ATTACHMENT 3 TO APPENDIX D

Methods to Calculate Phosphorus Load Reductions for Structural Storm Water Best Management Practices at a Designated Discharge (DD) Site

This attachment provides methods to determine design storage volume capacities and to calculate phosphorus load reductions for the following structural Best Management Practices (structural BMPs) for a Designated Discharge (DD) Site:

1) Infiltration Trench;
2) Infiltration Basin or other surface infiltration practice;
3) Bioretention Practice;
4) Gravel Wetland System;
5) Porous Pavement;
6) Wet Pond or wet detention basin;
7) Dry Pond or detention basin; and
8) Water Quality Swale.

Methods and examples are provided in this Attachment to calculate phosphorus load reductions for structural BMPs for the four following purposes:

1) To determine the design volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area is 100% impervious;
2) To determine the phosphorus load reduction for a structural BMP with a known design volume when the contributing drainage area is 100% impervious;
3) To determine the design volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area has impervious and pervious surfaces; and
4) To determine the phosphorus load reduction for a structural BMP with a known design volume when the contributing drainage area has impervious and pervious surfaces.

The methods and annual phosphorus export load rates presented in this attachment are for the purpose of counting load reductions for various BMPs treating storm water runoff from varying site conditions (i.e., impervious or pervious surfaces) and different land uses (e.g. commercial and institutional). The estimates of annual phosphorus load and load reductions by BMPs are to demonstrate compliance with the permittee's Phosphorus Reduction Requirement under the permit. It may also be used by a municipality in whose CMPP a permittee is participating for the purpose of gauging the municipality's compliance with phosphorus reduction requirements under its MS4 permit.

For each structural BMP type identified above, long-term cumulative performance information is provided to calculate phosphorus load reductions or to determine needed design storage volumes to achieve a specified reduction target (e.g., 65% phosphorus load reduction). The performance information is expressed as cumulative phosphorus load removed (% removed) depending on the physical storage capacity of the structural BMP (expressed as inches of runoff from impervious area) and is provided at the end of this Attachment (see Tables 3-1 through 3-18 and performance curves Figures 3-1 through 3-18). Multiple tables and performance curves are provided for the infiltration practices to represent cumulative phosphorus load reduction performance for six infiltration rates (IR), 0.17, 0.27, 0.53, 1.02, 2.41, and 8.27 inches/hour. The permittee may use the performance curves provided in this attachment to interpolate phosphorus load removal reductions for field measured infiltration rates that are different than the infiltration rates used to develop the performance curves. Otherwise, the permittee shall use the performance curve for the IR that is nearest, but less than, the field measured rate.

EPA will consider phosphorus load reductions calculated using the methods provided below to be valid for the purpose of complying with the terms of this permit provided that the design, construction, and operation and maintenance of the structural BMPs are consistent with the requirements specified in the Massachusetts Storm Water Handbook.

Alternative Methods:
A permittee may propose alternative long-term cumulative performance information or alternative methods to calculate phosphorus load reductions for the structural BMPs identified above or for other structural BMPs not identified in this Attachment.

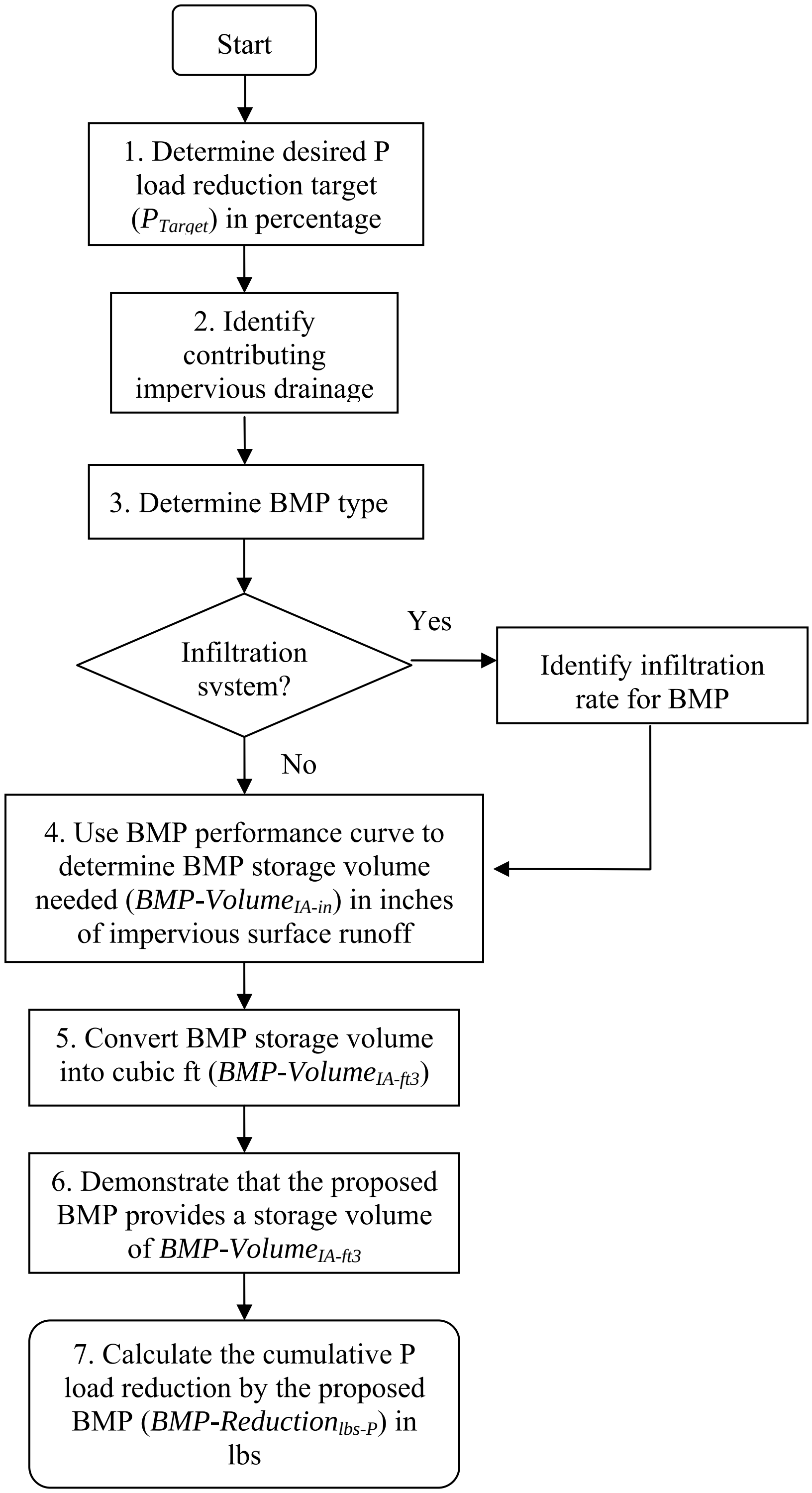
EPA will consider alternative long-term cumulative performance information and alternative methods to calculate phosphorus load reductions for structural BMPs provided that the permittee provides EPA with adequate supporting documentation. At a minimum, the supporting documentation shall include:

1) Results of continuous BMP model simulations representing the structural BMP, using a verified BMP model and representative long-term (i.e., 10 years) climatic data including hourly rainfall data;
2) Supporting calculations and model documentation that justify use of the model, model input parameters, and the resulting cumulative phosphorus load reduction estimate; and
3) Identification of references and sources of information that support the use of the alternative information and method.

If EPA determines that the long-term cumulative phosphorus load reductions developed based on alternative information are not adequately supported, EPA will notify the permittee in writing, and the permittee may receive no phosphorus reduction credit other than a reduction credit calculated by the permittee using the default phosphorus reduction factors provided in this attachment for the identified practices. The permittee is required to submit to EPA valid phosphorus load reductions for structural BMPs at the DD Site in accordance with the submission schedule requirements specified in the permit and Appendix D.

(1) Method to determine the design volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area is 100% impervious:

Flow Chart 1 illustrates the steps to determine the design volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area is 100% impervious.



Flow Chart 1. Method to determine BMP design volume to achieve a known phosphorous load reduction when contributing drainage area is 100% impervious.

1) Determine the desired cumulative phosphorus load reduction target (P_{target});

2) Determine the contributing impervious drainage area (IA) in acres to the structural BMP;

3) Determine the structural BMP type (e.g., infiltration trench, gravel wetland). For infiltration systems, determine the appropriate infiltration rate for the location of the BMP on the DD Site;

4) Using the cumulative phosphorus removal performance curve for the selected structural BMP (Figures 3-1 through 3-18), determine the storage volume for the BMP (BMP-Volume $_{IA\text{-}in}$), in inches of runoff, needed to treat runoff from the contributing IA to achieve the reduction target;

5) Calculate the corresponding BMP storage volume in cubic feet (BMP-Volume $_{IA\text{-}ft^3}$) using BMP-Volume $_{IA\text{-}in}$ determined from step 4 and equation 3-1:

BMP-Volume $_{IA\text{-}ft^3}$ = IA (ac) x BMP-Volume $_{IA\text{-}in}$ x 3630 ft^3/ac-in **(Equation 3-1)**

6) Provide supporting calculations using the dimensions and specifications of the proposed structural BMP showing that the necessary storage volume, BMP-Volume $_{IA\text{-}ft^3}$, determined from step 5 will be provided to achieve the P_{Target}; and

7) Calculate the cumulative phosphorus load reduction in pounds of phosphorus (BMP-Reduction $_{lbs\text{-}P}$) for the structural BMP using the BMP Load (as calculated from the procedure in Attachment 1 to Appendix D) and P_{target} by using equation 3-2:

BMP-Reduction $_{lbs\text{-}P}$ = BMP Load x (P_{target} /100) **(Equation 3-2)**

Example 3-1: Determine design volume of a structural BMP with a 100% impervious drainage area to achieve a known phosphorus load reduction target:

A permittee of a commercial DD Site is considering a surface infiltration practice to capture and treat runoff from 2.57 acres of impervious area. The infiltration practice would be located adjacent to the impervious area. The permittee has measured an infiltration rate (IR) of 0.39 inches per hour (in/hr) in the vicinity of the proposed infiltration practice. Determine the:

A) Design storage volume needed for an surface infiltration practice to achieve a 70% reduction in annual phosphorus load from the contributing drainage area (BMP-Volume $_{IA\text{-}ft^3}$); and

B) Cumulative phosphorus reduction in pounds that would be accomplished by the BMP (BMP-Reduction $_{lbs\text{-}P}$)

Solution:

1) Contributing impervious drainages area (IA) = 2.57 acres

Solution continued:

2) BMP type is a surface infiltration practice (i.e., basin) with an infiltration rate (IR) of 0.39 in/hr

3) Phosphorus load reduction target (P_{target}) = 70%

4) The performance curve for the infiltration basin (i.e., surface infiltration practice), Figure 3-8, IR = 0.27 in/hr is used to determine the design storage volume of the BMP (BMP-Volume $_{IA\text{-}in}$) needed to treat runoff from the contributing IA and achieve a P_{target} = 70%. The curve for an infiltration rate of 0.27 in/hr is chosen because 0.27 in/hr is the nearest simulated IR that is less than the field measured IR of 0.39 in/hr. From Figure 3-8, the BMP-Volume $_{IA\text{-}in}$ for a P_{target} = 70% is 0.36 in.

5) The BMP-Volume $_{IA\text{-}in}$ is converted to cubic feet (BMP-Volume $_{IA\text{-}ft^3}$) using Equation 3-1:

BMP-Volume $_{IA\text{-}ft^3}$ = IA (acre) x BMP-Volume $_{IA\text{-}in}$ x 3,630 ft^3/acre-in
BMP-Volume $_{IA\text{-}ft^3}$ = 2.57 acre x 0.36 in x 3,630 ft^3/acre-in
= **3,359 ft^3**

6) A narrow infiltration basin with the following characteristics is proposed to achieve the P_{Target} of 70%:

Length (ft)	Design Depth (ft)	Bottom area (ft^2)	Pond surface area (ft^2)	Design Storage Volume (ft^3)
355	1.25	1,387	4,059	3,404

The volume of the proposed infiltration practice, 3,404 ft^3, exceeds the BMP-Volume $_{IA\text{-}ft^3}$ needed, 3,359 ft^3 and is sufficient to achieve the P Target of 70%.

7) The cumulative phosphorus load reduction in pounds of phosphorus for the infiltration practice (BMP-Reduction $_{lbs\text{-}P}$) is calculated using Equation 3-2. The BMP Load is first determined using the method in Attachment 1 to Appendix D.

BMP Load = IA x impervious cover phosphorus export loading rate for commercial use (see Table 1-1 from Attachment 1 to Appendix D)
= 2.57 acres x 2.23 lbs/acre/yr
= 5.73 lbs/yr

BMP-Reduction $_{lbs\text{-}P}$ = BMP Load x (P_{target} /100)
BMP-Reduction $_{lbs\text{-}P}$ = 5.73 lbs/yr x (70/100)
= **4.01 lbs/yr**

<u>Alternate Solution:</u> Alternatively, the permittee could determine the design storage volume needed for an IR = 0.39 in/hr by performing interpolation of the results from the surface infiltration performance curves for IR = 0.27 in/hr and IR = 0.52 in/hr as follows (replacing steps 3 and 4 on the previous page):

4 alternative) Using the performance curves for the infiltration basin (i.e., surface infiltration practice), Figures 3-8, IR = 0.27 in/hr and 3-9, IR = 0.52 in/hr, interpolate between the curves to determine the design storage volume of the BMP (BMP-Volume $_{IA\text{-}in}$) needed to treat runoff from the contributing IA and achieve a P $_{target}$ = 70%.

First calculate the interpolation adjustment factor (IAF) to interpolate between the infiltration basin performance curves for infiltration rates of 0.27 and 0.52 in/hr:

$$IAF = (0.39 - 0.27)/ (0.52 - 0.27) = 0.48$$

From the two performance curves, develop the following table to estimate the general magnitude of the needed storage volume for an infiltration swale with an IR = 0.39 in/hr and a P $_{target}$ of 70%.

Table Example 3-1. Interpolation Table for determining design storage volume of infiltration basin with IR = 0.39 in/hr and a phosphorus load reduction target of 70%.

