Appendix B

COUNTY OF SAN DIEGO BMP DESIGN MANUAL

Storm Water Pollutant Control Hydrologic Calculations and Sizing Methods for Structural BMPs

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Appendix B Storm Water Pollutant Control Hydrologic Calculations and Sizing Methods for Structural BMPs

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B.1 Step 1 - Determine DCV

The first step in performing storm water pollutant control calculations is to calculate the Design Capture Volume (DCV). The DCV represents the volume of storm water runoff that must be retained and/or biofiltered in order to satisfy pollutant control requirements. The DCV can be calculated through use of automated Worksheet B.1 depicted on the following page, or can be calculated manually by following Steps 1A through 1D presented in this section.

$$DCV = \frac{D}{12}\ x\ A\ x\ C - R$$

Where:
DCV: Design Capture Volume (ft^3)
D: Rainfall Depth (inches), refer to section B.1.1.
A: Tributary Area (ft^2), refer to Section B.1.2.
C: Runoff Factor (unitless), refer to section B.1.3.
R: Site Design Volume Reductions (ft^3), refer to Section B.1.4.

Worksheet B.1 Calculation of Design Capture Volume

Category	#	Description	*i*	Units
Standard Drainage Basin Inputs	1	Drainage Basin ID or Name		unitless
	2	85th Percentile 24-hr Storm Depth		inches
	3	Impervious Surfaces Not Directed to Dispersion Area (C=0.90)		sq-ft
	4	Semi-Pervious Surfaces Not Serving as Dispersion Area (C=0.30)		sq-ft
	5	Engineered Pervious Surfaces Not Serving as Dispersion Area (C=0.10)		sq-ft
	6	Natural Type A Soil Not Serving as Dispersion Area (C=0.10)		sq-ft
	7	Natural Type B Soil Not Serving as Dispersion Area (C=0.14)		sq-ft
	8	Natural Type C Soil Not Serving as Dispersion Area (C=0.23)		sq-ft
	9	Natural Type D Soil Not Serving as Dispersion Area (C=0.30)		sq-ft
Dispersion Area, Tree Well & Rain Barrel Inputs (Optional)	10	Does Tributary Incorporate Dispersion, Tree Wells, and/or Rain Barrels?		yes/no
	11	Impervious Surfaces **Directed to Dispersion Area** per SD-B (Ci=0.90)		sq-ft
	12	Semi-Pervious Surfaces **Serving as Dispersion Area** per SD-B (Ci=0.30)		sq-ft
	13	Engineered Pervious Surfaces **Serving as Dispersion Area** per SD-B (Ci=0.10)		sq-ft
	14	Natural Type A Soil **Serving as Dispersion Area** per SD-B (Ci=0.10)		sq-ft
	15	Natural Type B Soil **Serving as Dispersion Area** per SD-B (Ci=0.14)		sq-ft
	16	Natural Type C Soil **Serving as Dispersion Area** per SD-B (Ci=0.23)		sq-ft
	17	Natural Type D Soil **Serving as Dispersion Area** per SD-B (Ci=0.30)		sq-ft
	18	Number of Tree Wells Proposed per SD-A		#
	19	Average Mature Tree Canopy Diameter		ft
	20	Number of Rain Barrels Proposed per SD-E		#
	21	Average Rain Barrel Size		gal
Initial Runoff Factor Calculation	22	Total Tributary Area		sq-ft
	23	Initial Runoff Factor for Standard Drainage Areas		unitless
	24	Initial Runoff Factor for Dispersed & Dispersion Areas		unitless
	25	Initial Weighted Runoff Factor		unitless
	26	Initial Design Capture Volume		cubic-feet
Dispersion Area Adjustments	27	Total Impervious Area Dispersed to Pervious Surface		sq-ft
	28	Total Pervious Dispersion Area		sq-ft
	29	Ratio of Dispersed Impervious Area to Pervious Dispersion Area		ratio
	30	Adjustment Factor for Dispersed & Dispersion Areas		ratio
	31	Runoff Factor After Dispersion Techniques		unitless
	32	Design Capture Volume After Dispersion Techniques		cubic-feet
Tree & Barrel Adjustments	33	Total Tree Well Volume Reduction		cubic-feet
	34	Total Rain Barrel Volume Reduction		cubic-feet
Results	35	Final Adjusted Runoff Factor		unitless
	36	Final Effective Tributary Area		sq-ft
	37	Initial Design Capture Volume Retained by Site Design Elements		cubic-feet
	38	Final Design Capture Volume Tributary to BMP		cubic-feet

Worksheet B.1 Line Item Notes
1. User Input from stormwater plans.
2. User input from BMPDM Figure B.1-1.
3. User Input from stormwater plans.
4. User Input from stormwater plans.
5. User Input from stormwater plans.
6. User Input from stormwater plans.
7. User Input from stormwater plans.
8. User Input from stormwater plans.
9. User Input from stormwater plans.
10. User Input. Default is "No". Select Yes if any of the referenced elements are proposed.
11. User Input from stormwater plans. Must satisfy criteria from Fact Sheet SD-B.
12. User Input from stormwater plans. Must satisfy criteria from Fact Sheet SD-B.
13. User Input from stormwater plans. Must satisfy criteria from Fact Sheet SD-B.
14. User Input from stormwater plans. Must satisfy criteria from Fact Sheet SD-B.
15. User Input from stormwater plans. Must satisfy criteria from Fact Sheet SD-B.
16. User Input from stormwater plans. Must satisfy criteria from Fact Sheet SD-B.
17. User Input from stormwater plans. Must satisfy criteria from Fact Sheet SD-B.
18. User Input. Must satisfy criteria from Fact Sheet SD-A.
19. User Input. Must satisfy criteria from Fact Sheet SD-A. Acceptable range from 0-30 feet.
20. User Input. Must satisfy criteria from Fact Sheet SD-E. Cannot provide more than a 25% reduction to initial DCV.
21. User Input. Must satisfy criteria from Fact Sheet SD-E. Acceptable range 0-100 gallons for generic volume reductions.
22. Sum of Lines 3 through 17.
23. [0.9(Line 3) + 0.3(Line 4 + Line 9) + 0.1(Line 5 + Line 6) + 0.14(Line 7) + 0.23(Line 8)] /(Sum of Lines 3 through Line 9)
24. [0.9(Line 11) + 0.3(Line 12 + Line 17) + 0.1(Line 13 + Line 14) + 0.14(Line 15) + 0.23(Line 16)] /(Sum of Lines 11 through Line 17)
25. [(Line 23 x (Sum of Lines 3 through 9) + Line 24 x (Sum of Lines 11 through 17)) / Line 22]
26. (Line 2/12) x Line 22 x Line 25
27. Line 11
28. Summation of Lines 12-17.
29. [Line 27 / Line 28]. If greater than 4.0 dispersion benefits are not quantified.
30. Lookup values from Table B.1-1 weighted with respect to distribution of dispersion areas specified in Lines 12-17.
31. [Line 23 x (Sum of Lines 3 through Line 9) + Line 24 x Line 30 x (Sum of Lines 11 through Line 17)] / Line 22
32. (Line 2/12) x Line 22 x Line 31
33. [Line 18 x Lookup value from Section B.1.4 of BMP Design Manual]
34. [Line 20 x Line 21/7.48]. If Line 21>100 or Line 10 is "n/a" or "no", then this value must be zero.
35. Line 31 x [1 - ((Line 33 + Line 34)/(Line 32))]. Value must be between zero and one.
36. Line 22 x Line 35
37. [(Line 26 - Line 32) + Line 33 + Line 34]
38. [Line 26 - Line 37]. Minimum result of 0.

B.1.1 Step 1A - Rainfall Depth

The rainfall depth (D) used to calculate the DCV is determined through examination of the 85th percentile, 24-hour isopluvial map provided in Figure B.1-1. The isopluvial map represents rainfall depths as blue line work provided at 0.02" intervals. Appropriate rainfall depths should be determined by plotting the project location on the map, examining adjacent rainfall depths, and interpolating an appropriate depth to the nearest hundredth of an inch (i.e. 0.71 inch). GIS versions of the map are also available for download at the following links.

GIS Shapefile: (Under Ecology category)

http://www.sangis.org/download/index.html

GIS Viewer:
http://sdcounty.maps.arcgis.com/home/webmap/viewer.html?webmap=89523b7ae5db4e44a6569062ad9933e5

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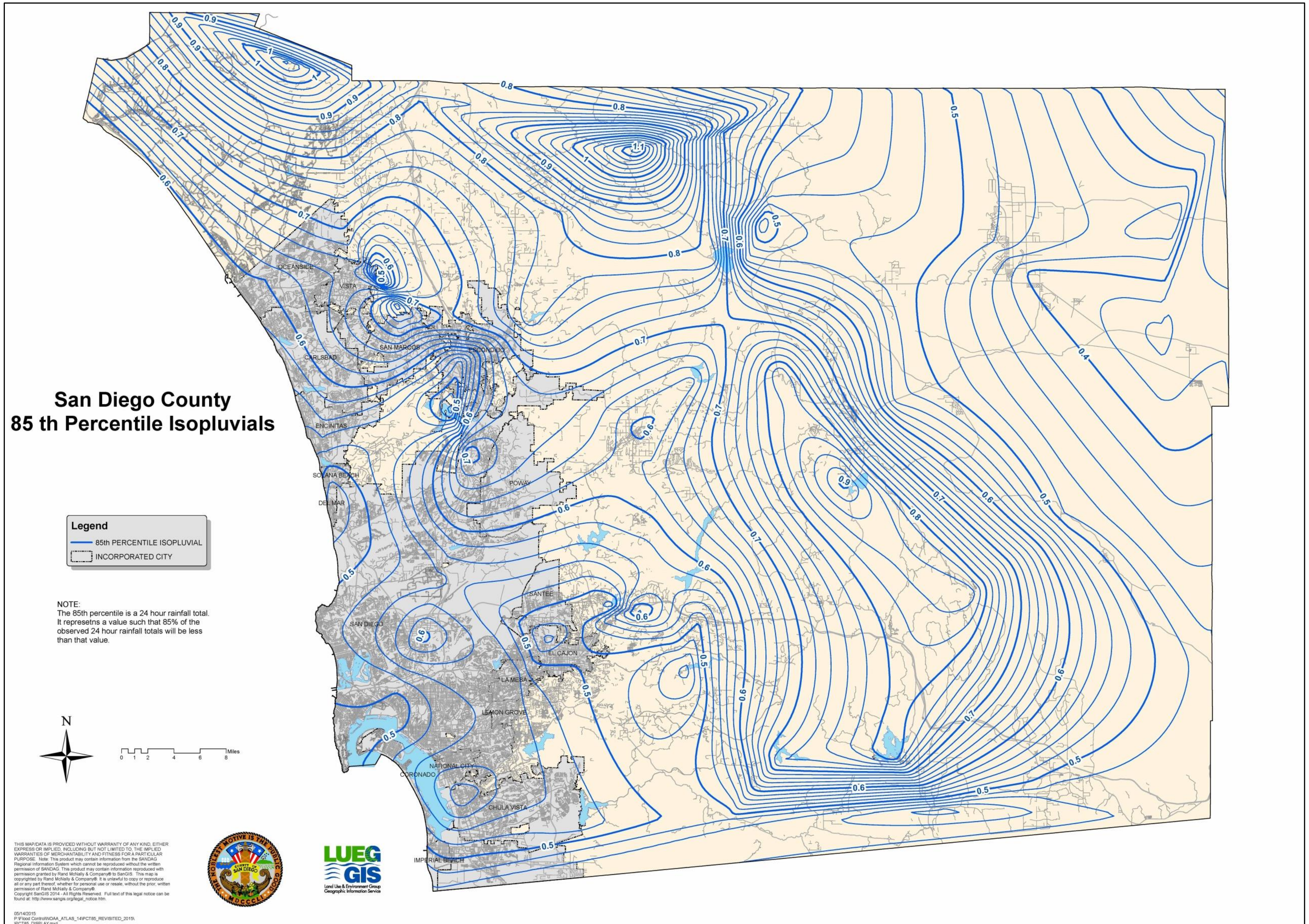

