Appendix B

Minnesota Pollution Control Agency: Calculating Credits for Tree Trenches and Tree Boxes

Calculating credits for tree trenches and tree boxes

Green Infrastructure: Trees can be an important tool for retention and detention of stormwater runoff. Trees provide additional benefits, including cleaner air, reduction of heat island effects, carbon sequestration, reduced noise pollution, reduced pavement maintenance needs, and cooler cars in shaded parking lots.

Recommended pollutant removal efficiencies, in percent, for tree trench/tree box BMPs. Sources. 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
85	link to table	link to table	link to table	50	35	95	80

Credit refers to the quantity of stormwater or pollutant reduction achieved toward meeting a runoff volume or water quality goal 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 [1]; [2]);
- meeting the MIDS performance goal; or
- meeting or complying with water quality objectives, including Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs).

This page provides a discussion of how tree trench/tree box practices can achieve stormwater credits. Tree systems with and without underdrains are both discussed, with separate sections for each type of system as appropriate.

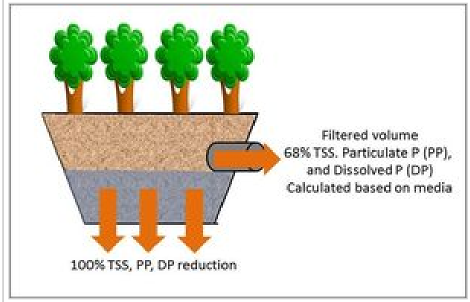
Contents

Overview

Tree trenches and tree boxes are specialized bioretention practices. They are therefore terrestrial-based (up-land as opposed to wetland) water quality and water quantity control process. Tree systems consist of an engineered soil layer designed to treat stormwater runoff via filtration through plant and soil media, evapotranspiration from trees, or through infiltration into underlying soil. Pretreatment is REQUIRED for all bioretention facilities, including tree-based systems, to settle particulates before entering the BMP. Tree practices may be built with or without an underdrain. Other common components may include a stone aggregate layer to allow for increased retention storage and an impermeable liner on the bottom or sides of the facility if located near buildings, subgrade utilities, or in karst formations.

Pollutant removal mechanisms

Like other bioretention practices, tree trenches and tree boxes have high nutrient and pollutant removal efficiencies (Mid-America Regional Council and American Public Works Association Manual of Best Management Practice BMPs for Stormwater Quality, 2012). Tree practices provide pollutant removal and volume reduction through filtration, evaporation, infiltration, transpiration, biological and microbiological uptake, and soil adsorption; the extent of these benefits is highly dependent on site specific conditions and design. In addition to phosphorus and total suspended solids (TSS), which are discussed in greater detail below, tree practices treat a wide variety of other pollutants.



Schematic illustrating how pollutant reductions (TSS, dissolved and particulate P) are calculated for a tree trench system-tree box.

Removal of phosphorus is dependent on the engineered media. Media mixes with high organic matter content typically leach phosphorus and can therefore contribute to water quality degradation. The Manual provides a detailed discussion of media mixes, including information on phosphorus retention.

Location in the treatment train

Stormwater treatment trains are multiple Best Management Practice (BMPs) 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. Tree trenches and tree boxes can be incorporated anywhere in the stormwater treatment train but are most often located in upland areas of the treatment train. The strategic distribution of tree BMPs help control runoff close to the source where it is generated.

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.

Tree practices generate credits for volume, TSS, and TP. Practices with underdrains 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. Tree practices are 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 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 tree 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 tree section of the Manual.

Warning: Pre-treatment is required for all filtration and infiltration practices

In the following discussion, the water quality volume (V_{WQ}) is delivered instantaneously to the BMP. The V_{WQ} is stored within the filter media. The V_{WQ} can vary depending on the stormwater management objective(s). For construction stormwater, V_{WQ} is 1 inch times the new impervious surface area. For MIDS, V_{WQ} is 1.1 inches times the impervious surface area.

