can be found here.

Designers may use the pollutant reduction values reported here 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 (https://bmpdatabase.org/).
- Select a pollutant removal reduction from literature that studied a dry swale device with site characteristics and climate similar to the device being considered for credits.
- When using data from an individual study, review the article to determine that the design principles of the studied dry swale are close to the design recommendations for Minnesota, as described here, and/or by a local permitting agency.
- Preference should be given 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 dry swale, considering such conditions as watershed characteristics, swale sizing, and climate factors.

- International Stormwater Best Management Practices (BMP) Database Pollutant Category Summary Statistical Addendum: TSS, Bacteria, Nutrients, and Metals (https://bmpdatabase.org/)
  - 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
- Updated BMP Removal Efficiencies from the National Pollutant Removal Database (2007) & Acceptable BMP Table for Virginia (http://lshs.tamu.edu/docs/lshs/end-notes/updated%20bmp%20removal%20efficiencies%20from%20the%20national%20pollutant%20re-2854375963/updated%20bmp%20removal%20efficiencies%20from%20the%20national%20pollutant%20removal%20database.pdf)
  - Provides data for several structural and non-structural BMP performance evaluations
- The Illinois Green Infrastructure Study (http://www.epa.state.il.us/green-infrastructure/docs/draft-final-report.pdf)
  - 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 (https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/wd-08-20b.pdf)
  - 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 (https://www3.epa.gov/region1/npdes/stormwater/tools/BMP-Performance-Analysis-Report.pdf). 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
- Weiss, P.T., J.S. Gulliver and A.J. Erickson. 2005. The Cost and Effectiveness of Stormwater Management Practices: Final Report (http://www.lrrb.org/media/reports/200523.pdf)
  - Table 8 and Appendix B provides pollutant removal efficiencies for TSS and P
  - Applicable to Wet Basins, Stormwater Wetlands, Bioretention Filter, Sand Filter, Infiltration Trench, and Filter Strips/Grass Swales

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.
   1. Which pollutants will be measured?
   2. Will the monitoring study the performance of a single BMP or multiple BMPs?
   3. Are there any variables that will affect the BMP performance? Variables could include design approaches, maintenance activities, rainfall events, rainfall intensity, etc.
   4. Will the results be compared to other BMP performance studies?
   5. 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:
   1. Equipment selection and placement
   2. Sampling protocols including selection, storage, delivery to the laboratory
   3. Laboratory services
   4. Health and Safety plans for field personnel
   5. Record keeping protocols and forms
   6. 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 (http://water.epa.gov/scitech/wastetech/guide/stormwater/monitor.cfm)

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) (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_565.pdf)

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 (http://wefstormwaterinstitute.org/wp-content/uploads/2016/08/WEF-STEPP-White-Paper_Final_02-06-142.pdf).

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 (http://stormwaterbook.safl.umn.edu/)

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.

- Level 1: Visual Inspection (https://stormwaterbook.safl.umn.edu/assessment-programs/visual-inspection)
- Level 2: Capacity Testing (https://stormwaterbook.safl.umn.edu/assessment-programs/capacity-testing)
- Level 3: Synthetic Runoff Testing (http://stormwaterbook.safl.umn.edu/assessment-programs/synthetic-runoff-testing)
- Level 4: Monitoring (https://stormwaterbook.safl.umn.edu/assessment-programs/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 (https://stormwaterbook.safl.umn.edu/water-budget-measurement)
- Sampling Methods (https://stormwaterbook.safl.umn.edu/sampling-methods)
- Analysis of Water and Soils (https://stormwaterbook.safl.umn.edu/analysis-water-and-soils)
- Data Analysis for Monitoring (https://stormwaterbook.safl.umn.edu/data-analysis)

Other pollutants

According to the International BMP Database (http://bmpdatabase.org/index.htm), studies have shown dry swales are effective at reducing concentration of other pollutants as well including solids, bacteria, metals, and nutrients. This database provides an overview of BMP performance in relation to various pollutant categories and constituents that were monitored in BMP studies within the database. The report notes that effectiveness and range of unit treatment processes can vary greatly depending on BMP design and location. Table 3-4 shows a list of the constituents and associated pollutant category for the monitored "media filters" data. The constituents shown all had data representing decreases in effluent pollutant loads for the median of the data points and the 95% confidence interval about the median. If dry swale design utilizes a bioretention base, additional pollutant removals may be applicable as well (For more information see the bioretention credit article). Pollutant removal percentages for dry swale BMPs can also be found on the WIKI page.

Dry swale pollutant load reduction
Link to this table

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

[1]Results are for total metals only

[2]Information on As was found only in the International Stormwater Database (https://bmpdatabase.org/) where removal was found to be low

References and suggested reading

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Related articles

- Dry swales
  - Terminology for swales (grass channels)
  - Overview for dry swale (grass swale)
  - Types of infiltration
  - Types of filtration
  - 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)
  - 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 (https://stormwater.pca.state.mn.us/index.php?title=Requirements,_recommendations_and_information_for_using_swale_without_an_underdrain_as_a_BMP_in_the_MIDS_calculator)
  - Requirements, recommendations and information for using dry swale (grass swale) with an underdrain in the MIDS calculator (https://stormwater.pca.state.mn.us/index.php?title=Requirements,_recommendations_and_information_for_using_swale_with_an_underdrain_as_a_BMP_in_the_MIDS_calculator)
  - Requirements, recommendations and information for using swale side slope as a BMP in the MIDS calculator
- Calculating credits
  - Calculating credits for bioretention
  - Calculating credits for infiltration basin
  - Calculating credits for infiltration trench
  - Calculating credits for permeable pavement
  - Calculating credits for green roofs
  - Calculating credits for sand filter
  - Calculating credits for stormwater ponds
  - Calculating credits for stormwater wetlands
  - Calculating credits for iron enhanced sand filter
  - Calculating credits for swale
  - Calculating credits for tree trenches and tree boxes
  - Calculating credits for stormwater and rainwater harvest and use/reuse