Figure B.1-1: 85th Percentile 24-hour Isopluvial Map

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B.1.2 Step 1B - Tributary Area

Determine the total tributary area through evaluation of the drainage area delineations performed as outlined in Section 3. These areas will be analyzed in additional detail in Step 1C below.

B.1.3 Step 1C - Runoff Factor

Runoff factors (C) represent the ratio of storm water runoff over rainfall that is anticipated for a particular surface type. Impervious surfaces typically have high runoff factors (0.90) as nearly all rainfall is converted into runoff. Pervious surfaces typically have low runoff factors (0.10) as much of the rainfall is retained in natural surface features. Applicants should evaluate all of the surface coverages within a drainage area and assign runoff factors consistent with the values in Table B.1-1.

Table B.1-1: Runoff factors for surfaces draining to BMPs – Pollutant Control BMPs

Category	Surface Type	Runoff Factor (C)
Impervious Surfaces	Roofs, Concrete, Asphalt, Unit Pavers (grouted)	0.90
Semi-Pervious Surfaces	Decomposed Granite, Cobbles, Crushed Aggregate, Compacted soil (unpaved parking)	0.30
Engineered Pervious Surfaces	Green Roofs per SD-C Permeable Pavement per SD-D, Amended Soils per SD-F, Landscaped/Mulched Soils, Permeable Pavement per INF-3	0.10
Natural Pervious Surfaces	Type A Soil	0.10
	Type B Soil	0.14
	Type C Soil	0.23
	Type D Soil	0.30
Impoundments	Swimming pools, fountains, ponds, etc.	0.00
Dispersion Areas	Areas routed to or serving as a dispersion area per SD-B	See Dispersion Area Text Below

If a drainage area is comprised of more than one surface type, an area-weighted runoff factor must be calculated per the following equation where C represents the runoff coefficient and A represents the area of each surface.

$$C_{area-weighted} = \frac{\sum C_{surface\ 1}\, A_{surface\ 1} + C_{surface\ 2}\, A_{surface\ 2} + C_{surface\ x} A_{surface\ x}}{\sum A_{all\ surfaces}}$$

<u>Dispersion Area Runoff Factor Adjustments</u>

Adjustment to runoff factors may be permitted when storm water runoff from impervious surfaces is dispersed through pervious dispersion areas in accordance with the SD-B fact sheet located in Appendix E. Note that pervious dispersion areas may be used to eliminate the DCV requiring treatment and thereby fully satisfy pollutant control requirements when designed as significant site design BMPs (SSD-BMPs). Refer to Appendix I for sizing methods and criteria to use dispersion areas as SSD-BMPs.

Runoff factor adjustments may be applied to drainage areas with a 4:1 maximum ratio of impervious to pervious area. In order to be eligible for runoff factor adjustments, impervious areas must have a runoff factor of 0.90 and must be directed towards a pervious dispersion area with a runoff factor of 0.30 or less.

Table B.1-2 presents runoff factor adjustments as a function of the ratio of impervious to pervious area and the hydrologic soil group of the pervious dispersion area. Applicants applying runoff factor adjustments must identify appropriate factors in the table below and multiply that factor by the original composite runoff factor of the impervious area and the dispersion area.

Table B.1-2: Impervious area adjustment factors that account for dispersion

Characteristics of Pervious Area	Ratio = Impervious area/Pervious area			
	<=1	2	3	4
Type A or Amended Soils	0.00	0.00	0.21	0.32
Type B Soils	0.00	0.24	0.38	0.48
Type C Soils	0.31	0.50	0.60	0.67
Type D Soils	0.77	0.84	0.87	0.90

When using adjustment factors from Table B.1-2:

a) The underlying soil group need not be considered if amended soils implemented per SD-F.

b) Linear interpolation must be performed if the impervious to pervious area ratio of the site is in between one of ratios for which an adjustment factor was developed;

c) Use adjustment factor for a ratio of 1 when the impervious to pervious area ratio is less than 1

B.1.4 Step 1D - Site Design Volume Reductions

Site design volume reductions (R) account for the effects of incorporating non-structural BMPs such as tree wells and rain barrels into the site design. Effective use of these site design elements can significantly reduce the DCV requiring treatment through structural BMP strategies. Note that tree wells may be used to eliminate the DCV requiring treatment and thereby fully satisfy pollutant control requirements when designed as significant site design BMPs (SSD-BMPs). Refer to Appendix I for sizing methods and criteria to use tree wells as SSD-BMPs.

Tree wells designed per the SD-A fact sheet provide the following volume reductions to the DCV. The maximum volume reduction for any individual tree is 420 cubic feet.

Table B.1-3: Tree Well Volume Reductions

Mature Tree Canopy Diameter (ft)	Volume Reduction (cubic feet/tree)
0	0
5	10
10	40
15	100
20	180
25	290
30	420

Rain barrels designed per SD-E fact sheet can also provide limited volume reductions to the DCV. The effects of rain barrels are typically less substantial than tree wells and are subject to the following restrictions: 1) individual rain barrel volumes are no greater than 100 gallons, 2) the total rain barrel volume is no greater than 0.25 DCV, and 3) the site must have landscape areas of at least 30% of the project footprint. If the proposed rain barrels do not meet these criteria, design volume reductions may still be achieved through Cistern criteria presented in fact sheet HU-1.

Table B.1-4: Rain Barrel Volume Reductions

Rain Barrel Size (gallon)	Volume Reduction (cubic feet)
0	0.0
20	2.7
40	5.3
60	8.0
80	10.7
100	13.4

B.2 Step 2 - Determine Retention Requirements

The second step in performing storm water pollutant control calculations is to determine the retention requirements for each drainage area. Retention requirements can be calculated through use of the automated Worksheet B.2 depicted below, or can be calculated manually by following Steps 2A through 2D presented in this section.

Worksheet B.2 Retention Requirements

Category	#	Description	*i*	Units
Basic Analysis	1	Drainage Basin ID or Name		uniless
	2	85th Percentile Rainfall Depth		inches
	3	Predominant NRCS Soil Type Within BMP Location		unitless
	4	Is proposed BMP location Restricted or Unrestricted for Infiltration Activities?		unitless
	5	Nature of Restriction		unitless
	6	Do Minimum Retention Requirements Apply to this Project?		yes/no
	7	Are Habitable Structures Greater than 9 Stories Proposed?		yes/no
Advanced Analysis	8	Has Geotechnical Engineer Performed an Infiltration Analysis?		yes/no
	9	Design Infiltration Rate Recommended by Geotechnical Engineer		in/hr
Result	10	Design Infiltration Rate Used To Determine Retention Requirements		in/hr
	11	Percent of Average Annual Runoff that Must be Retained within DMA		percentage
	12	Fraction of DCV Requiring Retention		ratio
	13	Required Retention Volume		cubic-feet

Worksheet B.2 Line Item Notes

1. User input from stormwater plans.
2. User input from BMPDM Figure B.1-1.
3. User input from stormwater plans.
4. User input from BMPDM Section B.2.2.
5. User input from BMPDM Section B.2.2.
6. Default value of "Yes" for Priority Development Projects.
7. User input from BMPDM Section B.2.1. If "Yes", separate capture and use evaluation must be provided.
8. User input from BMPDM Section B.2.3. If "Yes", geotechnical report excerpts must be provided.
9. User input from BMPDM Section B.2.3.
10. Rates of 0.300, 0.200, 0.100, 0.025, or 0.000 for A, B, C, D, or Restricted soils respectively. Or rate from Geotechnical Engineer.
11. Determined Per BMPDM Section B.2.4.
12. Determined Per BMPDM Section B.2.4.
13. Determined Per BMPDM Section B.2.4.

B.2.1 Step 2A - Capture and Use Analysis

Projects that <u>do not</u> propose habitable structures over 9 stories tall may skip this step (proceed to Step 2B).

Projects that propose habitable structures over 9 stories tall are required to perform a capture and use analysis to identify whether the DCV from the project site can be utilized for onsite toilet flushing and/or irrigation within 36 hours of the storm. If the results indicate capture and use is possible, then the project is required to implement capture and use. Guidance for performing this analysis is provided in B.3.8.

B.2.2 Step 2B – Infiltration Restrictions

The SWQMP Preparer is responsible for evaluating the infiltration restrictions in Table B.2-1 below and characterizing each drainage area as Restricted or Unrestricted for infiltration.

Restriction elements are divided into Mandatory Considerations and Optional Considerations. Mandatory Considerations include elements that may pose a significant risk to human health and safety. These elements must always be evaluated and discretion regarding the setbacks is not permitted. Optional Considerations include elements that are not necessarily associated with human health and safety, so analysis is not mandated through this guidance document.