BMP Storage Volume	% Phosphorus Load Reduction IR = 0.27 in/hr ($PR_{IR=0.27}$)	% Phosphorus Load Reduction IR = 0.52 in/hr ($PR_{IR=0.52}$)	Interpolated % Phosphorus Load Reduction IR = 0.39 in/hr ($PR_{IR=0.39}$) **$PR_{IR=0.39}$= IAF($PR_{IR=0.52}$ – $PR_{IR=0.27}$) + $PR_{IR=0.27}$**
0.3	64%	67%	65%
0.4	74%	77%	75%
0.5	79%	82%	80%

As indicated from Table Example 3-1, the BMP-Volume $_{IA\text{-}in}$ for $PR_{IR=0.39}$ of 70% is between 0.3 and 0.4 inches and can be determined by interpolation:

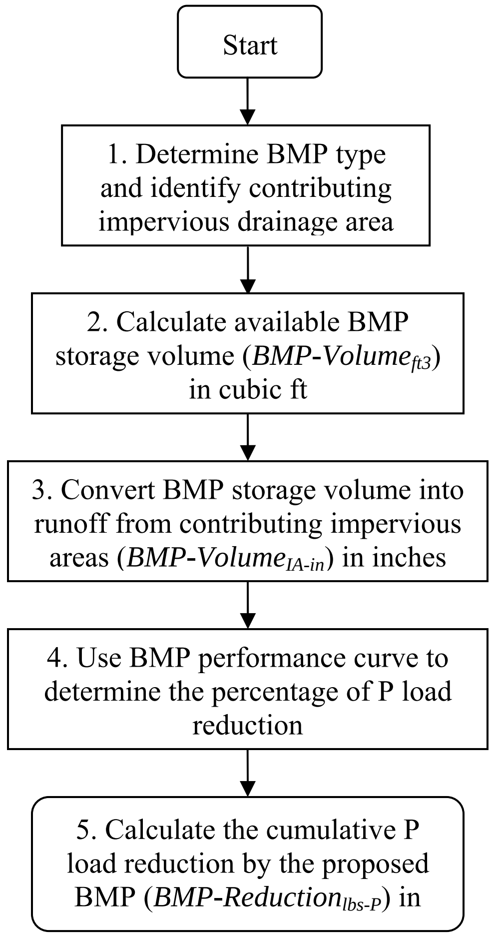
$$\text{BMP-Volume}_{IA\text{-}in} = (70\% - 65\%)/ (75\% - 65\%) \times (0.4 \text{ in} - 0.3 \text{ in}) + 0.3 \text{ in}$$
$$= 0.35 \text{ inches}$$

5 alternative) Convert the resulting BMP-Volume $_{IA\text{-}in}$ to cubic feet (BMP-Volume $_{IA\text{-}ft^3}$) using equation 3-1:

$$\text{BMP-Volume}_{IA\text{-}ft^3} = 2.57 \text{ acre} \times 0.35 \text{ in} \times 3{,}630 \text{ ft}^3/\text{acre-in}$$
$$= 3{,}265 \text{ ft}^3$$

(2) <u>Method to determine the phosphorus load reduction for a structural BMP with a known design volume when the contributing drainage area is 100% impervious:</u>

Flow Chart 2 illustrates the steps to determine the phosphorus load reduction for a structural BMP with a known design volume when the contributing drainage area is 100% impervious.



Flow Chart 2. Method to determine the phosphorus load reduction for a BMP with a known design volume when contributing drainage area is 100% impervious.

1) Identify the structural BMP type and contributing impervious drainage area (IA);

2) Document the available storage volume (ft^3) of the structural BMP (BMP-Volume $_{ft}{}^3$) using the BMP dimensions and design specifications (e.g., maximum storage depth, filter media porosity);

3) Convert BMP-Volume $_{ft}{}^3$ into inches of runoff from the contributing impervious area (BMP-Volume $_{IA-in}$) using equation 3-3:

BMP-Volume $_{IA-in}$ = BMP-Volume $_{ft}{}^3$/ IA (acre) x 12 in/ft x 1 acre/43560 ft^2
(Equation 3-3)

4) Determine the % phosphorus load reduction for the structural BMP (BMP Reduction $_{\%-P}$) using the appropriate BMP performance curve (Figures 3-1 through 3-18) and the BMP-Volume $_{IA-in}$ calculated in step 3; and

5) Calculate the cumulative phosphorus load reduction in pounds of phosphorus for the structural BMP (BMP Reduction $_{lbs\text{-}P}$) using the BMP Load as calculated from the procedure in Attachment 1 to Appendix D and the percent phosphorus load reduction (BMP Reduction $_{\%\text{-}P}$) determined in step 4 by using equation 3-4:

BMP Reduction $_{lbs\text{-}P}$ = BMP Load x (BMP Reduction $_{\%\text{-}P}$/100) **(Equation 3-4)**

Example 3-2: Determine the phosphorus load reduction for a structural BMP with a known storage volume capacity when the contributing drainage area is 100% impervious:

A permittee of an industrial DD Site is considering a bioretention system to treat runoff from 1.49 acres of impervious area. Site constraints would limit the bioretention system to have a surface area of 1200 ft^2 and the system would have to be located next to the impervious drainage area to be treated. Following Massachusetts storm water design standards, the design parameters for the bioretention system are presented in Table Example 3-2.

Table Example 3-2. Design parameters for bioretention system for Example 3-2

Components of representation	Parameters	Value
Ponding	Maximum depth	6 in
	Surface area	1200 ft^2
	Vegetative parameter[a]	85-95%
Soil mix	Depth	30 in
	Porosity	40%
	Hydraulic conductivity	4 inches/hour
Gravel layer	Depth	8 in
	Porosity	40%
	Hydraulic conductivity	14 inches/hour
Orifice #1	Diameter	6 in

[a] Refers to the percentage of surface covered with vegetation

Determine the:

A) Percent phosphorus load reduction (BMP Reduction $_{\%\text{-}P}$) for the specified bioretenion system and contributing impervious drainage area; and

B) Cumulative phosphorus reduction in pounds that would be accomplished by the bioretention system (BMP-Reduction $_{lbs\text{-}P}$)

<u>Solution:</u>

1) The BMP is a bioretention system that will treat runoff from 1.49 acres of impervious area (IA = 1.49 acre);

2) The available storage volume capacity (ft^3) of the bioretention system (BMP-Volume $_{BMP\text{-}ft^3}$) is determined using the surface area of the system, depth of ponding, and the porosity of the filter media:

BMP-Volume $_{BMP\text{-}ft^3}$ = (surface area x pond maximum depth) + ((soil mix depth + gravel layer depth)/12 in/ft) x surface area x gravel layer porosity)
= (1,200 ft^2 x 0.5 ft) + ((38/12) x 1,200 ft^2 x 0.4)
= 2,120 ft^3

Solution continued:

3) The available storage volume capacity of the bioretention system in inches of runoff from the contributing impervious area (BMP-Volume $_{IA-in}$) is calculated using equation 3-3:

BMP-Volume $_{IA-in}$ = (BMP-Volume $_{ft}{}^3$/ IA (acre) x 12 in/ft x 1 acre/43560 ft^2
BMP-Volume $_{IA-in}$ = (2120 ft^3/1.49 acre) x 12 in/ft x 1 acre/43560 ft^2
= 0.39 in

4) Using the bioretention performance curve shown in Figure 3-13, a **51%** phosphorus load reduction (BMP Reduction %-P) is determined for a bioretention system sized for 0.39 in of runoff from 1.49 acres of impervious area; and

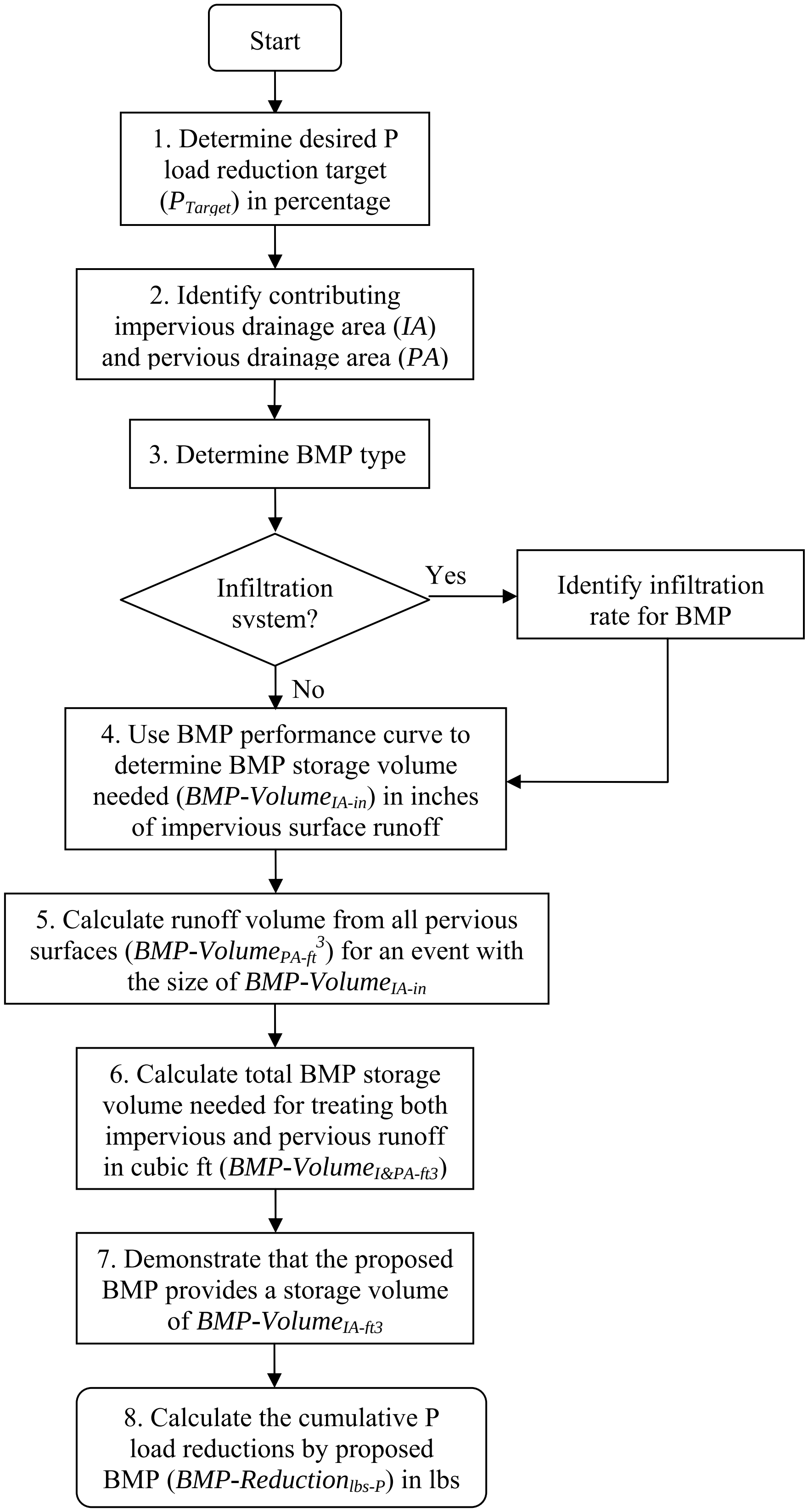
5) Calculate the cumulative phosphorus load reduction in pounds of phosphorus for the bioretention system (BMP Reduction $_{lbs-P}$) using the BMP Load as calculated from the procedure in Attachment 1 to Appendix D and the BMP Reduction $_{\%-P}$ determined in step 4 by using equation 3-4. First, the BMP Load is determined as specified in Attachment 1:

BMP Load = IA (acre) x impervious cover phosphorus export loading rate for industrial use (see Table 1-1 from Attachment 1 to Appendix D)
= 1.49 acres x 1.78 lbs/acre/yr
= 2.65 lbs/yr

BMP Reduction $_{lbs-P}$ = BMP Load x (BMP Reduction $_{\%-P}$/100)
BMP Reduction $_{lbs-P}$ = 2.65 lbs/yr x (51/100)
= **1.35 lbs/yr**

(3) Method to determine the design storage volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area has impervious and pervious surfaces:

Flow Chart 3 illustrates the steps to determine the design storage volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area has impervious and pervious surfaces.



Flow Chart 3. Method to determine the design storage volume of a BMP to reach a known P load reduction when both impervious and pervious drainage areas are present.

1) Determine the desired cumulative phosphorus load reduction target (P Target).

2) Characterize the contributing drainage area to the structural BMP by identifying the following information for the impervious and pervious surfaces:

Impervious area (IA) - Area (acre) and land use (e.g., commercial)

Pervious area (PA) – Area (acre) and initial abstraction (I_a) based on hydrologic soil group (HSG) and condition of pervious area. I_a values indicate the depth of rainfall that will not generate runoff. Table 3-3-1 provides values of I_a for various pervious surfaces and HSGs. Soils are assigned to an HSG on the basis of their permeability. HSG A is the most permeable, and HSG D is the least permeable. HSG categories for pervious areas on the DD Site shall be estimated by consulting local soil surveys prepared by the National Resource Conservation Service (NRCS) or by a storm water professional evaluating soil testing results from the DD Site. For grassed areas on commercial, industrial, and institutional DD Sites, the permittee should select the Ia based on the condition and percent coverage.

Table 3-3-1. Initial abstraction (Ia) values for various land use and Hydrologic Soil Groups (HSGs)

Land use/cover conditions		Initial abstraction (Ia) (inch)			
		HSG A	**HSG B**	**HSG C**	**HSG D**
Open space	Poor - grass cover < 50%	0.94	0.53	0.33	0.25
	Fair - grass cover 50–75%	2.08	0.90	0.53	0.38
	Good - grass cover > 75%	3.13	1.28	0.70	0.50
Residential	1/8 acre or less	0.60	0.35	0.22	0.17
	1/4 acre	1.28	0.67	0.41	0.30
	1/3 acre	1.51	0.78	0.47	0.33
	1/2 acre	1.70	0.86	0.50	0.35
	1 acre	1.92	0.94	0.53	0.38
	2 acres	2.35	1.08	0.60	0.44
Brush	Poor - cover < 50%	2.17	0.99	0.60	0.41
	Fair - cover 50–75%	3.71	1.57	0.83	0.60
	Good - cover > 75%	4.67	2.17	1.08	0.74
Woods	Poor - cover < 50%	2.44	1.03	0.60	0.41
	Fair - cover 50–75%	3.56	1.33	0.74	0.53
	Good - cover > 75%	4.67	1.64	0.86	0.60

Source: Adapted from USDA-NRCS. Urban Hydrology for Small Watersheds, TR-55. 1986.

3) Determine the structural BMP type (e.g., infiltration trench, gravel wetland). For infiltration systems, determine the appropriate infiltration rate for the location of the BMP on the DD Site.

4) Using the cumulative phosphorus removal performance curve for the selected structural BMP, determine the storage volume capacity of the BMP in inches needed to treat runoff from the contributing impervious area (BMP-Volume $_{IA\text{-}in}$);

5) Using Equation 3-5 below and the pervious information developed from step 1, determine the total volume of runoff from the contributing pervious drainage area in cubic feet (BMP Volume $_{PA\text{-} ft^3}$) for a rainfall size equal to the sum of BMP Volume $_{IA\text{-}in}$, determined in step 4. The runoff volume for each distinct pervious area must be determined.

BMP-Volume $_{PA\ acre\text{-}in} = \sum (PA \times (\text{BMP-Volume}_{IA\text{-}in} - I_a) \times 3{,}630\ ft^3/\text{acre-in})_{(PA1,\ldots PAn)}$
(Equation 3-5)

6) Using equation 3-6 below, calculate the BMP storage volume in cubic feet (BMP-Volume $_{IA\&PA\text{-}ft^3}$) needed to treat the runoff depth from the contributing impervious (IA) and pervious areas (PA).

BMP-Volume $_{IA\&PA\text{-}ft^3}$ = BMP Volume $_{PA\text{-}ft^3}$ + (BMP Volume $_{IA\text{-}in}$ x IA (acre) x 3,630 ft^3/acre-in)
(Equation 3-6)

7) Provide supporting calculations using the dimensions and specifications of the proposed structural BMP showing that the necessary storage volume determined in step 6, BMP-Volume $_{I\&PA\text{-}ft^3}$, will be provided to achieve the P $_{Target}$; and

8) Calculate the cumulative phosphorus load reduction in pounds of phosphorus (BMP-Reduction $_{lbs\text{-}P}$) for the structural BMP using the BMP Load (as calculated from the procedure in Attachment 1 to Appendix D) and the P $_{target}$ by using equation 3-2:

BMP-Reduction $_{lbs\text{-}P}$ = BMP Load x (P $_{target}$ /100) **(Equation 3-2)**

<u>Example 3-3: Determine the design storage volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area has impervious and pervious surfaces</u>

A permittee with high-density residential (HDR) DD Site is considering a gravel wetland system to treat runoff from the site. The site is 7.50 acres of which 4.00 acres are impervious surfaces and 3.50 acres are pervious surfaces. The pervious area is made up of 2.5 acres of lawns in good condition surrounding cluster housing units and 1.00 acre of stable unmanaged woodland. Soils information indicates that all of the woodland and 0.50 acres of the lawn is hydrologic soil group (HSG) B and the other 2.00 acres of lawn are HSG C. The permittee wants to size the gravel wetland system to achieve a cumulative phosphorus load reduction (P $_{Target}$) of 55% from the entire 7.50 acres. Determine the:

A) Design storage volume needed for a gravel wetland system to achieve a 55% reduction in annual phosphorus load from the contributing drainage area (BMP-Volume $_{IA\&PA\text{-}ft^3}$); and

B) Cumulative phosphorus reduction in pounds that would be accomplished by the BMP (BMP-Reduction $_{lbs\text{-}P}$)

.

