Calculating Ohio's Water Quality Volume

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Ohio Stormwater Conference
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Ohio Environmental Protection Agency

“For construction activities disturbing 2 or more acres, the post construction BMP(s) chosen shall be able to manage storm water runoff for protection of stream channels, stream stability, and water quality.

The BMPs chosen must be sized to treat the Water Quality Volume (WQv) and ensure compliance with Ohio’s Water Quality Standards.”

General Permit Authorization for Storm Water Discharges Associated with Construction Activity Under The NPDES. OHC00005, Effective 4/22/2018

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Water Quality Volume (WQv)

A melding of concepts:

- Capturing smaller storms captures the majority of annual precipitation volume[1].
- Drawdown time balances treatment time and readiness[2].
- TSS as a surrogate.[3]
- 80% TSS removal treatment goal.[4]
- Stream morphology.

1 WEF/ASCE. Design of Urban Stormwater Controls. (2012)
2 Wef/ASCE. Urban Runoff Quality Management. (1998); Urbonas, B., Guo, J. and Tucker, L. Sizing a Capture Volume for stormwater Quality Enhancement. (1989)
3 USEPA. The Use of BMPs in Urban Watersheds. (2004); Rushton, B. BMP Monitoring: Methods & Evaluations. SW Florida Water Management District (undated); James, R. Solids in Storm Water Runoff. (1999)
4 NOAA. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, Ch 4, Management Measures for Urban Areas. 1993.

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Water Quality Volume (WQv)

Ohio's Approach:

Mandates standard BMPs assumed capable of ~90% efficiency that capture 90% of the annual runoff volume resulting in 80% TSS removal on an annual basis.

– NOT flood control

– NOT a "first flush"

– NOT a statistical or percentile event

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Water Quality Volume (WQv)

$$WQv = P_{wq} \times Rv \times A \div 12$$

WQv = water quality volume (ac-ft)

P_{wq} = 0.90 inches

Rv = volumetric runoff coefficient

A = disturbed <u>or</u> contributing drainage area (acres)

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Runoff Coefficient

$$R_v = 0.05 + 0.9(i)$$

- i = fraction impervious (impervious area ÷ total area)
- Linear relationship w/ impervious area
  - Fully pervious area represented as 0.05
  - Fully impervious area represented as 0.95
- Volumetric, not influenced by conditions such as intensity
  - Similar but not same as rational method coefficient “C”

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Sample Calculation

NEW CONSTRUCTION

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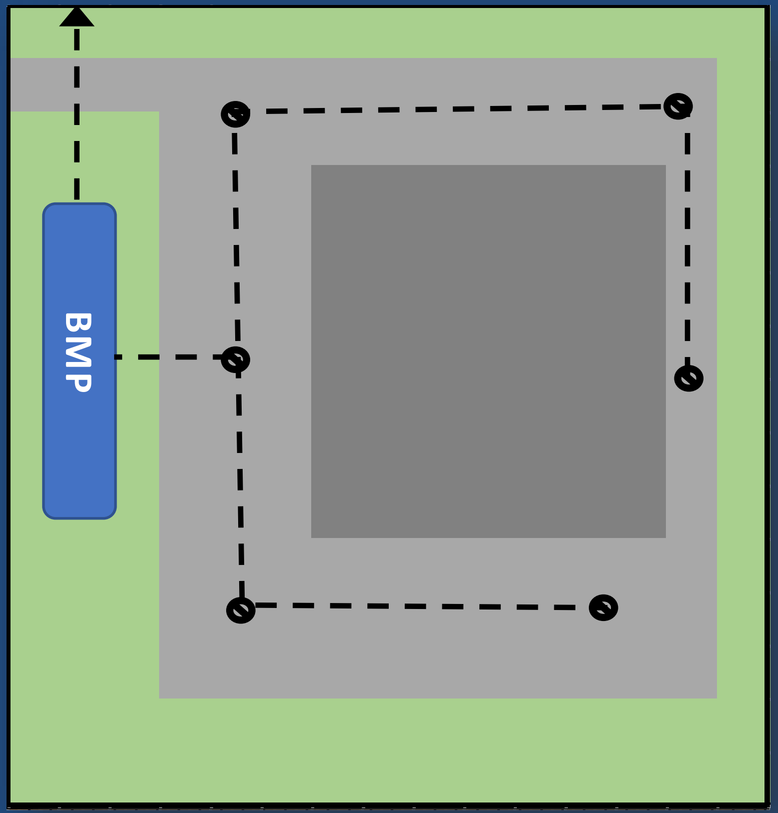
Example Site

Total site area:	2.25 acres
Total disturbed area:	2.25 acres
Planned impervious area:	1.35 acres



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WQv Required

$$WQv = P_{wq} \times Rv \times A_{disturbed} \div 12$$

$$Rv = 0.05 + 0.9(i)$$

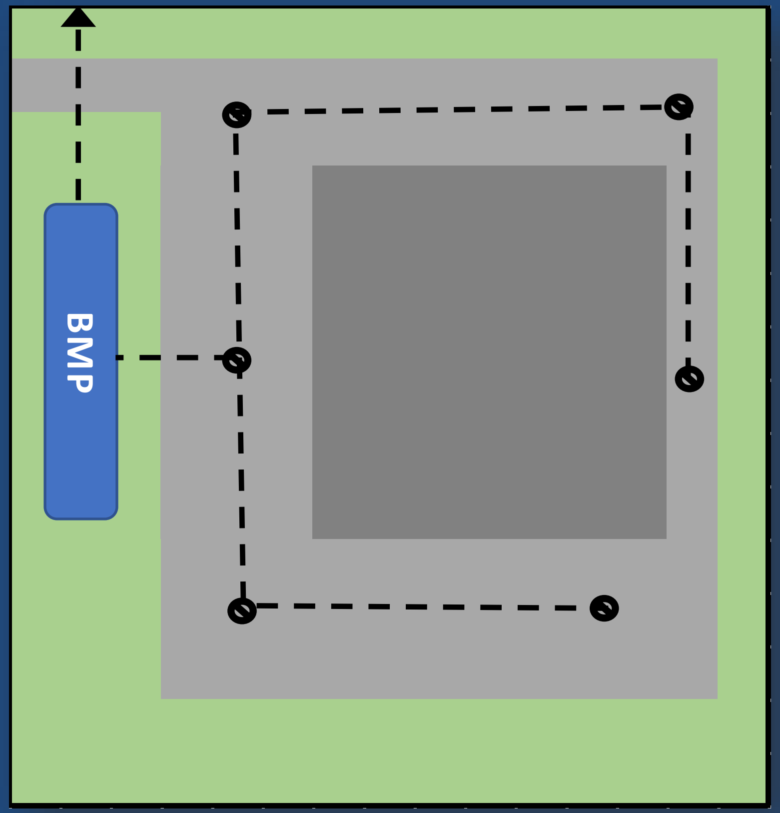
Where:

i = 1.35 ac ÷ 2.25 ac = 0.60 (60%)

Rv = 0.05 + 0.9(0.60) = 0.59

P_{wq} = 0.90 in

A = 2.25 ac



WQv (required) = 0.100 ac-ft (4,337 ft^3)

All WQv's will be shown in cubic feet

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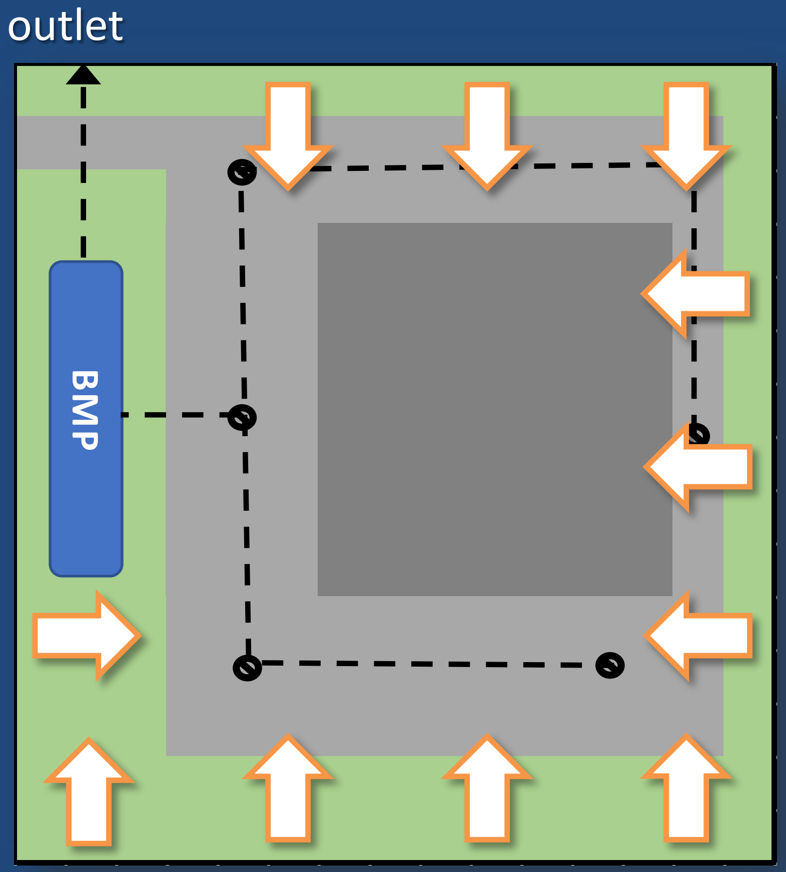
WQv Design

The site is required to treat 4,337 ft^3 with post-construction BMPs; however each post-construction BMP must be designed to treat 100% of the WQv for its contributing area.

