APPENDIX F

SAMPLE DESIGN CALCULATIONS & WORKSHEETS

The information provided in this appendix was taken from the Los Angeles County Department of Public Works' *Development Planning for Stormwater Management, A Manual for the Standard Urban Stormwater Mitigation Plan, Appendix A, Volume and Flow Rate Calculations*, issued on May 2000 (LACDPW, 2000). No modifications were made. For Predominate Soil Type information, please refer to appendix A of the reference above, Los Angeles County Department of Public Works- Hydrology / Sedimentation Appendix

Note: For Predominate Soil Type information, please refer to appendix A of the reference above, Los Angeles County Department of Public Works- Hydrology / Sedimentation Appendix

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NOMENCLATURE

A_I = Impervious Area (acres)
A_P = Pervious Area (acres)
A_U = Contributing Undeveloped Upstream Area (acres)
A_{Total} = Total Area of Development and Contributing Undeveloped Upstream Area (acres)
C_D = Developed Runoff Coefficient
C_U = Undeveloped Runoff Coefficient
I_X = Rainfall Intensity (inches / hour)
Q_{PM} = Peak Mitigation Flow Rate (cfs)
T_C = Time of Concentration (minutes, must be between 5-30 min.)
V_M = Mitigation Volume (ft^3)

EQUATIONS

$A_{Total} = A_I + A_P + A_U$

$A_I = (A_{Total} \bullet \text{\% of Development which is Impervious})$

$A_P = (A_{Total} \bullet \text{\% of Development which is Pervious})$

$A_U = (A_{Total} \bullet \text{\% of Contributing Undeveloped Upstream Area***})$

$C_D = (0.9 \bullet \text{Imp.}) + [(1.0 - \text{Imp.}) \bullet C_U]$ If $C_D < C_U$, use $C_D = C_U$

$Q_{PM} = C_D \bullet I_X \bullet A_{Total} \bullet (1 \text{ hour} / 3{,}600 \text{ seconds}) \bullet (1 \text{ ft} / 12 \text{ inches}) \bullet (43{,}560 \text{ ft}^2 / 1 \text{ acre})$
$= C_D \bullet I_X \bullet A_{Total} \bullet (1.008333 \text{ ft}^3\text{-hour / acre-inches-seconds})$

$T_C = 10^{-0.507} \bullet (C_D \bullet I_X)^{-0.519} \bullet \text{Length}^{0.483} \bullet \text{Slope}^{-0.135}$

$V_M = (0.75 \text{ inches}) \bullet [(A_I)(0.9) + (A_P + A_U)(C_U)] \bullet (1 \text{ ft} / 12 \text{ inches}) \bullet (43{,}560 \text{ ft}^2 / 1 \text{ acre})$
$= (2{,}722.5 \text{ ft}^3 / \text{acre}) \bullet [(A_I)(0.9) + (A_P + A_U)(C_U)]$

***** Contributing Undeveloped Upstream Area is an area where stormwater runoff from an undeveloped upstream area will flow directly or indirectly to the Post-construction Best Management Practices (BMPs) proposed for the development. This additional flow must be included in the flow rate and volume calculations to appropriately size the BMPs.**

PROVIDE PROPOSED PROJECT CHARACTERISTICS

A_{Total} __________________ Acres

Type of Development __________________

Predominate Soil Type # __________________

% of Project Impervious __________________

% of Project Pervious __________________

% of Project Contributing Undeveloped Area __________________

A_I __________________ Acres

A_P __________________ Acres

A_U __________________

DETERMINING THE PEAK MITIGATED FLOW RATE (Q_{PM}):

In order to determine the peak mitigated flow rate (Q_{PM}) from the new development, use the Los Angeles County Department of Public Works *Hydrology Manual*. Use the Modified Rational Method for calculating the peak mitigation Q_{PM} for compliance with the Standard Urban Stormwater Mitigation Plan (SUSMP). Use attached **Table 1** for all maximum intensity (I_X) values used.

By trial and error, determine the time of concentration (T_C), as shown below:

CALCULATION STEPS:

1. Assume an initial T_C value between 5 and 30 minutes.

T_C ___________ minutes

2. Using Table 1, look up the assumed T_C value and select the corresponding I_X intensity in inches/hour.

I_X ___________ inches/hour

3. Determine the value for the Undeveloped Runoff Coefficient, C_U, using the runoff coefficient curve corresponding to the predominant soil type.