<u>Solution:</u>

1) The contributing impervious area (IA_{BMP}) = 4.00 acres and is high density residential. The contributing pervious area (PA_{BMP}) = 3.50 acres, and is further summarized in Table Example 3-3-A. This table uses information provided for the DD Site and information

Solution continued:

from Table 3-3-1. To determine I_a, the grassed pervious areas are estimated to represent residential at ½ acre density due to the clustering of housing units on the site.

Table Example 3-3-A. Pervious area characteristics for high density residential DD Site

ID	Type	Area (acre)	Condition	Hydrologic Soil Group	I_a (in)
PA1	Grass	2.00	Good	C	0.50
PA2	Grass	0.50	Good	B	0.86
PA3	Woods	1.00	Good	B	1.64

2) The BMP type is gravel wetland system.

3) The phosphorus load reduction target (P_{Target}) = 55%.

4) Using the cumulative phosphorus removal performance curve for the gravel wetland system shown in Figure 3-14, the storage volume capacity in inches needed to treat runoff from the contributing impervious area (BMP Volume $_{IA\text{-}in}$) is 0.71 in;

5) Using equation 3-5 and the pervious information developed from step 1, the volume of runoff from the contributing pervious drainage area in cubic feet (BMP Volume $_{PA-ft^3}$) for a rainfall size equal to 0.71 in is summarized in Table Example 3-3-B.

Table Example 3-3-B. Runoff contributions from pervious areas for high density residential DD Site

ID	Type	Pervious Area (acre)	Rainfall (in)	I_a (in)	Runoff = (rainfall - I_a) x PA (acre-in)	Runoff = Runoff (acre-in) x 3630 ft^3/acre-in (ft^3)
PA1	Grass	2.00	0.71	0.50	0.42	1,525
PA2	Grass	0.50	0.71	0.86	0.0	0.0
PA3	Woods	1.00	0.71	1.64	0.0	0.0
Total	-----	**3.50**	-----	-----	**0.42**	**1,525**

6) Using equation 3-6, determine the BMP storage volume in cubic feet (BMP-Volume $_{IA\&PA\text{-}ft^3}$) needed to treat 0.71 inches of runoff from the contributing impervious area (IA) and the net runoff of 0.42 acre-in from the contributing pervious areas, determined in step 5 is:

BMP Volume$_{IA\&PA\text{-}ft^3}$ = BMP Volume $_{PA\ ac\text{-}in}$ + (BMP Volume $_{IA\text{-}in}$ x IA (acre)) x 3,630 ft^3/acre-in)

BMP Volume$_{IA\&PA\text{-}ft^3}$ = (1,525 ft^3+ (0.71 in x 4.00 acre)) x 3,630 ft^3/acre-in

= 11,834 ft^3

7) Table Example 3-3-C provides design details for of a potential gravel wetland system (based on Chapter 2 of the Massachusetts Stormwater Handbook).

Solution continued:

Table Example 3-3-C. Design details for gravel wetland system

Gravel Wetland System Components	Design Detail	Depth (ft)	Surface Area (ft^2)	Volume (ft^3)
Sediment Forebay	**10% of Treatment Volume**			
Pond area	----	1.33	896	1,192
Wetland Cell #1	**45% of Treatment Volume**	---------------	-------------------	---------------
Pond area	----	2.00	1,914	3,828
Gravel layer	porosity = 0.4	2.00	1,914	1,531
Wetland Cell #2	**45% of Treatment Volume**	---------------	------------------	---------------
Pond area	----	2.00	1,914	3,828
Gravel layer	porosity = 0.4	2.00	1,914	1,531

The total design storage volume for the proposed gravel wetland system identified in Table Example 3-3-C is 11,910 ft^3. This volume is greater than 11,834 ft^3 ((BMP-Volume $_{IA\&PA\text{-}ft^3}$), calculated in step 6) and is therefore sufficient to achieve a P $_{Target}$ of 55%.

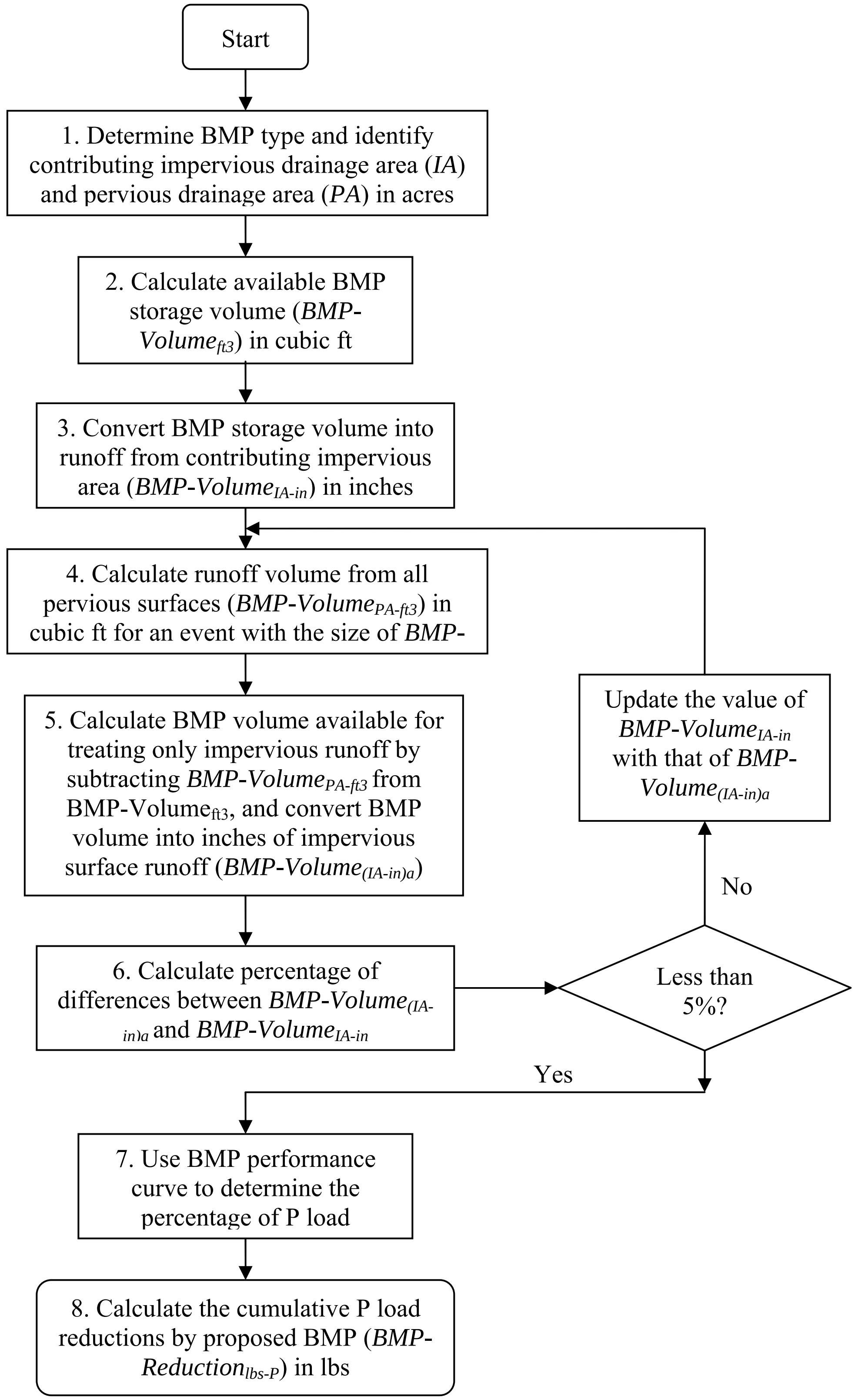
8) The cumulative phosphorus load reduction in pounds of phosphorus (BMP-Reduction $_{lbs\text{-}P}$) for the proposed gravel wetland system is calculated by using equation 3-2 with the BMP Load (as determined by the procedure in Attachment 1 to Appendix D) and the P $_{target}$ = 55%.

BMP-Reduction $_{lbs\text{-}P}$ = BMP Load x (P $_{target}$ /100) (**Equation 3-2**)

Using Table 1-1 from Attachment 1 to Appendix D, the BMP Load is calculated:
BMP Load = (IA x impervious cover phosphorus export loading rate for HDR)
+ (PA $_{lawn}$ x pervious cover phosphorus export loading rate for HDR)
+ (PA $_{woods}$ x pervious cover phosphorus export loading rate for forest)
= (4.00 acre x 2.23 lbs/acre/yr) + (2.50 acre x 0.27 lbs/acre/yr) + (1.00 acre x 0.09 lbs/acre/yr)
= 9.69 lbs/yr
BMP-Reduction $_{lbs\text{-}P}$ = BMP Load x (P $_{target}$ /100)
BMP-Reduction $_{lbs\text{-}P}$ = 9.69 lbs/yr x 55/100
= **5.33 lbs**

(4) Method to determine the phosphorus load reduction for a structural BMP with a known storage volume when the contributing drainage area has impervious and pervious surfaces:

Flow Chart 4 illustrates the steps to determine the phosphorus load reduction for a structural BMP with a known storage volume when the contributing drainage area has impervious and pervious surfaces.



Flow Chart 4. Method to determine the phosphorus load reduction for a BMP with known storage volume when both pervious and impervious drainage areas are present.

1) Identify the type of structural BMP and characterize the contributing drainage area to the structural BMP by identifying the following information for the impervious and pervious surfaces:

Impervious area (IA) – Area (acre) and land use (e.g., commercial)

Pervious area (PA) – Area (acre) and initial abstraction (I_a) based on hydrologic soil group (HSG) and condition of pervious area. I_a values indicate the depth of rainfall that will not generate runoff. Table 3-3-1 provides values of I_a for various pervious surfaces and HSGs. Soils are assigned to an HSG based on their permeability. HSG categories for pervious areas on the DD Site shall be estimated by consulting local soil surveys prepared by the National Resource Conservation Service (NRCS) or by a storm water professional evaluating soil testing results from the DD Site;

2) Determine the available storage volume (ft^3) of the structural BMP (BMP-Volume $_{ft^3}$) using the BMP dimensions and design specifications (e.g., maximum storage depth, filter media porosity);

3) To estimate the phosphorus load reduction of a BMP with a known storage volume capacity, it is first necessary to determine the portion of available BMP storage capacity (BMP-Volume $_{ft^3}$) that would treat the runoff volume generated from the contributing impervious area (IA) for a rainfall event with a depth of *i* inches (in). This will require knowing the corresponding amount of runoff volume that would be generated from the contributing pervious area (PA) for the same rainfall event (depth of *i* inches). Using equation 3-6a below, solve for the BMP capacity that would be available to treat runoff from the contributing imperious area for the unknown rainfall depth of *i* inches (see equation 3-6b):

$$\text{BMP-Volume}_{ft^3} = \text{BMP-Volume}_{(IA\text{-}ft^3)i} + \text{BMP-Volume}_{(PA\text{-}ft^3)i} \qquad \textbf{(Equation 3-6a)}$$

Where:

BMP-Volume $_{ft^3}$	=	the available storage volume of the BMP
BMP-Volume $_{(IA\text{-}ft^3)i}$	=	the available storage volume of the BMP that would fully treat runoff generated from the contributing impervious area for a rainfall event of size *i* inches
BMP-Volume $_{(PA\text{-}ft^3)i}$	=	the available storage volume of the BMP that would fully treat runoff generated from the contributing pervious area for a rainfall event of size *i* inches

Solving for BMP-Volume $_{(IA\text{-}ft^3)i}$:

$$\text{BMP-Volume}_{(IA\text{-}ft^3)i} = \text{BMP-Volume}_{ft^3} - \text{BMP-Volume}_{(PA\text{-}ft^3)i} \qquad \textbf{(Equation 3-6b)}$$

To determine BMP-Volume $_{(IA\text{-}ft^3)i}$, requires performing an iterative process of refining estimates of the rainfall depth used to calculate runoff volumes until the rainfall depth used results in the sum of runoff volumes from the contributing IA and PA equaling the available BMP storage capacity (BMP-Volume $_{ft^3}$). For the purpose of estimating BMP performance, it will be considered adequate when the IA runoff depth (in) is within 5% IA runoff depth used in the previous iteration.

For the first iteration (1), convert the BMP-Volume $_{ft^3}$ determined in step 2 into inches of runoff from the contributing impervious area (BMP Volume $_{(IA\text{-}in)1}$) using equation 3-7a.

BMP-Volume $_{(IA\text{-}in)1}$ = (BMP-Volume$_{ft^3}$/ IA (acre)) x (12 in/ft /43,560 ft^2/acre)
(Equation 3-7a);

For iterations 2 through n (2…n), convert the BMP Volume $_{(IA\text{-}ft^3)2\ldots n}$, determined in step 5a below, into inches of runoff from the contributing impervious area (BMP Volume $_{(IA\text{-}in)2\ldots n}$) using equation 3-7b.

BMP-Volume $_{(IA\text{-}in)2\ldots n}$ = (BMP-Volume $_{(IA\text{-}ft^3)2\ldots n}$ / IA (acre)) x (12 in/ft /43,560 ft^2/acre)
(Equation 3-7b);

4) For 1 to n iterations, use the pervious information developed from step 1 and equation 3-8 to determine the total volume of runoff (ft^3) from the contributing PA (BMP Volume $_{PA\text{-}ft^3}$) for a rainfall size equal to the sum of BMP-Volume $_{(IA\text{-}in)1}$, determined in step 3. The runoff volume for each distinct pervious area must be determined.

BMP Volume $_{(PA\text{-}ft^3)1\ldots n}$ = $\sum$ ((PA x (BMP Volume $_{(IA\text{-}in)1..n}$ – I_a)$_{(PA1,\ PA2..PAn)}$ x (3,630 ft^3/acre-in)
(Equation 3-8)

5) For iteration 1, estimate the portion of BMP Volume that is available to treat runoff from only the IA by subtracting BMP-Volume $_{PA\text{-}ft^3}$, determined in step 4, from BMP-Volume $_{ft^3}$, determined in step 2, and convert to inches of runoff from IA (see equations 3-9a and 3-9b):

BMP-Volume $_{(IA\text{-}ft^3)2}$ = ((BMP-Volume$_{ft^3}$- BMP Volume $_{(PA\text{-}ft^3)1}$) **(Equation 3-9a)**

BMP-Volume $_{(IA\text{-}in)2}$ = (BMP-Volume $_{(IA\text{-}ft^3)2}$/IA (acre)) x (12 in/ft x 1 acre/43,560 ft^2)
(Equation 3-9b)

If additional iterations (i.e., 2 through n) are needed, estimate the portion of BMP volume that is available to treat runoff from only the IA (BMP-Volume $_{(IA\text{-}in)3..n+1}$) by subtracting BMP Volume $_{(PA\text{-}ft^3)2..n}$, determined in step 4, from BMP Volume $_{(IA\text{-}ft^3)3..n+1}$, determined in step 5, and by converting to inches of runoff from IA using equation 3-9b):

6) For iteration a (an iteration between 1 and n+1), compare BMP Volume $_{(IA\text{-}in)a}$ to BMP Volume $_{(IA\text{-}in)a-1}$ determined from the previous iteration (a-1). If the difference in these values is greater than 5% of BMP Volume $_{(IA\text{-}in)a}$ then repeat steps 4 and 5, using BMP Volume $_{(IA\text{-}in)a}$ as the new starting value for the next iteration (a+1). If the difference is less than or equal to 5 % of BMP Volume $_{(IA\text{-}in)a}$ then the permittee may proceed to step 7.