The full 2.25 acre disturbance is graded toward a single post-construction BMP. In this case, the disturbed area and BMP drainage area are both 2.25 acres with Rv = 0.59:

$$\text{WQv (design)} = \text{WQv (required)} = 4{,}337 \text{ ft}^3$$



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Sample Calculation

DRAINAGE AREA EXCEEDS DISTURBANCE

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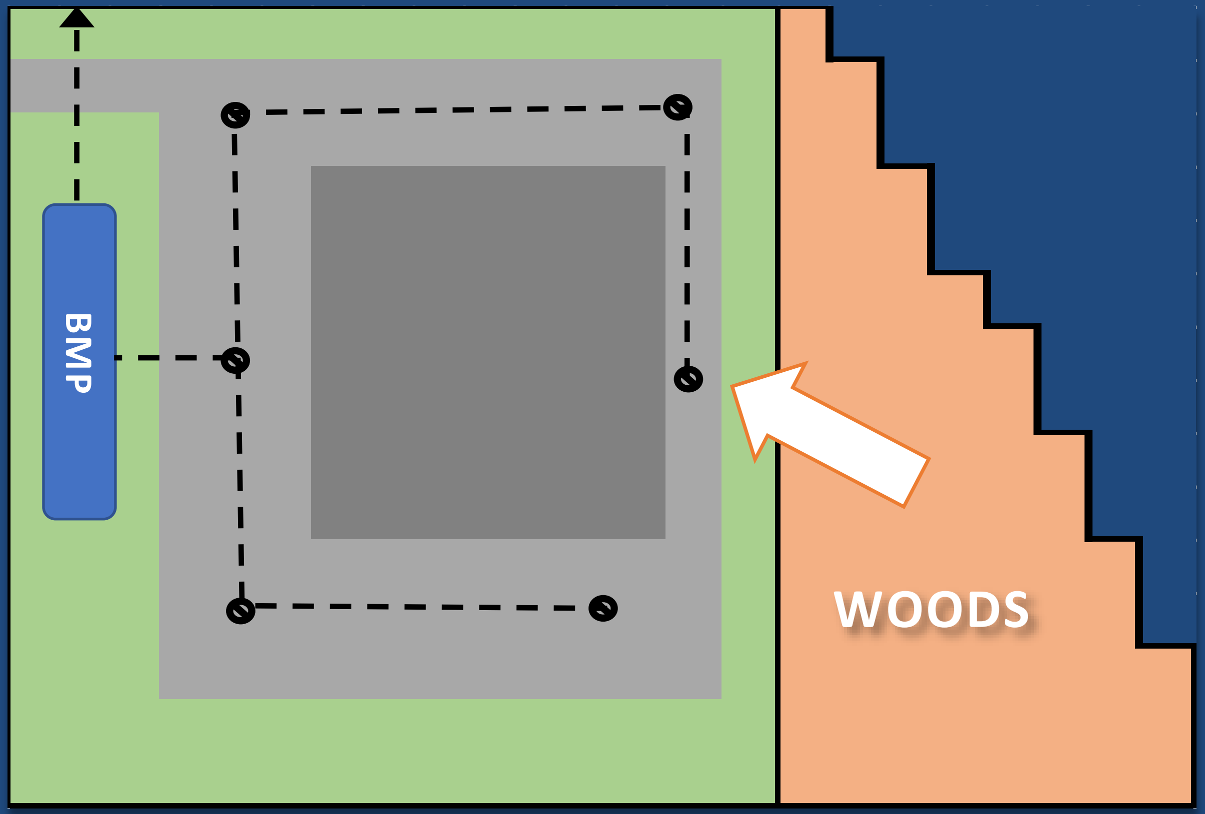
Offsite Run-on

An additional 0.75 acres runs onto the site from beyond the disturbance, draining to the post-construction BMP.

Unless diverted, the BMP design WQv must include this contributing drainage area.



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Offsite Run-on

$$Rv = 0.05 + 0.9(i)$$

i = 1.35 ac ÷ 3.00 ac = 0.45 (45%)

Rv = 0.05 + 0.9(0.45) = 0.455

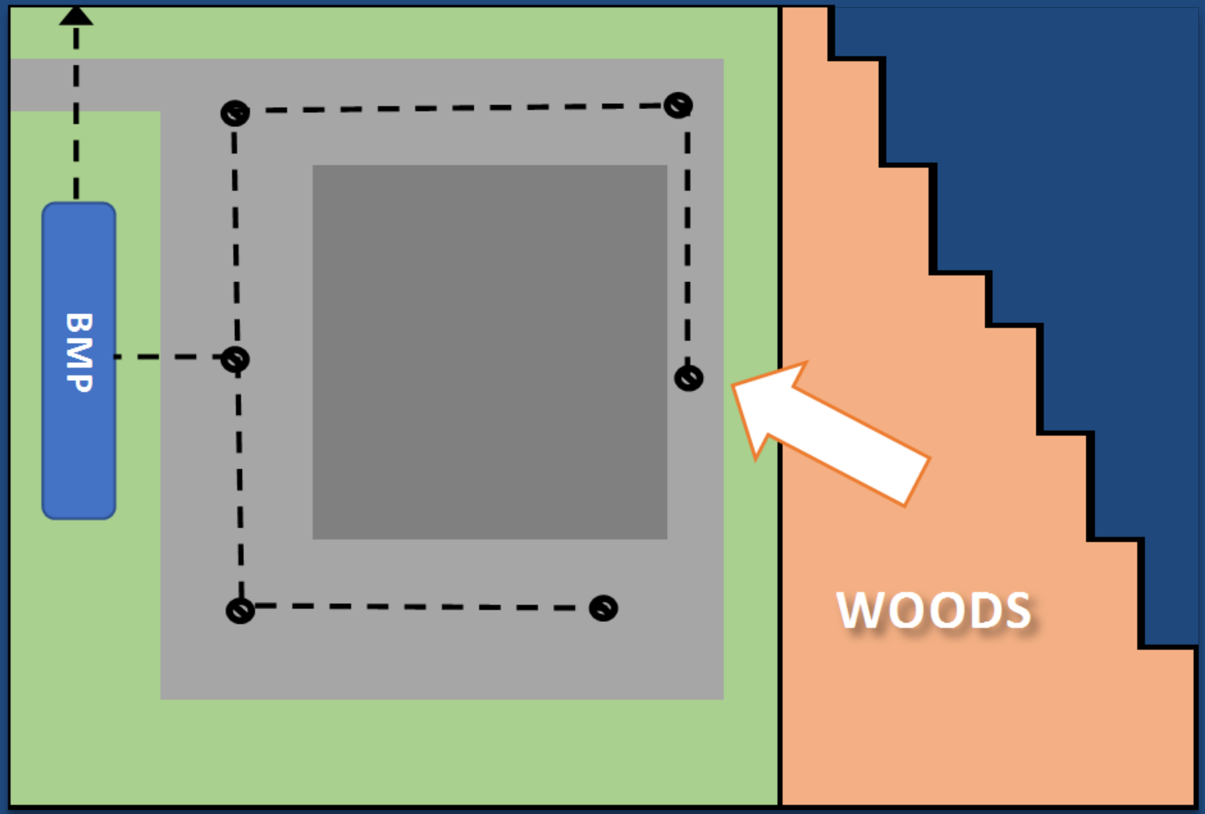
$$WQv = P_{wq} \times Rv \times A_{drained} \div 12$$

Where:

P_{wq} = 0.90 in

Rv = 0.455

A = 3.00 ac



WQv (design) = 4,460 ft^3

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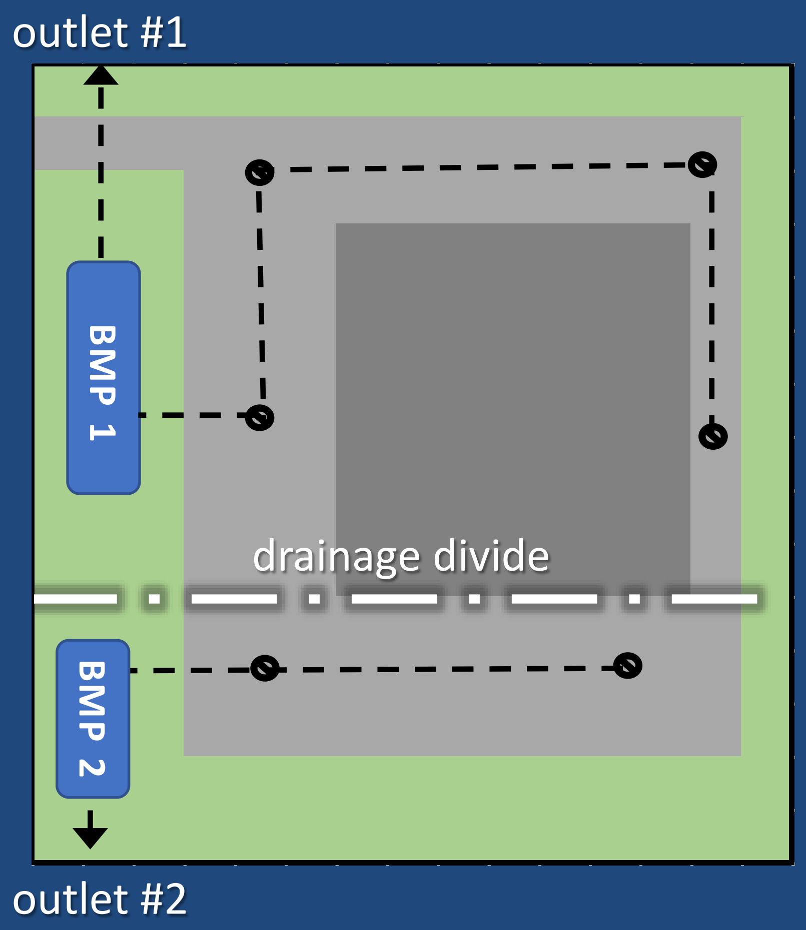
Sample Calculation

MULTIPLE DRAINAGE AREAS

Multiple Drainage Areas

If the disturbed area contains separate drainage areas, each must have a post construction BMP sized to its contributing drainage area.



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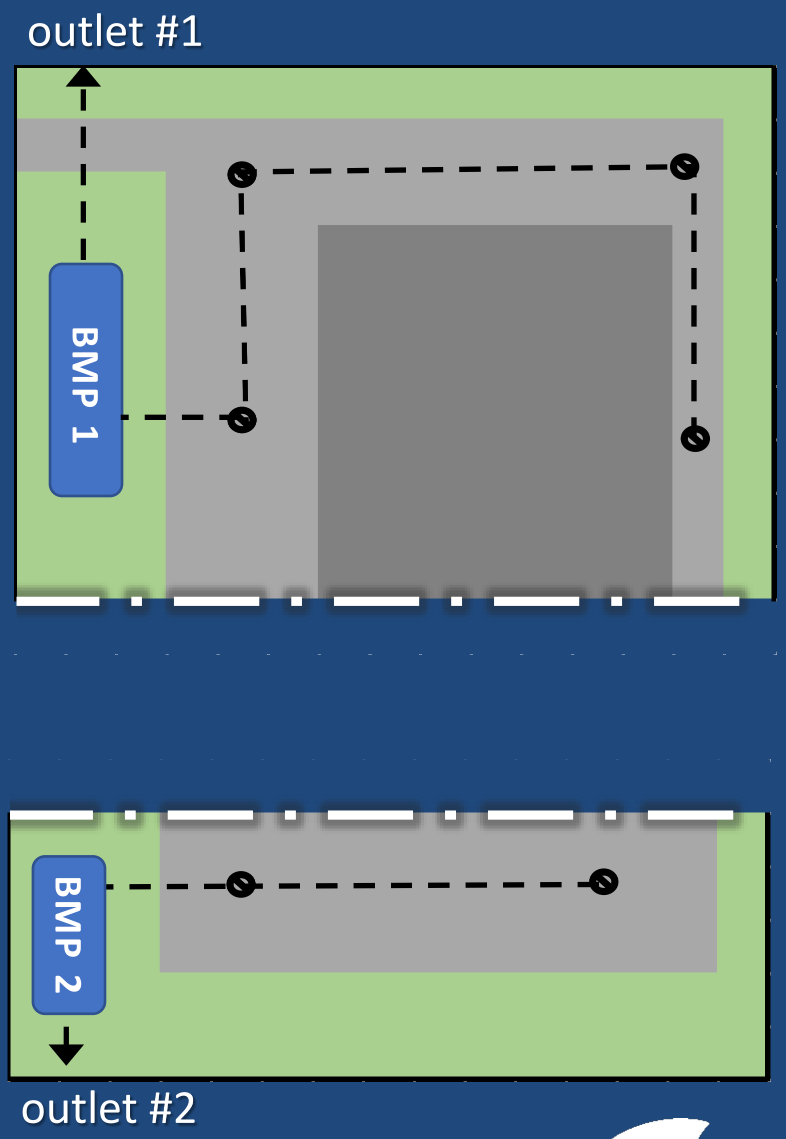
Multiple Drainage Areas



Drainage Area #1

Total area: 1.50 ac

Impervious: 68%

$Rv = 0.05 + 0.9(0.68) = 0.662$

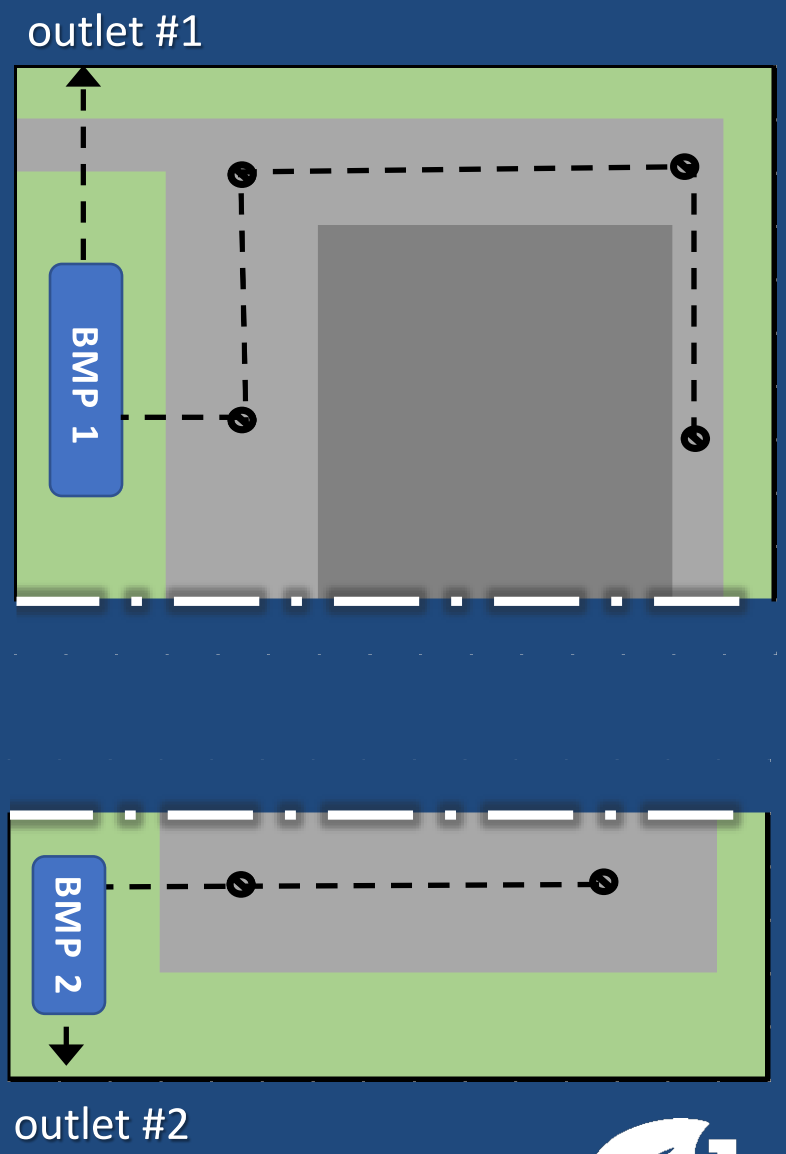
Drainage Area #2

Total area: 0.75 ac

Impervious: 44%

$Rv = 0.05 + 0.9(0.44) = 0.446$

Multiple Drainage Areas



Drainage Area #1

WQv = 0.90 in x 0.662 x 1.50 ac ÷ 12

WQv (design) = 3,244 ft^3

Drainage Area #2

WQv = 0.90 in x 0.446 x 0.75 ac ÷ 12

WQv (design) = 1,093 ft^3

WQv (design) = 3,244 + 1,093 = 4,337 ft^3

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Previously Developed Areas

The WQv for previously developed areas is met by:

1. Reducing the site Rv at least 20%, or
2. A combination of reduced impervious area and a post-construction BMP.
    1. The WQv is calculated with a weighted Rv to account for the change in impervious area.