Analysis of these elements is outside of the scope of typical geotechnical engineering investigations; therefore, it is the responsibility of the SWQMP Preparer to perform this evaluation. If a geotechnical engineer is consulted to complete this portion of the analysis, additional discretion on the mandatory considerations may be permitted if supported by the geotechnical reporting.

Table B.2-1: Infiltration Restrictions

Restriction Element		Is Element Applicable? (Yes/No)
Mandatory Considerations	BMP is within 100’ of Contaminated Soils	
	BMP is within 100’ of Industrial Activities Lacking Source Control	
	BMP is within 100’ of Well/Groundwater Basin	
	BMP is within 50’ of Septic Tanks/Leach Fields	
	BMP is within 10’ of Structures/Tanks/Walls	
	BMP is within 10’ of Sewer Utilities	
	BMP is within 10’ of Groundwater Table	
	BMP is within Hydric Soils	
	BMP is within Highly Liquefiable Soils and has Connectivity to Structures	
	BMP is within 1.5 Times the Height of Adjacent Steep Slopes (≥25%)	
	County Staff has Assigned “Restricted” Infiltration Category	
Optional Considerations	BMP is within Predominantly Type D Soil	
	BMP is within 10’ of Property Line	
	BMP is within Fill Depths of ≥5’ (Existing or Proposed)	
	BMP is within 10’ of Underground Utilities	
	BMP is within 250’ of Ephemeral Stream	
	Other (Provide detailed geotechnical support)	
Result	**Unrestricted**. None of the restriction elements above are applicable.	
	Restricted. One or more of the restriction elements above are applicable.	

The following table summarizes public data sources available for the infiltration restriction analysis.

Table B.2-2: Public Data Sources for Infiltration Restriction Analysis

Resources	Description
Geotracker	**Website:** geotracker.waterboards.ca.gov **Reference Layers:** Groundwater Depths, Contaminated Sites/Soils
SANGIS	**Website:** sangis.org **Reference Layers:** Land Use Current, Gas Stations, Wells, Groundwater Basins, Flowlines, Liquefaction, Soils, Steep Slopes, Sewer, Topography, Elevation Grids
Web Soil Survey (NRCS Soil Type)	**Website:** websoilsurvey.sc.egov.usda.gov/App **Reference Layers:** Hydrologic Soil Group, Map Unit Names
Watershed Management Area Analysis	**Website:** projectcleanwater.org/watershed-management-area-analysis-wmaa **Reference Layers:** Electronic Data from Appendix C of WMAA
Survey Records System	**Website:** srs.sandiegocounty.gov **Reference Layers:** Grading Plans, Surveys, Drainage Plans, Topography Maps, Tentative Parcel Maps
Applicant Plans	**Website:** n/a **Reference Layers:** Utility Plans, Grading Plans, Existing Site Conditions, Proposed Site Conditions, Nearby geotechnical reports.
Geotechnical Engineer	**Website:** n/a **Reference Layers:** At discretion of Geotechnical Engineer

B.2.3 Step 2C – Design Infiltration Rate

The design infiltration rate for each drainage area must be determined through either a basic or advanced analysis. The basic analysis allows the SWQMP Preparer to assign a default design infiltration rate based on the predominant NRCS soil type present within the proposed BMP footprint. The advanced analysis allows for a geotechnical engineer to assign a more specific design infiltration rate based on field testing outlined in Appendix D. Table B.2-3 below identifies the design infiltration rates that can be used for each analysis. Please note that the basic analysis is not permitted for BMPs that lack an underdrain.

Table B.2-3: Design Infiltration Rate

Infiltration Restrictions	Design Infiltration Rate (in/hr)	
	Option 1: Basic Analysis	Option 2: Advanced Analysis
Unrestricted	Type A Soil = 0.300	Rate recommended by geotechnical engineer (Reference Appendix D)
Unrestricted	Type B Soil = 0.200	
Unrestricted	Type C Soil = 0.100	
Unrestricted	Type D Soil = 0.025	
Restricted	Any Soil = 0.000	0.000

B.2.4 Step 2D - Retention Requirements

Using information determined in previous steps, the retention requirements for each drainage area can now be determined. Retention requirements can be expressed as a function of the DCV or as a percentage of annual runoff that must be retained within the drainage area.

Part 1) Using Figure B.2-1, locate the applicable Design Infiltration Rate (determined in Step 2A) along the x-axis. Trace vertically from the x-axis result to the intersect with the plot representing the project's 85th Percentile Rainfall Depth (determined in Step 1A).

Note: Data presented in Figure B.2-1 represents ranges of rainfall depth. Users should choose the range that includes their specific rainfall depth rather than interpolating or extrapolating discrete values between the plotted lines.

Part 2) Trace horizontally from the intersect result to the right hand y-axis to identify the fraction of the DCV that must be retained to satisfy retention requirements (F).

Note: Retention requirements can also be expressed as a fraction of annual runoff by tracing horizontally from the intersect result to the left hand y-axis. This method is appropriate if the proposed retention elements have drawdown times significantly different than 36-hours.

Part 3) Determine the total volume required to be retained for the drainage as follows.

$$V_{REQ} = DCV\ x\ F_{DCV}$$

Where:
V_{REQ}: Total volume that must be retained within the drainage area (ft^3)
DCV: Design capture volume (ft^3)
F_{DCV}: Fraction of DCV requiring retention (unitless)
Retention requirements can be satisfied at the project-scale if DMA scale is not achieved.

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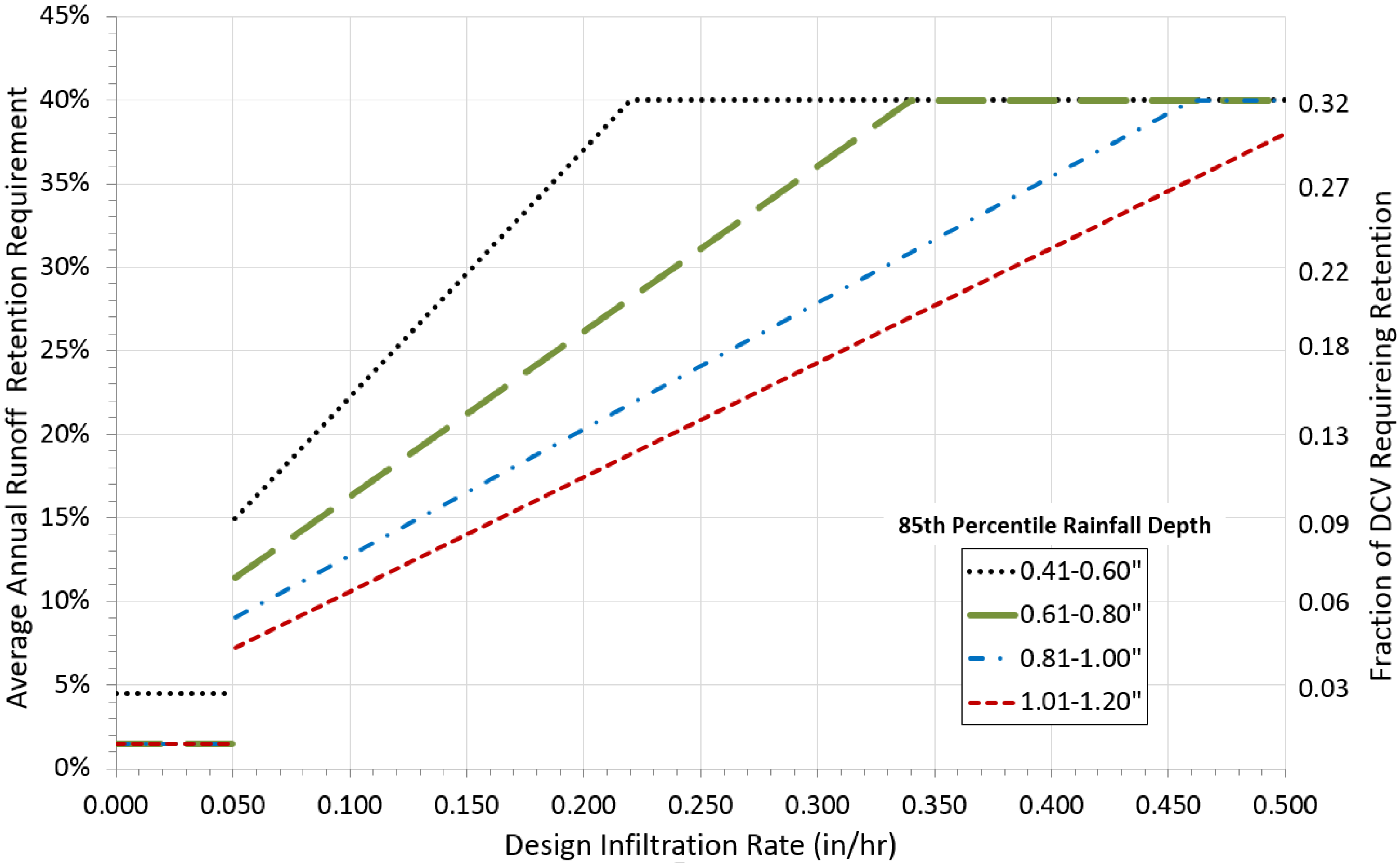
Figure B.2-1: Retention Requirements



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B.3 Step 3 - Determine BMP Performance

The third step in performing stormwater pollutant control calculations is to design a structural BMP with the characteristics that provide stormwater treatment for the DCV and meet the minimum retention requirements for the drainage area. Demonstration of appropriate BMP design can be calculated through use of automated Worksheet B.3 on the next page, or can be calculated manually by following Steps 3A through 3E presented in this section.