7) Determine the % phosphorus load reduction for the structural BMP (BMP Reduction $_{\%\text{-}P}$) using the appropriate BMP performance curve and the BMP-Volume $_{(IA\text{-}in)n}$ calculated in the final iteration of step 5; and

8) Calculate the cumulative phosphorus load reduction in pounds of phosphorus for the structural BMP (BMP Reduction $_{lbs\text{-}P}$) using the BMP Load as calculated from the procedure in Attachment 1 to Appendix D and the percent phosphorus load reduction (BMP Reduction $_{\%\text{-}P}$) determined in step 7 by using equation 3-4:

BMP Reduction $_{lbs\text{-}P}$ = BMP Load x (BMP Reduction $_{\%\text{-}P}$/100) **(Equation 3-4)**

Example 3-4: Determine the phosphorus load reduction for a structural BMP with a known design volume when the contributing drainage area has impervious and pervious surfaces

A permittee responsible for managing an industrial DD Site is considering an infiltration basin to capture and treat runoff from a portion of the site. The contributing drainage area is 16.55 acres and is 71 % impervious. The pervious drainage area (PA) is grass in fair condition and is 80% HSG D and 20% HSG C. An infiltration basin with the following specifications can be placed at the down-gradient end of the contributing drainage area where soil testing results indicates an infiltration rate (IR) of 0.28 in/hr:

Structure	Bottom area (acre)	Top surface area (acre)	Maximum pond depth (ft)	Design storage volume (ft^3)	Infiltration Rate (in/hr)
Infiltration basin	0.65	0.69	1.65	48,155	0.28

Determine the:

A) Percent phosphorus load reduction (BMP Reduction $_{\%\text{-}P}$) for the specified infiltration basin and the contributing impervious and pervious drainage area; and

B) Cumulative phosphorus reduction in pounds that would be accomplished by the BMP (BMP-Reduction $_{lbs\text{-}P}$)

Solution:

1) A surface infiltration basin is being considered. Information for the contributing impervious (IA) and pervious (PA) areas are summarized in Tables Example 3-4-A and Example 3-4-B, respectively. Table 3-3-1 is used to provide estimates of the initial abstraction I_a for the pervious areas.

Table Example 3-4-A Impervious area characteristics for industrial DD Site

ID	Land use	Area (acre)
IA1	Industrial	11.75

Table Example 3-4-B Pervious area characteristics for industrial DD Site

ID	Type	Area (acre)	Condition	Hydrologic Soil Group (HSG)	I_a (in)
PA1	Grass	3.84	Fair	D	0.38
PA2	Grass	0.96	Fair	C	0.53

Solution continued:

2) The available storage volume (ft^3) of the infiltration basin (BMP-Volume $_{ft^3}$) is determined from the design details and basin dimensions; BMP-Volume $_{ft^3}$ = 48,155 ft^3.

3) To determine what the BMP design storage volume is in terms of runoff depth (in) from IA, an iterative process is undertaken:

Solution Iteration 1

For the first iteration (1), the BMP-Volume$_{ft^3}$ is converted into inches of runoff from the contributing impervious area (BMP Volume $_{(IA-in)1}$) using equation 3-5a.

BMP Volume $_{(IA-in)1}$ = (48,155 ft^2/ 11.75 acre) x (12 in/ft /43,560 ft^2/acre)
= 1.13 in

4-1) The total volume of runoff (ft^3) from the contributing PA (BMP Volume $_{PA-ft^3}$) for a rainfall size equal to the sum of BMP Volume $_{(IA-in)1}$ determined in step 3 is determined for each distinct pervious area using the information summarized in Table Example 3-4-B and equation 3-5.

BMP Volume $_{(PA-ft^3)1}$ = ((3.84 acre x (1.13 in – 0.38 in)
+ (0.96 acre x (1.13 in – 0.53 in)) x 3,630 ft^3/acre-in
= 12,545 ft^3

5-1) For iteration 1, the portion of BMP Volume that is available to treat runoff from only the IA is estimated by subtracting the BMP Volume $_{(PA-ft^3)1}$, determined in step 4-1, from BMP Volume$_{ft^3}$, determined in step 2, and converted to inches of runoff from IA:

BMP Volume $_{(IA-ft^3)\,2}$ = 48,155 ft^3 – 12,545 ft^3
= 35,701 ft^3

BMP Volume $_{(IA-in)\,2}$ = (35,701 ft^3/11.75 acre) x (12 in/ft x 1 acre/43,560 ft^2)
= 0.84 in

6-1) The % difference between BMP Volume $_{(IA-in)\,2}$, 0.84 in, and BMP Volume $_{(IA-in)1}$, 1.13 in is determined and found to be significantly greater than 5%:

% Difference = ((1.13 in – 0.84 in)/0.84 in) x 100
= 35%

Therefore, steps 4 through 6 are repeated starting with BMP Volume $_{(IA-in)\,2}$ = 0.84 in.

Solution Iteration 2

4-2) BMP-Volume $_{(PA-ft^3)2}$ = ((3.84 acre x (0.84 in– 0.38 in)
+ (0.96 acre x (0.84 in– 0.53 in)) x 3,630 ft^3/acre-in
= 7,492 ft^3

5-2) BMP-Volume $_{(IA-ft^3)\,3}$ = 48,155 ft^3 – 7,492 ft^3
= 40,663 ft^3

Solution continued:

BMP-Volume $_{(IA\text{-}in)\,3}$ = (40,663 ft^3/11.75 acre) x (12 in/ft x 1 acre/43,560 ft^2)
= 0.95 in

6-2) % Difference = ((0.95 in – 0.84 in)/0.95 in) x 100
= 12%

The difference is greater than 5%, therefore, steps 4 through 6 are repeated starting with BMP Volume $_{(IA\text{-}in)\,3}$ = 0.95 in.

Solution Iteration 3

4-3) BMP Volume $_{(PA\text{-}ft^3)3}$ = ((3.84 acre x (0.95 in – 0.38 in)
+ (0.96 acre x (0.95 in – 0.53 in)) x 3,630 ft^3/acre-in
= 9,409 ft^3

5-3) BMP Volume $_{(IA\text{-}ft^3)\,4}$ = 48,155 ft^3 – 9,409 ft^3)
= 38,746 ft^3

BMP Volume $_{(IA\text{-}in)\,4}$ = (38,746 ft^3/11.75 acre) x (12 in/ft x 1 acre/43,560 ft^2)
= 0.91 in

6-3) % Difference = ((0.95 in – 0.91 in)/0.91 in) x 100
= 4%

The difference of 4% is acceptable.

7) The % phosphorus load reduction for the infiltration basin (BMP Reduction $_{\%\text{-}P}$) is determined by using the infiltration basin performance curve for an infiltration rate of 0.27 in/hr and the treatment volume (BMP-Volume $_{Net\ IA\text{-}in}$ = 0.91 in) calculated in step 5-3 and is **BMP Reduction $_{\%\text{-}P}$ = 92%**.

The performance curve for IR = 0.27 is used rather than interpolating between the performance curves for IR = 0.27 in/hr and 0.52 in/hr to estimate performance for IR = 0.28 in/hr. An evaluation of the performance curves for IR = 0.27 in/hr and IR = 0.52 in/hr for a design storage volume is 0.91 in and indicate a small difference in estimated performance (BMP Reduction $_{\%\text{-}P}$ = 92% for IR = 0.27 in/hr and BMP Reduction $_{\%\text{-}P}$ = 94% for IR = 0.52 in/hr).

8) The cumulative phosphorus load reduction in pounds of phosphorus (BMP-Reduction $_{lbs\text{-}P}$) for the proposed infiltration basin is calculated by using equation 3-2 with the BMP Load (as determined by the procedure in Attachment 1 to Appendix D) and the P $_{target}$ of 92%.

BMP-Reduction $_{lbs\text{-}P}$ = BMP Load x (P $_{target}$ /100) **(Equation 3-2)**

Using Table 1-1 from Attachment 1, the BMP load is calculated:

BMP Load = (IA x impervious cover phosphorus export loading rate for industrial)
+ (PA $_{lawn}$ x pervious cover phosphorus export loading rate for HDR)
= (11.75 acre x 1.78 lbs/acre/yr) + (4.80 acre x 0.27 lbs/acre/yr)
= 22.21 lbs/yr

BMP-Reduction $_{lbs\text{-}P}$ = 22.21 lbs/yr x 92/100 = **20.43 lbs**

Table 3-1

Infiltration Trench (IR = 0.17 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	14.7%	27.6%	48.6%	64.1%	74.9%	82.0%	91.6%	95.4%
Cumulative Phosphorus Load Reduction	18%	33%	57%	73%	83%	90%	97%	99%

Figure 3-1

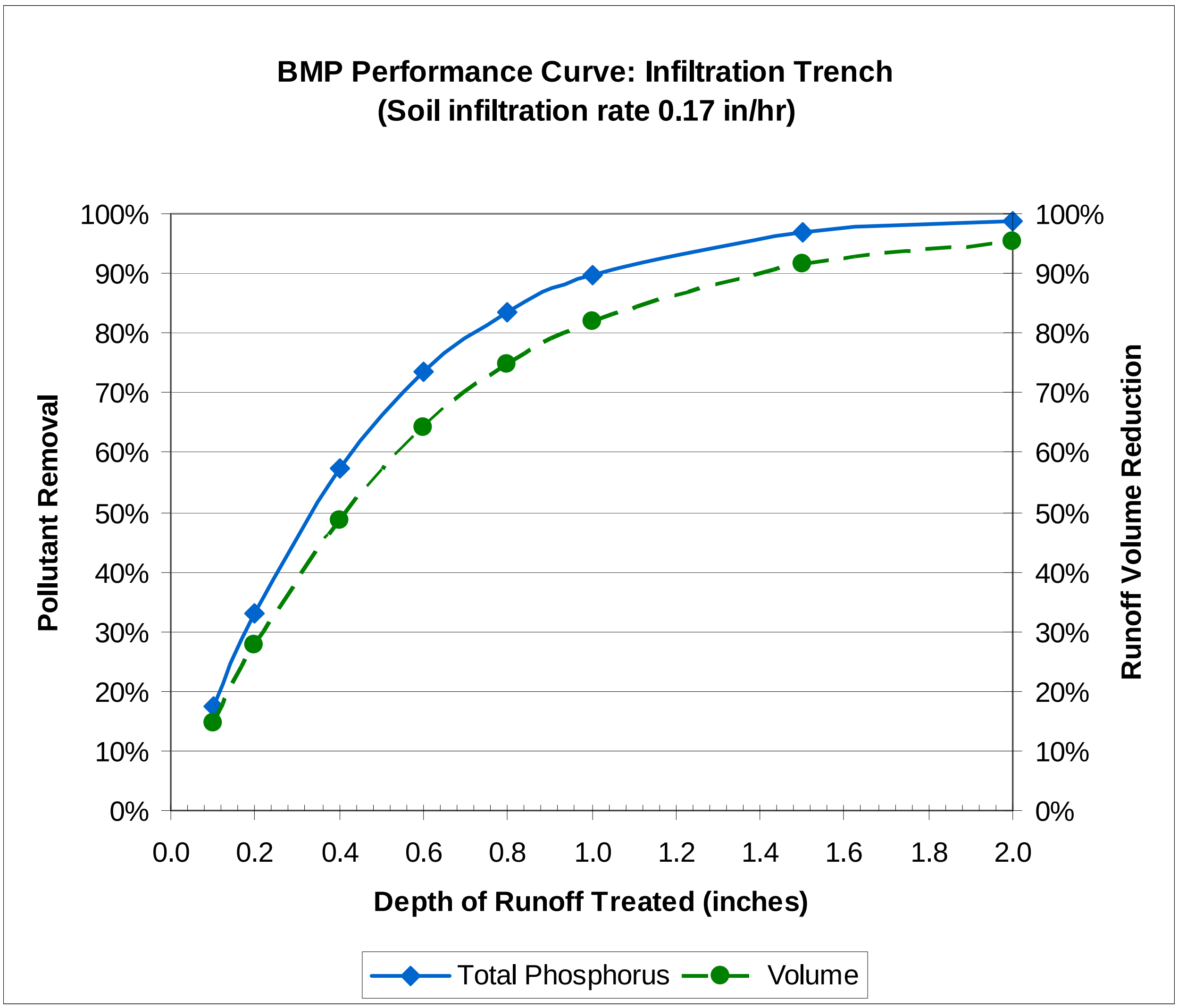


Table 3-2

Infiltration Trench (IR = 0.27 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	17.8%	32.5%	55.0%	70.0%	79.3%	85.2%	93.3%	96.3%
Cumulative Phosphorus Load Reduction	20%	37%	63%	78%	86%	92%	97%	99%

Figure 3-2

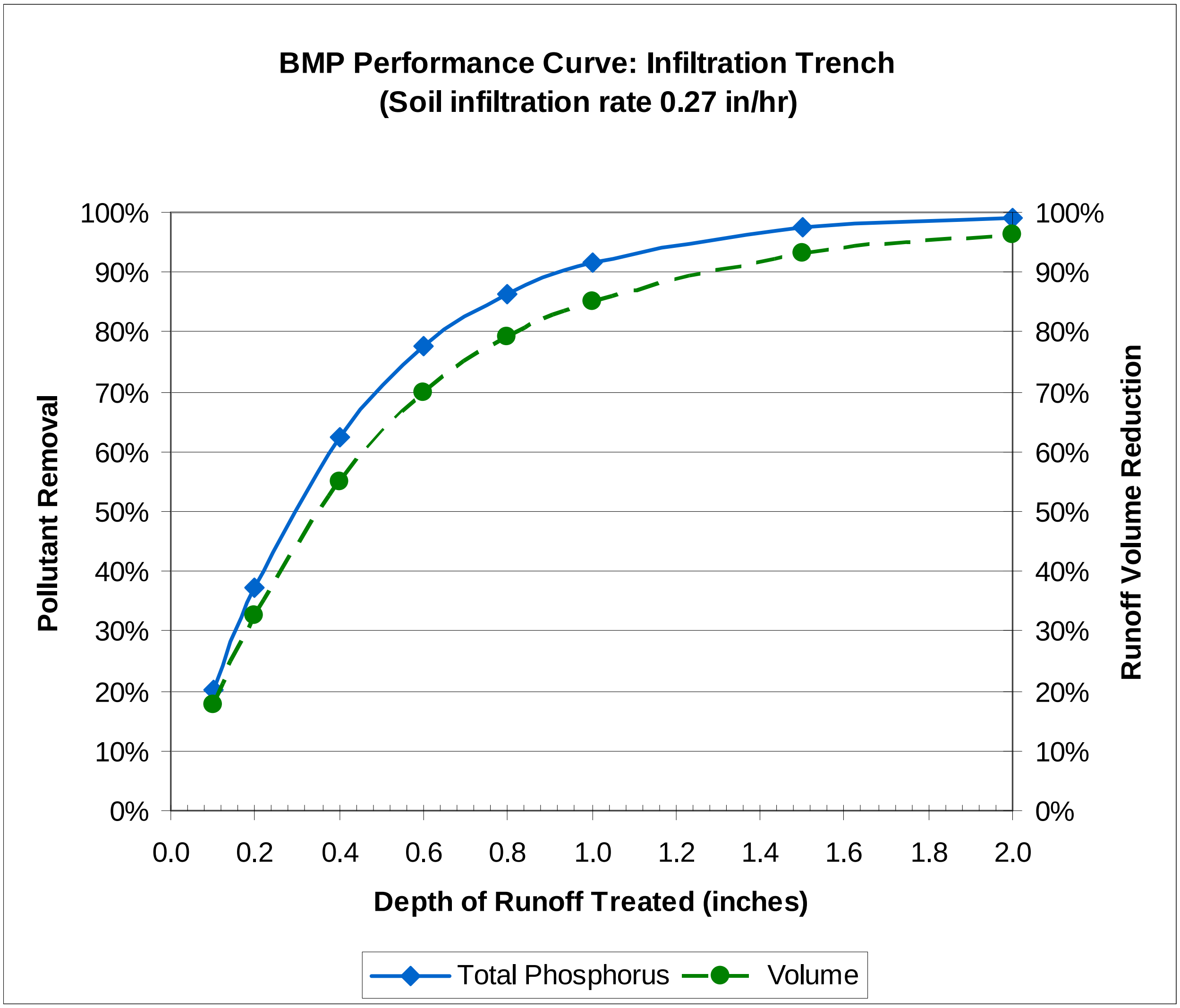


Table 3-3

Infiltration Trench (IR = 0.52 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	22.0%	38.5%	61.8%	75.7%	83.7%	88.8%	95.0%	97.2%
Cumulative Phosphorus Load Reduction	23%	42%	68%	82%	89%	94%	98%	99%

