Memorandum

To: MIDS Work Group
From: Barr Engineering Company
Subject: Turf, Phase 2, MIDS Task 2.2: Recommend Credits for MIDS Practices
Date: May 31, 2013
Project: 23/62 1050 MIDS

Barr was asked to evaluate the performance of turf as a stormwater Best Management Practice (BMP), in terms of quantifying runoff volume reduction and pollutant removal. The two types of "turf" BMPs evaluated, as identified by the MIDS turf technical team, include:

1) vegetated pervious areas that capture runoff from impervious surfaces ("Impervious Surface Disconnection")

2) vegetated pervious areas that do not capture runoff from impervious surfaces, but are maintained or amended to increase infiltration ("Soil Improvements")

This memorandum summarizes Barr's modeling efforts to quantify potential runoff and pollutant reductions from implementation of impervious surface disconnection and better turf BMPs, as well as suggested approaches to incorporating these BMPs into the MIDS calculator.

On May 17, 2013, the MIDS Work Group approved a draft version of this memorandum and recommended that parameters of effective impervious standards be developed and incorporated into the MIDS calculator and Minnesota Stormwater Manual. Furthermore, the group suggested that updates to the Minnesota Stormwater Manual include specifications for soil loosening and soil amendments. The MIDS Work Group suggested that soil amendments include, at a minimum, importation of different soils that will increase infiltration rates. In addition, the Work Group discussed crediting systems that other organizations use where soil amendments only permit applicants to use an infiltration rate of a different Hydrologic Soil Group (e.g., a site with HSG C soils could be analyzed as HSG B soils if amendments are included, a HSG B soils site must use HSG C soil infiltration rates unless amendments are included, etc.).

Impervious Surface Disconnection

Impervious surface disconnection is the redirection of stormwater runoff from impervious surfaces (e.g., sidewalks, parking lots, rooftops, etc.) to vegetated areas instead of the runoff being discharged offsite via a storm sewer system or other conveyance methods. Redirection of impervious surface runoff to vegetated areas promotes increased infiltration and reduces overall site runoff. The reduction in site runoff from impervious surface disconnection can vary considerably, depending on many factors, including the size of the contributing drainage area, size and infiltration capacity of the vegetated area receiving the additional stormwater, and numerous other site conditions such as slope and site grading.

Modeling Analysis and Results

To estimate the runoff reduction from impervious surface disconnection, Barr focused on evaluating two primary variables: 1) ratio of impervious area to pervious area (I/P Ratio), and 2) infiltration capacity of the vegetated area. Barr conducted a modeling analysis to quantify the runoff reduction achieved from redirecting runoff from impervious areas to pervious areas of varying size and soil type. The long-term, 35-year continuous simulation XP-SWMM model developed in support of the MIDS performance goal development (Barr, 2011) was modified to represent watersheds with I/P ratios ranging from 0.2:1 to 50:1 and hydrologic soil types of A, B, C, and D. See the *Assessment of MIDS Performance Goal Alternatives: Runoff Volumes, Runoff Rates, and Pollutant Removal Efficiencies* report for additional information on the hydrologic model input parameters utilized for this model. As described in the report, all soil types were assumed to be frozen and impervious to infiltration each year from December 6 to April 7. Hydrologic soil type and I/P ratio are therefore assumed to have no effect on runoff volume during the frozen ground period.

Figure 1 shows the average annual runoff depths for all modeled I/P ratios and soil types. Note that the annual runoff depths are based on the assumption that runoff from the frozen ground period is 4.0 inches for all I/P ratios and soil types. Figure 2 shows the average annual runoff reductions for all modeled I/P ratios and soil types. The runoff reduction is greatest from the sites with the smallest I/P ratio of 0.2:1 (for example, 100 square feet of impervious surface redirected to 500 square feet of pervious area), and decreases as the I/P ratio increases. For a given I/P ratio, the runoff reduction is greatest for A soils and least for D soils, as would be expected.

Suggested Credit Calculations

Determination of "Effective" Impervious Area

Impervious surface disconnection spreads runoff generated from parking lots, driveways, rooftops, sidewalks and other impervious surfaces onto adjacent pervious areas where it can be infiltrated. As shown in Figure 2, the larger the pervious area is in comparison to the redirected impervious area, the greater the runoff reduction achieved. However, when applying the modeling results presented in Figures 1 and 2, it is important to recognize that the "effective" pervious area on a site may be less than the available pervious area, as redirected flows will tend to channelize at flow lengths greater than 100 feet (WinTR-55, 2009) and prevent runoff from being distributed over the entire available area. To prevent overestimating the effectiveness of impervious surface disconnection, we suggest that the "effective" pervious area be limited to a flow length of 100 feet beyond the impervious surface runoff discharge point (see Figure 3 for an example) and have less than a five percent slope. A more detailed definition of "effective" pervious area, to potentially include minimum widths, lengths, and required building setbacks, may be warranted in the upcoming Minnesota Stormwater Manual update.

Conformance with MIDS Performance Goal

For new developments that create more than one acre of new impervious surface on sites without restrictions, the MIDS performance goal is that stormwater runoff volumes will be controlled and the post-construction runoff volume shall be retained on site for 1.1 inches of runoff from impervious surfaces statewide. Our suggested approach for quantifying the volume reduction benefit achieved from impervious surface disconnection in terms of the MIDS performance goal is summarized below. An example calculation is included as Attachment A.

Step 1: Calculate Pre-disconnection Site Runoff

$$Pre\text{-}disconnection\ RO = (Area_P)(RD_P) + (Area_I)(RD_I)$$

Where,

Pre-disconnection RO = runoff volume from site if impervious surface is not redirected to pervious area

$Area_P$ = total pervious area

RD_P = runoff depth from pervious area (determined from model results)

$Area_I$ = impervious area

RD_I = runoff depth from impervious area (determined from model results)

Step 2: Calculate I/P Ratio

$$\frac{I}{P}\ Ratio = \left(Area_{I\ redirect}\right) \div \left(Area_{P\ eff}\right)$$

Where,

I/P Ratio = ratio of redirected impervious area to "effective" impervious area

$Area_{I\ redirect}$ = impervious area redirected to pervious area

$Area_{P\ eff}$ = "effective" pervious area receiving redirected impervious runoff

Step 3: Determine Post-disconnection Site Runoff Volume

$$Post\text{-}disconnection\ RO = \left(Area_{I\ redirect} + Area_{P\ eff}\right)\left(RD_{redirect}\right) + \left(Area_{P\ noneff}\right)\left(RD_P\right) + \left(Area_{I\ nonredirect}\right)\left(RD_I\right)$$

Where,

Post-disconnection RO = post-disconnection runoff volume from entire site

$Area_{I\ redirect}$ = impervious area redirected to pervious area

$Area_{P\ eff}$ = "effective" pervious area receiving redirected impervious runoff