C_U ___________

4. Calculate the Developed Runoff Coefficient, $C_D = (0.9 \cdot \text{Imp.}) + [(1.0 - \text{Imp.}) \cdot C_U]$

C_D ___________

5. Calculate the value for $C_D \cdot I_X$

$C_D * I_X$ ___________

6. Calculate the time of concentration, $T_C = 10^{-0.507} \cdot (C_D \cdot I_X)^{-0.519} \cdot \text{Length}^{0.483} \cdot \text{Slope}^{-0.135}$

Calculated T_C ___________ minutes

7. Calculate the difference between the initially assumed T_C and the calculated T_C, if the difference is greater than 0.5 minutes. Use the calculated T_C as the assumed initial T_C in the second iteration. If the T_C value is within 0.5 minutes, round the acceptable T_C value to the nearest minute.

TABLE FOR ITERATIONS:

Iteration No.	Initial T_C (min)	I_X (in/hr)	C_U	C_D	C_D*I_X (in/hr)	Calculated T_C (min)	Difference (min)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Acceptable T_C value ______________ minutes

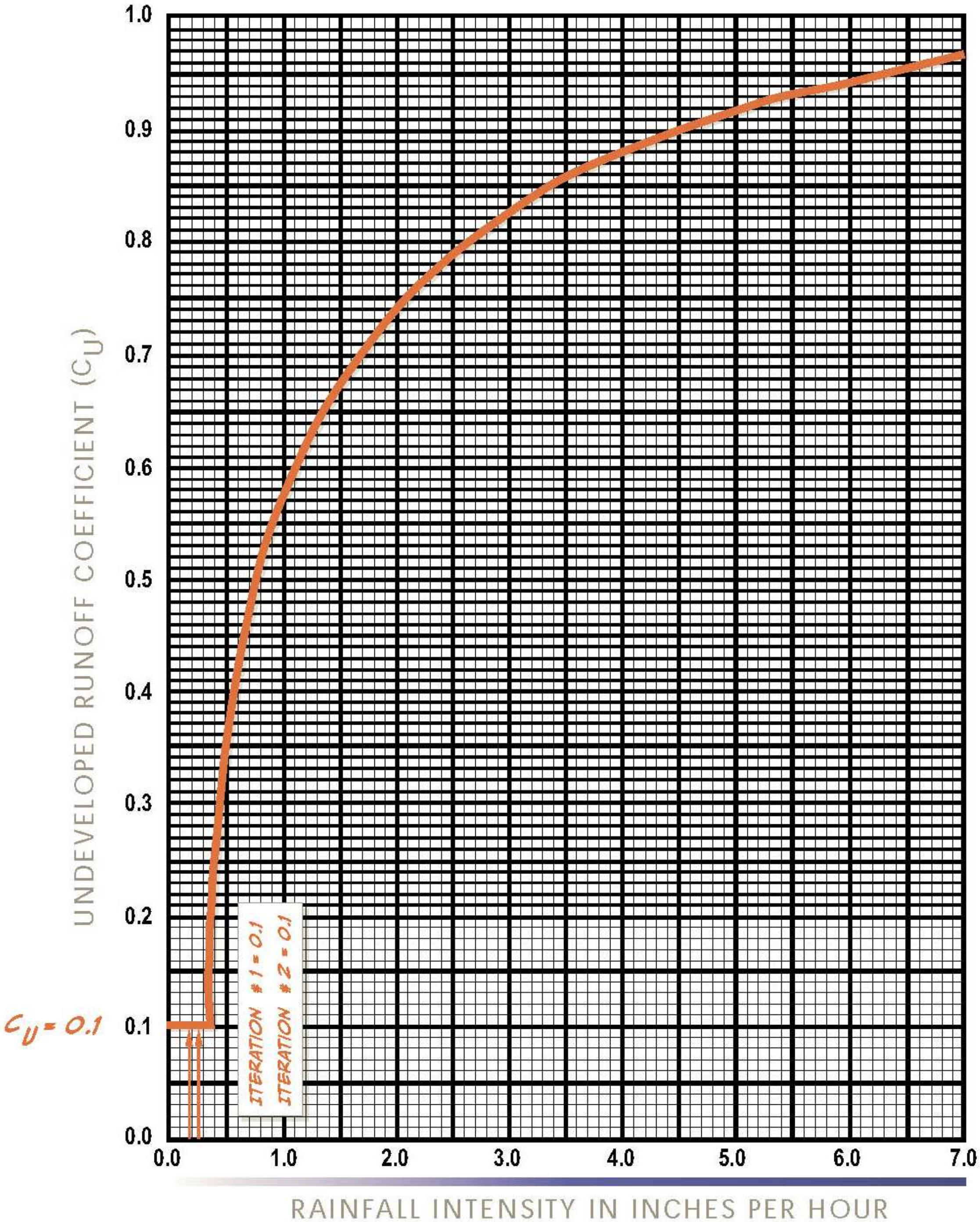
8. Calculate the Peak Mitigation Flow Rate,
$Q_{PM} = C_D \bullet I_X \bullet A_{Total} \bullet$ (1.008333 ft^3-hour / acre-inches-seconds)