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Previously Developed Areas

$$\mathbf{WQv} = [(\mathbf{0.2} \times \mathbf{Rv_1}) + (\mathbf{Rv_2} - \mathbf{Rv_1})] \times \mathbf{P_{wq}} \times \mathbf{A_{dist}}$$

Where:

Rv_1 = Pre-development runoff coefficient

Rv_2 = Post-development runoff coefficient

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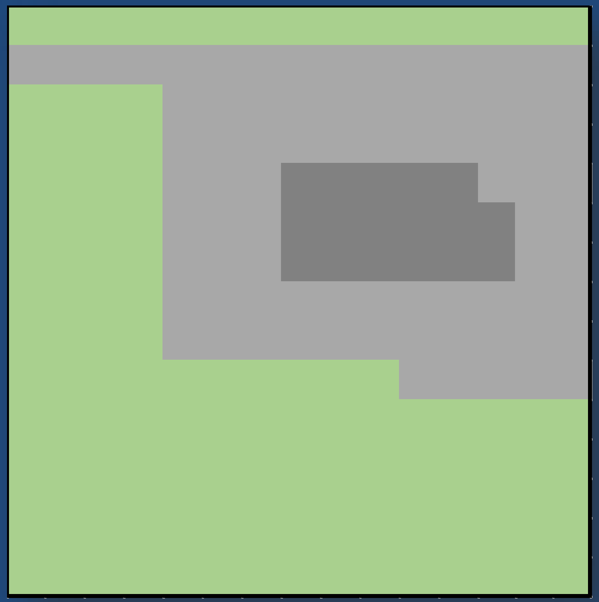
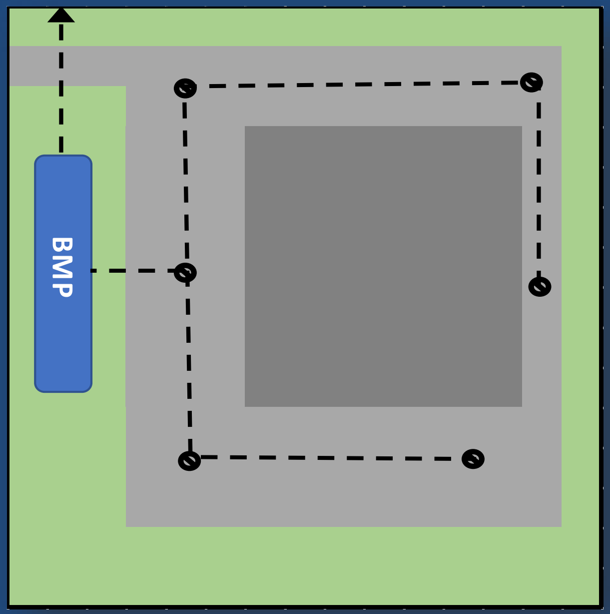
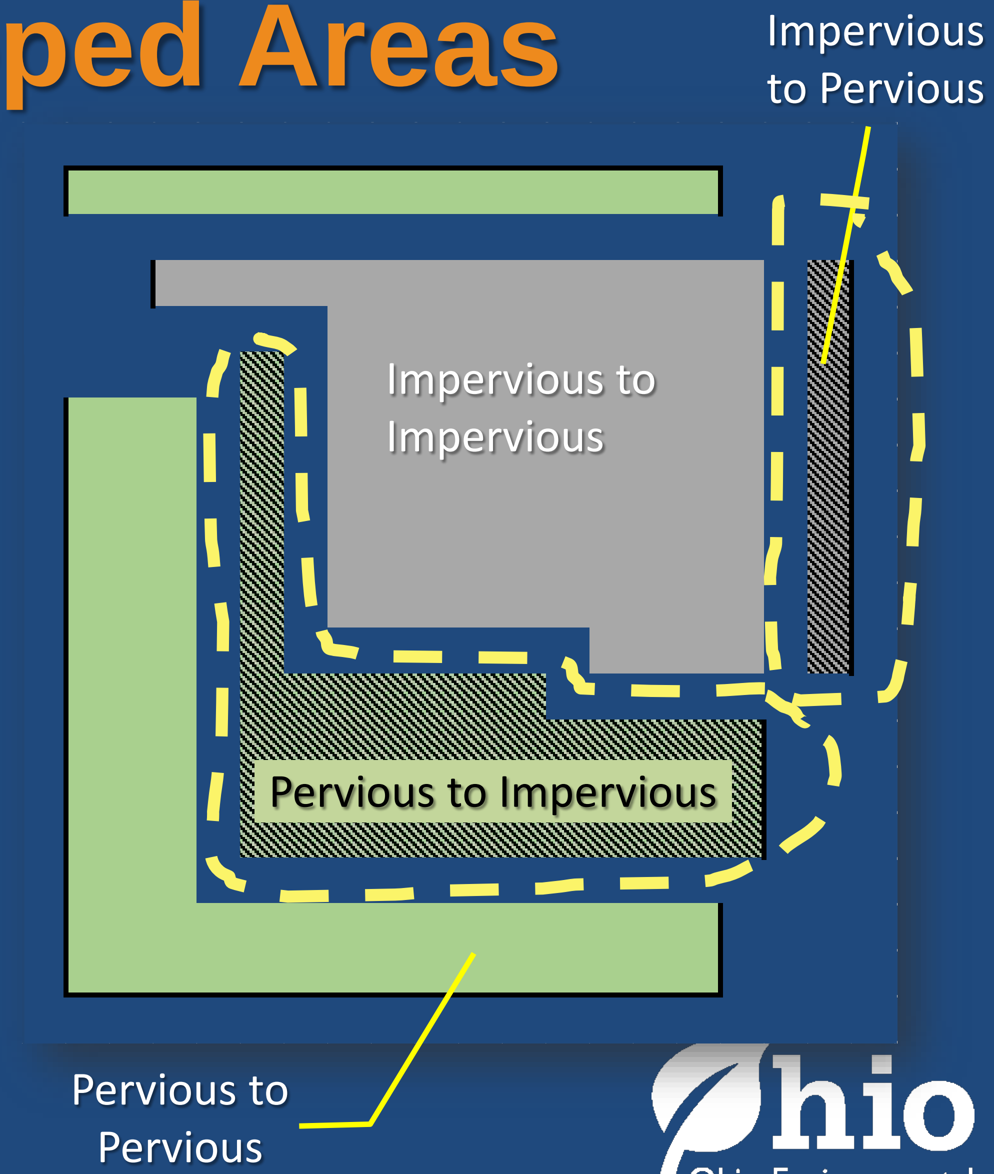
Previously Developed Areas

Effectively counts the existing conditions as 20%, plus the full WQv for new imperious area.







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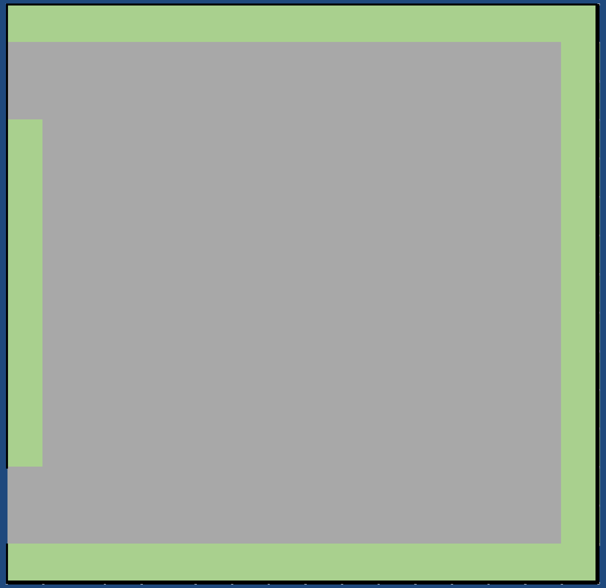
Sample Calculation