$RD_{redirect}$ = runoff depth from redirected impervious area and effective pervious area (determined from modeling results based on soil type and I/P ratio)

$Area_{P\ noneff}$ = pervious area not considered "effective" for receiving redirected impervious runoff

RD_P = runoff depth from pervious area (determined from model results based on soil type)

$Area_{I\ nonredirect}$ = impervious area not redirected to pervious area

RD_I = runoff depth from non-redirected impervious area (determined from model results)

Step 4: Calculate "Adjusted" Impervious Runoff

$$Adjusted\ Impervious\ RO = \left(Post\text{-}disconnection\ RO\right) - \left(Area_P\right)\left(RD_P\right)$$

Where,

Adjusted Impervious RO = adjusted runoff volume from impervious area as a result of redirection to pervious area

Post-disconnection RO = post-disconnection runoff volume from entire site

$Area_P$ = total pervious area

RD_P = runoff depth from pervious area (determined from model results based on soil type)

Step 5: Calculate "Adjusted" Impervious Area

$$Area_{I\,adj} = (Adjusted\ Impervious\ RO) \div (RD_I)$$

Where,

$Area_{I\,adj}$ = adjusted impervious area for calculation of performance goal conformance

Adjusted Impervious RO = adjusted runoff volume from impervious area as a result of redirection to pervious area

RD_I = runoff depth from impervious area (determined from model results)

Step 6: Calculate Performance Goal Credit (typically calculated in cubic feet)

$$BMP\ Volume\ Credit = \left[\left(Area_I - Area_{I\,adj}\right) \times 1.1\ inches\ \times unit\ conversion\right]$$

Where,

$Area_I$ = impervious area

$Area_{I\,adj}$ = adjusted impervious area for calculation of performance goal conformance

Annual Performance

Volume Reduction

The approach described in the steps above results in an equivalent BMP volume credit that can be used to evaluate conformance with the MIDS performance goal. To estimate the annual runoff volume reduction that is achieved by implementation of impervious surface disconnection, we recommend applying the performance curves developed for assessing annual performance of bioretention basins. These performance curves, which were developed for sites ranging from 10 to 90 percent imperviousness and hydrologic soils groups A, B, and C, allow for estimation of the average annual runoff volume reduction based on an equivalent BMP volume per tributary drainage area (see Figure 4 for an example performance curve and Attachment A for an example calculation).

Pollutant Removal

The MIDS calculator estimates the average annual removal of total phosphorus, dissolved phosphorus, and total suspended solids from stormwater runoff as a result of BMP implementation. For runoff that is infiltrated as a result of the impervious surface disconnection, 100% pollutant removal is suggested. For runoff that is not infiltrated, but conveyed across the effective pervious area, pollutant removal consistent with that of a filter strip is suggested (current draft of MIDS calculator uses 68% annual TSS removal and 0% TP and DP removal). If pollutant removal credit is included in the calculator for runoff conveyed over the effective pervious area, additional definition of effective pervious area may be warranted in the upcoming Minnesota Stormwater Manual update to ensure that the pervious flow length is sufficient to achieve the sedimentation expected to occur during flow through a filter strip. See Attachment A for an example calculation. For pervious areas that extend beyond the effective pervious area, a treatment train approach could be used in the MIDS calculator by treating the additional pervious area as a filter strip.

Soil Improvements

The amount of runoff from pervious surfaces is dependent on many characteristics, with a primary factor being the infiltration capacity of the soil. While the infiltration capacity and runoff potential vary among soil types, other factors such as compaction or soil loosening can result in more or less runoff for a given soil type or texture. Maintaining and/or amending soils in vegetated areas to increase infiltration, termed "Soil Improvements" in this memorandum, is a method of reducing runoff from pervious areas. Soil maintenance and amendment includes loosening or ripping of existing soils to decrease the soil density or modifying or replacing existing soil to achieve increased infiltration.

Modeling Analysis and Results

Barr conducted a modeling analysis to estimate the runoff reduction from maintaining and/or amending soils in vegetated areas using the long-term, 35-year continuous simulation XP-SWMM model developed in support of the MIDS performance goal development (Barr, 2011). To assess the difference in average annual runoff depths under compacted, average, and loosened soil conditions, the saturated hydraulic conductivity (K_{sat}) values in the XP-SWMM model were adjusted as shown in Table 1. The "average" values presented in Table 1 represent the mean K_{sat} values for each soil texture based on a national database of over 1,000 observed saturated hydraulic conductivities (Rawls, 1998). The "compacted" and "loosened" values presented in Table 1 represent the geometric mean K_{sat} values for soils within the national database developed by Rawls that have bulk densities higher and lower than the NRCS recommended value for the soil texture class, respectively (Rawls, 1998). Figure 5 shows the average annual runoff depths under compacted, average, and loosened soil conditions for A, B, and C hydrologic soil groups, as well as average conditions for D soils. It should be noted that due to the empirical methodology used to define the K_{sat} values, loosened C soils have a higher K_{sat} than loosened B soils, and thus a lower runoff depth. Given this, it is suggested that the runoff depth from "loosened" C soils be approximated as equivalent to the runoff from "average" B soils for credit calculations.

Table 1. Saturated hydraulic conductivity values used in long-term continuous simulation modeling analysis

Hydrologic Soil Group	Representative Soil Texture	Saturated Hydraulic Conductivity (in/hr)		
		Compacted[2]	Average[1]	Loosened[2]
A	Sandy Loam	0.50	0.90	2.20
B	Loam	0.15	0.205	0.24
C	Sandy Clay Loam	0.11	0.14	0.30
D	Silty Clay	N/A	0.06	N/A

[1] The Ksat values termed "average" for the modeling analysis represent the mean K_{sat} values for each soil texture based on a national database of over 1,000 observed saturated hydraulic conductivities (Rawls, 1998).

[2] The Ksat values termed "compacted" and "loosened" for the modeling analysis represent the geometric mean Ksat values for soils within the national database developed by Rawls that have bulk densities higher and lower than the NRCS recommended value for the given soil texture class, respectively (Rawls, 1998).

Suggested Credit Calculations

Conformance with MIDS Performance Goal

For new developments that create more than one acre of new impervious surface on sites without restrictions, the MIDS performance goal is that stormwater runoff volumes will be controlled and the post-construction runoff volume shall be retained on site for 1.1 inches of runoff from impervious surfaces statewide. Our suggested approach to quantifying the volume reduction benefit achieved from maintaining and/or amending soils in vegetated areas in terms of the MIDS performance goal is summarized below. Note that the determination of appropriate soil conditions prior to and following soil improvements will be site dependent.