Q_{PM} ___________ cfs

TABLE 1

INTENSITY - DURATION DATA FOR 0.75-INCHES OF RAINFALL
FOR ALL RAINFALL ZONES

Duration, TC (min)	Rainfall Intensity, IX (in/hr)
5	0.447
6	0.411
7	0.382
8	0.359
9	0.339
10	0.323
11	0.309
12	0.297
13	0.286
14	0.276
15	0.267
16	0.259
17	0.252
18	0.245
19	0.239
20	0.233
21	0.228
22	0.223
23	0.218
24	0.214
25	0.210
26	0.206
27	0.203
28	0.199
29	0.196
30	0.193



EQUATION:

$C_D = (0.9 * IMP) + (1.0 — IMP)\ C_U$

Where: C_D = Developed runoff coefficient.

IMP = Proportion impervious.

C_U = Undeveloped runoff coefficient.

Los Angeles County
Department of Public Works

RUNOFF COEFFICIENCY CURVE
SOIL TYPE NO. 006

Hydrology/Sedimentation Appendix D-25 December 1990

DETERMINING THE VOLUME (V_M)

9. In order to determine the volume (V_M) of stormwater runoff to be mitigated from the new development, use the following equation:

$$V_M = (2{,}722.5 \text{ ft}^3 / \text{acre}) \bullet [(A_I)(0.9) + (A_P + A_U)(C_U)]$$

BMP TYPE AND SIZE

10. List the BMP Type(s) to be used in managing the calculated V_m, and size it per the design criteria listen in Section 4

.

A.2 FLOW RATE AND VOLUME CALCULATION EXAMPLE

PROJECT NAME

Commercial Site Example___________________

PROVIDE PROPOSED PROJECT CHARACTERISTICS

A_{Total}	**1.15**	Acres
Type of Development	**Commercial**	
Predominate Soil Type #	**6**	
% of Project Impervious	**87 %**	
% of Project Pervious	**13%**	
% of Project Contributing Undeveloped Area	**0 %**	
A_I	**1.0**	Acres
A_P	**0.15**	Acres
A_U	**0**	

DETERMINING THE PEAK MITIGATED FLOW RATE (Q_{PM}):

In order to determine the peak mitigated flow rate (Q_{PM}) from the new development, use the Los Angeles County Department of Public Works *Hydrology Manual*. Use the Modified Rational Method for calculating the peak mitigation Q_{PM} for compliance with the Standard Urban Stormwater Mitigation Plan (SUSMP). Use attached **Table 1** for all maximum intensity (I_X) values used.

By trial and error, determine the time of concentration (T_C), as shown below:

<u>CALCULATION STEPS:</u>

1. Assume an initial T_C value between 5 and 30 minutes.

T_C __**5**__ minutes

2. Using Table 1, look up the assumed T_C value and select the corresponding I_X intensity in inches/hour.

I_X __**0.447**__ inches/hour

3. Determine the value for the Undeveloped Runoff Coefficient, C_U, using the runoff coefficient curve corresponding to the predominant soil type.

C_U __**0.1**__

4. Calculate the Developed Runoff Coefficient, $C_D = (0.9 \cdot \text{Imp.}) + [(1.0 - \text{Imp.}) \cdot C_U]$

C_D __**0.796**__

5. Calculate the value for $C_D \cdot I_X$

$C_D * I_X$ __**0.356**__

6. Calculate the time of concentration, $T_C = 10^{-0.507} \cdot (C_D \cdot I_X)^{-0.519} \cdot \text{Length}^{0.483} \cdot \text{Slope}^{-0.135}$

Calculated T_C __**14.28**__ minutes

7. Calculate the difference between the initially assumed T_C and the calculated T_C, if the difference is greater than 0.5 minutes. Use the calculated T_C as the assumed initial T_C in the second iteration. If the T_C value is within 0.5 minutes, round the acceptable T_C value to the nearest minute.