PREVIOUSLY DEVELOPED AREAS: R_V DECREASES

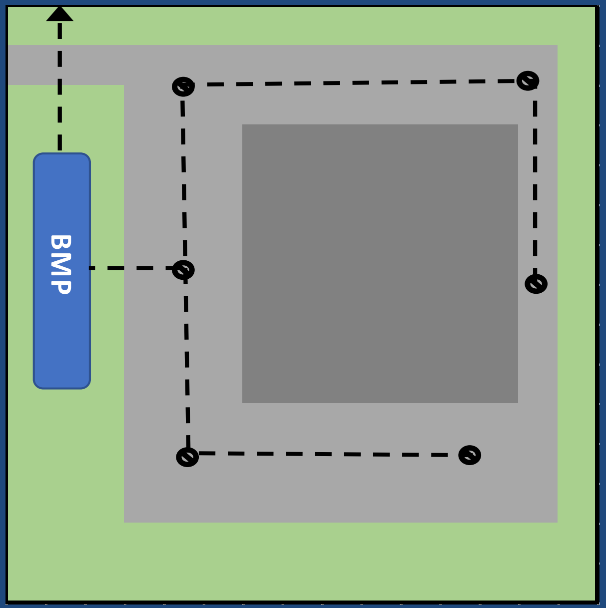
Rv Decreases ≥ 20%



Existing site

impervious = 77%

$Rv_1 = 0.05 + 0.9(0.77) = 0.743$



Proposed site

impervious = 60%

$Rv_2 = 0.05 + 0.9(0.60) = 0.590$

(0.59 ÷ 0.743) - 100% = 21% decrease

Rv decreases by 20%, no additional BMP required

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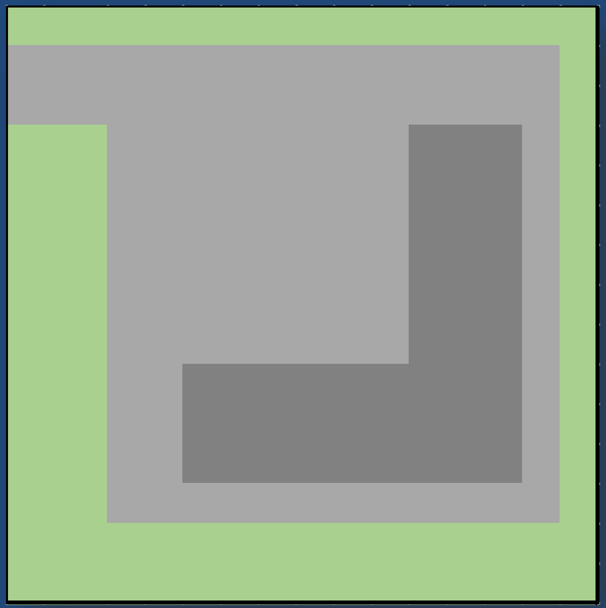
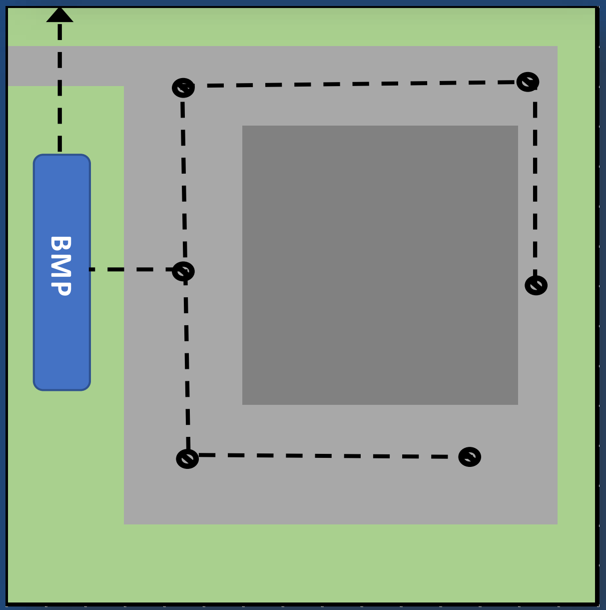
Rv Decreases < 20%



Existing site

impervious = 66%

$Rv_1 = 0.05 + 0.9(0.66) = 0.644$



Proposed site

impervious = 60%

$Rv_2 = 0.05 + 0.9(0.60) = 0.590$

100% - (0.590 ÷ 0.644) = 8.4% decrease

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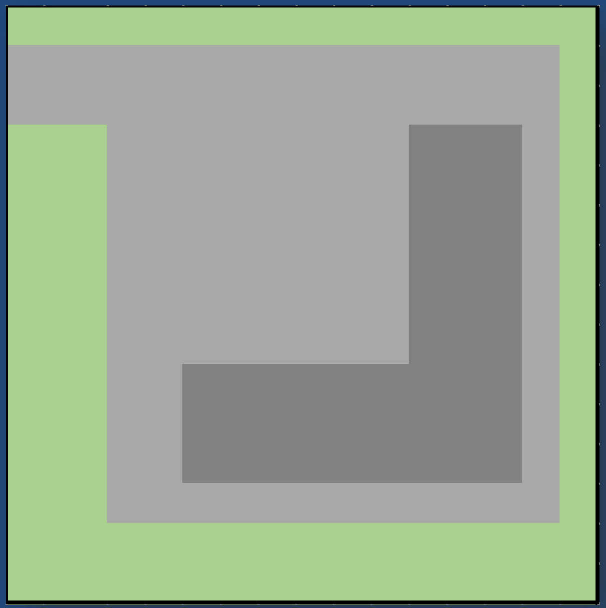
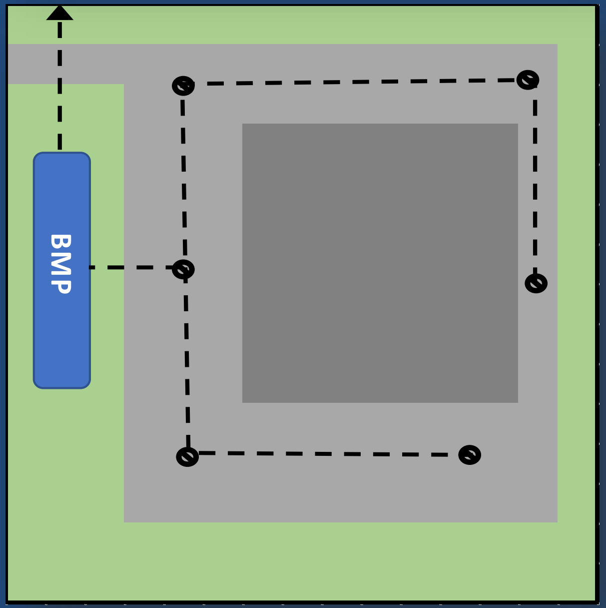
Rv Decreases < 20%





A post construction BMP is required for the WQv as calculated:

$$WQv = [(Rv_1 \times 0.2) + (Rv_2 - Rv_1)] \times P_{wq} \times A_{dist}$$

$$= [(0.644 \times 0.2)+(0.590 - 0.644)] \times 0.9 \text{ in} \times 2.25 \text{ ac}$$

WQv (required) = 550 ft^3

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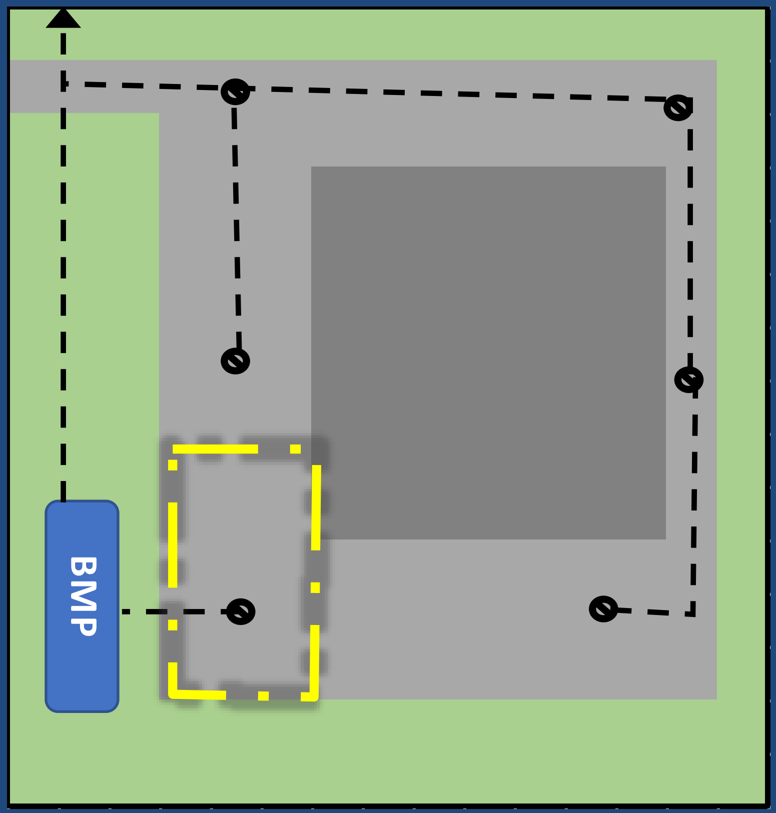
Rv Decreases < 20% - Applied

The site is required to treat 550 ft^3 with post-construction BMPs; however each post-construction BMP must be designed to treat 100% of the WQv for its contributing area. Place the BMP such that its drainage area* is equal to or greater than:

$$A_{drainage} = \frac{WQ_v}{P_{wq} \times Rv} \times \frac{12}{43{,}560}$$

$$\frac{550\ \text{ft}^3}{0.9'' \times 0.95} \times \frac{12}{43{,}560} = 0.18\ \text{ac}$$



* Should be highest expected pollutant load area

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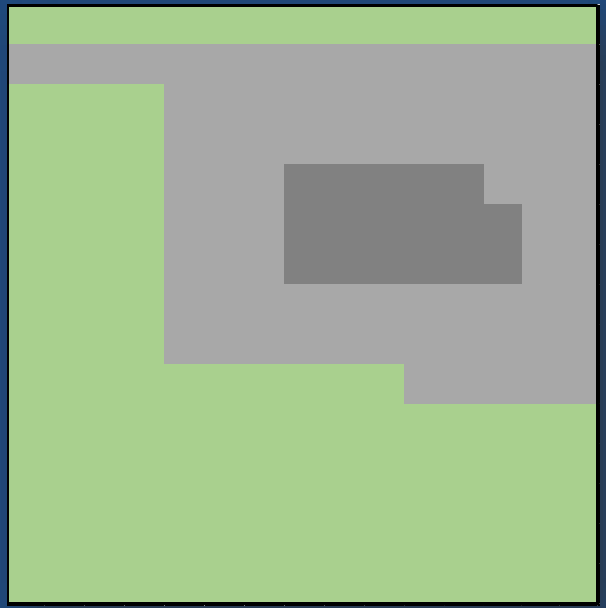
Sample Calculation