Figure 3-3

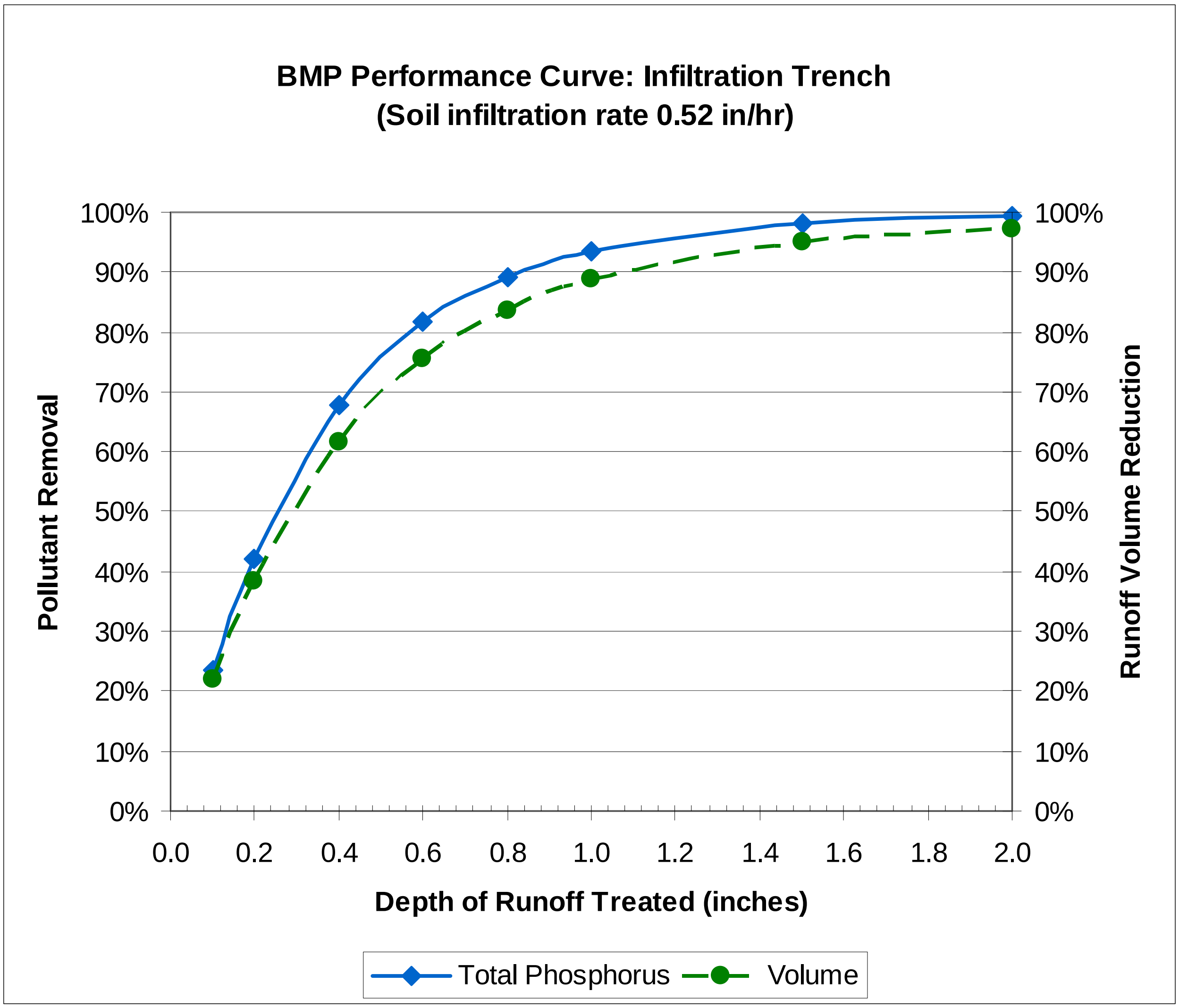


Table 3-4

Infiltration Trench (IR = 1.02 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	26.3%	44.6%	68.2%	81.0%	88.0%	92.1%	96.5%	98.3%
Cumulative Phosphorus Load Reduction	27%	47%	73%	86%	92%	96%	99%	100%

Figure 3-4

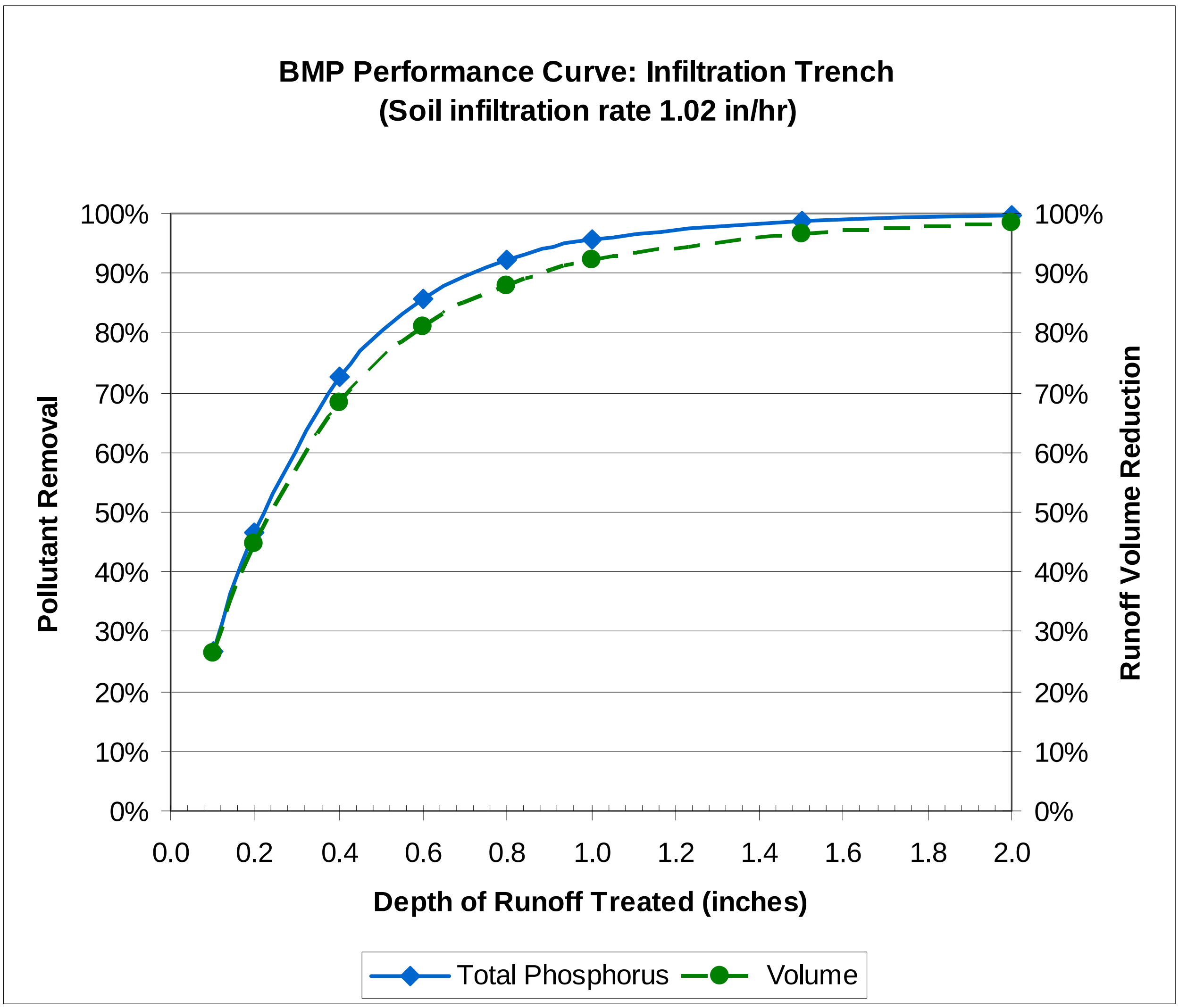


Table 3-5

Infiltration Trench (IR = 2.41 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	34.0%	54.7%	78.3%	88.4%	93.4%	96.0%	98.8%	99.8%
Cumulative Phosphorus Load Reduction	33%	55%	81%	91%	96%	98%	100%	100%

Figure 3-5

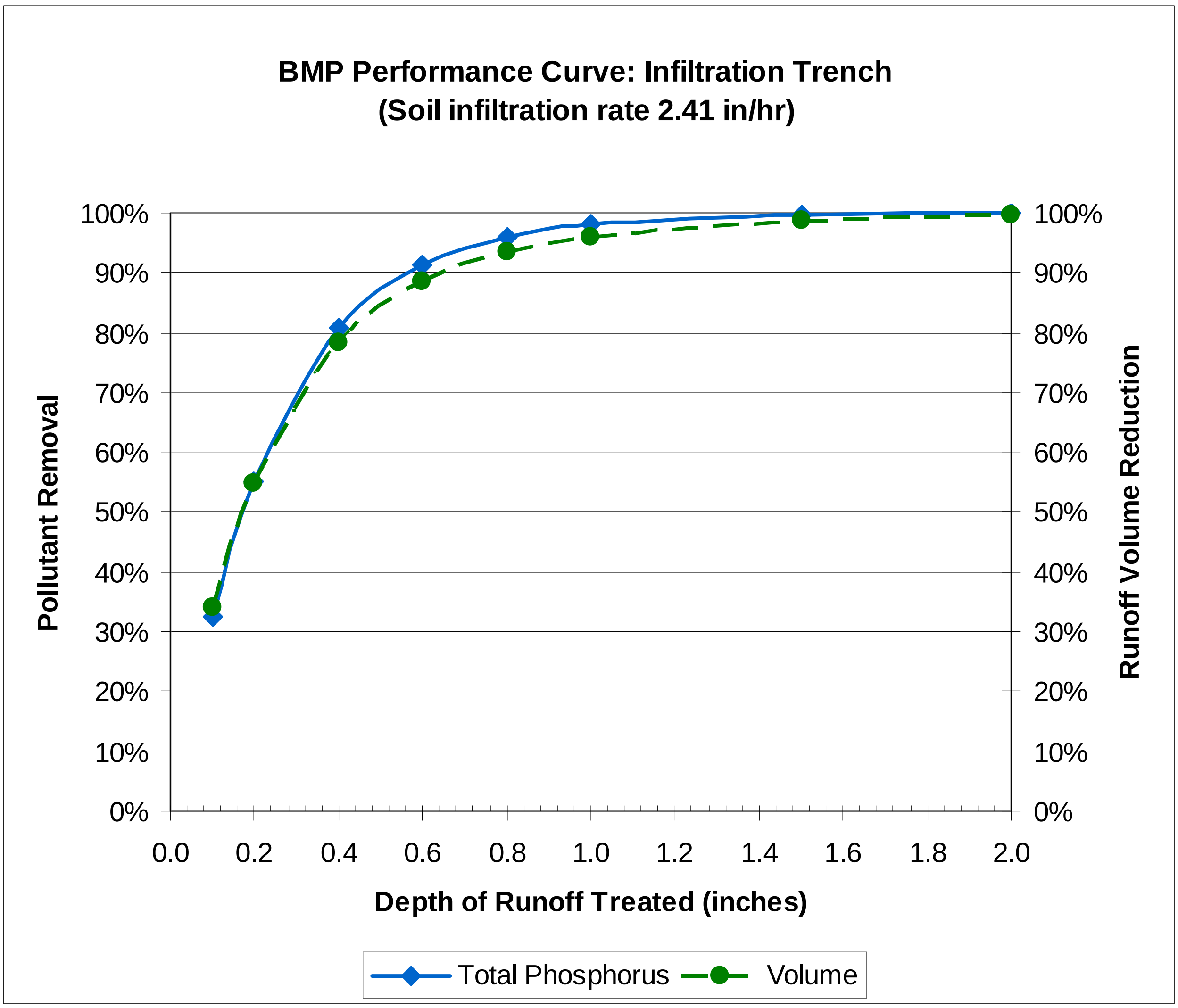


Table 3-6

Infiltration Trench (8.27 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	53.6%	76.1%	92.6%	97.2%	98.9%	99.5%	100.0%	100.0%
Cumulative Phosphorus Load Reduction	50%	75%	94%	98%	99%	100%	100%	100%