Step 1: Calculate Site Runoff Prior to Soil Improvements

$$Pre\text{-}Soil\ Improvement\ RO = (Area_P)(RD_{Po}) + (Area_I)(RD_I)$$

Where,

Pre-Soil Improvement RO = runoff volume from site if soils not improved

$Area_P$ = total pervious area

RD_{Po} = runoff depth from pervious area reflecting pre-project soil conditions, typically compacted or average (determined from model results, Figure 5)

$Area_I$ = impervious area

RD_I = runoff depth from impervious area (22.5 inches, based on Figure 1)

Step 2: Calculate Site Runoff Following Soil Improvements

$$Post\text{-}Soil\ Improvement\ RO = \left(Area_{P\ imp}\right)\left(RD_{P\ imp}\right) + \left(Area_{P\ unimp}\right)(RD_{Po}) + (Area_I)(RD_I)$$

Where,

Post-Soil Improvement RO = runoff volume from site following soil improvements

$Area_{P\ imp}$ = pervious area with improved soils

$RD_{P\ imp}$ = runoff depth from pervious area reflecting improved soil conditions, typically average or loosened (determined from model results, Figure 5)

$Area_{P\ unimp}$ = pervious area without improved soils

RD_{Po} = runoff depth from pervious areas with unimproved soil conditions, typically compacted or average (determined from model results, Figure 5)

$Area_I$ = impervious area

RD_I = runoff depth from impervious area (22.5 inches, based on Impervious Surface Disconnection modeling)

Step 3: Calculate "Adjusted" Impervious Runoff to Determine Credit

$$Adjusted\ Impervious\ RO = Post\text{-}Soil\ Improvement\ RO - [(Area_P)(RD_{Po})]$$

Where,

Adjusted Impervious RO = adjusted impervious runoff volume to represent equivalent runoff reduction from pervious soil improvements

Post-Soil Improvement RO = runoff volume from site following soil improvements

$Area_P$ = total pervious area

RD_{Po} = runoff depth from pervious areas with unimproved soil conditions, typically compacted or average (determined from model results, Figure 5)

Step 4: Calculate "Adjusted" Impervious Area

$$Area_{I\ adj} = (Adjusted\ Impervious\ RO\ ) \div (RD_I)$$

Where,

$Area_{I\ adj}$ = adjusted impervious area for calculation of performance goal conformance

Adjusted Impervious RO = adjusted impervious runoff volume to represent equivalent runoff reduction from pervious soil improvements

RD_I = runoff depth from impervious area (22.5 inches, Figure 1)

Step 5: Calculate Performance Goal Credit (typically calculated in cubic feet)

$$BMP\ Volume\ Credit = \left[\left(Area_I - Area_{I\ adj}\right) \times 1.1\ inches \times unit\ conversion\right]$$

Where,

$Area_I$ = impervious area

$Area_{I\ adj}$ = adjusted impervious area for calculation of performance goal conformance

A summary of BMP volume credits using this proposed approach for sites of varying imperviousness and soil types is provided in Attachment B. An example calculation is provided as Attachment C.

Annual Performance

Volume Reduction

The approach described in the steps above results in an equivalent BMP volume credit that can be used to evaluate conformance with the MIDS performance goal. To estimate the annual runoff volume reduction that is achieved by implementation of soil improvements, we recommend applying the performance curves developed for assessing the annual performance of bioretention basins. These performance curves, which were developed for sites ranging from 10 to 90 percent imperviousness and hydrologic soils groups A, B, and C, allow for estimation of the average annual runoff volume reduction based on an equivalent BMP volume per tributary drainage area (see Figure 4 for an example performance curve).

Pollutant Removal

The MIDS calculator estimates the average annual removal of total phosphorus, dissolved phosphorus, and total suspended solids from stormwater runoff as a result of BMP implementation. For runoff that is infiltrated as a result of soil improvements in the vegetated pervious areas, 100% pollutant removal is suggested. For runoff that is not infiltrated, 0% pollutant removal is suggested. For example, if a 5% annual runoff volume reduction is estimated as a result of soil improvements, the average annual total phosphorus, dissolved phosphorus, and total suspended sediment reductions will be 5%. For the 95% of annual runoff discharged from a site, no additional pollutant removal will be credited.

References

Barr Engineering Company. Assessment of MIDS Performance Goal Alternatives: Runoff Volumes, Runoff Rates, and Pollutant Removal Efficiencies. 2011.

Rawls, W.J., D. Gimenez, and R. Grossman. Use of Soil Texture, Bulk Density, and Slope of the Water Retention Curve to Predict Saturated Hydraulic Conductivity. 1998. Transactions of the ASAE. Vol. 41(4):983-988.

U.S. Department of Agriculture, Natural Resources Conservation Service. Small Watershed Hydrology WinTR-55 User Guide. 2009.