PREVIOUSLY DEVELOPED AREAS: R_V INCREASES

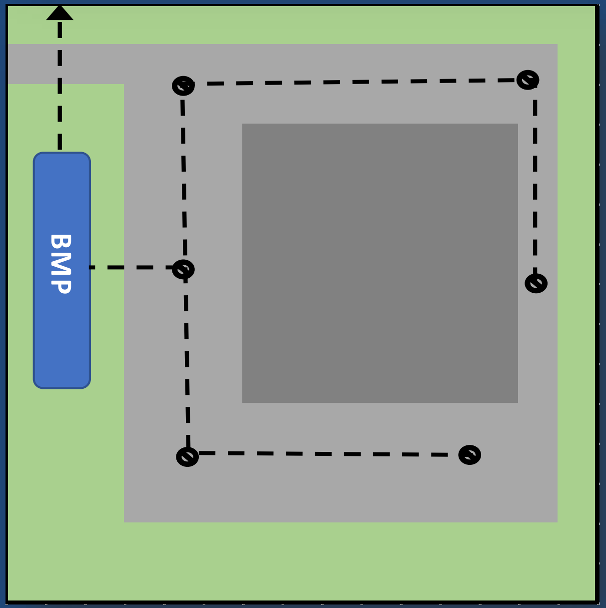
Rv Increases



Existing site

impervious = 43%

$Rv_1 = 0.05 + 0.9(0.43) = 0.437$



Proposed site

impervious = 60%

$Rv_2 = 0.05 + 0.9(0.60) = 0.590$

$(0.590 \div 0.437) - 100\% = 35\%$ increase

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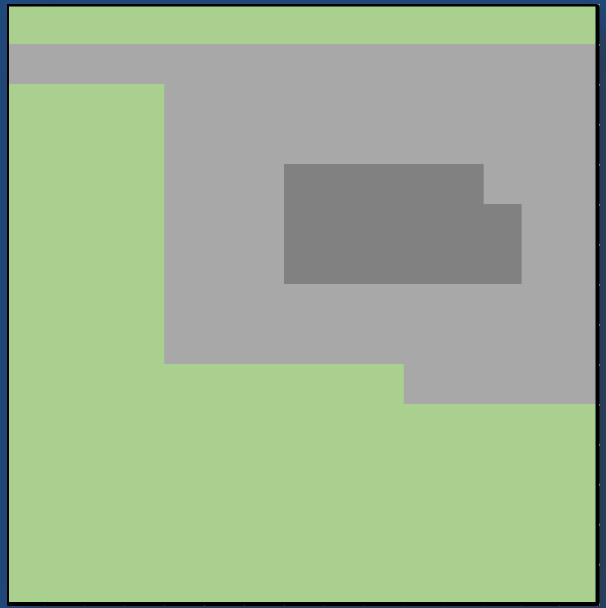
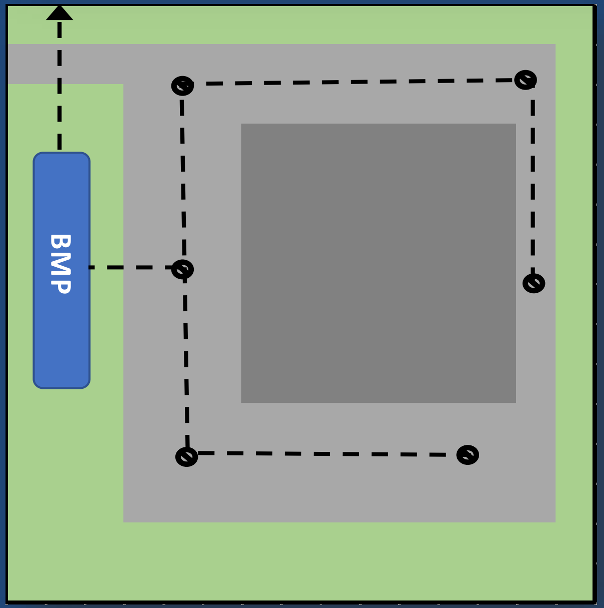
Rv Increases





The required WQv is calculated as:

$$WQv = [(Rv_1 \times 0.2) + (Rv_2 - Rv_1)] \times P_{wq} \times A_{dist}$$

$$= [(0.437 \times 0.2) + (0.590 - 0.437)] \times 0.9 \text{ in} \times 2.25 \text{ ac}$$

WQv (required) = 1,766 ft^3

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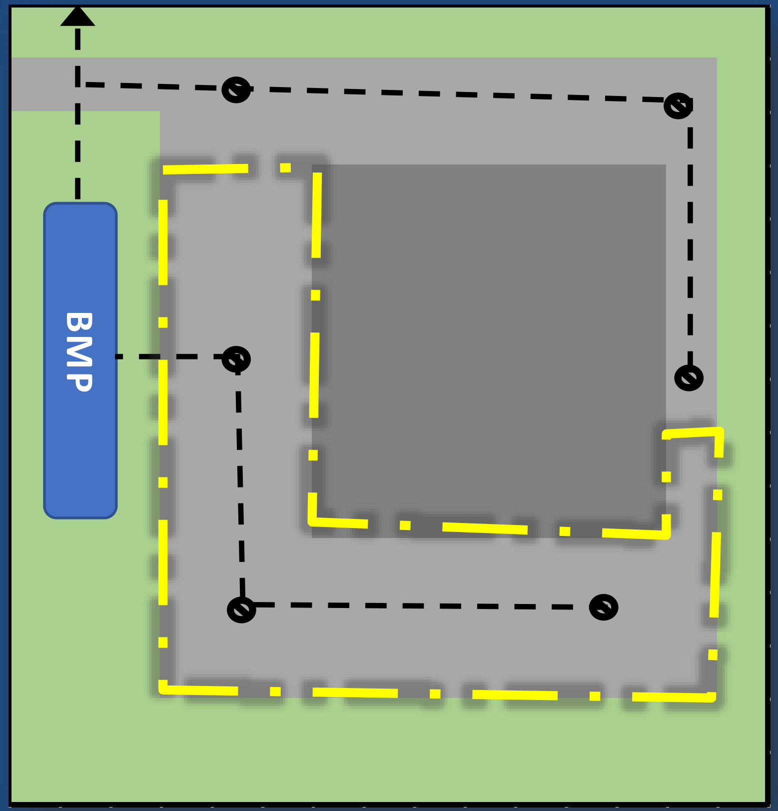
Rv Increases - Applied

The site is required to treat 1,766 ft^3 with post-construction BMPs; however each post-construction BMP must be designed to treat 100% of the WQv for its contributing area. Place the BMP such that its drainage area* is equal to or greater than:

$$A_{drainage} = \frac{WQ_v}{P_{wq} \times Rv} \times \frac{12}{43{,}560}$$

$$\frac{1{,}766 \text{ ft}^3}{0.9 \text{ in} \times 0.95} \times \frac{12}{43{,}560} = 0.57 \text{ ac}$$

* Should be highest expected pollutant load area



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Sample Calculation

WATER QUALITY FLOW

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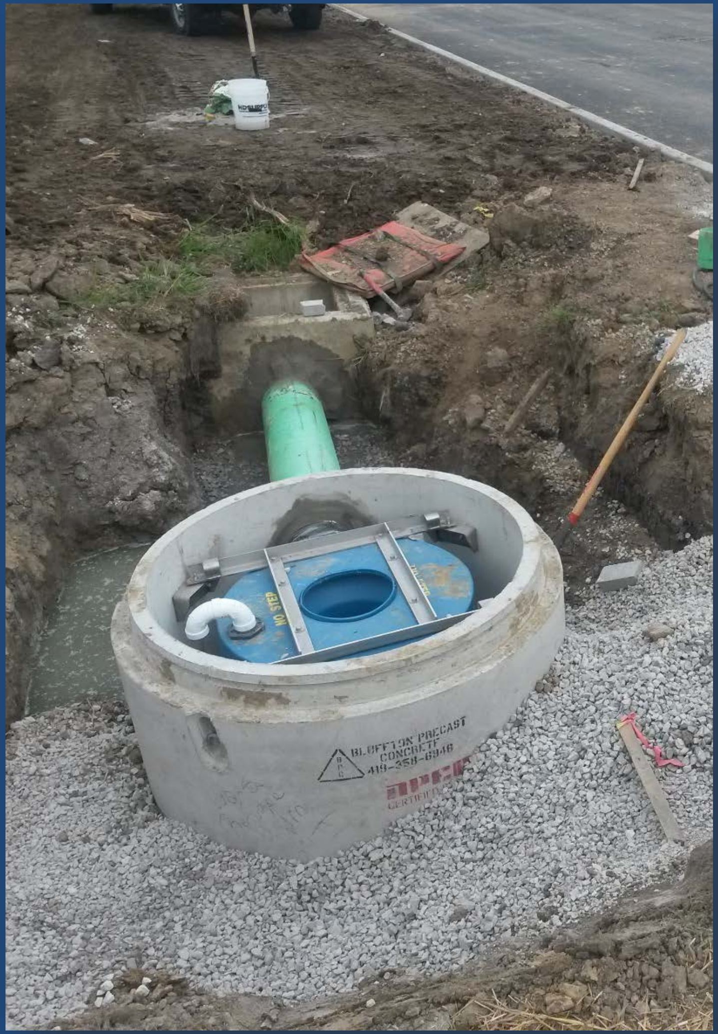
Water Quality Flow



Flow-through practices that do not provide a significant detention volume must use the Water Quality Flow (WQF):

$$WQF = C \times i \times A$$

Where:

WQF = water quality discharge rate (cfs)

C = runoff coefficient for use with rational method for estimating peak discharge

i = rainfall intensity (in/hr)

A = drainage area (ac)

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Water Quality Flow

WQF = C × i × A

The runoff coefficient (C) for use with rational method for estimating peak discharge.