Figure 3-6

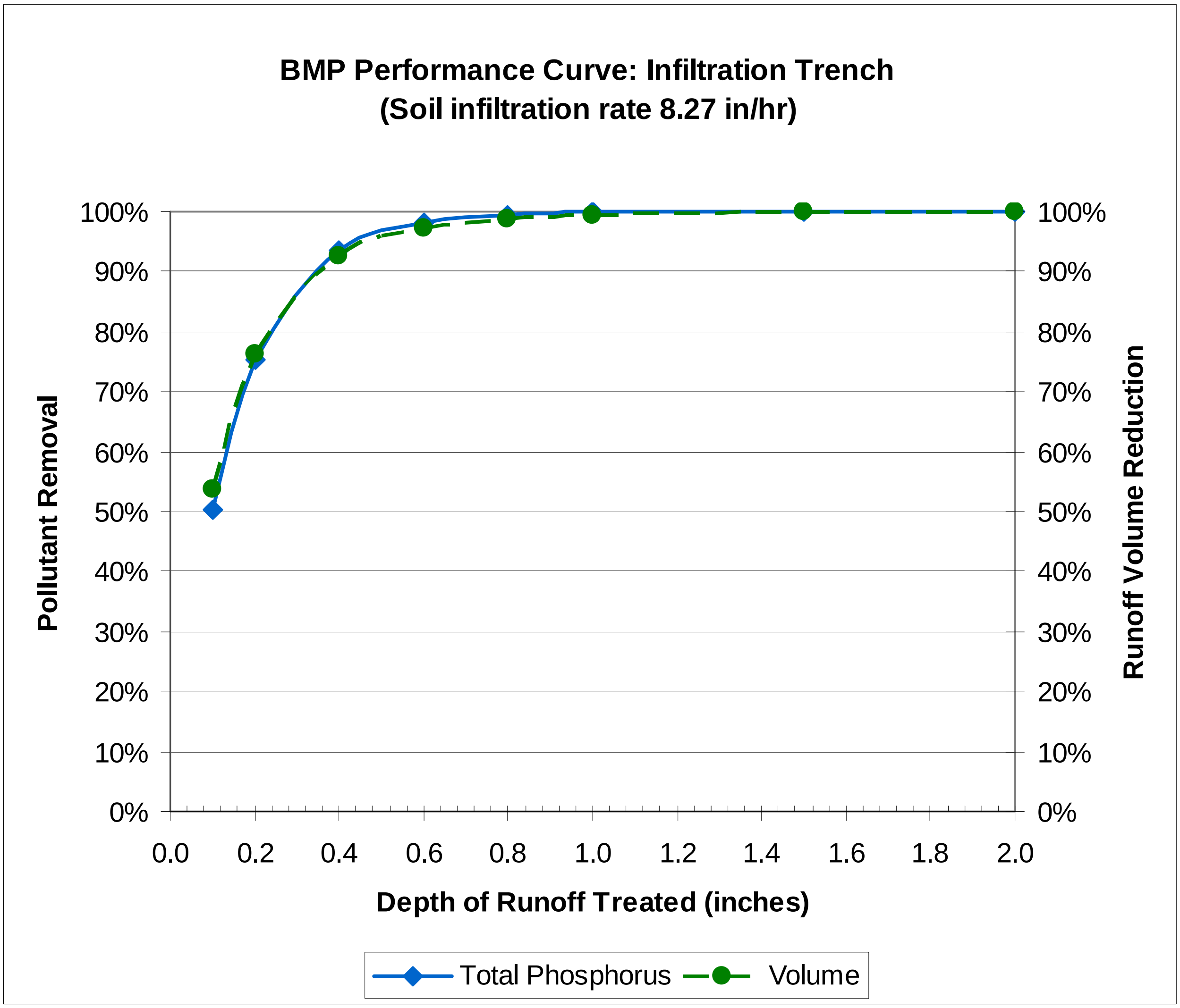


Table 3-7

Infiltration Basin (0.17 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	13.0%	24.6%	44.2%	59.5%	70.6%	78.1%	89.2%	93.9%
Cumulative Phosphorus Load Reduction	35%	52%	72%	82%	88%	92%	97%	99%

Figure 3-7

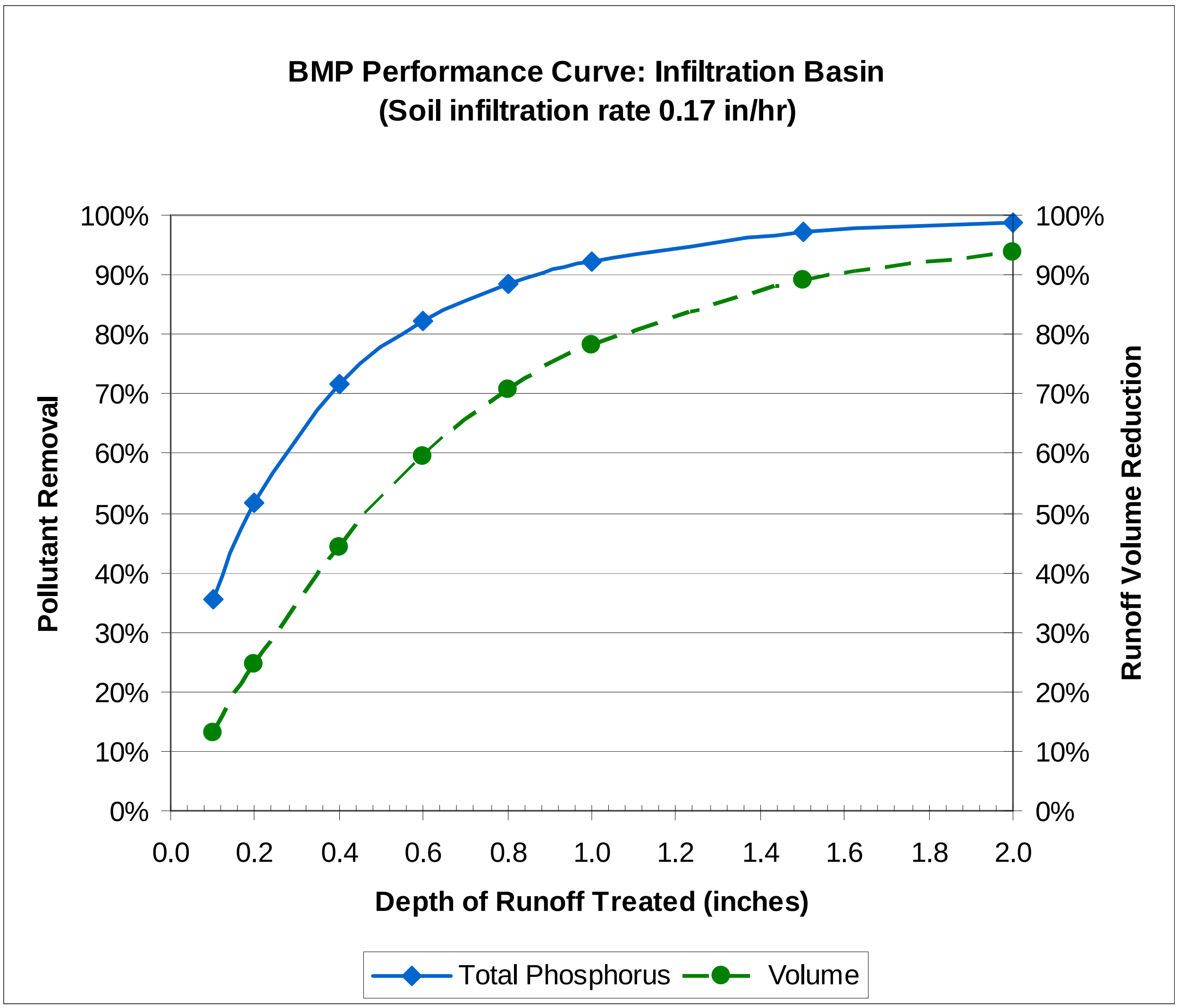


Table 3-8

Infiltration Basin (0.27 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	16.3%	29.8%	51.0%	66.0%	76.0%	82.4%	91.5%	95.2%
Cumulative Phosphorus Load Reduction	37%	54%	74%	85%	90%	93%	98%	99%

Figure 3-8

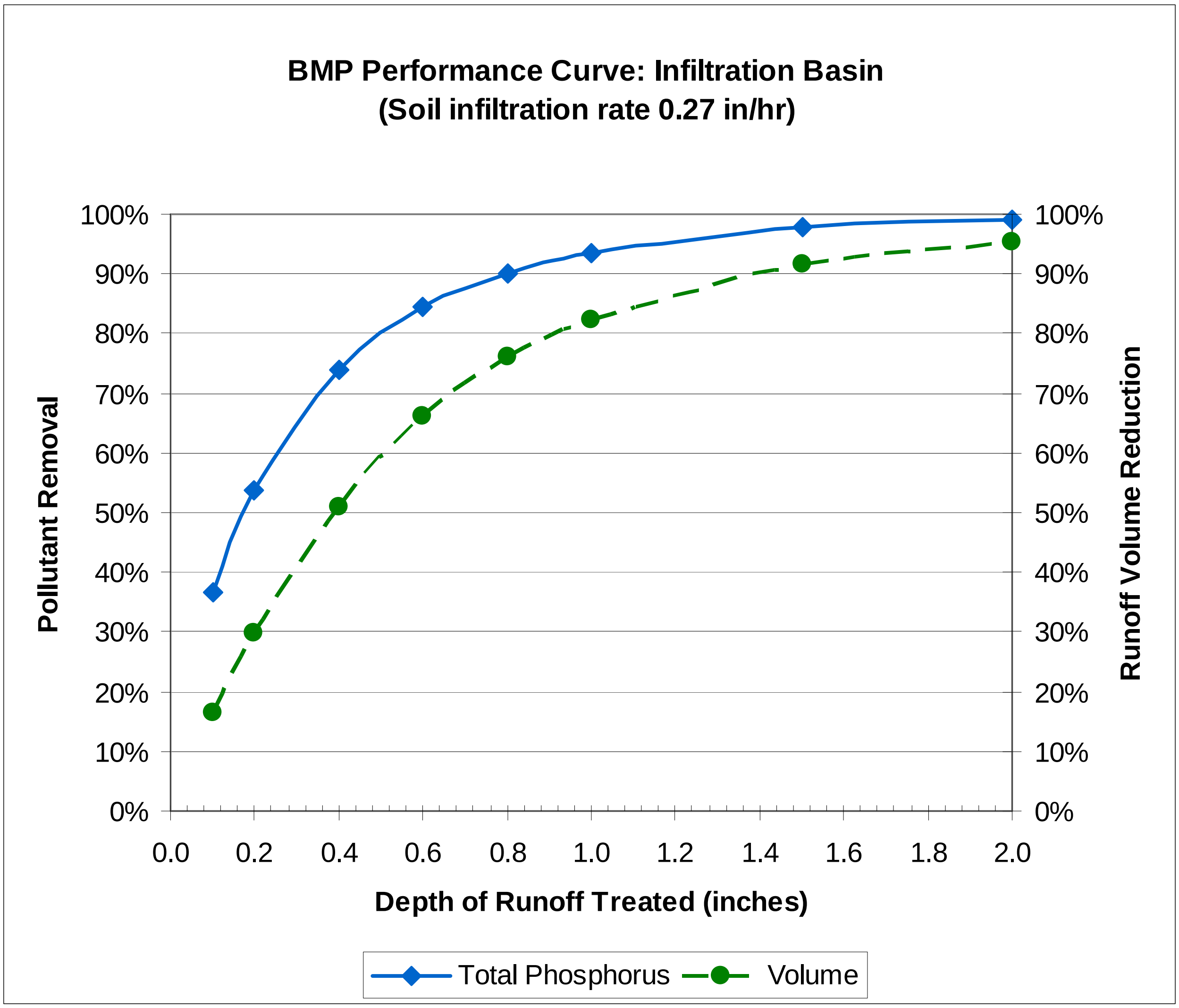


Table 3-9

Infiltration Basin (0.52 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	20.2%	35.6%	58.0%	72.6%	81.3%	86.9%	94.2%	96.7%
Cumulative Phosphorus Load Reduction	38%	56%	77%	87%	92%	95%	98%	99%

Figure 3-9

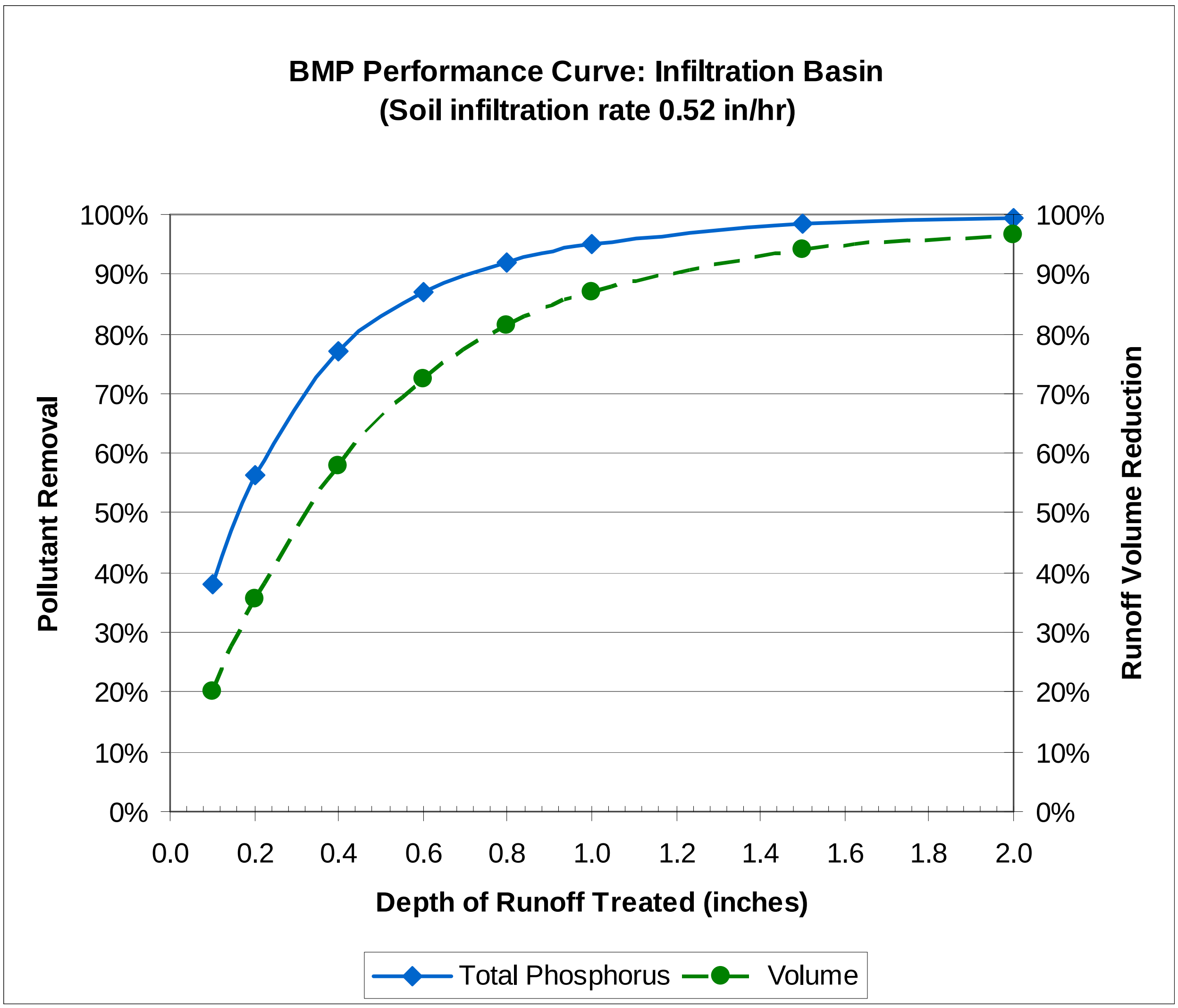


Table 3-10

Infiltration Basin (1.02 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	24.5%	42.0%	65.6%	79.4%	86.8%	91.3%	96.2%	98.1%
Cumulative Phosphorus Load Reduction	41%	60%	81%	90%	94%	97%	99%	100%