TABLE FOR ITERATIONS:

Iteration No.	Initial T_C (min)	I_X (in/hr)	C_U	C_D	C_D*I_X (in/hr)	Calculated T_C (min)	Difference (min)
1	5	0.447	0.3	0.87	0.39	15.28	10.58
2	15.58	0.276	0.1	0.86	0.23	20.49	4.91
3	20.49	0.233	0.1	0.86	0.20	22.00	1.50
4							
5							
6							
7							
8							
9							
10							

Acceptable T_C value __**20**__ minutes

8. Calculate the Peak Mitigation Flow Rate,
   $Q_{PM} = C_D \cdot I_X \cdot A_{Total} \cdot$ (1.008333 ft^3-hour / acre-inches-seconds)

   Q_{PM} = __0.23 cfs__

   C_D = 0.83

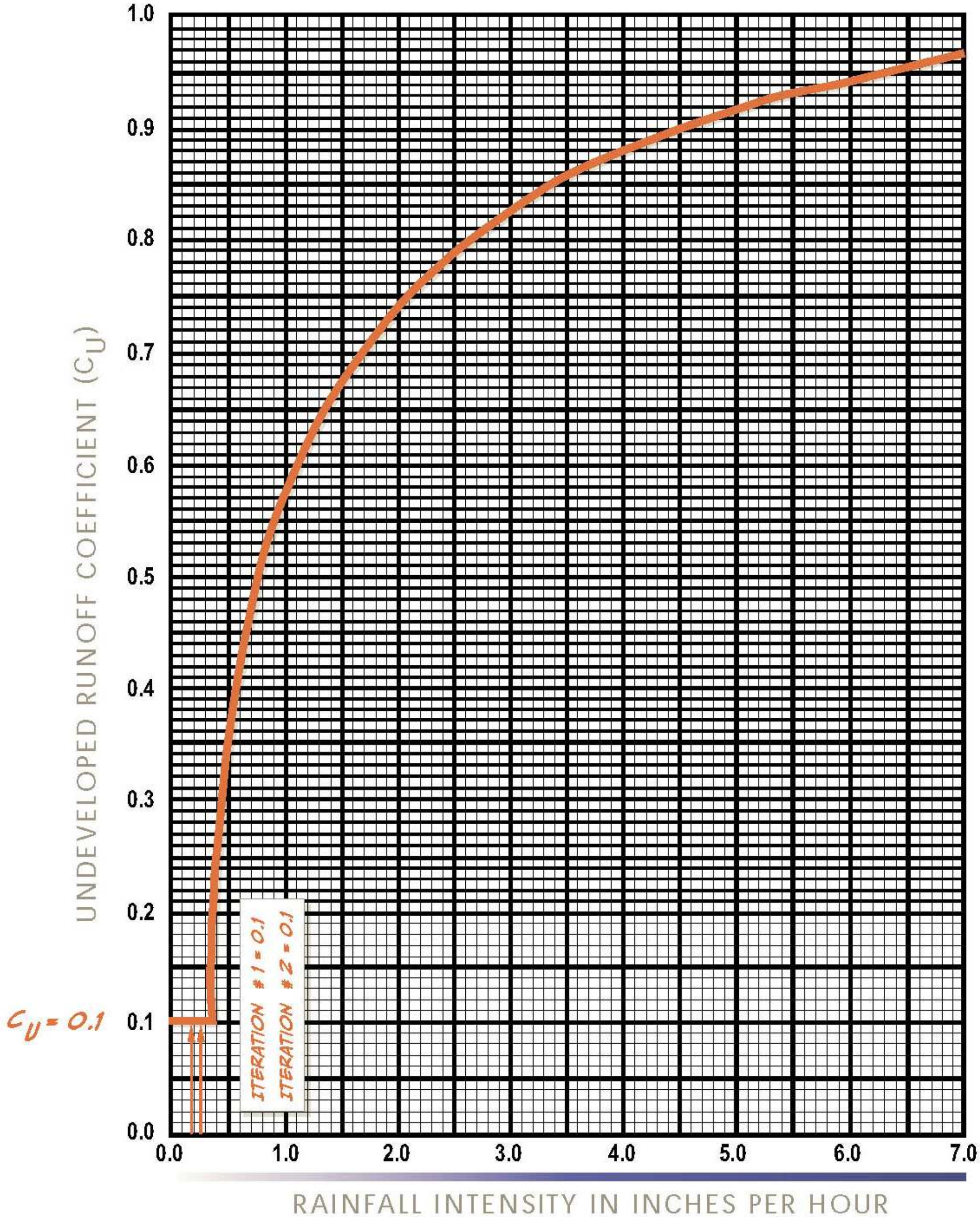
   I_{20} = 0.23 *(from Table 1)*

   A_{Total} = 1.15 acres

TABLE 1

INTENSITY - DURATION DATA FOR 0.75-INCHES OF RAINFALL
FOR ALL RAINFALL ZONES

Duration, TC (min)	Rainfall Intensity, IX (in/hr)
5	0.447
6	0.411
7	0.382
8	0.359
9	0.339
10	0.323
11	0.309
12	0.297
13	0.286
14	0.276
15	0.267
16	0.259
17	0.252
18	0.245
19	0.239
20	0.233
21	0.228
22	0.223
23	0.218
24	0.214
25	0.210
26	0.206
27	0.203
28	0.199
29	0.196
30	0.193



EQUATION:

$C_D = (0.9 * IMP) + (1.0 — IMP)\ C_U$

Where:
- C_D = Developed runoff coefficient.
- IMP = Proportion impervious.
- C_U = Undeveloped runoff coefficient.

Los Angeles County
Department of Public Works

RUNOFF COEFFICIENCY CURVE
SOIL TYPE NO. 006

Hydrology/Sedimentation Appendix D-25 December 1990

DETERMINING THE VOLUME (V_M)

9. In order to determine the volume (V_M) of stormwater runoff to be mitigated from the new development, use the following equation:

$V_M = (\ 2{,}722.5\ ft^3 / \text{acre}\ ) \cdot [\ (\ A_I\ )(\ 0.9\ ) + (\ A_P + A_U\ )(\ C_U\ )\ ]$

A_I = 1.0 acres

A_P = 0.15 acres

C_U = 0.1

V_M = 2,492 ft^3

BMP TYPE AND SIZE

10. List the BMP Type(s) to be used in managing the calculated V_m, and size it per the design criteria listen in Section 4.