Volume credit calculations - no underdrain

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, evapotranspiration (ET) from trees, and interception of rainfall by the tree canopy. The total volume credit, V in cubic feet, is given by

$$V = V_{inf_b} + V_{ET} + V_I$$

where

V_{inf} is the volume of captured water that is infiltrated, in cubic feet;
V_{ET} is the volume of captured water that is lost to evapotranspiration, in cubic feet; and
V_I is the volume of precipitation intercepted by the tree canopy, in cubic feet.

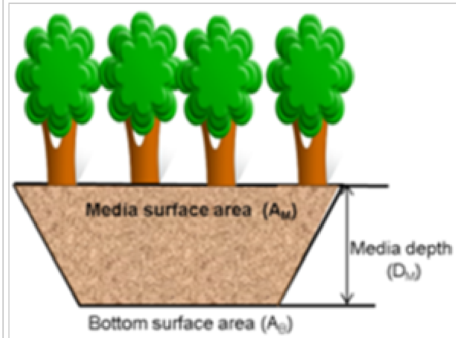
Interception credit

Water intercepted by a tree canopy may evaporate or be slowly released such that it does not contribute to stormwater runoff. An interception credit is given by a simplified value of the interception capacity (I_c), as presented by Breuer et al. (2003) for deciduous and coniferous tree species.

- $I_{c\ coniferous}$ = 0.087 inches (2.2 millimeters)
- $I_{c\ deciduous}$ = 0.043 inches (1.1 millimeters)

This credit is per storm event.

Infiltration and ET credits



Schematic illustrating terms used for calculating credits for a tree trench system.

The infiltration and ET 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 be instantly stored in the bioretention media. The volume of water between saturation and field capacity 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

$$V_{inf_b} = (n - FC)\ D_M\ (A_M + A_B)\ /2$$

where

n is the porosity of the media in cubic feet per cubic foot;
FC is the field capacity of the media in cubic feet per cubic foot;
A_M is the area at the surface of the media, in square feet;
A_B is the area at the bottom of the media, in square feet; and
D_M is the media depth within the BMP, in feet.

V_{inf_b} should be calculated to infiltrate within a specific drawdown time. The construction stormwater permit has a 48 hour drawdown requirement (24 hours is recommended for discharges to trout streams).

ET is calculated as the volume of water between field capacity and the permanent wilting point. Two calculations are needed to determine the evapotranspiration (ET) credit. The smaller of the two calculated values will be used as the ET credit.

The first calculation is the volume of water available for ET. This equals the water stored between field capacity and the wilting point. Note this calculation is made for the entire thickness of the media.

The second calculation is the theoretical ET. The theoretical volume of ET lost (Lindsey and Bassuk, 1991) per day per tree is given by

$$ET = (CP)(LAI)(E_{rate})(E_{ratio}) * 3$$

Where:

CP is the canopy projection area (square feet);
LAI is the Leaf Area Index;
E_{rate} is the evaporation rate per unit time (feet per day);
E_{ratio} is the evaporation ratio; and
3 accounts for the number of days over which ET occurs (the average number of days between rain events in Minnesota).

Caution: The theoretical ET must be adjusted if the actual soil volume is less than the recommended volume. See the adjustment calculation below.

The canopy projection area (CP) is the perceived tree canopy diameter at maturity and is given by

$$CP = \Pi(d/2)^2$$

where d is the diameter of the canopy as measured at the dripline (feet).

CP varies by tree species. Please refer to the Tree Species List for these values. Default values can be used in place of calculating CP. Defaults for CP are based on tree size and are

- 315 for a small tree;
- 490 for a medium sized tree; and
- 707 for a large tree.

The leaf area index (LAI) should be stratified by type into either

- deciduous tree species (LAI = 3.5 for small trees, 4.1 for medium-sized trees, and 4.7 for large trees), or

- coniferous tree species (LAI = 5.47).