Figure 3-10

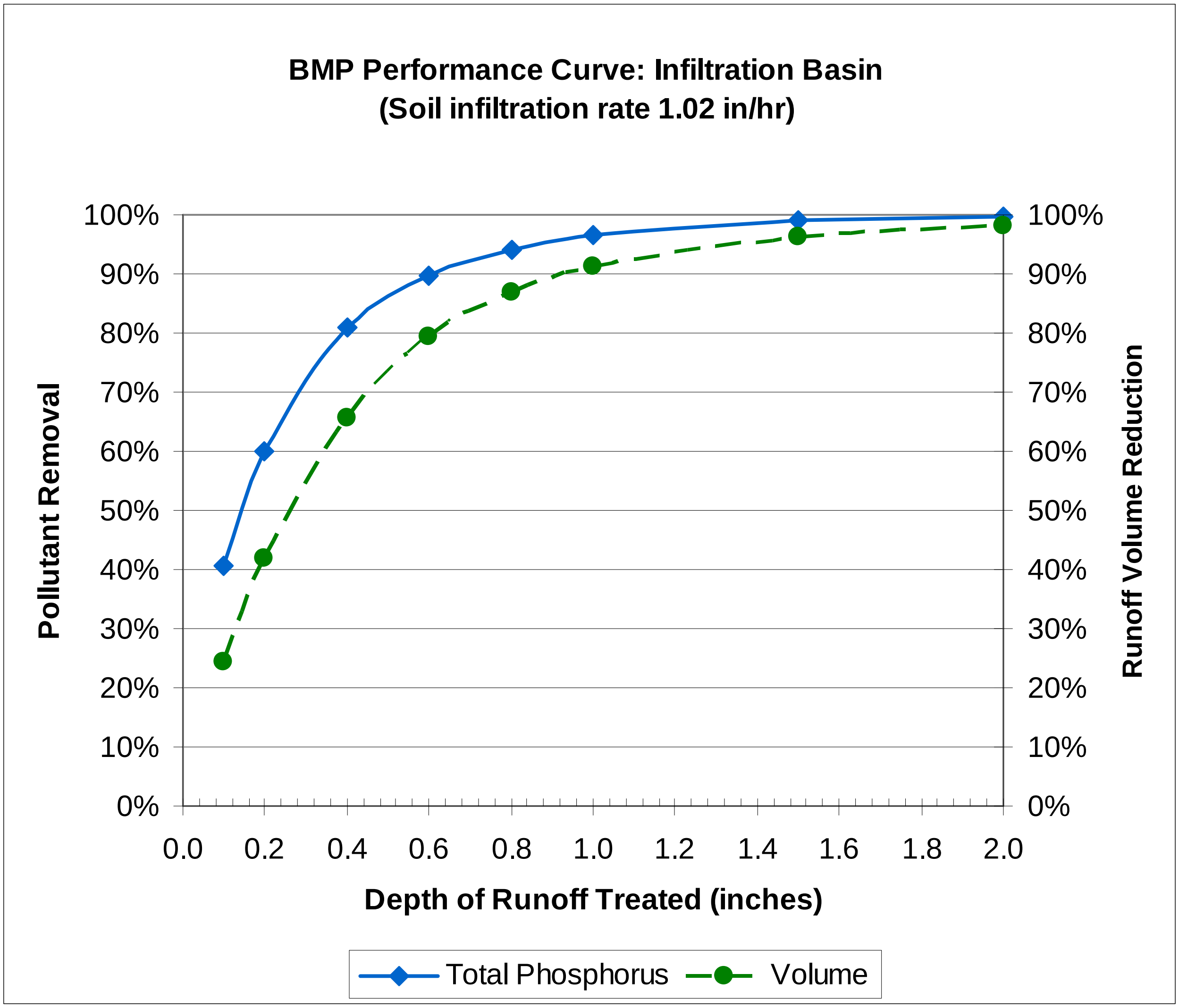


Table 3-11

Infiltration Basin (2.41 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	32.8%	53.8%	77.8%	88.4%	93.4%	96.0%	98.8%	99.8%
Cumulative Phosphorus Load Reduction	46%	67%	87%	94%	97%	98%	100%	100%

Figure 3-11

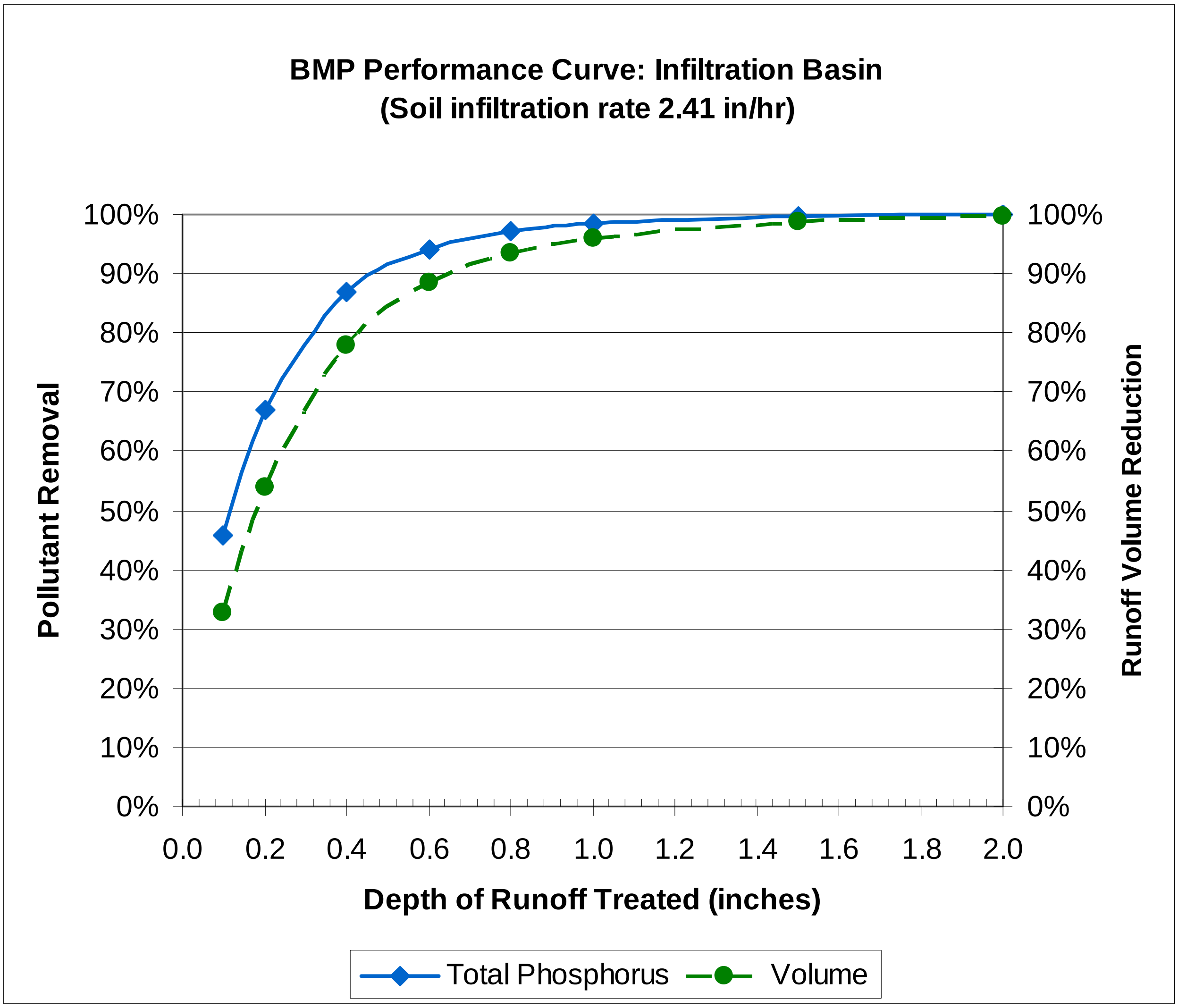


Table 3-12

Infiltration Basin (8.27 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Runoff Volume Reduction	54.6%	77.2%	93.4%	97.5%	99.0%	99.6%	100.0%	100.0%
Cumulative Phosphorus Load Reduction	59%	81%	96%	99%	100%	100%	100%	100%

Figure 3-12

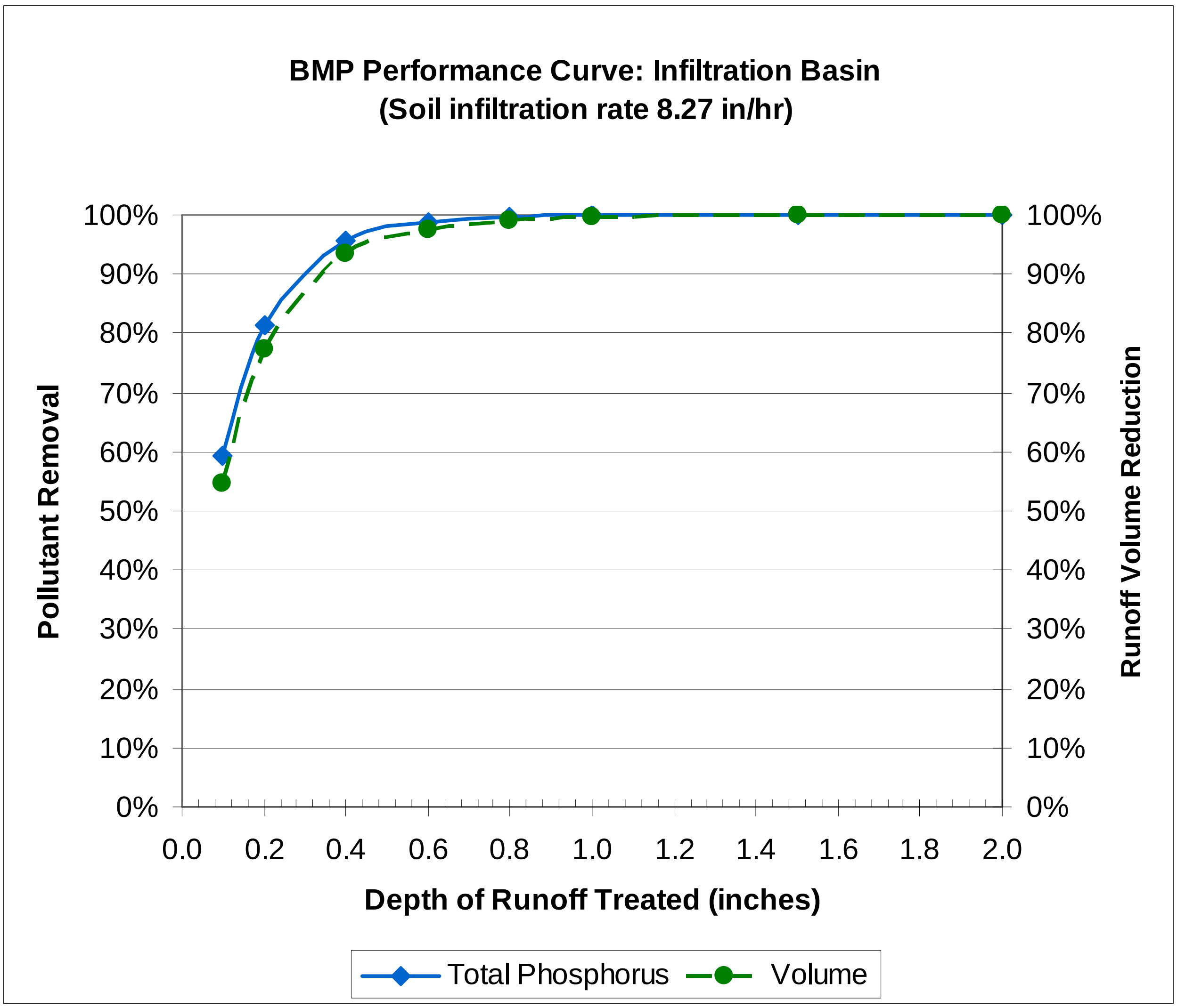


Table 3-13

Bioretention BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Cumulative Phosphorus Load Reduction	19%	34%	53%	64%	71%	76%	84%	89%

Figure 3-13

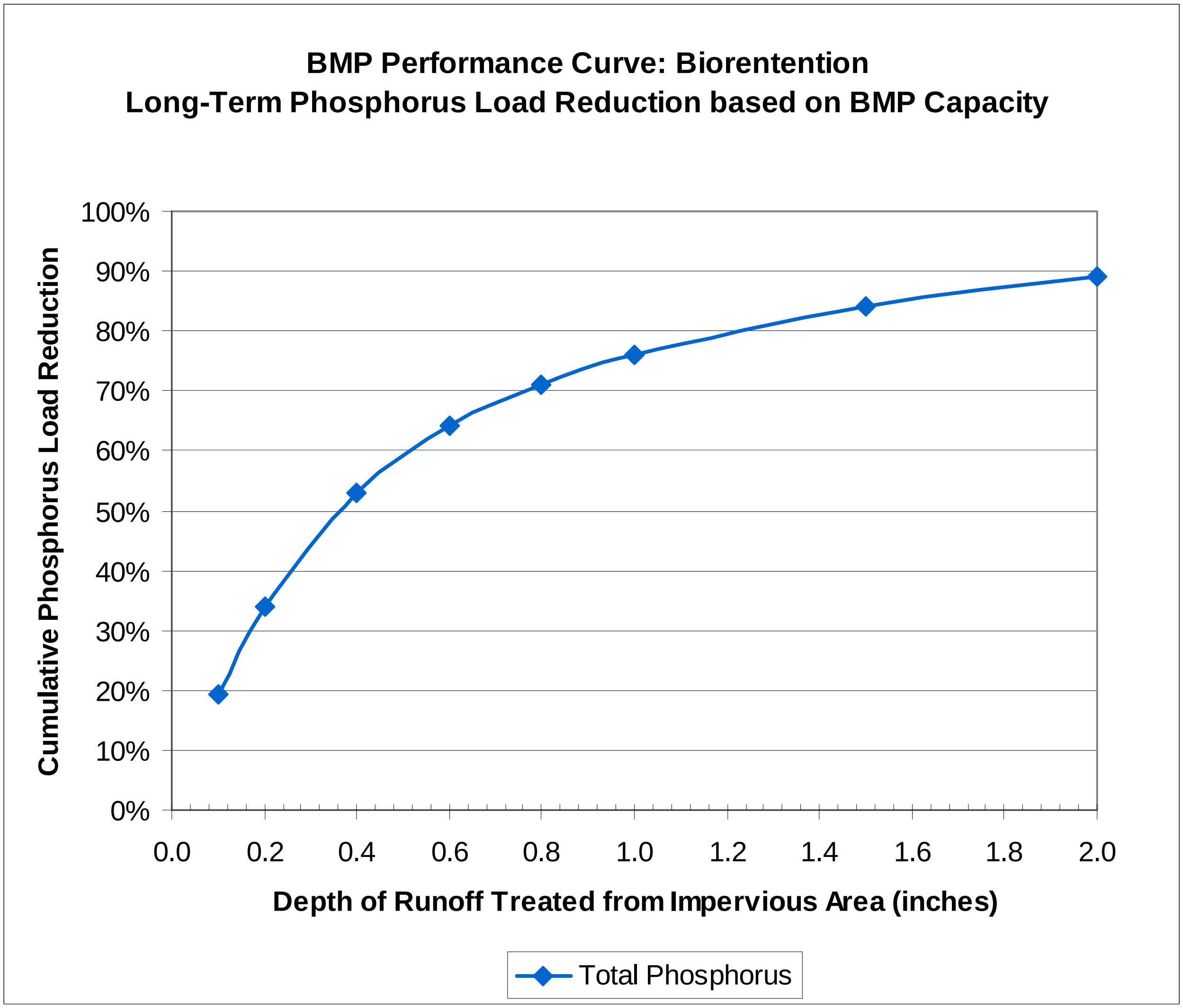


Table 3-14

Gravel Wetland BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Cumulative Phosphorus Load Reduction	19%	26%	41%	51%	57%	61%	65%	66%