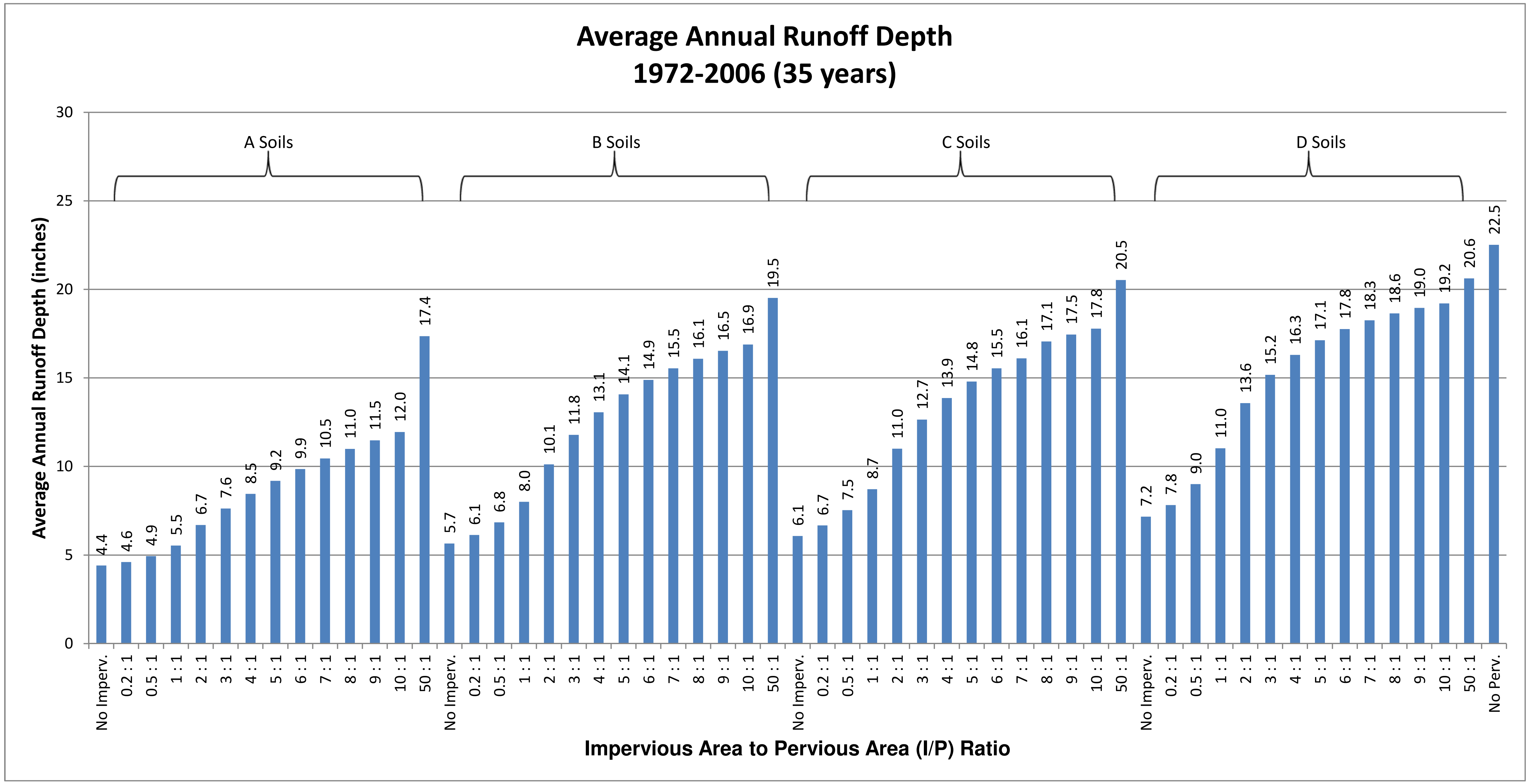


Figure 1. Average Annual Runoff Depth Grouped by I/P Ratio and Soil Type

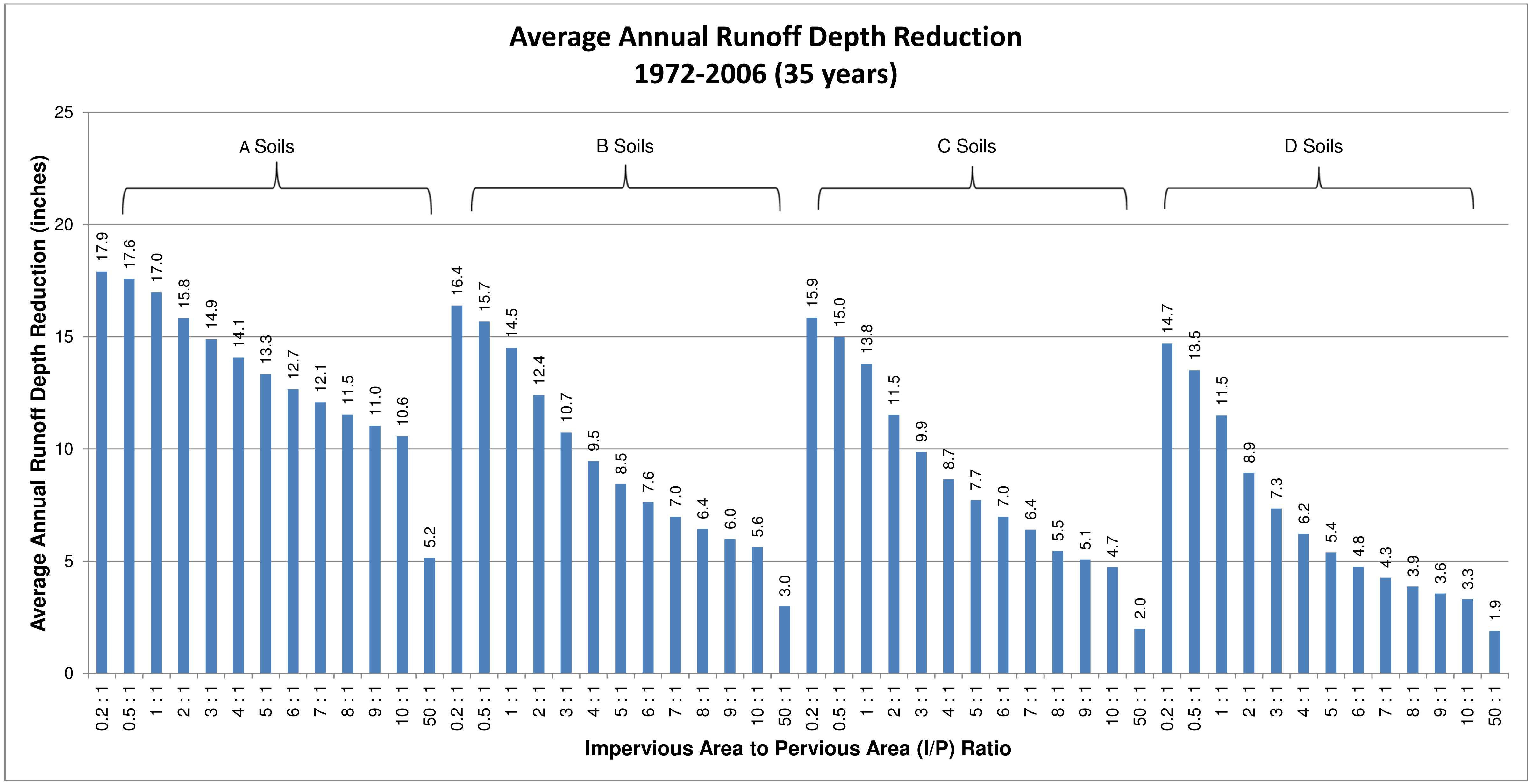


Figure 2. Average Annual Runoff Depth Reduction Grouped by I/P Ratio and Soil Type