Worksheet B.3: BMP Performance

Category	#	Description	*i*	Units
BMP Inputs	1	Drainage Basin ID or Name		sq-ft
	2	Design Infiltration Rate Recommended		in/hr
	3	Design Capture Volume Tributary to BMP		cubic-feet
	4	Is BMP Vegetated or Unvegetated?		unitless
	5	Is BMP Impermeably Lined or Unlined?		unitless
	6	Does BMP Have an Underdrain?		unitless
	7	Does BMP Utilize Standard or Specialized Media?		unitless
	8	Provided Surface Area		sq-ft
	9	Provided Surface Ponding Depth		inches
	10	Provided Soil Media Thickness		inches
	11	Provided Gravel Thickness (Total Thickness)		inches
	12	Underdrain Offset		inches
	13	Diameter of Underdrain or Hydromod Orifice (Select Smallest)		inches
	14	Specialized Soil Media Filtration Rate		in/hr
	15	Specialized Soil Media Pore Space for Retention		unitless
	16	Specialized Soil Media Pore Space for Biofiltration		unitless
	17	Specialized Gravel Media Pore Space		unitless
Retention Calculations	18	Volume Infiltrated Over 6 Hour Storm		cubic-feet
	19	Ponding Pore Space Available for Retention		unitless
	20	Soil Media Pore Space Available for Retention		unitless
	21	Gravel Pore Space Available for Retention (Above Underdrain)		unitless
	22	Gravel Pore Space Available for Retention (Below Underdrain)		unitless
	23	Effective Retention Depth		inches
	24	Fraction of DCV Retained (Independent of Drawdown Time)		ratio
	25	Calculated Retention Storage Drawdown Time		hours
	26	Efficacy of Retention Processes		ratio
	27	Volume Retained by BMP (Considering Drawdown Time)		ratio
	28	Design Capture Volume Remaining for Biofiltration		cubic-feet
Biofiltration Calculations	29	Max Hydromod Flow Rate through Underdrain		CFS
	30	Max Soil Filtration Rate Allowed by Underdrain Orifice		in/hr
	31	Soil Media Filtration Rate per Specifications		in/hr
	32	Soil Media Filtration Rate to be used for Sizing		in/hr
	33	Depth Biofiltered Over 6 Hour Storm		inches
	34	Ponding Pore Space Available for Biofiltration		unitless
	35	Soil Media Pore Space Available for Biofiltration		unitless
	36	Gravel Pore Space Available for Biofiltration (Above Underdrain)		unitless
	37	Effective Depth of Biofiltration Storage		inches
	38	Drawdown Time for Surface Ponding		hours
	39	Drawdown Time for Effective Biofiltration Depth		hours
	40	Total Depth Biofiltered		inches
	41	Option 1 - Biofilter 1.50 DCV: Target Volume		cubic-feet
	42	Option 1 - Provided Biofiltration Volume		cubic-feet
	43	Option 2 - Store 0.75 DCV: Target Volume		cubic-feet
	44	Option 2 - Provided Storage Volume		cubic-feet
	45	Portion of Biofiltration Performance Standard Satisfied		ratio
Result	46	Do Site Design Elements and BMPs Satisfy Annual Retention Requirements?		yes/no
	47	Overall Portion of Performance Standard Satisfied (BMP Efficacy Factor)		ratio
	48	**Deficit of Effectively Treated Stormwater**		cubic-feet

Worksheet B.3 Line Item Notes
1. Populated per user input from Worksheet B.1.
2. Populated per user input from Worksheet B.1.
3. Populated per result of Worksheet B.1.
4. User input. Unvegetated may be permitted in full infiltration conditions and/or Green Infrastructure Projects.
5. User input in reference to the bottom of the BMP.
6. User input.
7. User input. Default is "Standard" If specialized media is proposed, refer to BMPDM Sections F.1 - F.3 for guidance.
8. User input.
9. User input.
10. User input, 18 inches minimum.
11. User input. Value represents the total gravel thickness above and below the underdrain.
12. User input. Offset represents the distance between the bottom of the gravel layer to the invert of the underdrain.
13. User input. Select underdrain diameter or hydromod orifice diameter, whatever is smallest.
14. User input. If specialized media is proposed, refer to BMPDM Sections F.1 - F.3 for guidance.
15. User input. If specialized media is proposed, refer to BMPDM Sections F.1 - F.3 for guidance.
16. User input. If specialized media is proposed, refer to BMPDM Sections F.1 - F.3 for guidance.
17. User input. If specialized media is proposed, refer to BMPDM Sections F.1 - F.3 for guidance.
18. For unlined BMPs: Minimum of Line 3 or [Line 8 x (Line 2/12) x 6.00]. For Lined BMPs use zero.
19. Populated per Table B.3-1 of BMPDM. Values vary with respect to BMP elements such as vegetation, underdrain, liners.
20. Populated per Table B.3-1 of BMPDM. Values vary with respect to BMP elements such as vegetation, underdrain, liners.
21. Populated per Table B.3-1 of BMPDM. Values vary with respect to BMP elements such as vegetation, underdrain, liners.
22. Populated per Table B.3-1 of BMPDM. Values vary with respect to BMP elements such as vegetation, underdrain, liners.
23. (Line 9 x Line 19) + (Line 10 x Line 20) + ((Line 11-Line12) x Line 21) + (Line 12 x Line 22)
24. [(Line 23/12) x Line 8 + Line 18 / Line 3]. Maximum value of 1.
25. [Line 23 / Line 2]. Assume 120 hours for all lined biofiltration BMPs.
26. Look up value from Retention Percent Capture Curves, and divide by 0.80. Maximum of 1.00.
27. Line 26 x Line 3
28. Line 3 - Line 27
29. If flow controls are provided, calculate per orifice equation: $Q=CA\sqrt{2gh}$
30. If flow controls are provided, calculate as [(Line 29 x 12 x 3600)/Line 8]
31. Default = 5.00. If specialized media is proposed, refer to BMPDM Section Sections F.1 - F.3 for guidance.
32. Minimum of Line 30 or Line 31
33. [Line 32 x 6]
34. Populated per Table B.3-2 of BMPDM. Values vary with respect to BMP elements such as vegetation, underdrain, liners.
35. Populated per Table B.3-2 of BMPDM. Values vary with respect to BMP elements such as vegetation, underdrain, liners.
36. Populated per Table B.3-2 of BMPDM. Values vary with respect to BMP elements such as vegetation, underdrain, liners.
37. [(Line 9 x Line 34) + (Line 10 x Line 35) + ((Line 11 - Line 12) x Line 36))]
38. For lined basins use [Line 9/Line 32]. For unlined basins use [Line 9/(Line 32 + Line 2)]
39. For lined basins use [Line 37/Line 32]. For unlined basins use [Line 37/(Line 32 + Line 2)]
40. [Line 33 + Line 37]
41. [1.50 x Line 28]
42. [Minimum of Line 41 or ((Line 40/12) x Line 8))]
43. [0.75 x Line 28]
44. [Minimum of Line 43 or [(Line 37/12) x Line 8]]
45. [Maximum of (Line 42/Line 41) or (Line 44/Line 43)]
46. Yes/No. Determined per BMPDM Section B.3.5.
47. [Line 26 + Line 45]. Maximum of 1.00.
48. [Line 47 x Line 3] - Line 3

B.3.1 Step 3A - BMP Characteristics

The performance of a BMP is a function of its retention and biofiltration processes, which are directly related to the proposed BMP geometry and design components. The SWQMP Preparer should design the BMP characteristics summarized below to satisfy pollutant control performances standards for treatment of the DCV and minimum retention requirements.

- BMP geometries identify the area and depth over which retention and/or biofiltration processes occur. Critical BMP geometries include: BMP surface area, surface ponding depth, biofiltration soil media depth, gravel depth, underdrain depth, and underdrain diameter.
- BMP components dictate how retention and biofiltration processes occur over the BMP footprint. Critical BMP components include: vegetation vs no vegetation, standard biofiltration soil media vs non-standard biofiltration soil media, impermeable liner vs no impermeable liner, underdrain vs no underdrain, and design infiltration rates.

The most common BMPs proposed for storm water compliance are infiltration BMPs, bioretention BMPs, and biofiltration BMPs. By default, these BMPs must be sized to provide a surface area that is equal to at least 3% of the tributary effective impervious area. If a smaller BMP surface area is desired, the applicant must complete Major Maintenance Interval calculations presented in Appendix B.4.1.

B.3.2 Step 3B - Retention Processes

BMP retention processes include infiltration and evapotranspiration occurring within the BMP. This section presents how to calculate the retention processes.

Part 1) Determine the volume of infiltration occurring within the BMP during a 6 hour storm event. This volume is a function of the design infiltration rate, BMP surface area, and duration of the storm event as shown below.

$$V_{R6} = \frac{I}{12} x\ B\ x\ 6\ hours$$

Where:
V_{R6}: Volume infiltrated during a 6 hour storm event (ft^3)
I: Design infiltration rate (in/hr)
B: BMP surface area (ft^2)

Part 2) Determine the static retention capacity of the BMP assuming it is entirely full. This volume is a function of the BMP surface area and the effective retention depth as shown below.

$$V_{RS} = B\ x\ E_D$$

Where:
V_{RS}: Static retention capacity of the BMP (ft^3)
B: BMP surface area (ft^2)
E_D: The effective retention depth within all layers of the BMP (ft). This depth is calculated by multiplying the geometric depth (ft) of each BMP layer by the appropriate retention pore space factor in Table B.3-1 below and summing all of the layers.

Table B.3-1: Retention Pore Space Factors

BMP Characteristics	Unlined BMPs Without Underdrain	All Other Biofiltration/Retention BMPs
Ponding Pore Space	1.00	0.00
Media Pore Space	0.25 vegetated 0.40 non-vegetated	0.05
Gravel Pore Space Above Underdrain	0.40	0.00
Gravel Pore Space Below Underdrain	n/a	0.40*

*BMPs with an impermeable liner, must provide 3" of gravel beneath the underdrain invert (no more or no less is permitted in this case).

Part 3) Determine the fraction of the DCV retained by the BMP. This value is a function of the DCV, volume infiltrated during the 6 hour storm event, and static retention capacity of the BMP as shown below.

$$F_{DCV} = \frac{V_{R6} + V_{RS}}{DCV}$$

Where:
F_{DCV}: Fraction of the DCV retained by the BMP (decimal)
V_{R6}: Volume infiltrated during a 6 hour storm event (ft^3)
V_{RS}: Static retention capacity of the BMP (ft^3)
DCV: Design Capture Volume (ft^3)

Part 4) Determine the drawdown time for the effective retention depth. This value is a function of the effective retention depth and the design infiltration rate of the BMP as shown below.

$$T_R = \frac{E_D}{I/12}$$

Where:
T_R: Drawdown time for effective retention depth (hrs)
E_D: The effective retention depth within all layers of the BMP (ft).
I: Design infiltration rate (in/hr). If this rate is 0.000 (i.e. lined BMP), a 120 hour drawdown time for the effective retention depth may be assumed.

Part 5) Determine the average annual percent capture provided by the BMP using Figure B.3-1 on the next page.

a) Identify the fraction of the DCV retained by the BMP (F_{DCV}) on the x axis.
b) Trace vertically from the x-axis result to the intersect with the plot representing the drawdown time for the effective retention depth (T_R). Interpolation between the plotted drawdown times may be necessary.
c) Trace horizontally from the intersect result to identify the average annual percent capture of the proposed BMP.