Figure 3-14

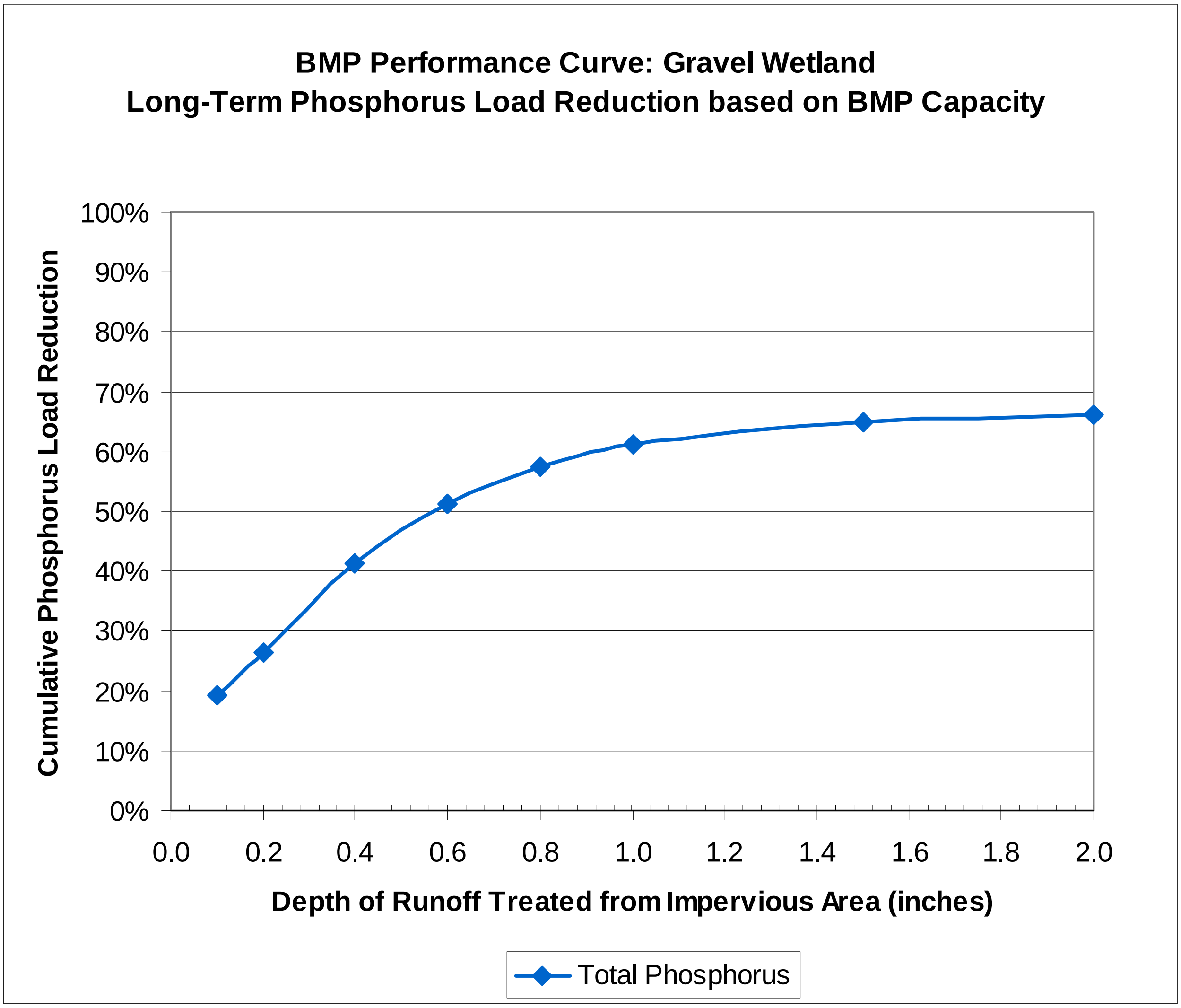


Table 3-15

Porous Pavement BMP Performance Table: Long-Term Phosphorus Load Reduction				
BMP Capacity: Depth of Filter Course Area (inches)	12.0	18.0	24.0	32.0
Cumulative Phosphorus Load Reduction	62%	70%	75%	78%

Figure 3-15

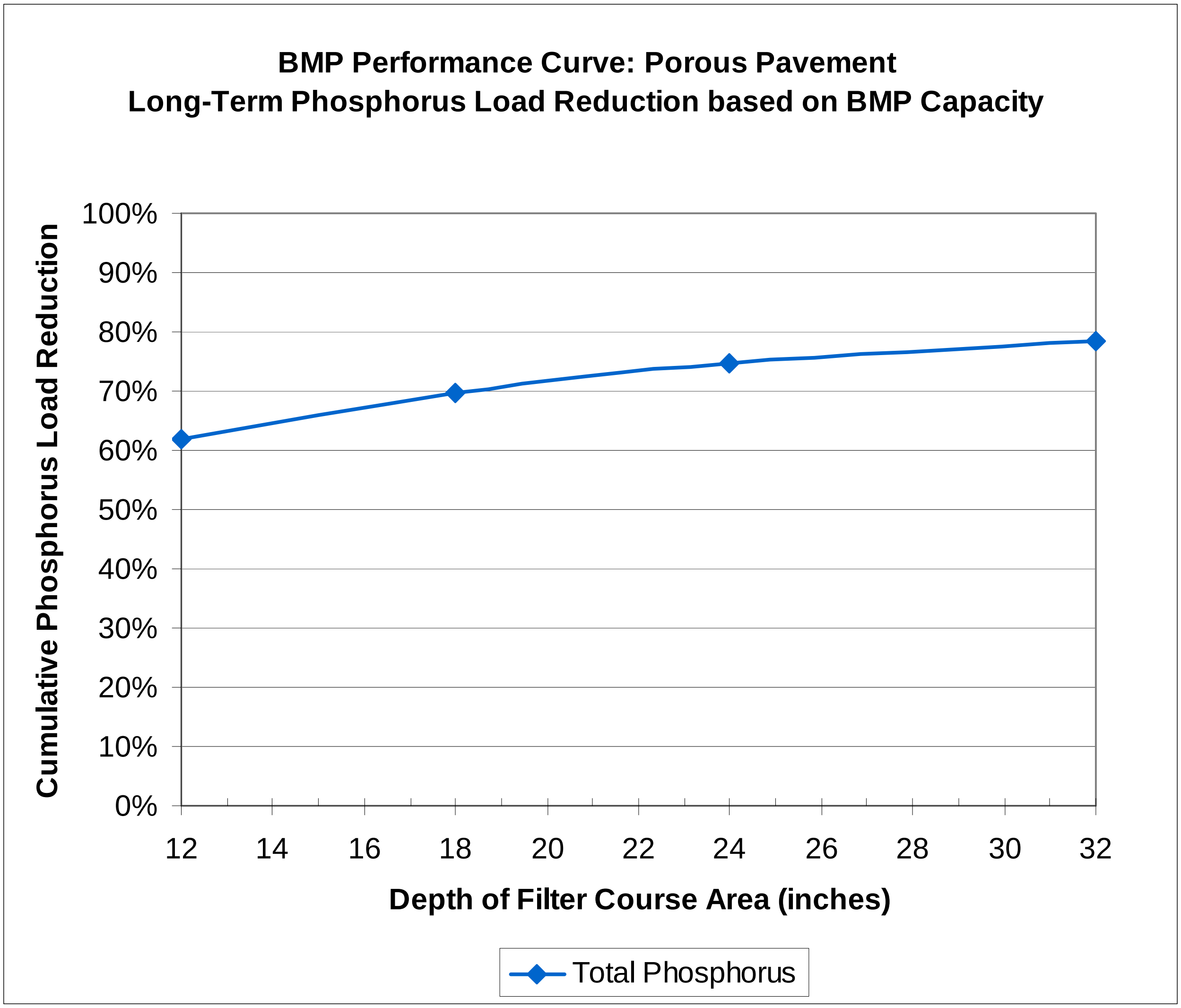


Table 3-16

Wet Pond BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Cumulative Phosphorus Load Reduction	2%	4%	8%	11%	15%	18%	24%	30%

Figure 3-16

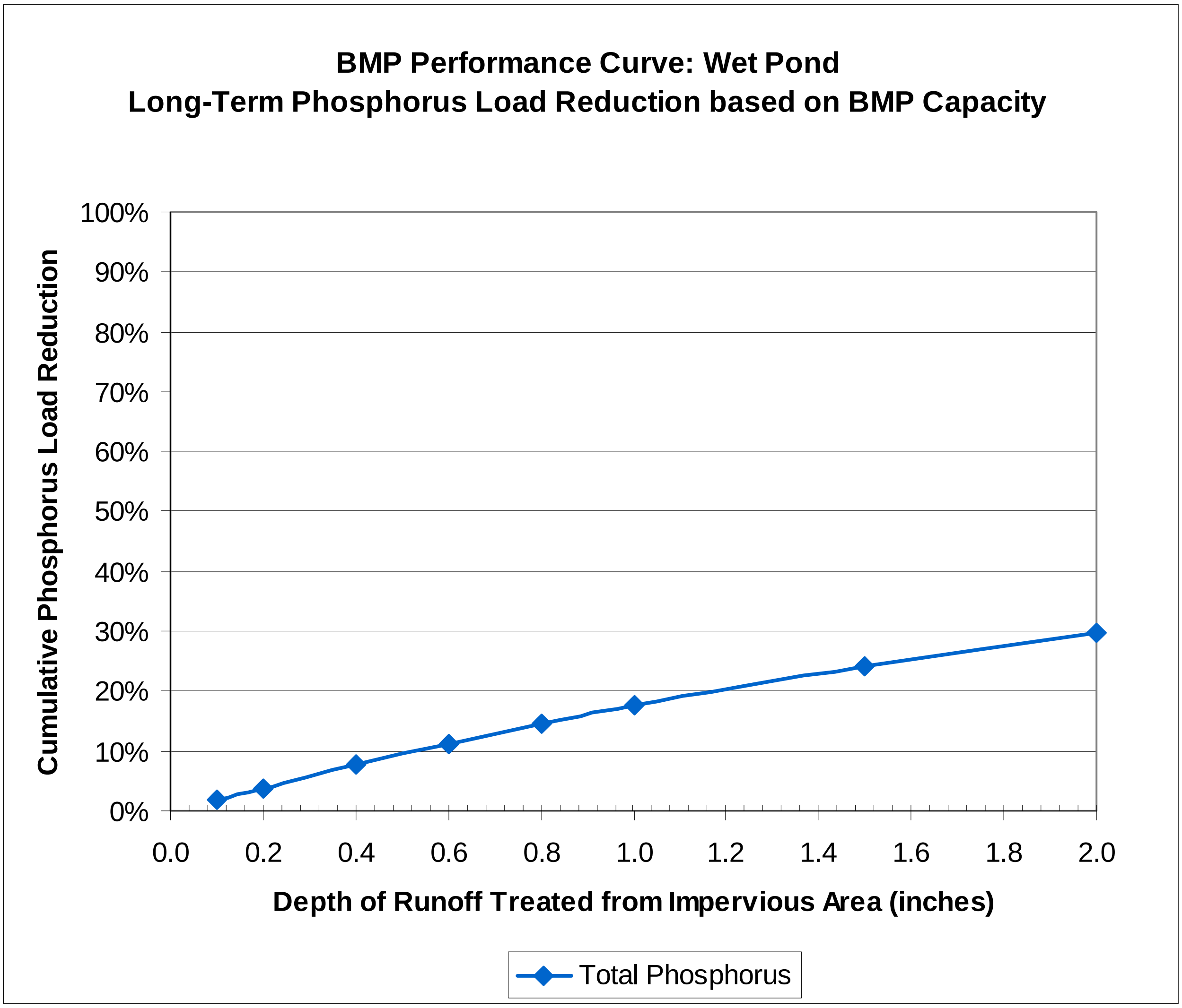


Table 3-17

Dry Pond BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Cumulative Phosphorus Load Reduction	3%	6%	8%	9%	11%	12%	13%	14%

Figure 3-17

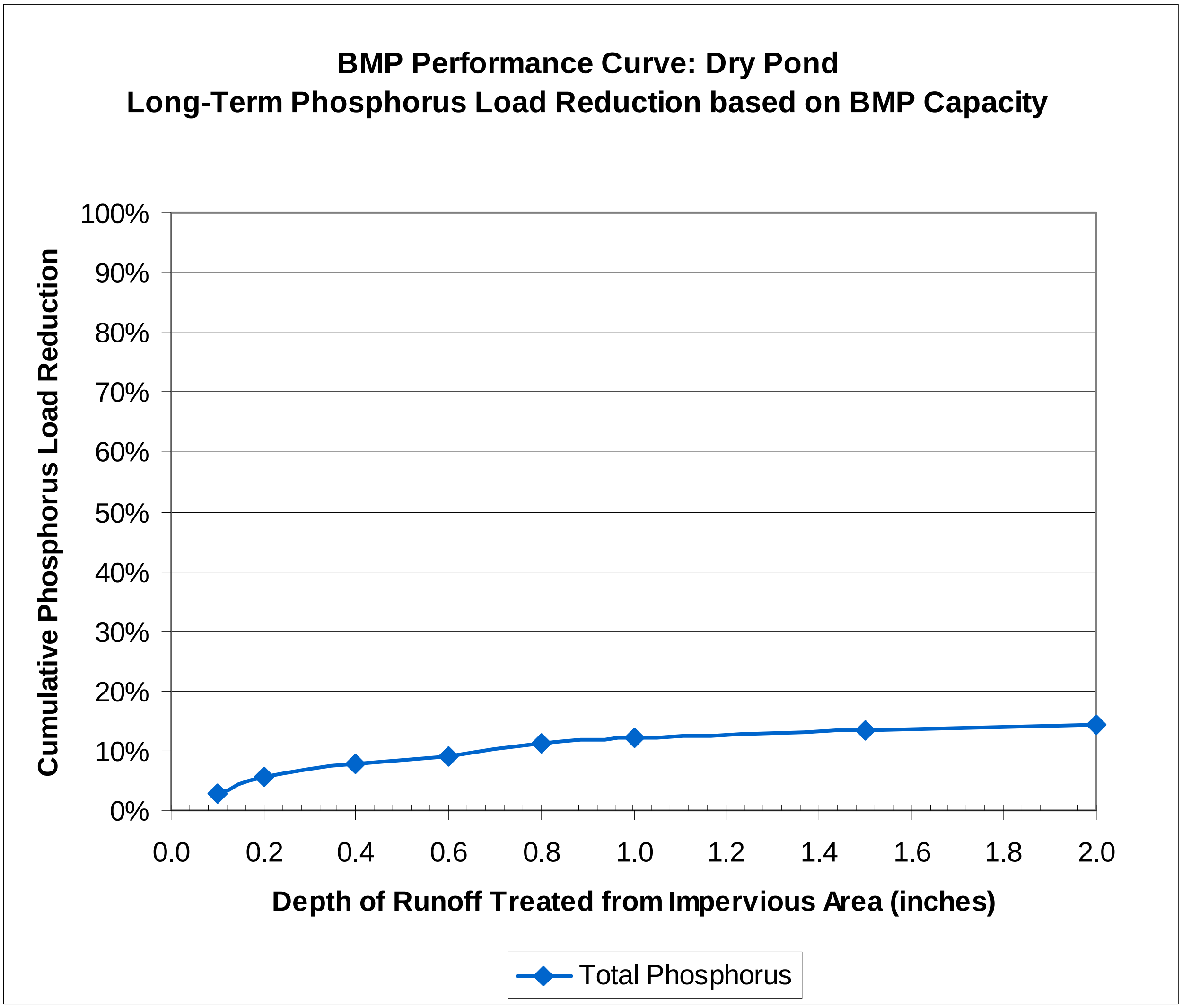


Table 3-18

Grass Swale BMP Performance Table: Long-Term Phosphorus Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1.0	1.5	2.0
Cumulative Phosphorus Load Reduction	2%	5%	9%	13%	17%	21%	29%	36%

Figure 3-18