These values are based on collected research for global leaf area from 1932-2000 (Scurlock, Asner and Gower, 2002).

The evaporation rate (E_{rate}) per unit time can be calculated using a pan evaporation rate for the given area, as available at NOAA. This should be estimated as a per day value.

The evaporation ratio (E_{ratio}) is the equivalent that accounts for the efficiency of the leaves to transpire the available soil water or, alternately, the stomatal resistance of the canopy to transpiration and water movement. This is set at 0.20, or 20 percent based on research by Lindsey and Bassuk (1991). This means that a 1 square centimeter leaf transpires only about 1/5 as much as 1 square centimeter of pan surface.

If the soil volume is less than the recommended volume, the theoretical ET must be adjusted. Since the recommended soil volume equals 2 times the canopy project area (CP), the adjustment term is given by

$$Adjustment = (S_v)/(2CP)$$

Where S_v is the actual soil volume in cubic feet. Multiply the theoretical ET by the adjustment term to arrive at the true value for theoretical ET.

It is recommended that calculations be based over a three day period. To determine the credit, compare the volume of water available for ET to the theoretical ET over a 3 day period. The credit is the smaller of these two values.

Recommended values for porosity, field capacity and wilting point for different soils.[1]
Link to this table.

Soil	Hydrologic soil group	Porosity [2] (volume/volume)	Field capacity (volume/volume)	Wilting point (volume/volume)	Porosity minus field capacity (volume/volume)[3]	Field capacity minus wilting point (volume/volume)[4]
Sand	A (GM, SW, or SP)	0.43	0.17	0.025 to 0.09	0.26	0.11
Loamy sand	A (GM, SW, or SP)	0.44	0.09	0.04	0.35	0.05
Sandy loam	A (GM, SW, or SP)	0.45	0.14	0.05	0.31	0.09
Loam	B (ML or OL)	0.47	0.25 to 0.32	0.09 to 0.15	0.19	0.16
Silt loam	B (ML or OL)	0.50	0.28	0.11	0.22	0.17
Sandy clay loam	C	0.4		0.07		
Clay loam	D	0.46	0.32	0.15	0.14	0.17
Silty clay loam	D	0.47 to 0.51	0.30 to 0.37	0.17 to 0.22	0.16	0.14
Sandy clay	D	0.43		0.11		
Silty clay	D	0.47		0.05		
Clay	D	0.47	0.32	0.20	0.15	0.12

[1]Sources of information include Saxton and Rawls (2006), Cornell University, USDA-NIFA, Minnesota Stormwater Manual

[2]Soil saturation is assumed to be equal to the porosity.

[3]This value may be used to represent the volume of water that will drain from a bioretention media.

[4]This value may be used to estimate the amount of water available for evapotranspiration

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 water quality volume. 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**

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 - underdrain

Volume credits for a tree system with an underdrain include the ET and interception credits discussed above and an infiltration credit. The main design variables impacting the infiltration volume credit 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 media top surface area, underdrain location, basin bottom area, total depth of media, soil water holding capacity and media porosity, and infiltration rate of underlying soils. The total volume credit (V_{inf}), in cubic feet, is given by

$$V_{inf} = V_{inf_b} \ + V_{inf_s} \ + V_U + V_{ET} \ + V_I$$

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_U = volume of water stored beneath the underdrain that will infiltrate into the underlying soil (cubic feet);
- V_{ET} = volume of captured water that is lost to evapotranspiration, in cubic feet; and
- V_I = volume of precipitation intercepted by the tree canopy, in cubic feet.

Volume credits for ET and canopy interception remain the same as shown above

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 and the BMP permanently removes a portion of the stormwater runoff via infiltration through sidewalls or beneath the underdrain piping. 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

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

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).