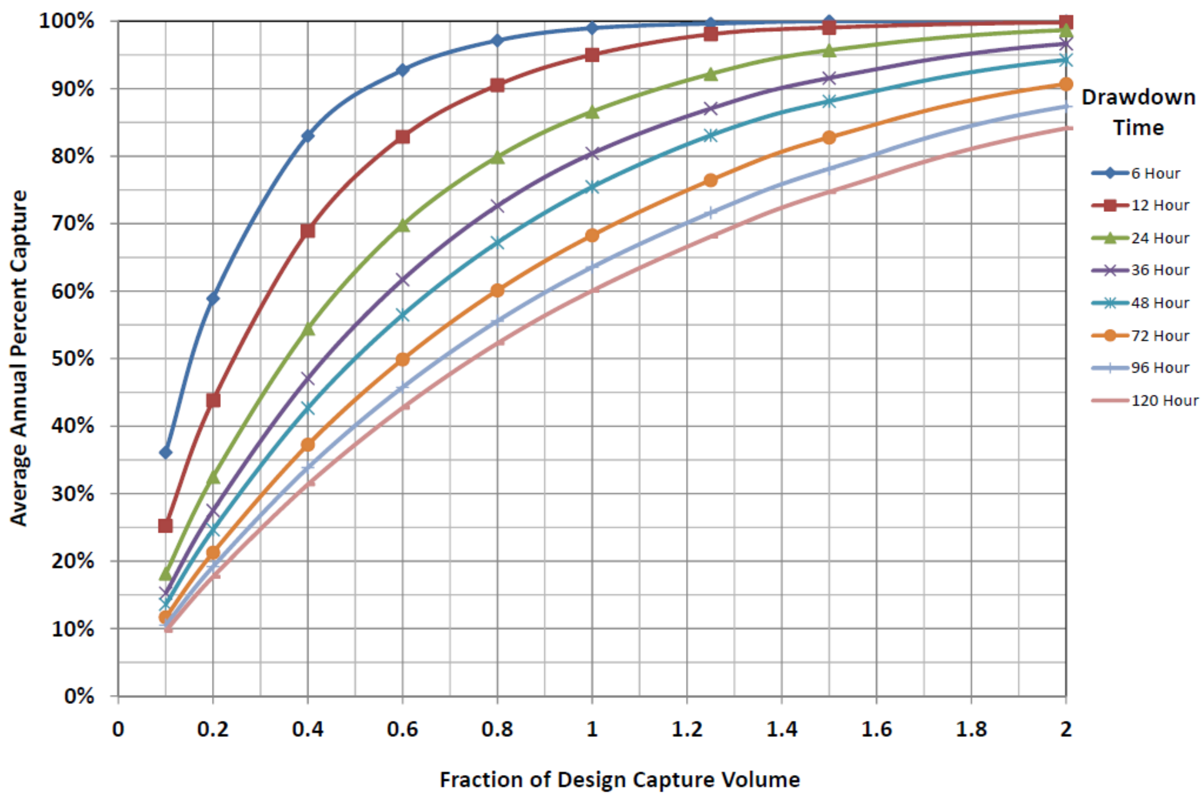

Figure B.3-1: Percent Capture Nomograph

Part 6) Determine the efficacy of the retention processes provided by the BMP. This value represents the portion of the pollutant control performance standard that is satisfied through retention processes of the BMP and is calculated as follows.

$$E_R = \frac{P_C}{80\%}$$

Where:
E_R: Efficacy of retention processes (decimal)
P_C: Average Annual Percent Capture (%)

Part 7) Determine the total volume retained by the proposed BMP.

$$V_{RBMP} = \text{DCV x } E_R$$

Where:
V_{RBMP}: Total volume retained by BMP (ft^3)
DCV: Design capture volume (ft^3)
E_R: Efficacy of retention processes (decimal)

Part 8) Determine the volume of storm water runoff still available for biofiltration treatment as shown below. If the entire volume is retained, then consideration of biofiltration processes in the next step are not required.

$$V_A = \text{DCV} - V_{RBMP}$$

Where:
V_A: Volume of storm water runoff still available for biofiltration treatment (ft^3)
DCV: Design capture volume (ft^3)
V_{RBMP}: Total volume retained by BMP (ft^3)

B.3.3 Step 3C - Biofiltration Processes

Any portion of the DCV that has not been retained within site design or structural BMP elements must be biofiltered. BMP biofiltration processes include filtration, sedimentation, sorption, biochemical processes and/or vegetative uptake. This section presents how to calculate the biofiltration processes occurring within the proposed BMP.

Part 1) Determine the filtration rate (in/hr) of the proposed BMP. This is the rate in which storm water biofilters through the BMP and exits through the underdrain. Filtration rates can be governed by characteristics of the biofiltration soil media or by flow restrictions experienced due to the design of the BMP underdrain/orifice. Applicants must evaluate the rates associated with each of these components per the equations below and then select the lowest filtration rate for use in determining the BMP performance.

$$F_{underdrain} = \left(43{,}200 C A_0 \sqrt{2GH}\right)/B$$

$$F_{soil} = 5\ in/hr$$

$$F_{BMP} = Minimum\ (F_{underdrain,}\ F_{soil})$$

Where:
$F_{underdrain}$: The filtration rate (in/hr) accommodated by the proposed BMP underdrain/orifice.
C: Orifice Coefficient (default 0.60)
A_o: Area of Underdrain/Orifice (ft^2)
G: Gravitational acceleration (32.2 ft/sec^2)
H: Height of water from underdrain invert to top of surface ponding (ft)
B: BMP Surface Area (ft^2)
F_{soil}: The filtration rate (in/hr) accommodated by the proposed biofiltration soil media in typical conditions. The default soil media filtration rate is 5 in/hr; however, a higher rate may be used if supported per criteria in Section F.2.
F_{BMP}: The filtration rate (in/hr) of the proposed BMP

Part 2) Determine the volume of biofiltration occurring within the BMP during a 6 hour storm event. This volume is a function of the BMP filtration rate, BMP surface area, and the rainfall duration as shown below.

$$V_{B6} = \frac{F_{BMP}}{12} \ x \ B \ x \ 6 \ hours$$

Where:
V_{B6}: Volume of water (ft^3) biofiltered during a 6 hour storm event.
F_{BMP}: Filtration rate (in/hr) of the proposed BMP.
B: BMP surface area (ft^2)

Part 3) Determine the static biofiltration capacity of the BMP assuming it is entirely full. This volume is a function of the BMP surface area and the effective biofiltration depth as shown below.

$$V_{BS} = B \ x \ E_{DB}$$

Where:
V_{BS}: Static biofiltration capacity of the BMP (ft^3)
B: BMP surface area (ft^2)
E_{DB}: The effective biofiltration depth within all layers of the BMP (ft). This depth is calculated by multiplying the geometric depth (ft) of each BMP layer by the appropriate biofiltration pore space factor in Table B.3-2 below and summing all of the layers.

Table B.3-2: Biofiltration Pore Space Factors

BMP Characteristics	Unlined BMPs Without Underdrain	All Other Biofiltration/Retention BMPs
Ponding Pore Space	n/a	1.00
Media Pore Space	n/a	0.20 vegetated; 0.35 non-vegetated
Gravel Pore Space Above Underdrain	n/a	0.40
Gravel Pore Space Below Underdrain	n/a	0.00

Part 4) Determine the drawdown time (hours) for surface ponding. This is the ponding depth divided by the sum of the design infiltration rate and BMP filtration rate. Surface ponding depths of 24 hours or less are typically required; however, longer drawdown times up to 96 hours may be proposed if supported by a landscape architect/agronomist and no safety hazards are anticipated due to excessive ponding. Surface ponding drawdown times over 96 hours are not permitted due to vector concerns.

$$T_P = \frac{D_P}{I + F_{BMP}}$$

Where:
T_p: Time (hours) for the BMP surface ponding depth to draw down.
D_P: Surface ponding depth (inches) of the proposed BMP.
I: Design infiltration rate (in/hr)
F_{BMP}: BMP filtration rate (in/hr)

Part 5) Determine the efficacy of the biofiltration processes provided by the BMP. This value represents the portion of the pollutant control standard that is satisfied through the biofiltration processes of the BMP. There are two options available for establishing the biofiltration performance standard. Applicants may select the option of their choice. Option 1 requires that the BMP treat 1.5

times the portion of the DCV not reliably retained onsite (assuming a 6 hour routing period). Option 2 requires that the BMP treat 1.0 times the portion of the DCV not reliably retained onsite; and additionally check that the system has a total static (i.e., non-routed) storage volume, including pore spaces and pre-filter detention volume, equal to at least 0.75 times the portion of the DCV not reliably retained onsite.

$$E_{B1} = \frac{V_{B6} + V_{BS}}{1.50\ DCV - V_{RT}}$$

$$E_{B2} = \frac{V_{BS}}{0.75\ DCV - V_{RT}}$$

$$E_B = Maximum\ (E_{B1}, E_{B2})$$

Where:
E_{B1}: Efficacy of biofiltration processes under option 1 (decimal).
V_{B6}: The volume biofiltered (ft^3) during the 6 hour storm event.
V_{BS}: The static biofiltration capacity (ft^3) of the BMP.
DCV: Design capture volume (ft^3) delivered to BMP.
V_{RT}: The volume retained (ft^3) within the BMP.
E_{B2}: Efficacy of biofiltration processes under option 2 (decimal).
E_B: Efficacy of biofiltration processes provided by the BMP (decimal).

B.3.4 Step 3D - Satisfaction of Pollutant Control Requirements

The performance of a BMP with respect to the pollutant control performance standards is referred to as the BMP efficacy. The total BMP efficacy is a function of the previously calculated retention efficacy and biofiltration efficacy as shown below.

$$E_T = E_R + (1.00 - E_R)\ x\ E_B$$

Where:
E_T: Total BMP Efficacy (decimal)
E_R: Efficacy of retention processes (decimal)
E_B: Efficacy of biofiltration processes (decimal)

To satisfy pollutant control performance standards, the total BMP efficacy must be 100%. If this level of efficacy is not achieved, applicants should consider reconfiguring drainage layout and/or BMP designs as needed. If this level of efficacy still can't be achieved, applicants may elect to implement flow-thru treatment control at the project site and also participate in the County's Offsite Alternative Compliance Program outlined in Appendix J.