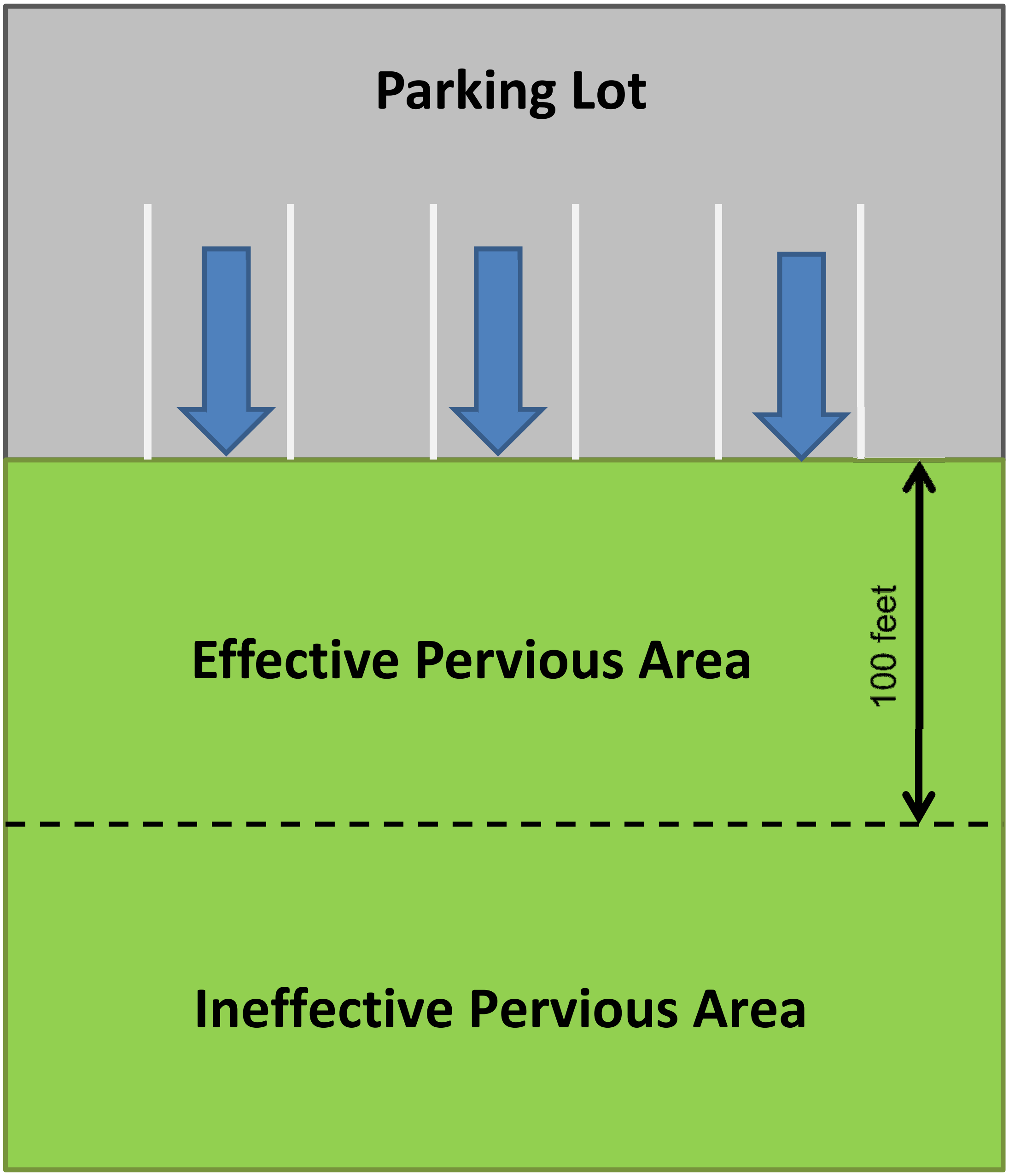


Figure 3. Effective Pervious Area Example

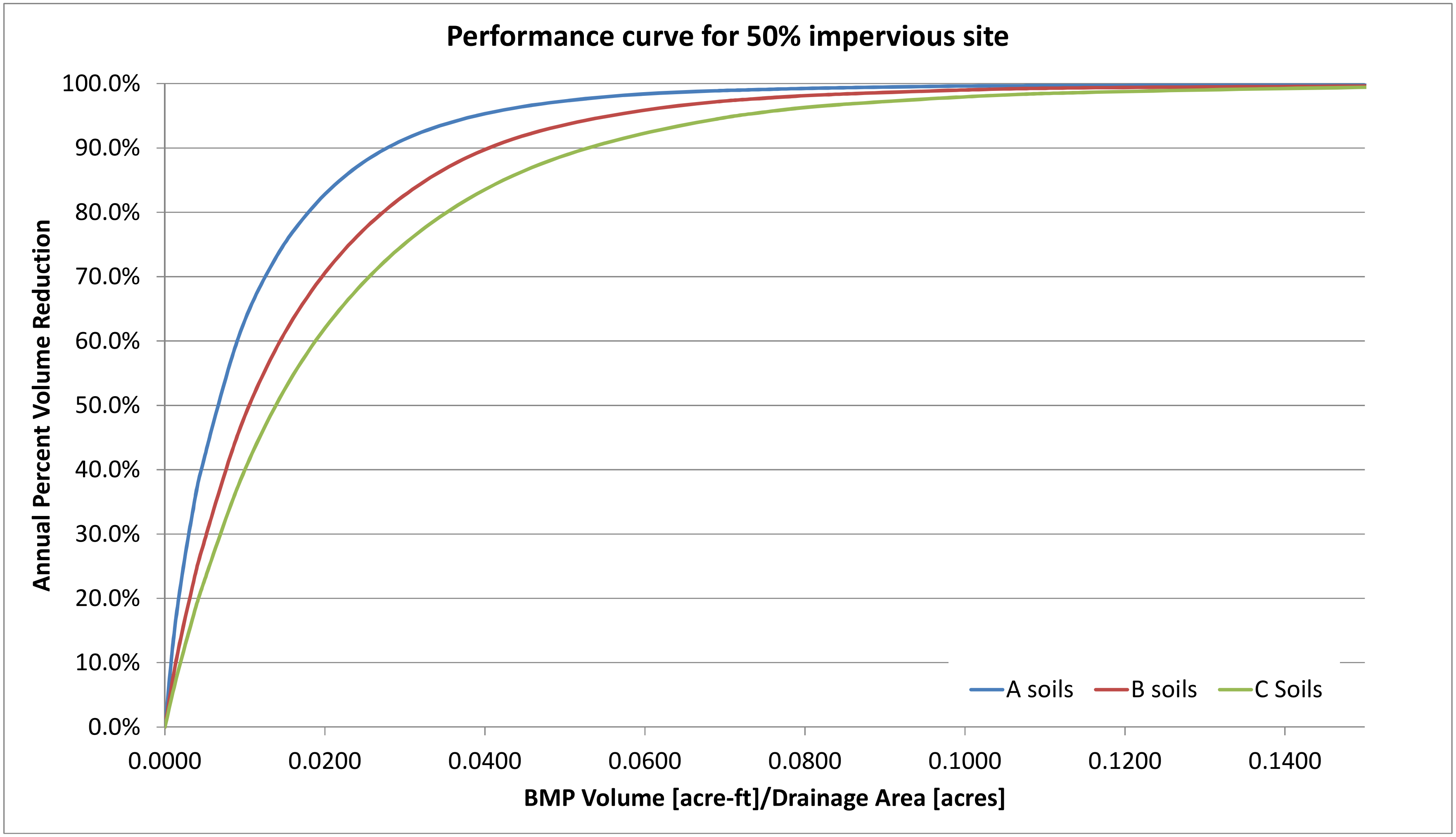
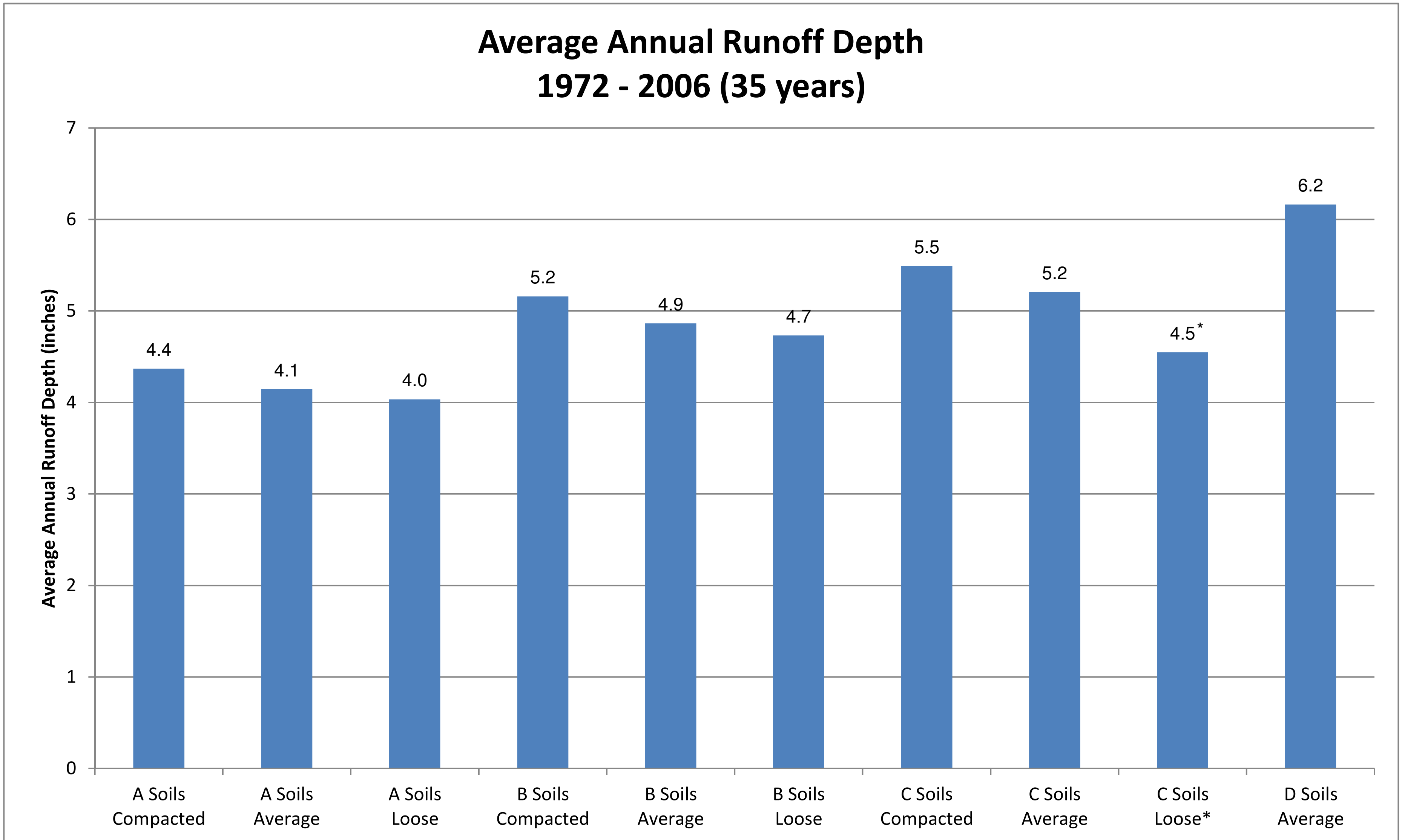