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 Construction Stormwater permit 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

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

where

- A_M = the area at the media surface (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 equation assumes water between the soil porosity and field capacity will infiltrate into the underlying soil. Water stored below the underdrain should infiltrate within a specified drawdown time. The construction stormwater permit has a 48 hour requirement for drawdown (24 hours is recommended when discharges are to trout streams).

The ET and infiltration 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 or other appropriate modeling tools. Assuming an instantaneous volume will somewhat overestimate actual storage when the majority of water is being captured by the underdrains.

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.

Example calculation

A parking lot is developed and will contain tree trenches containing red maple (Acer rubrum). The tree trench has 1000 cubic feet of sandy loam per tree. Note that the following calculations are on a per tree basis. Total volume credit for the BMP will equal the per tree value times the number of trees, assuming all trees are of the same relative size (large in this case).

Infiltration credit

The infiltration credit is given by

$$(soilvolume)(porosity - fieldcapacity) = 1000 * 0.31 = 310 cubicfeet$$

Evapotranspiration credit

Using the tree morphology table, red maple is a large tree with a mature canopy of 30 feet. The available storage volume is given by

$$Soilvolume(fieldcapacity - wiltingpoint) = 1000 * 0.09 = 90 cubicfeet$$

The theoretical ET volume is given by

$$(CP)(LAI)(E_{rate})(E_{ratio})(adjustment)(3days) = 707 * 4.7 * 0.02 * 0.2 * (1000/(2 * 707)) * 3 = 28.2 cubicfeet$$

The smaller value is the theoretical ET (28.2 cubic feet), so that is the volume credit. Note that if the recommended soil volume of 1414 cubic feet had been used the credit would be 39.9 cubic feet.

To make this calculation we used the default value of 707 for CP and the soil volume information from the table above. The evaporation rate (E_{rate}) of 0.24 inches per day (0.02 feet per day) was from data collected at the Southwest Research and Outreach Center in Lamberton, Minnesota.

Interception credit

The interception credit is given by

$$707(0.043/12) = 2.5 cubicfeet$$

The division by 12 converts the calculation to feet.

Total credit

The total credit is the sum of the infiltration, ET and interception credits and equals (310 + 28.2 + 2.5) or 340.7 cubic feet.

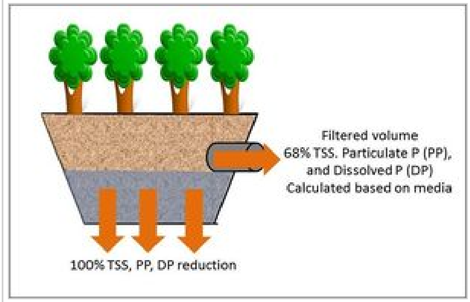
Total suspended solids credit calculations

TSS reduction credits correspond with volume reduction through infiltration/ET and filtration of water captured by the tree BMP and are given by

$M_{TSS} = M_{TSS_{i+ET}} + M_{TSS_f}$

where

M_{TSS} = TSS removal (pounds);
$M_{TSS_{i+ET}}$ = TSS removal from infiltrated and evapotranspired water (pounds); and
M_{TSS_f} = TSS removal from filtered water (pounds).



Schematic illustrating how pollutant reductions (TSS, dissolved and particulate P) are calculated for the tree trench system-tree box with an underdrain BMP in the MIDS calculator. If there is no underdrain, pollutant removal for infiltrated water is 100 percent.

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

- underdrain - $M_{TSS_{i+ET}} = 0.0000624\ (V_{inf_b} + V_{inf_s} + V_U + V_{ET})\ EMC_{TSS}$
- no underdrain - $M_{TSS_{i+ET}} = 0.0000624\ V_{WQ}\ EMC_{TSS}$

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. If there is no underdrain, the water quality volume (V_{WQ}) is used in this calculation.

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 provides a recommended value for R_{TSS} of 0.85 (85 percent removal) for filtered water, while the MIDS calculator provides a value of 0.65 (65 percent). 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

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

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.