B.3.5 Step 3E - Satisfaction of Minimum Retention Requirements

Minimum retention requirements can be satisfied by demonstrating that the all of the retention elements incorporated within a drainage area (rain barrels, tree wells, dispersion areas, and BMPs) retain a volume of water that is greater than or equal to what is required.

Part 1) Determine the total volume retained through site design and structural BMP elements as follows.

$$V_{RT} = V_{RRB} + V_{RTW} + V_{RD} + V_{RBMP}$$

Where:
V_{RT}: Total volume retained within the drainage area (ft^3)
V_{RRB}: Volume retained by rain barrels (ft^3)
V_{RTW}: Volume retained by tree wells (ft^3)
V_{RD}: Volume retained by dispersion areas (ft^3)
V_{RBMP}: Volume retained by the BMP (ft^3)

Part 2) Demonstrate that the total volume retained through site design and structural BMP elements meets retention requirements.

$$V_{RT} \geq V_{REQ}$$

Where:
V_{RT}: Total volume retained within the drainage area (ft^3)
V_{REQ}: Total volume that must be retained within the drainage area (ft^3)

B.4 Less Common Pollutant Control Calculations

This section presents methodologies for performing less common pollutant control calculations including: determination of BMP major maintenance intervals, capture and use evaluation, use of offline BMPs, and BMPs located downstream of a storage unit.

B.4.1 Major Maintenance Intervals for Reduced Size BMPs

BMPs with a surface area sized at less than 3% of the tributary effective impervious area must perform additional calculations to determine the anticipated major maintenance intervals.

Major maintenance activities include items such as rehabilitation and/or replacement of the entire BMP or BMP components, which are independent of regularly scheduled annual maintenance. BMP major maintenance intervals can be calculated through use of automated Worksheet B.4 below, or can be calculated manually by following Steps 4A-4C presented in this section.

Worksheet B.4: Major Maintenance Intervals for Reduced Size BMPs

Category	#	Description	*i*	Units
Drainage Basin Info	1	Drainage Basin ID or Name		unitless
	2	Final Effective Tributary Area		sq-ft
	3	Provided BMP Surface Area		sq-ft
Biofiltration Clogging Inputs	4	Average Annual Precipitation		inches
	5	Load to Clog (default =2.0)		lb/sq-ft
	6	TSS Pretreatment Efficacy		ratio
	7	Percentage "Commercial"		percentage
	8	Percentage "Education"		percentage
	9	Percentage "Industrial"		percentage
	10	Percentage "Low Traffic Areas"		percentage
	11	Percentage "Multi-Family Residential"		percentage
	12	Percentage "Roof Areas"		percentage
	13	Percentage "Single Family Residential"		percentage
	14	Percentage "Transportation"		percentage
	15	Percentage "Vacant/Open Space"		percentage
	16	Percentage "Steep Hillslopes"		percentage
Minimum Footprint Calculations	17	Total Percentage of Above Land Uses	0%	percentage
	18	Average TSS Concentration for Tributary After Pretreatment	0	mg/L
	19	Average Annual Runoff Volume	0	cubic-feet
	20	Average Annual TSS Load	0	lb/yr
	21	Available Sediment Storage within BMP	0	lb
Result	22	Anticipated Major Maintenance Frequency	-	years

Worksheet B.4 Line Item Notes
1. Populated per user input from Worksheet B.1.
2. Populated per result of Worksheet B.1.
3. Populated per user input from Worksheet B.3.
4. User Input
5. User Input, Default=2.0. See BMPDM Table B.4-2 for guidance on revisions.
6. User Input. Default=0.00. See BMPDM Section B.4.1.1 for guidance on revisions.
7. User Input. (Commercial TSS Loading TSS = 128 mg/L, C=0.80)
8. User Input. (Education TSS Loading TSS = 132 mg/L, C=0.50)
9. User Input. (Industrial TSS Loading TSS = 125 mg/L, C=0.90)
10. User Input (Low Traffic Areas TSS Loading TSS = 50 mg/L, C=0.50)
11. User Input (Multi-Family Residential TSS Loading TSS = 40 mg/L, C=0.60)
12. User Input (Roof Areas TSS Loading TSS = 14 mg/L, C=0.90)
13. User Input (Single Family Residential TSS Loading TSS = 123 mg/L, C=0.40)
14. User Input (Transportation TSS Loading TSS = 78 mg/L, C=0.90)
15. User Input (Vacant/Open Space TSS Loading TSS = 216 mg/L, C=0.10)
16. User Input (Steep Hillslopes TSS Loading TSS = 797 mg/L, C=0.30)
17. $\sum_{\text{Lines 7-16}}$
18. [($\sum_{\text{Lines 7-16}}$ Land Use Percentage x Runoff Coefficient x TSS Concentration) / Line 17] x (1-Line 6)
19. [(Line 4/12) x Line 2
20. Line 18 x 0.000062428 x Line 19
21. Line 3 x Line 5
22. Line 21 / Line 20

B.4.1.1 Annual Sediment Load Delivered to BMP

The annual sediment load delivered to a BMP is a function of the average annual storm water runoff, land use characteristics, and pretreatment elements applicable to the drainage area.

Part 1) Determine the average sediment concentration in storm water runoff from the land uses present within the drainage area by referring to the total suspended solid (TSS) concentrations listed for various land uses in Table B.4-1 below.

Table B.4-1: TSS Concentrations by Land Use

Land Use	TSS Concentration (mg/L)	C	Source
Single Family Residential	123	0.40	San Diego SBPAT EMC Dataset
Commercial	128	0.80	
Industrial	125	0.90	
Education (Municipal)	132	0.50	
Multi-family Residential	40	0.60	
Open Space	216	0.10	
Transportation/Pavement	78	0.90	LA SBPAT EMC Dataset
Roof Runoff	14	0.90	Charters et al. (2015)
Low Traffic Areas/Sidewalk	50	0.50	Davis and McCuen (2005)
Steep Hillslopes	797	0.30	Model BMPDM

If a drainage area is comprised of more than one land use type, a runoff-weighted TSS concentration must be calculated per the following equation.

$$TSS_{AVG} = \frac{\sum TSS_1\, F_1 + TSS_2\, F_2 + TSS_x\, F_x}{\sum F_1 + F_2 + F_x}$$

Where:
TSS_{AVG}: Average sediment concentration in storm water from all tributary land uses (mg/L)
TSS_1: TSS concentration from land use 1 (mg/L)
F_1: Fraction of total DCV from land use 1 (%)
TSS_2: TSS concentration from land use 2 (mg/L)
F_2: Fraction of total DCV from land use 2 (%)
TSS_x: TSS concentration from land use x (mg/L)
F_x: Fraction of total DCV from land use x (%)

Part 2) Determine the average sediment concentration in storm water runoff as it enters the BMP. This is the concentration of TSS determined in part 1 after consideration of any "pretreatment" elements incorporated as shown below.

$$TSS_{BMP} = TSS_{AVG}\ x\ (1 - P)$$

Where:
TSS_{BMP}: Average sediment concentration in runoff entering the BMP (mg/L)
TSS_{AVG}: Average sediment concentration in storm water from all tributary land uses (mg/L)
P: Pretreatment removal efficiency (%).

- P value of 0.00 should be used if there is no pretreatment.
- P value of 0.25 should be used when pretreatment is included.
- P value of 0.50 should be used if pretreatment consistent with Washington TAPE "Pre-treatment" BMP performance criteria are satisfied (>50% TSS removal)
- P value of 0.80 should be used if pretreatment consistent with Washington TAPE "Basic Treatment" performance criteria are satisfied (>80% TSS removal)

Part 3) Determine the average annual runoff volume entering the BMP. This is a function of the average annual precipitation, runoff factor, and drainage area as shown below.

$$V_{annual} = \frac{D_{annual}}{12}\ x\ A\ x\ C$$

Where:
V_{annual}: Average annual runoff volume entering the BMP (ft^3/year)
D_{annual}: Average annual precipitation (inches/year)
A: Tributary Area (ft^2)
C: Runoff factor (unitless)

Part 4) Determine the annual sediment load delivered to the BMP. This is a function of the average annual runoff volume and the average sediment concentration in stormwater from all tributary land uses as shown below.

$$L_{annual} = TSS_{BMP}\ x\ V_{annual}\ x\ 0.0000624$$

Where:
L_{annual}: Annual sediment load delivered to the BMP (lbs/year)
TSS_{BMP}: Average sediment concentration in runoff entering the BMP (mg/L)
V_{annual}: Average annual runoff volume entering the BMP (ft^3)

B.4.1.2 BMP Sediment Capacity

The BMP sediment capacity is the weight of sediment (lbs) that can be stored within the BMP before significant clogging impacts begin to occur. The BMP sediment capacity can be determined as follows.

Part 1) Determine the appropriate load to clog value by referencing Table B.4-2 below and identifying the BMP configuration that best characterizes the proposed BMP design.

Table B.4-2: Guidance for Selecting Load to Clog (Lc)

BMP Configuration	Load to Clog, L_c, lb/sq-ft
Default Load to Clog Value	2
≥75% vegetative cover	3
≥20 in/hr media permeability and outlet flow control	3
≥75% vegetative cover, ≥30 in/hr media permeability, and outlet control	4

Part 2) Determine the BMP Sediment Capacity (lbs) by multiplying the BMP Load to Clog by the BMP surface area.

$$C_{BMP} = B\ x\ L_c$$

Where:
C_{BMP}: BMP sediment capacity (lbs)
B: BMP Surface Area (ft^2)
L_c: BMP load to clog value (lbs/ft^2)

B.4.1.3 Major Maintenance Frequency

The major maintenance frequency can be calculated by dividing the BMP sediment capacity by the annual sediment load delivered to the BMP as shown below.

$$M_{BMP} = \frac{C_{BMP}}{L_{annual}}$$

Where:
M_{BMP}: Major maintenance frequency for BMP (years)
C_{BMP}: BMP sediment capacity (lbs)
L_{annual}: Annual sediment load delivered to the BMP (lbs/yr)

The calculated major maintenance frequency must be 10 years or greater. If the calculated major maintenance frequency is less than 10 years, the applicant must take steps to increase the BMP sediment capacity and/or reduce the annual sediment load delivered to the BMP. In limited circumstances, frequencies of less than 10 years may be acceptable if supported to the satisfaction of the County plan reviewer.

B.4.2 Capture and Use Evaluation

If the proposed project includes habitable structures over 9 stories in height, the applicant must perform a capture and use evaluation as outlined herein.