Figure 4. Bioretention Basin Volume Reduction Performance Curves for A, B, and C Soil Types on a 50% Impervious Site



* Due to the empirical methodology used to define the K_{sat} values, loosened C soils have a higher K_{sat} than loosened B soils, and thus a lower runoff depth. Given this, it is suggested that the runoff depth from "loosened" C soils be approximated as equivalent to the runoff from "average" B soils for credit calculations.

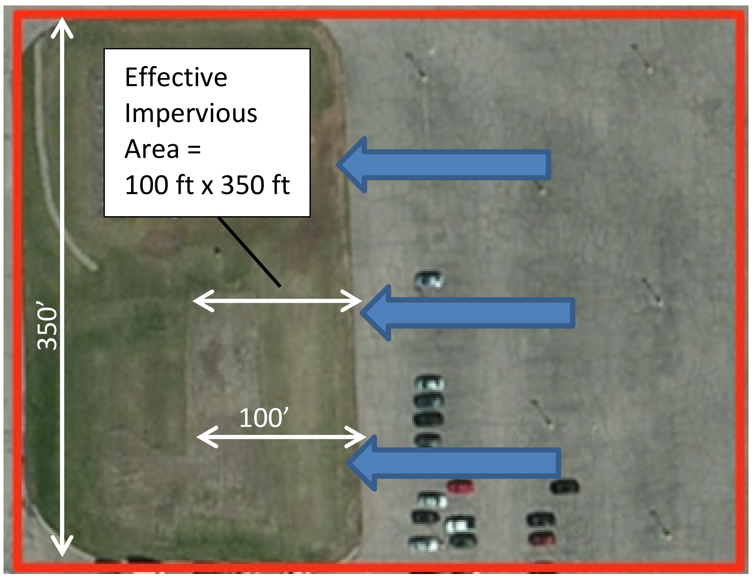
Figure 5. Comparison of Average Annual Runoff Grouped by Soil Type and Condition

Attachment A

Examples of suggested BMP volume and pollutant reduction credit calculations for impervious surface disconnection

Scenario 1:

- 3-acre, 50% impervious site
- A soils, with all of the impervious area draining to the pervious area next to the parking lot (see image)



Calculate conformance with performance goal:

Total pervious area = 1.5 acres

Total impervious area = 1.5 acres

"Effective" pervious area = (100 ft)*(350 ft) /(43560 ft^2/ac) = 0.8 acres

Runoff depth from impervious area (RD_I) = 22.5 inches (from model results)

Step 1: Pre-disconnection Site Runoff = [(1.5 ac)(4.4 in) + (1.5 ac)(22.5 in)](43,560 ft^2/ac) (1ft/12in) = =146,471 ft^3

Step 2: I/P_{eff} Ratio = (1.5 ac)/(0.8 ac) = 1.9

Step 3: Post-disconnection Site Runoff Volume =

= [(1.5 ac+0.8 ac)(6.55 in)+(1.5 ac – 0.8 ac)(4.4 in)](43,560 ft^2/ac)(1ft/12in) = 65,866 ft^3

Note: $RD_{redirect}$= 6.55 (based on interpolation of modeling results for A soils for I/P ratio of 1.9)

Step 4: "Adjusted" Impervious Runoff = (65,866 ft^3) – (1.5 ac)(4.4 in)(43,560 ft^2/ac)(1ft/12in) =41,908 ft^3

Step 5: "Adjusted" Impervious Area = (41,908 ft^3)/[(22.5 in)(1ft/12in)] = 22,351 ft^2 (0.513 acres)