The following examples have been provided as a reference:

Infiltration BMPs:
- Infiltration Trench
- Dry Well
- Infiltration Basin

Capture and Use

Biofiltration
- Vegetated Swale
- Planter Box

Infiltration BMP - Design for Infiltration Trench

Givens:

- V_m = 2,492 ft^3 *(from step 9)*
- $K_{Sat, Measured}$ = 2 in/hr
- T = 48 hrs *(from Table 4.4)*
- FS = 3 *(from Table 4.4)*
- Gravel void ratio = 40%

i. Determine $K_{Sat, Design}$

$$K_{Sat,Design} = \frac{K_{Sat,Measured}}{FS} = \frac{2\ in/hr}{3} = 0.667\ in/hr$$

ii. Determine Minimum Bottom Infiltration, A_{min}:

$$A_{\min} = \frac{Vm \bullet 12\, in/ft}{K_{Sat,Design} \bullet T}$$

$$A_{\min} = \frac{2{,}492\, ft^3 \bullet 12\, in/ft}{0.667 in/hr \bullet 48\ hr} = 934\, ft^2$$

iii. Determine the minimum storage volume, $V_{Storage}$:

$$V_{Storage} = \frac{V_m}{Void\ ratio} = \frac{2{,}492\ ft^3}{0.4} = 6{,}230\, ft^3$$

iv. Determine Design Depth:

$$D_{Design} = \frac{V_{Storage}}{A_{\min}} = \frac{6{,}230\ ft^3}{934\ ft^2} = 6.7\, ft$$

Infiltration BMP – Design for Dry Well

Givens:

- V_m = 2,492 ft^3 *(from step 9)*
- $K_{Sat, Measured}$ = 2 in/hr
- Gravel void ratio = 40%
- Factor of Safety = 3 *(per table 4.4)*
- A_{min} = 934 ft^2
- D = 6 ft (r = 3 ft)

i. Required dry well depth for the infiltration zone, h:

$$h = \frac{A_{\min} - \pi r^2}{2\pi r}$$

$$h = \frac{934\, ft^2 - 28.26\, ft^2}{18.84\, ft} = 48 \; ft$$

ii. Determine required storage volume, $V_{Storage}$:

$$\begin{aligned} V_{Storgae} &= V_m - (V_{DryWell} \bullet Void \;\; Ratio) \\ &= 2{,}492\, ft^3 - (\pi r^2 h \bullet 40\%) \\ &= 2{,}492\, ft^3 - [\pi \bullet (3\, ft)^2 \bullet 48\, ft \bullet 0.4] \\ &= 1{,}949.1 \;\; ft^3 \end{aligned}$$