The capture and use evaluation should be performed at the project-scale, and not be limited to a single DMA. This evaluation must identify the potential demand for using stormwater for indoor toilets and outdoor irrigation use and determine if this demand is sufficient to drawdown the DCV within a 36 hour time period.

B.4.2.1 Toilet and Urinal Flushing Demand Calculations*

The following guidelines should be followed for computing harvested water demand from toilet and urinal flushing:

- If reclaimed water is planned for use for toilet and urinal flushing, then the demand for harvested storm water is equivalent to the total demand minus the reclaimed water supplied, and should be reduced by the amount of reclaimed water that is available during the wet season.
- Demand calculations for toilet and urinal flushing should be based on the average rate of use during the wet season for a typical year.
- Demand calculations should include changes in occupancy over weekends and around holidays and changes in attendance/enrollment over school vacation periods.
- For facilities with generally high demand, but periodic shut downs (e.g., for vacations, maintenance, or other reasons), a project specific analysis should be conducted to determine whether the long term storm water capture performance of the system can be maintained despite shut downs.
- Such an analysis should consider the statistical distributions of precipitation and demand, most importantly the relationship of demand to the wet seasons of the year.

Table B.4-3 provides planning level demand estimates for toilet and urinal flushing per resident, or employee, for a variety of project types. The per capita use per day is based on daily employee or resident usage. For non-residential types of development, the “visitor factor” and “student factor” (for schools) should be multiplied by the employee use to account for toilet and urinal usage for non-employees using facilities.

Note: At the time of publication of this document, there is not a program in place to permit the use of storm water for indoor use. Check with PDS prior to calculating indoor water use.

Table B.4-3: Toilet and Urinal Water Usage per Resident or Employee

Land Use Type	Toilet User Unit of Normalization	Per Capita Use per Day		Visitor Factor[4]	Water Efficiency Factor	Total Use per Resident or Employee
		Toilet Flushing[1, 2]	Urinals[3]			
Residential	Resident	18.5	NA	NA	0.5	9.3
Office	Employee (non-visitor)	9.0	2.27	1.1	0.5	7 (avg)
Retail	Employee (non-visitor)	9.0	2.11	1.4	0.5	
Schools	Employee (non-student)	6.7	3.5	6.4	0.5	33
Various Industrial Uses (excludes process water)	Employee (non-visitor)	9.0	2	1	0.5	5.5

1 - Based on American Waterworks Association Research Foundation, 1999. Residential End Uses of Water. Denver, CO: AWWARF

2 - Based on use of 3.45 gallons per flush and average number of per employee flushes per subsector, Table D-1 for MWD (Pacific Institute, 2003)

3 - Based on use of 1.6 gallons per flush, Table D-4 and average number of per employee flushes per subsector, Appendix D (Pacific Institute, 2003)

4 - Multiplied by the demand for toilet and urinal flushing for the project to account for visitors. Based on proportion of annual use allocated to visitors and others (includes students for schools; about 5 students per employee) for each subsector in Table D-1 and D-4 (Pacific Institute, 2003)

5 - Accounts for requirements to use ultra low flush toilets in new development projects; assumed that requirements will reduce toilet and urinal flushing demand by half on average compared to literature estimates. Ultra low flush toilets are required in all new construction in California as of January 1, 1992. Ultra low flush toilets must use no more than 1.6 gallons per flush and Ultra low flush urinals must use no more than 1 gallon per flush. Note: If zero flush urinals are being used, adjust accordingly.

B.4.2.2 Planning Level Irrigation Demands

To simplify the planning process, the method described above has been used to develop daily average wet season demands for a one-acre irrigated area based on the plant/landscape type. These demand estimates can be used to calculate the drawdown of harvest and use systems for the purpose of LID BMP sizing calculations.

Table B.4-4: Planning Level Irrigation Demand by Plant Factor and Landscape Type

General Landscape Type	36-Hour Planning Level Irrigation Demand (gallons per irrigated acre per 36 hour period)
Hydrozone – Low Plant Water Use	390
Hydrozone – Moderate Plant Water Use	1,470
Hydrozone – High Plant Water Use	2,640
Special Landscape Area	2,640

B.4.3 BMPs Downstream of a Storage Unit

Incorporation of upstream storage units (cisterns, vaults, etc) into a project's design can regulate flows to downstream biofiltration BMPs and potentially optimize the required BMP footprints. Use of this approach is not supported by County automated worksheets, but compliance with stormwater pollutant control requirements can be demonstrated through the following steps.

- Step 1) Determine the flow rate from the upstream storage unit
  - Use the orifice equation to determine outflow from the storage unit when it is filled to the depth associated with the DCV.
- Step 2) Demonstrate that the proposed BMP can accommodate flows from the storage unit
  - Multiply the BMP surface area (ft^2) by the filtration rate of the biofiltration soil media (in/hr) and divide by 43,200 to convert the units into CFS. For proprietary BMPs, this rate should correspond with the rates from certified testing the manufacturer has performed.
- Step 3) Demonstrate that the proposed BMP biofilters 92% of the annual runoff volume
  - If continuous simulation modeling has been performed, provide output reports from SWMM or SDHM modeling.
  - If continuous simulation modeling has not been performed, reference the percent capture nomographs in Figure B.3-1 to determine the percentage of annual runoff that is biofiltered. To use the nomographs, applicants must represent the BMP storage capacity as a fraction of the DCV along the x-axis, trace a line vertically to the colored line representing the drawdown time of the system, and then determine the percentage of annual runoff biofiltered by tracing horizontally to the y-axis.
- Step 4) If the downstream biofiltration BMP is <3% of the effective tributary area, provide information supporting use of compact biofiltration as generally outlined below.
  - Retention Requirements: Demonstrate that minimum retention requirements from Section B.2 are satisfied.
  - Maintenance Requirements: Demonstrate that the BMP design is expected to last 10 years before major maintenance is anticipated per Appendix B.4.1.
  - Proprietary Requirements (if applicable): Provide proprietary information demonstrating that the device meets biofiltration criteria outlined in Appendices F.1-F.2.

B.4.4 Onsite Alternative Compliance

If desired, a PDP applicant may generate stormwater pollutant control and/or hydromodification flow control benefits by managing stormwater flows from "excess areas" that are conveyed to the site. Management of flows from these excess areas may be used to offset flows from "required areas" that lack management.

Required areas are the areas of a project for which the Permit mandates pollutant control and/or HMP flow control requirements. Excess areas are the areas of a project for which the Permit does not mandate pollutant control and/or HMP flow control requirements. Areas of offsite run-on to the PDP site may always be considered excess areas. Additionally, for redevelopment projects falling under the 50% redevelopment threshold, onsite areas that are not being redeveloped may also be considered excess areas.

Compliance with stormwater pollutant control requirements using this onsite alternative compliance approach can be demonstrated as outlined below.

- Step 1) Determine the untreated DCV from the required area
- Step 2) Determine the treated DCV from the excess area
  - If required areas and excess areas contain different land uses, a land use factor must be applied to account for variations in pollutant concentrations. In most cases, this factor results in a lower treatment volume being credited. Refer to the Water Quality Equivalency (WQE) document for guidance on determining a land use factor and note that the WQE terms "ACP tributary" and "reference tributary" correlate with "excess areas" and "required areas" respectively.
- Step 3) Demonstrate compliance
  - Show that the treated DCV from the excess area is greater than or equal to the untreated DCV from the required area (Step 2 ≥ Step 1).
  - Use of this onsite alternative compliance approach does not mandate flow-thru treatment of untreated flows from required areas; however, applicants are encouraged to do so where feasible.

B.4.5 Offline BMPs

Diversion flow rates for offline BMPs must be sized to convey the maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of every storm event. The following hydrologic method must be used to calculate the diversion flow rate for off-line BMPs:

$$Q = C \times i \times A$$

Where:
Q = Diversion flow rate in cubic feet per second
C = Runoff factor, area weighted estimate using Table B.1-1
i = Rainfall intensity of 0.2 in/hr
A = Tributary area (acres)

B.5 Backup Information on Pollutant Control Standards

This sections presents backup information describing the rationale for the following elements relating to pollutant control: establishment of the pollutant control performance standard, establishment of retention requirements, establishment of 85th percentile rainfall depths, backup information on tree well retention values, and backup information on BMP major maintenance frequency calculations.

B.5.1 Pollutant Control Performance Standard Backup

Storm water BMPs can be conceptualized as having a storage volume and a treatment rate, in various proportions. Both are important in the long-term performance of the BMP under a range of actual storm patterns, depths, and inter-event times. Long-term performance is measured by the operation of a BMP over the course of multiple years, and provides a more complete metric than the performance of a BMP during a single event, which does not take into account antecedent conditions, including multiple storms arriving in short timeframes. A BMP that draws down more quickly would be expected to capture a greater fraction of overall runoff (i.e., long-term runoff) than an identically sized BMP that draws down more slowly. This is because storage is made available more quickly, so subsequent storms are more likely to be captured by the BMP. In contrast a BMP with a long drawdown time would stay mostly full, after initial filling, during periods of sequential storms. The volume in the BMP that draws down more quickly is more "valuable" in terms of long term performance than the volume in the one that draws down more slowly. The MS4 permit definition of the DCV does not specify a drawdown time, therefore the definition is not a complete indicator of a BMP's level of performance. An accompanying performance-based expression of the BMP sizing standard is essential to ensure uniformity of performance across a broad range of BMPs and helps prevents BMP designs from being used that would not be effective.

An evaluation of the relationships between BMP design parameters and expected long term capture efficiency has been conducted to address the needs identified above. Relationships have been developed through a simplified continuous simulation analysis of precipitation, runoff, and routing, that relate BMP design volume and storage recovery rate (i.e., drawdown time) to an estimated long term level of performance using United States Environmental Protection Agency (USEPA) SWMM and parameters listed in Appendix G for Lake Wohlford, Lindbergh, and Oceanside rain gages. Comparison of the relationships developed using the three gages indicated that the differences in relative capture estimates are within the uncertainties in factors used to develop the relationships. For example, the estimated average annual capture for the BMP sized for the DCV and 36 hour drawdown using Lake Wohlford, Lindbergh, and Oceanside are 80%, 76% and 83% respectively. In an effort to reduce the number of curves that are made available, relationships developed using Lake Wohlford are included in this manual for use in the whole San Diego County region.