Step 6: BMP Volume Credit = (1.5 ac – 0.51 ac)(1.1 in)(43,560 ft2/ac)(1ft/12in) = <u>3,941 ft^3</u>

Equivalent inches off impervious surface provided = 0.7 inches

Note: Treatment volume required to meet 1.1-inch performance goal = 5,990 ft^3

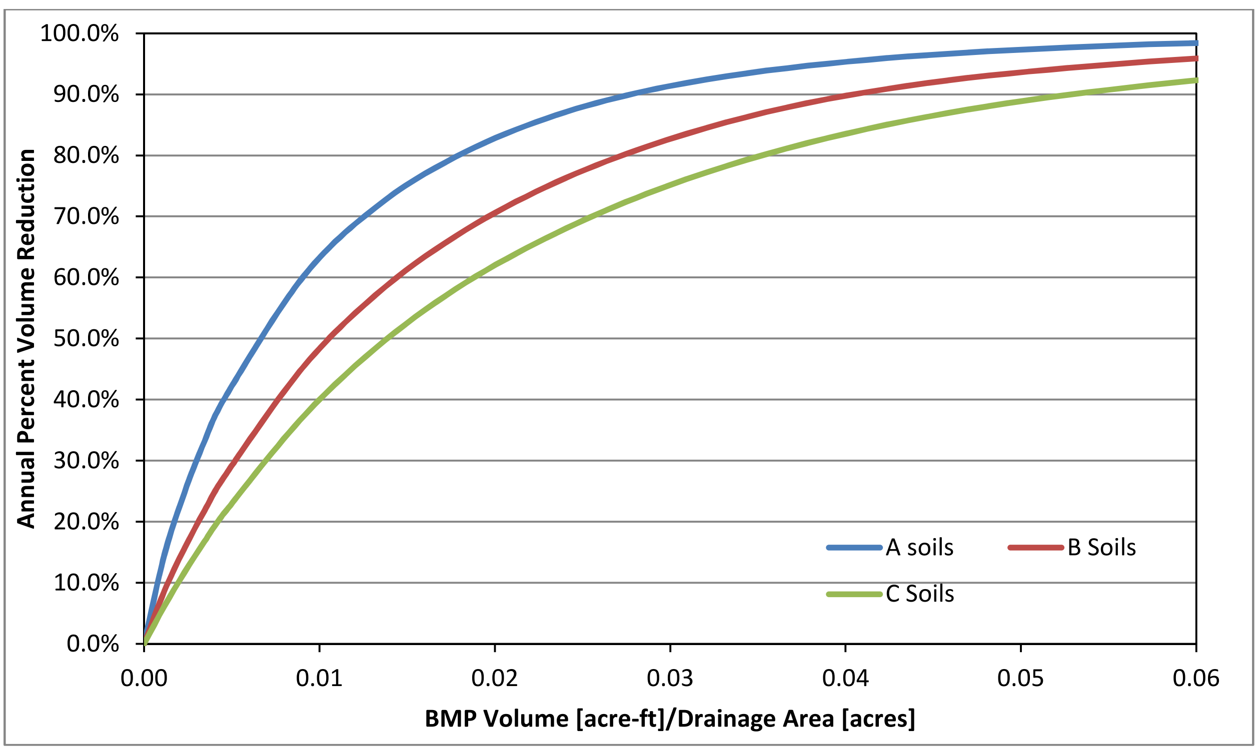
<u>Calculate annual volume reduction using performance curve for 50% impervious site (see Figure 4):</u>

BMP Volume /Drainage Area = (3941 ft^3)/(43560ft^2/ac)/(3 acres) = 0.03

Corresponding annual volume removal (from performance curve, for A soils, 50% impervious site) = 91%

Annual TP removal = annual volume removal = 91%

Annual TSS removal = (91%)*(100%) + (9%)(68%) = 97%



Scenario 2 (Same as Scenario 1, but with B soils):

- 3-acre, 50% impervious site
- B soils, with all of the impervious area draining to the pervious area next to the parking lot (see image)

Calculate conformance with performance goal:

Step 1: Pre-disconnection Site Runoff = [(1.5 ac)(5.7 in) + (1.5 ac)(22.5 in)](43,560 ft^2/ac) (1ft/12in) =

= 153,549 ft^3

Step 2: I/P_{eff} Ratio = (1.5 ac)/(0.8 ac) = 1.9

Step 3: Post-disconnection Site Runoff Volume =

= [(1.5 ac+0.8 ac)(9.84 in)+(1.5 ac – 0.8 ac)(5.7 in)](43,560 ft^2/ac)(1ft/12in) = 96,638 ft^3

Note: $RD_{redirect}$= 9.84 (based on interpolation of modeling results for B soils for I/P ratio of 1.9)

Step 4: "Adjusted" Impervious Runoff = (96,638 ft^3) – (1.5 ac)(5.7 in)(43,560 ft^2/ac)(1ft/12in) =65,601 ft^3

Step 5: "Adjusted" Impervious Area = (65,601 ft^3)/[(22.5 in)(1ft/12in)] = 34,987 ft^2 (0.8 acres)

Step 6: BMP Volume Credit = (1.5 ac – 0.8 ac)(1.1 in)(43,560 ft2/ac)(1ft/12in) = <u>2,795 ft^3</u>

Equivalent inches off impervious surface provided = 0.5 inches

Note: Treatment volume required to meet 1.1-inch performance goal = 5,990 ft^3

Calculate annual volume reduction using performance curve for 50% impervious site (see Figure 4):

BMP Volume /Drainage Area = (2795 ft^3)/(43,560ft^2/ac)/(3 acres) = 0.02

Corresponding annual volume removal (from performance curve, for B soil, 50% impervious site) = 68%

Annual TP removal = annual volume removal = 68%

Annual TSS removal = (68%)*(100%) + (32%)(68%) = 90%

Attachment B

Summary of BMP Volume Credits for range of sites (20%, 50%, 80% impervious) and soil types (A, B, C)

Hydrologic Soil Group	Impervious Area (ac)	Pervious Area w/Soil Improvements (ac)	% Site Imperviousness	Initial Soil Condition	Improved Soil Condition	BMP Volume Credit	Equivalent Inches Off Impervious Surface (in)
A	2	8	20	Compact	Average	426	0.059
A	2	8	20	Average	Loosened	142	0.020
A	2	8	20	Compact	Loosened	568	0.078
A	5	5	50	Compact	Average	266	0.015
A	5	5	50	Average	Loosened	89	0.005
A	5	5	50	Compact	Loosened	355	0.020
A	8	2	80	Compact	Average	106	0.004
A	8	2	80	Average	Loosened	35	0.001
A	8	2	80	Compact	Loosened	142	0.005
B	2	8	20	Compact	Average	426	0.059
B	2	8	20	Average	Loosened	284	0.039
B	2	8	20	Compact	Loosened	710	0.098
B	5	5	50	Compact	Average	266	0.015
B	5	5	50	Average	Loosened	177	0.010
B	5	5	50	Compact	Loosened	444	0.024
B	8	2	80	Compact	Average	106	0.004
B	8	2	80	Average	Loosened	71	0.002
B	8	2	80	Compact	Loosened	177	0.006
C	2	8	20	Compact	Average	426	0.059
C	2	8	20	Average	Loosened	426	0.059
C	2	8	20	Compact	Loosened	852	0.117
C	5	5	50	Compact	Average	266	0.015
C	5	5	50	Average	Loosened	266	0.015
C	5	5	50	Compact	Loosened	532	0.029
C	8	2	80	Compact	Average	106	0.004
C	8	2	80	Average	Loosened	106	0.004
C	8	2	80	Compact	Loosened	213	0.007