Phosphorus credit calculations

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

$M_{TP} = M_{TP_{i+ET}} + M_{TP_f}$

where

M_{TP} = TP removal (pounds);
$M_{TP_{i+ET}}$ = TP removal from infiltrated and evapotranspired 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 and ET, in pounds, is given by

- underdrain - $M_{TP_{i+ET}} = 0.0000624\ (V_{inf_b} + V_{inf_s} + V_U + V_{ET})\ EMC_{TP}$
- no underdrain - $M_{TP_{i+ET}} = 0.0000624\ V_{WQ})\ EMC_{TP}$

where

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

The EMC_{TP} entering the BMP is a function of the contributing land use and treatment by upstream tributary BMPs.

The filtration credit for TP in an underdrained system assumes removal rates based on the soil media mix used and the presence or absence of amendments. 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

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

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 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 80 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

$$R_{TP} = (0.8 * 0.55) + (0.45 * ((0.2 * (D_{MU_{max=2}})/2) + 0.40_{ifamendmentisused})) * 100$$

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 following table can be used to calculate phosphorus credits.

Phosphorus credits for bioretention systems with an underdrain.
Link to this table

Particulate phosphorus	Dissolved phosphorus
Is Media Mix C or D being used or, if using a mix other than C or D, is the media phosphorus content 30 mg/kg or less per the Mehlich 3 (or equivalent) test[1]? ▪ If yes, particulate credit = 80% of the particulate fraction (assumed to be 55% of total P) ▪ If no or unknown, particulate credit = 0%	1. Is Media Mix C or D being used or, if using a mix other than C or D, is the media phosphorus content 30 mg/kg or less per the Mehlich 3 (or equivalent) test[1]? ▪ If yes, credit as a % (up to a maximum of 20%) = 20 * (depth of media above underdrain, in feet/2) ▪ If no or unknown, credit = 0% 2. Does the system include approved P-sorbing soil amendments[2]? ▪ If yes, additional 40% credit
TP removal credit ▪ Particulate fraction (55% of TP) * removal rate for that fraction (80%) = 0.55 * 0.80 = 0.44 or 44%	**TP removal credit** ▪ TP removal if dissolved credit is 20% = Dissolved fraction (45%) * removal rate for that fraction (20%) = 0.09 or 9 percent ▪ Adjust TP removal if depth is less than 2 feet ▪ Adjust TP removal if dissolved credit is higher due to use of P-sorbing soil amendments

[1]Other widely accepted soil P tests may be used. Note: a basic conversion of test results may be necessary

[2]Acceptable P sorption amendments include

- 5% by volume elemental iron filings above IWS or elevated underdrain
- minimum 5% by volume sorptive media above IWS or elevated underdrain
- minimum 5% by weight water treatment residuals (WTR) to a depth of at least 10 cm
- other P sorptive amendments with supporting third party research results showing P reduction for at least 20 year lifespan, P credit commensurate with research results

Example calculations

Example 1 Assume the following:

- A tree trench with an underdrain has 1 foot of media above the underdrain
- 50 percent of annual runoff is infiltrated into the underlying soil
- 40 percent of annual runoff is captured by the underdrain
- 10 percent of annual runoff bypasses the BMP
- Media Mix A is used and soil phosphorus is 32 milligrams per kilogram
- Water Treatment Residuals, 7 percent by weight, have been mixed into the top 15 centimeters of the media.

The credits are as follows

- 100 percent credit for infiltrated runoff = 50 percent of annual runoff = 50 percent of annual phosphorus load
- For water that is captured by the underdrain
  - The media is Mix A with a P content greater than 30 milligrams per kilogram, resulting in no credit for particulate or dissolved phosphorus
  - A P-sorbing amendment has been added to the media and meets the requirements for a credit of 40 percent. The credit applies to the dissolved portion of phosphorus, which is 45 percent of total phosphorus. The credit is therefore 40 percent times 45 percent times the annual runoff volume of 40 percent, resulting in a credit of 7 percent of total annual P (0.4 * 0.45 * 0.4).
- No credit for water that bypasses the BMP
- The total credit is 57 percent of the annual P load.