Well published for common land uses, often with ranges or qualifiers such as soil type, slope, RI.

Table 1: Runoff coefficients for the Rational method

Hydrologic Soil Group	A			B			C			D		
Recurrence Interval	5	10	100	5	10	100	5	10	100	5	10	100
Land Use Or Surface Characteristics												
Business:												
A. Commercial Area	.75	.80	.95	.80	.85	.95	.80	.85	.95	.85	.90	.95
B. Neighborhood Area	.50	.55	.65	.55	.60	.70	.60	.65	.75	.65	.70	.80
Residential:												
A. Single Family	.25	.25	.30	.30	.35	.40	.40	.45	.50	.45	.50	.55
B. Multi-Unit (Detached)	.35	.40	.45	.40	.45	.50	.45	.50	.55	.50	.55	.65
C. Multi-Unit (Attached)	.45	.50	.55	.50	.55	.65	.55	.60	.70	.60	.65	.75
D. 1/2 Lot Or Larger	.20	.20	.25	.25	.25	.30	.35	.40	.45	.40	.45	.50
E. Apartments	.50	.55	.60	.55	.60	.70	.60	.65	.75	.65	.70	.80
Industrial												
A. Light Areas	.55	.60	.70	.60	.65	.75	.65	.70	.80	.70	.75	.90
B. Heavy Areas	.75	.80	.95	.80	.85	.95	.80	.85	.95	.80	.85	.95
Parks, Cemeteries Playgrounds	.10	.10	.15	.20	.20	.25	.30	.35	.40	.35	.40	.45
Schools	.30	.35	.40	.40	.45	.50	.45	.50	.55	.50	.55	.65
Railroad Yard Areas	.20	.20	.25	.30	.35	.40	.40	.45	.45	.45	.50	.55
Streets												
A. Paved	.85	.90	.95	.85	.90	.95	.85	.90	.95	.85	.90	.95
B. Gravel	.25	.25	.30	.35	.40	.45	.40	.45	.50	.40	.45	.50
Drives, Walks, & Roofs	.85	.90	.95	.85	.90	.95	.85	.90	.95	.85	.90	.95
Lawns												
A. 50%-75% Grass (Fair Condition)	.10	.10	.15	.20	.20	.25	.30	.35	.40	.30	.35	.40
B. 75% Or More Grass (Good Condition)	.05	.05	.10	.15	.15	.20	.25	.25	.30	.30	.35	.40
Undeveloped Surface[1] (By Slope)[2]												
A. Flat (0-1%)	0.04-0.09			0.07-0.12			0.11-0.16			0.15-0.20		
B. Average (2-6%)	0.09-0.14			0.12-0.17			0.16-0.21			0.20-0.25		
C. Steep	0.13-0.18			0.18-0.24			0.23-0.31			0.28-0.38		

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Water Quality Flow

Rainfall intensity (i) is determined from an intensity-duration-frequency curve for an event.

- The intensity should be selected for a duration equal to the time of concentration (tc) of the site.
- I-D curve for Water Quality Event is provided in tabular format in Appendix C of the CGP.
- Tc should utilize a velocity based equation for each flow condition encountered (sheet, shallow concentrated, pipe, open channel, etc.)
- If the total Tc is <5 minutes, a 5 minute duration should be used[1]
- Sub areas may yield larger peak discharges than then entire area and should be evaluated separately.[2]

1 FWHA, HEC-22, third edition, Urban Drainage Design Manual (2009)
2 WEF/ASCE, Design and Construction of Urban Stormwater Management Systems (1992)

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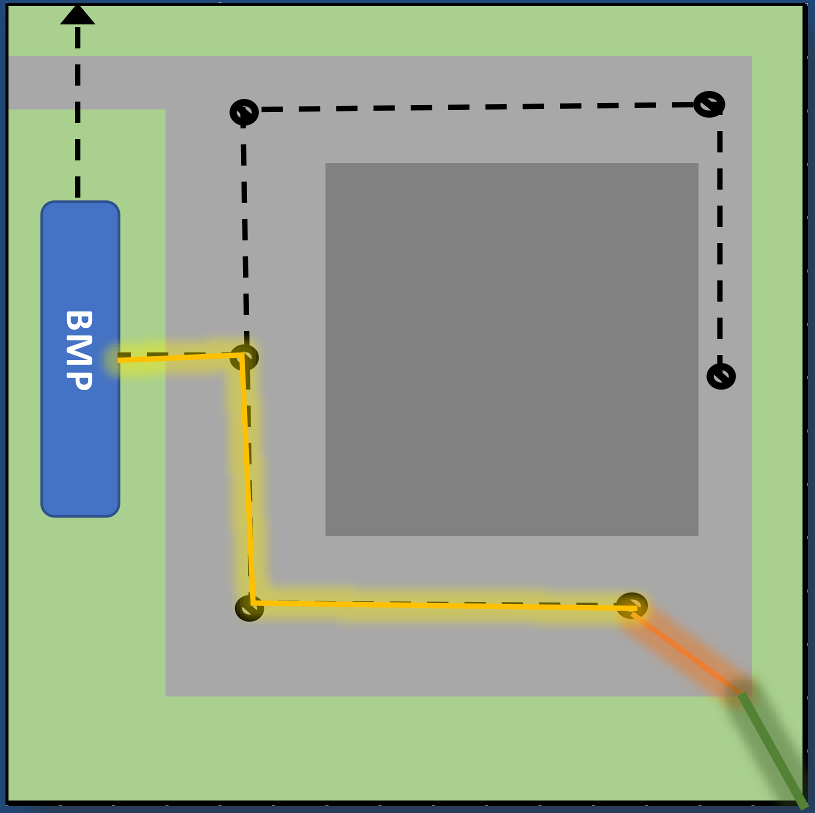
Time of Concentration (t_c)

WQF for the entire drainage area:



50’	overland grass	26.7 min
60’	overland pavement	2.0 min
300’	pipe flow	1.3 min
410’	total	Tc = 30 minutes

DURATION t_c (minutes)	WATER QUALITY INTENSITY [i_{wq}] (inches/hour)
5	2.37
28	1.05
29	1.03
30	1.01
31	0.99
32	0.97

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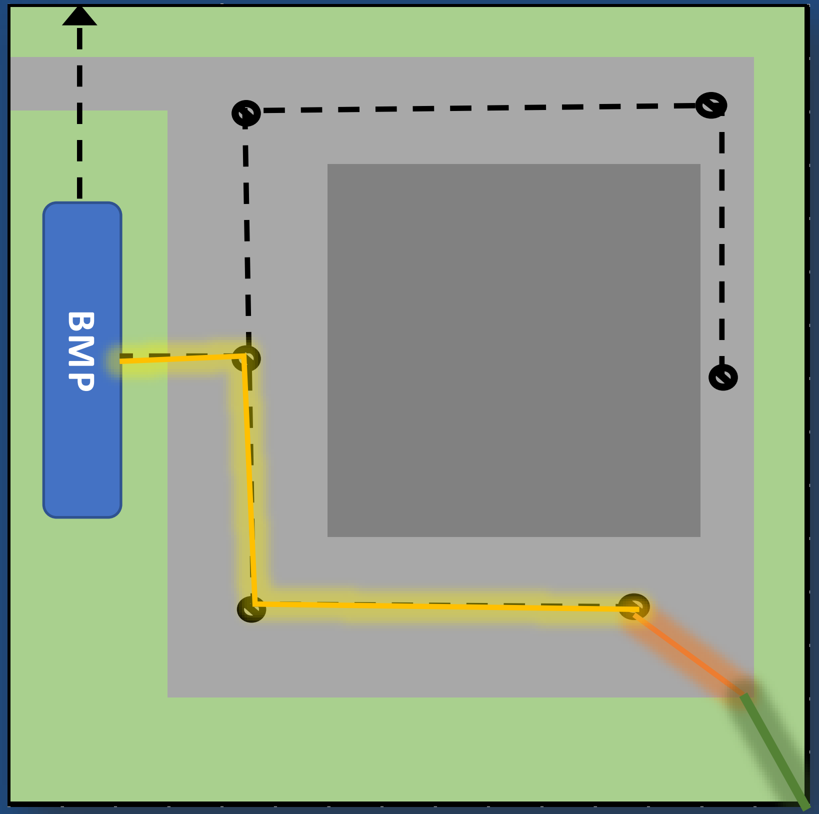
Water Quality Flow

WQF for the entire drainage area:

$$WQF = C \times i \times A$$



Where:

C = 0.85 (commercial area)

i = 1.01 in/hr

A = 2.25 ac

WQF = 0.85 × 1.01 in/hr × 2.25 ac

WQF = 1.93 cfs

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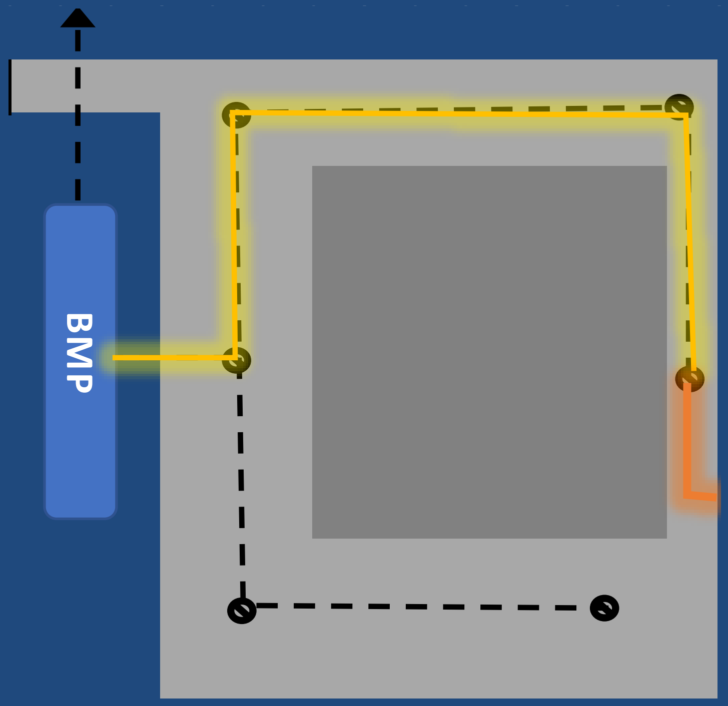
Time of Concentration (t_c)

WQF for the impervious sub-area:



0’	overland grass	0.0 min
50’	overland pavement	1.8 min
420’ pipe flow		1.8 min
470’ total		Tc = 3.6 minutes

DURATION t_c (minutes)	WATER QUALITY INTENSITY [i_{wq}] (inches/hour)
5	2.37
6	2.26
7	2.15
8	2.04
9	1.94
10	1.85
11	1.76
12	1.68
13	1.62
14	1.56
15	1.51

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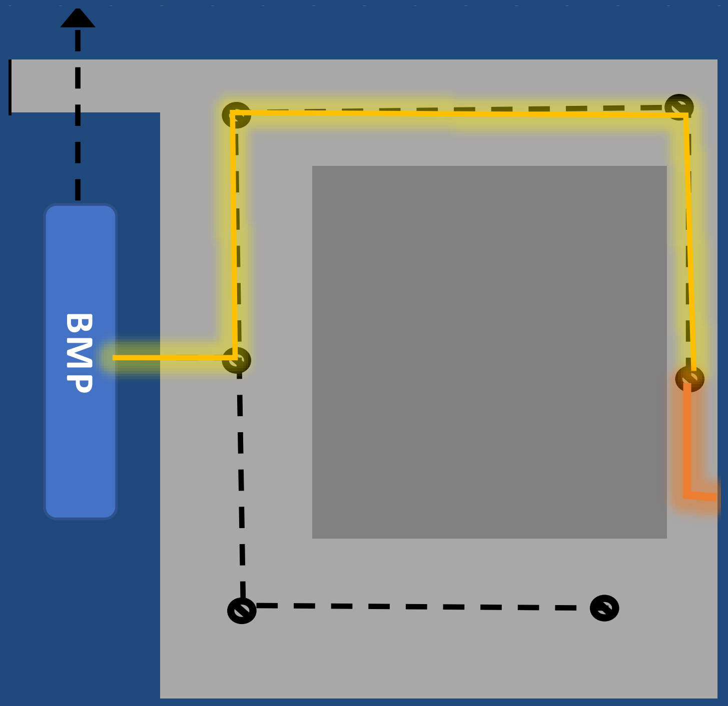
Water Quality Flow

WQF for the impervious sub-area:

$$WQF = C \times i \times A$$



Where:

C = 0.90 (impervious, flat)

i = 2.37 in/hr

A = 1.35 ac

WQF = 0.90 × 2.37 in/hr × 1.35 ac

WQF = 2.88 cfs

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Redevelopment

WATER QUALITY FLOW

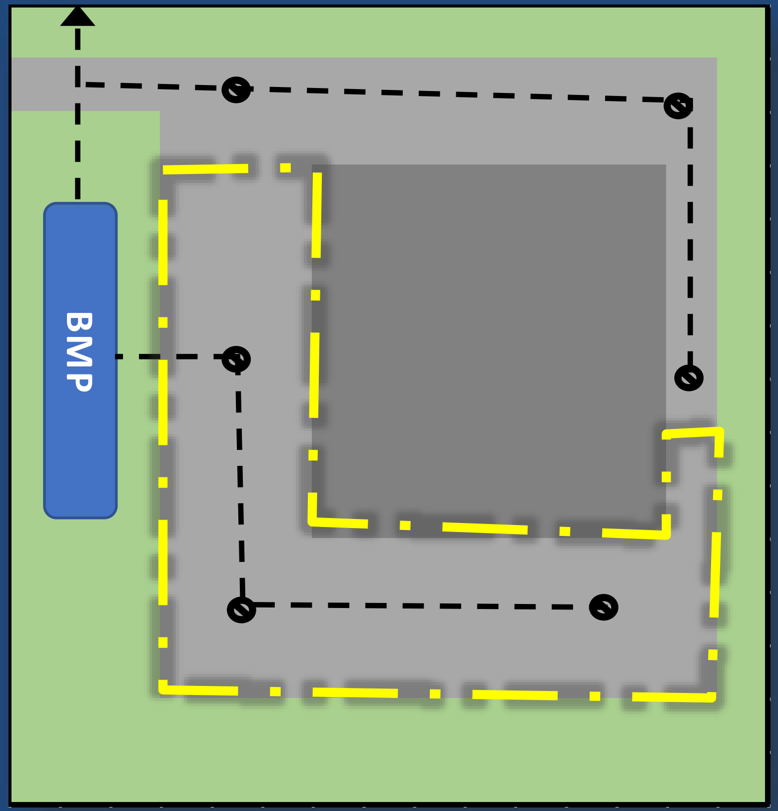
Water Quality Flow - Redevelopment

From our previous redevelopment example:

The site is required to treat 1,766 ft^3 with post-construction BMPs; however each post-construction BMP must be designed to treat 100% of the WQv for its contributing area. Place the BMP such that its drainage area* is equal to or greater than:

$$A_{drainage} = \frac{WQ_v}{P_{wq} \times Rv} \times \frac{12}{43{,}560}$$

$$\frac{1{,}766 \text{ ft}^3}{0.9 \text{ in} \times 0.95} \times \frac{12}{43{,}560} = 0.57 \text{ ac}$$



* Should be highest expected pollutant load area

Water Quality Flow - Redevelopment

$$WQF = C \times i \times A$$

Where:

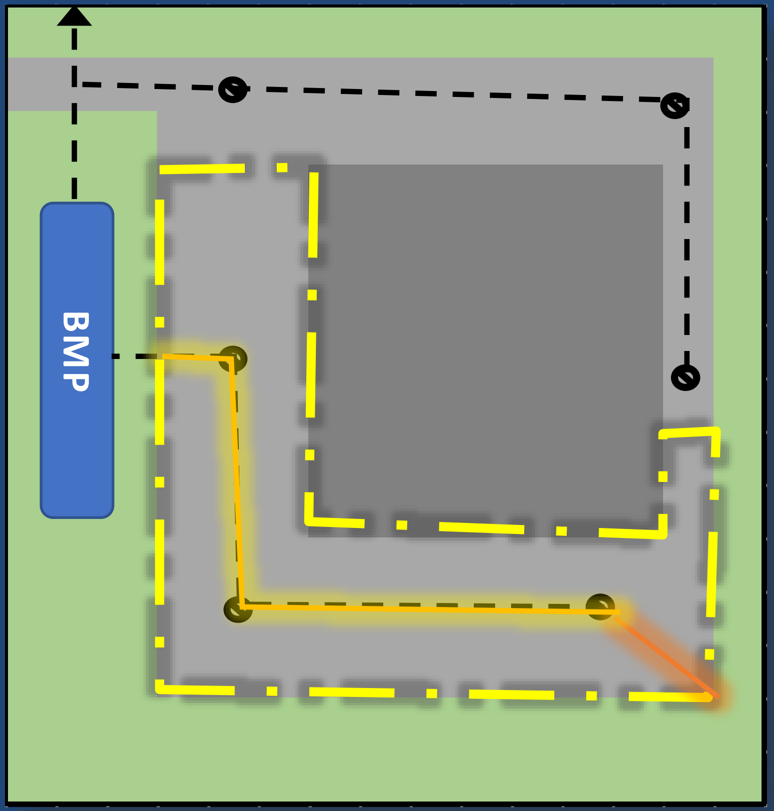
C = 0.90

i = 2.37 in/hr [tc = 3.3 min.]

A = 0.57 ac

WQF = 0.90 × 2.37 in/hr × 0.57 ac

WQF = 1.22 cfs



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Ohio Stormwater Conference
Sandusky, Ohio
May 10, 2018

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