Figure B.4-1 demonstrated that a BMP sized for the runoff volume from the 85th percentile, 24-hour storm event (i.e., the DCV), which draws down in 36 hours is capable of managing approximately 80 percent of the average annual. There is long precedent for 80 percent capture of average annual runoff as approximately the point at which larger BMPs provide decreasing capture efficiency benefit (also known as the "knee of the curve") for BMP sizing. The characteristic shape of the plot of capture efficiency versus storage volume in Figure B.3-1 illustrates this concept.

As such, this equivalency (between DCV draw down in 36-hours and 80 percent capture) has been utilized to provide a common currency between volume-based BMPs with a wide range of drawdown rates. This approach allows flexibility in the design of BMPs while ensuring consistent performance.

B.5.2 Retention Requirement Backup

In May 2016, the RWQCB provided clarification on the 2013 MS4 Permit requirement for the BMPDM to "…provide guidance for hydraulic loading rates and other biofiltration design criteria necessary to maximize the storm water retention and pollutant removal of treatment control BMPs." Through coordination with the RWQCB, a quantifiable minimum retention requirement for treatment control BMPs was established based on the assumption that BMPs would be sized at 3% of the effective tributary area and be unlined where feasible.

The retention curves presented in Figure B.2-1 were developed using Version 1.4 automated pollutant control worksheets assuming various rainfall depths (0.60 to 1.20 inches) and design infiltration rates (0.000 to 0.500 in/hr). BMPs were sized at 3% of the effective impervious tributary area, provided 18" soil media depth, 3" of gravel above the underdrain, 6" underdrains with no hydromodification management orifices, 3" of gravel beneath the underdrain, and varied surface ponding depths as needed to fully satisfy pollutant removal standards.

B.5.3 Rainfall Depth Backup

The method of calculating the 85th percentile is to produce a list of values, order them from smallest to largest, and then pick the value that is 85 percent of the way through the list. Only values that are capable of producing run off are of interest for this purpose. Lacking a legislative definition of rainfall values capable of producing runoff, Flood Control staff in San Diego County have observed that the point at which significant runoff begins is rather subjective, and is affected by land use type and soil moisture. In highly-urbanized areas, the soil has a high impermeability and runoff can begin with as little as 0.02" of rainfall. In rural areas, soil impermeability is significantly lower and even 0.30" of rain on dry soil will frequently not produce significant runoff. For this reason, San Diego County has chosen to use the more objective method of including all non-zero 24-hour rainfall totals when calculating the 85th percentile. To produce a statistically significant number, only stations with 30 years or greater of daily rainfall records are used.

A collection of 56 precipitation gage points was developed with 85th percentile precipitation values based on multiple years of gage data. A raster surface (grid of cells with values) was interpolated from that set of points. The surface initially did not cover the County's entire jurisdiction. A total of 13 dummy points were added. Most of those were just outside the County boundary to enable the software to generate a surface that covered the entire County. A handful of points were added to enforce a plausible surface. In particular, one point was added in the desert east of Julian, to enforce a gradient from high precipitation in the mountains to low precipitation in the desert. Three points were added near the northern boundary of the County to adjust the surface to reflect the effect of elevation in areas lacking sufficient operating gages.

Several methods of interpolation were considered. The method chosen is named by Environmental Systems Research Institute as the Natural Neighbor technique. This method produces a surface that is highly empirical, with the value of the surface being a product of the values of the data points nearest each cell. It does not produce peaks or valleys of surface based on larger area trends, and is free of artifacts that appeared with other methods.

B.5.4 Tree Well Backup

Tree Well credit volume is estimated based on typical characteristics of Tree Wells as follows:

It is assumed that each tree is considered a single BMP, with calculations based on the soil media reservoir volume and/or the individual tree within the tree BMP as appropriate. Tree Well credit volume is calculated as:

$$TWCV = TIV + TCIV + TETV$$

Where:
TWCV = Tree Well credit volume (ft^3)
TIV = Total infiltration volume of all storage layers within tree BMPs (ft^3)
TCIV = Total canopy interception volume of tree BMPs (ft^3)
TETV = Total evapotranspiration volume, sums the media evapotranspiration storage within each tree BMP (ft^3)

Total infiltration volume is calculated as the total volume stored within the tree BMP soil media reservoir. Infiltration volume was assumed to be 20% of the total BMP soil media reservoir volume, the available pore space in the soil media reservoir (porosity – field capacity).

Total canopy interception volume was calculated as the average interception capacity for the entire mature tree canopy projection area. Interception capacity was determined to be 0.04 inches per square foot for all tree sizes, an average from the findings published by Breuer et al (2003) for coniferous and deciduous trees.

Total evapotranspiration volume is the available evapotranspiration storage volume (field capacity – wilting point) within the BMP storage layer media. TEVT is assumed to be 10% of the minimum soil volume. The minimum soil volume as required by SD-A fact sheet of 2 cubic feet per unit canopy projection area was assumed for estimating reduction in DCV.

There may be rain events that generate more runoff than the tree well can handle. Installing an overflow above the design storm water retention level of the reservoir can prevent system failure during extreme weather events. Placement of the overflow should be determined based on the infiltration rate of the subsoil. If infiltration is not adequate to remove water from the rooting zone (the top 18 to 24 inches of soil media reservoir) within 48 hours, the depth of the soil media reservoir may be increased, and the overflow should be placed such that if water rises to the level of the rooting zone it will drain in less than 48 hours.

B.5.5 Sediment Clogging Backup

Under the 2011 Model SUSMP, a sizing factor of 4 percent was used for sizing biofiltration BMPs. This value was derived based on the goal of treating the runoff from a 0.2 inch per hour uniform precipitation intensity at a constant media flow rate of 5 inches per hour. While this method was simple, it was considered to be conservative as it did not account for significant transient storage present in biofiltration BMPs (i.e., volume in surface storage and subsurface storage that would need to fill before overflow occurred). Under this manual, biofiltration BMPs will typically provide subsurface storage to promote infiltration losses; therefore typical BMP profiles will tend to be somewhat deeper than those provided under the 2011 Model SUSMP. A deeper profile will tend to provide more transient storage and allow smaller footprint sizing factors while still providing similar or better treatment capacity and pollutant removal. Therefore a reduction in the minimum sizing factor from the factor used in the 2011 Model SUSMP is supportable. However, as footprint decreases, issues related to potential performance, operations, and/or maintenance can increase for a number of reasons:

1) As the surface area of the media bed decreases, the sediment loading per unit area increases, increasing the risk of clogging. While vigorous plant growth can help maintain permeability of soil, there is a conceptual limit above which plants may not be able to mitigate for the sediment loading. Scientific knowledge is not conclusive in this area.

2) With smaller surface areas and greater potential for clogging, water may be more likely to bypass the system via overflow before filling up the profile of the BMP.

3) As the footprint of the system decreases, the amount of water that can be infiltrated from subsurface storage layers and evapotranspire from plants and soils tends to decrease.

4) With smaller sizing factors, the hydraulic loading per unit area increases, potentially reducing the average contact time of water in the soil media and diminishing treatment performance.

The MS4 Permit requires that volume and pollutant retention be maximized. Therefore, a minimum sizing factor was determined to be needed. This minimum sizing factor does not replace the need to conduct sizing calculations as described in this manual; rather it establishes a lower limit on required size of biofiltration BMPs as the last step in these calculations. Additionally, it does not apply to alternative biofiltration designs that utilize the checklist in Appendix F (Biofiltration Standard and Checklist). Acceptable alternative designs (such as proprietary systems meeting Appendix F criteria) typically include design features intended to allow acceptable performance with a smaller footprint and have undergone field scale testing to evaluate performance and required O&M frequency.

Sediment Clogging Calculations

As sediment accumulates in a filter, the permeability of the filter tends to decline. The lifespan of the filter bed can be estimated by determining the rate of sediment loading per unit area of the filter bed. To determine the media bed surface area sizing factor needed to provide a target lifespan, simple sediment loading calculations were conducted based on typical urban conditions. The inputs and results of this calculation are summarized in Table B.5-1.

Table B.5-1: Inputs and Results of Clogging Calculation

Parameter	Value	Source
Representative TSS Event Mean Concentration, mg/L	100	Approximate average of San Diego Land Use Event Mean Concentrations from San Diego River and San Luis Rey River WQIP
Runoff Coefficient of Impervious Surface	0.90	Table B.1-1
Runoff Coefficient of Pervious Surface	0.10	Table B.1-1 for landscape areas
Imperviousness	40% to 90%	Planning level assumption, covers typical range of single family to commercial land uses
Average Annual Precipitation, inches	11 to 13	Typical range for much of urbanized San Diego County

Parameter	Value	Source
Load to Initial Maintenance, kg/m^2	10	Pitt, R. and S. Clark, 2010. Evaluation of Biofiltration Media for Engineered Natural Treatment Systems.
Allowable period to initial clogging, yr	10	Planning-level assumption
Estimated BMP Footprint Needed for 10-Year Design Life	2.8 to 3.3%	Calculated

This analysis suggests that a 3 percent sizing factor, coupled with sediment source controls and careful system design, should provide reasonable protection against premature clogging. However, there is substantial uncertainty in sediment loading and the actual load to clog that will be observed under field conditions in the San Diego climate. Additionally this analysis did not account for the effect of plants on maintaining soil permeability. Therefore this line of evidence should be considered provisional, subject to refinement based on field scale experience. As field scale experience is gained about the lifespan of biofiltration BMPs in San Diego and the mitigating effects of plants on long term clogging, it may be possible to justify lower factors of safety and therefore smaller design sizes in some cases. If a longer lifespan is desired and/or greater sediment load is expected, then a larger sizing factor may be justified.

Generally, the purpose of a minimum sizing factor is to help improve the performance and reliability of standard biofiltration systems and limit the use of sizing methods and assumptions that may lead to designs that are less consistent with the intent of the MS4 Permit.

Ultimately, this factor is a surrogate for a variety of design considerations, including clogging and associated hydraulic capacity, volume reduction potential, and treatment contact time. A prudent design approach should consider each of these factors on a project-specific basis and identify whether site conditions warrant a larger or smaller factor. For example a system treating only rooftop runoff in an area without any allowable infiltration may have negligible clogging risk and negligible volume reduction potential – a smaller sizing factor may not substantially reduce performance in either of these areas. Alternatively, for a site with high sediment load and limited pre-treatment potential, a larger sizing factor may be warranted to help mitigate potential clogging risks. County staff has discretion to accept alternative sizing factor(s) based on project-specific or jurisdiction-specific considerations. Additionally, the recommended minimum sizing factor may change over time as more experience with biofiltration is obtained.

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