Example 2 Assume the following:

- A tree trench with an underdrain has 1 foot of media above the underdrain
- 50 percent of annual runoff is infiltrated into the underlying soil
- 40 percent of annual runoff is captured by the underdrain
- 10 percent of annual runoff bypasses the BMP
- Media Mix C is used

The credits are as follows

- 100 percent credit for infiltrated runoff = 50 percent of annual runoff = 50 percent of annual phosphorus load
- For water that is captured by the underdrain
  - The media is Mix C resulting in 80 percent credit for particulate phosphorus. Since particulate P is 55 percent of total P, the credit is 0.80 * 0.55 * 0.40 = 18 percent. The value of 0.4 in the equation accounts for 40 percent of the annual runoff volume.
  - The media mix is C and there is 1 foot of media above the underdrain. The credit is 0.2 * 1/2 * 0.45 = 5 percent. The 1/2 adjusts for the thickness of media above the underdrain and the 0.45 accounts for 45 percent of total phosphorus being in dissolved form.
- No credit for water that bypasses the BMP
- The total phosphorus credit is 73 percent of the annual P load (50 + 18 +5).

Methods for calculating credits

Tree trenches and tree boxes are specialized bioretention BMPs. This section provides specific information on generating and calculating credits from bioretention BMPS, including tree-based systems, 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:

1. Quantifying volume and pollution reductions based on accepted hydrologic models
2. The Simple Method and MPCA Estimator
3. MIDS Calculator
4. Quantifying volume and pollution reductions based on values reported in literature
5. Quantifying volume and pollution reductions based on field monitoring

Credits based on models

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. The available models described below 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 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 bioretention BMPs, including tree-based systems. In using this table, use the sort arrow on the table to select Infiltrator BMPs or Filter BMPs, depending on the type of tree BMP and the terminology used in the model.

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

Model name	BMP Category	Assess	Assess	Assess	Comments

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
Center for Neighborhood Technology Green Values National Stormwater Management Calculator	X	X	X		X		No	No	Yes	Does not compute volume reduction for some BMPs, including cisterns and tree trenches.
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	X		X		X		No	No	Yes	Primary purpose is to assess reductions in stormwater volume.
EPA SWMM	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
HydroCAD	X		X	X			No	No	Yes	Will assess hydraulics, volumes, and pollutant loading, but not pollutant reduction.
infoSWMM	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
infoWorks ICM	X	X	X	X			Yes	Yes	Yes	
i-Tree-Hydro			X				No	No	Yes	Includes simple calculator for rain gardens.
i-Tree-Streets							No	No	Yes	Computes volume reduction for trees, only.

Model name	BMP Category						Assess	Assess	Assess	Comments
	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices				
							TP removal?	TSS removal?	volume reduction?	
LSPC	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	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					X		Yes	No	Yes	Computes storage volume for stormwater reuse systems
Metropolitan Council Stormwater Reuse Guide Excel Spreadsheet					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	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)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
P8	X		X	X		X	Yes	Yes	Yes	
PCSWMM	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
PLOAD	X	X	X	X		X	Yes	Yes	No	User-defined practices with user-specified removal percentages.
PondNet	X						Yes	No	Yes	Flow and phosphorus routing in pond networks.
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			X				No	No	Yes	
SELECT	X	X	X	X		X	Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
SHSAM						X	No	Yes	No	Several flow-through structures including standard sumps, and proprietary systems such as CDS, Stormceptors, and Vortechs systems
SUSTAIN	X	X	X	X	X		Yes	Yes	Yes	Categorizes BMPs into Point BMPs, Linear BMPs, and Area BMPs