Attachment C

Example of BMP Volume Credit for Soil Improvement

Scenario:

- 10-acre, 50% impervious site
- B soils, with all of the impervious area being “improved” from “compacted” to “average” conditions

Calculate conformance with performance goal:

Treatment volume required to meet 1.1-inch performance goal = 19,965 ft^3

Soil Improvement BMP Volume Credit (see page 2 of attachment) = 266 ft^3

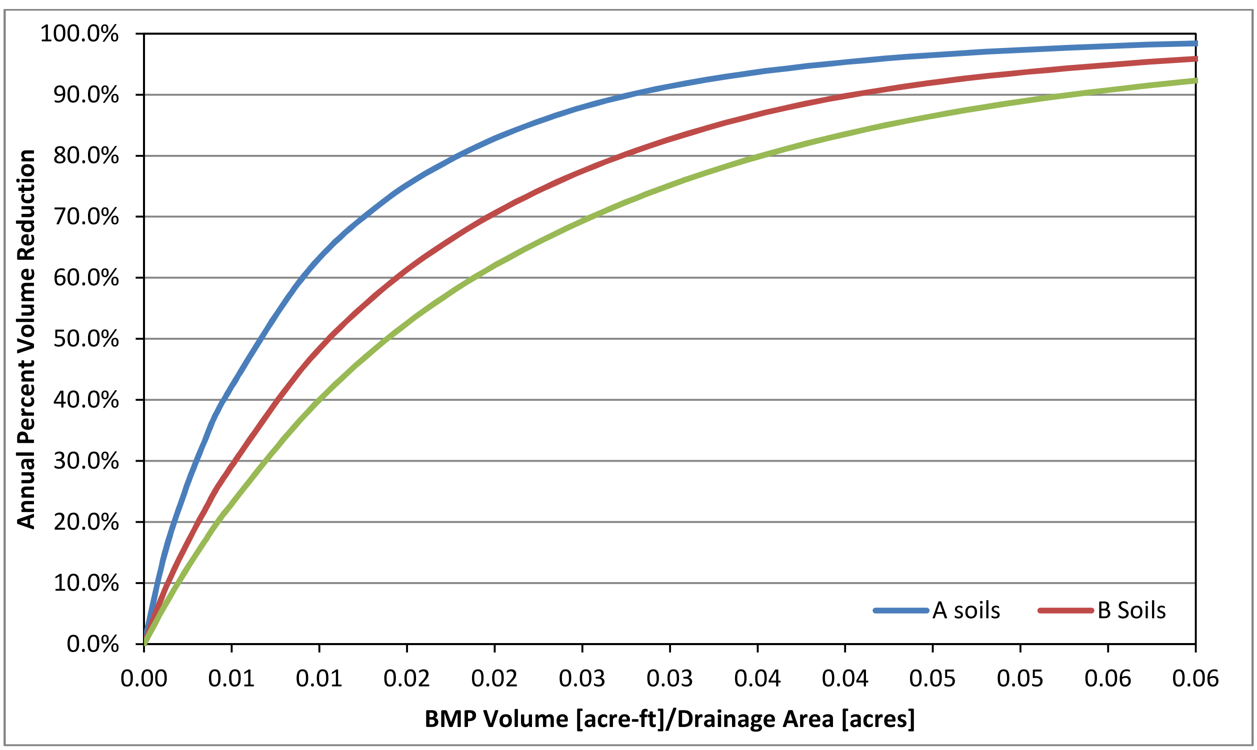
Equivalent inches off impervious surface provided = 0.01 inches

Calculate annual volume reduction using performance curve for 50% impervious site(see Figure 4):

BMP Volume /Drainage Area = (266 ft^3)/(43560ft^2/ac)/(10 acres) = 0.00061

Corresponding annual volume removal (from performance curve, for B soil, 50% impervious site) = 4.5%

Annual TP & TSS removal = annual volume removal = 4.5%



Fixed Input Values (based on XP-SWMM modeling)	A	B	C*	D
Runoff Depth from Pervious Area- Compacted (in)	4.4	5.2	5.5	-
Runoff Depth from Pervious Area- Average Density (in)	4.1	4.9	5.2	6.2
Runoff Depth from Pervious Area- Loosened (in)	4.0	4.7	4.9	-
RD_I: Runoff Depth from Impervious Area (in)	22.5			

* Due to the empirical methodology used to define the K_{sat} values, loosened C soils have a higher K_{sat} than loosened B soils, and thus a lower runoff depth. Given this, it is suggested that the runoff depth from "loosened" C soils be approximated as equivalent to the runoff from "average" B soils for credit calculations.

Site Inputs (blue cells):

Total Pervious Area (ac) =	5	
Pervious Area **with** Improved Soils (ac) =	5	
Pervious Area without Improved Soils (ac) =	0	
Impervious Area (ac) =	5	*Note: must be > 0
Total Site Area (ac) =	10	
Site soil type (A, B, C, or D) =	B	
Pre-project site conditions (C, A, or L) =	C	C = compacted, A = average, L =
Post-project site conditions (C, A, or L) =	A	loosened

Example Calculation

(note- no additional inputs required. Intermediate calculations shown in yellow cells)

Step 1: Calculate Site Runoff Prior to Soil Improvements

RD_{Po}= 5.2 Runoff depth from pervious area reflecting pre-project soil conditions (in)

Pre-soil Improvement RO = 502755 ft3

Step 2: Calculate Site Runoff Following Soil Improvements

$RD_{P\ imp}$= 4.9 Runoff depth from pervious area reflecting post-project soil conditions (in)

Post-soil Improvement RO = 497310 ft3

Step 3: Calculate "Adjusted" Impervious Runoff to Determine Credit

Adjusted Impervious RO = 402930 ft3

Step 4: Calculate "Adjusted" Impervious Area

Adjusted Impervious Area ($Area_{I\ adj}$) = 214896 ft^2

Step 5: Calculate Performance Goal Credit

BMP Volume Credit = 266 ft3

Treatment volume required to meet 1.1 inch goal? (based on site parameters entered above) 19965 ft3

BMP volume credit equates to how many inches off impervious surface? 0.01 inches off impervious surfaces