Model name	BMP Category						Assess	Assess	Assess	Comments
	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices				
							TP removal?	TSS removal?	volume reduction?	
SWAT	X	X	X				Yes	Yes	Yes	Model offers many agricultural BMPs and practices, but limited urban BMPs at this time.
Virginia Runoff Reduction Method	X	X	X	X	X	X	Yes	No	Yes	Users input Event Mean Concentration (EMC) pollutant removal percentages for manufactured devices.
WARMF	X	X					Yes	Yes	Yes	Includes agriculture BMP assessment tools. Compatible with USEPA Basins
WinHSPF	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	X	X	X	X			Yes	Yes	Yes	
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 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. 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 The Simple method to Calculate Urban Stormwater Loads or The Simple Method for estimating phosphorus export.

Some simple stormwater calculators utilize the Simple Method (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, 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.

Warning: 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 tree systems with an underdrain and without an underdrain. 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) entering the BMP. Concentration reductions resulting from treatment can be converted to mass reductions if the volume of stormwater treated is known.

Designers may use the pollutant reduction values reported in this manual 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 BMP 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 BMP 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.

Information: Tree trenches and tree boxes are bioretention practices, but there is limited information in the literature on pollutant removal in tree-based systems. The following references provide information for bioretention systems, which can be applied to tree-based practices

The following references summarize pollutant reduction values from multiple studies or sources that could be used to determine credits for bioretention systems. 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 bioretention device, considering such conditions as watershed characteristics, bioretention sizing, soil infiltration rates, 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
- Design Guidelines for Stormwater Bioretention Facilities. University of Wisconsin, Madison
  - Table 2-1 summarizes typical removal rates
  - Provides values for TSS, metals, TP, TKN, ammonium, organics, and bacteria
  - Applicable for bioretention
- BMP Performance Analysis. Prepared for US EPA Region 1, Boston MA.
  - Appendix B provides pollutant removal performance curves
  - Provides values for TP, TSS, and zinc
  - 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
  - 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.

- Establish the objectives and goals of the monitoring.
  - Which pollutants will be measured?
  - Will the monitoring study the performance of a single BMP or multiple BMPs?
  - Are there any variables that will affect the BMP performance? Variables could include design approaches, maintenance activities, rainfall events, rainfall intensity, etc.
  - Will the results be compared to other BMP performance studies?
  - 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?
- Plan the field activities. Field considerations include:
  - Equipment selection and placement
  - Sampling protocols including selection, storage, delivery to the laboratory
  - Laboratory services
  - Health and Safety plans for field personnel
  - Record keeping protocols and forms
  - Quality control and quality assurance protocols
- Execute the field monitoring
- 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, bioretention BMPs can reduce loading of other pollutants. According to the International Stormwater Database, studies have shown that bioretention BMPs are effective at reducing concentrations of pollutants, including metals, and bacteria. 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	Constituent	Treatment capabilities[1]
Metals[2]	Cadmium, Chromium, Copper, Zinc, Lead	High
Nitrogen[2]	Total nitrogen, Total Kjeldahl nitrogen	Low/medium
Bacteria[2]	Fecal coliform, e. coli	High
Organics	Petroleum hydrocarbons[3], Oil/grease[4]	High

[1] Low: < 30%; Medium: 30 to 65%; High: >65%

[2] International Stormwater Database, (2012)

[3] LeFevre et al., (2012)

[4] Hsieh and Davis (2005).

References and suggested reading

To see how some other cities are calculating tree credits, see Cities That are Pioneers in Developing Stormwater Credit Systems for Trees (Shanstrom, 2014)

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Related pages

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

- 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

The following pages address incorporation of trees into stormwater management under paved surfaces

- 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
- Requirements, recommendations and information for using trees with an underdrain as a BMP in the MIDS calculator

Categories: Trees | Calculating credits

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