Infiltration BMP – Design for Infiltration Basin

Givens:

- V_m = 2,492 ft^3 *(from step 9)*
- $K_{Sat, Measured}$ = 2 in/hr
- T = 48 hrs *(Table 4.4)*

i. Determine the design infiltration rate, $K_{Sat,Design}$:

$$K_{Sat,Design} = \frac{K_{Sat,Measured}}{FS} = \frac{2 \ in/hr}{3} = 0.667 \ in/hr$$

ii. Determine Minimum Bottom Infiltration, A_{min}:

$$A_{min} = \frac{Vm \bullet 12 \ in/ft}{Ksat, design \bullet T}$$

$$A_{min} = \frac{2{,}492 \ ft^3 \bullet 12 \ in/ft}{0.667 in/hr \bullet 48 \ hr} = 934 \ ft^2$$

iii. Determine the Basin Design, D_{Basin}:

$$D_{Basin} = \frac{V_{Storage}}{A_{min}} = \frac{2,,492 \ ft^3}{934 \ ft^2} = 2.7 \ ft$$

Design for: Capture & Use

Givens:

- $V_{Design} = 2{,}492\ ft^3$
- 0.15 acres of pervious area for drip irrigation
- Medium Planting Type → Planting Factor = 0.4

i. Determine the design volume in gallons:

$$V_{Design}(gal) = 2{,}492\, ft^3 \bullet 7.48\ {}^{gal}\!/\!_{ft^3} = 18{,}640\ \ gal$$

At a minimum, capture and use BMPs must be designed and maintained to ensure adequate capacity is available to capture the stormwater quality design volume within 3 days of a likely storm event. A likely storm event is any weather pattern that is forecast to have a 50% or greater probability of providing precipitation at the development site. Precipitation forecast information must be obtained from the National Weather Service Forecast Office (e.g. by entering the zip code of the developments location at http://www.srh.noaa.gov/forecast).

ii. Determine planting area (ft^2):

$$Planting\ \ Area\ \ (ft^2) = 0.15\ \ ac\ \bullet\ 43{,}560\ {}^{ft^2}\!/\!_{ac} = \ 6{,}534\ \ ft^2$$

iii. Determine Planter Factor, PF, (ft^2):

$$Planter\ \ Factor\ \ (ft^2) = 0.4\ \bullet\ 6{,}534\ \ ft^2 = \ 2{,}614\ \ ft^2$$

iv. Determine the 7- month (Oct 1 – April 30) Estimated Total Water Use (ETWU):

$$ETWU_{(7-month)} = ET_7\ \bullet\ 0.62 \bullet\ PF$$

$$ETWU_{(7-month)} = 21.7\ \bullet\ 0.62 \bullet\ 2{,}614\ \ ft^2 = 35{,}163\ \ gal$$

v. Verify captured volume is equal to or less than the irrigation demand from October 1 thru April 30.

$$V_{Design}(gal) = 18{,}640\ \ gal\ \ \le\ \ ETWU_{(7-month))} = 35{,}163\ \ gal \qquad \therefore\ \underline{\textbf{OK}}$$

Biofiltration BMP – Design for Vegetated Swale*

Givens:
- base of swale = 5 ft
- Slope = 3%

i. Determine the swale base width and corresponding unit length:

- Per Table 4.6 → Select swale base of 5 ft with corresponding unit length of 470 ft/ac.

ii. Determine the total swale length:

$$L_{Swale(ft)} = Catchment\ area\ (ft^2) \bullet \left(\frac{1\ acre}{43{,}560\ ft^2}\right) \bullet Swale\ lenght\ per\ catchment\ area\ (ft/acre)$$

$$Catchment\ area\ (ft^2) = (impervious\ area \bullet 0.9) + [(pervious\ area + undeveloped\ area) \bullet 0.1]$$

$$Catchment\ area\ (ft^2) = 43{,}560\ ft^2 \bullet [(1 \bullet 0.9) + [(0.15 + 0) \bullet 0.1]\ ]$$

$$Catchment\ area\ (ft^2) = 39{,}857.4\ ft^2$$

$$L_{Swale(ft)} = 39{,}857.4\ ft^2 \bullet \left(\frac{1\ acre}{43{,}560\ ft^2}\right) \bullet 470\ ft/acre$$

$$L_{Swale(ft)} = 430\ ft$$

iii. Determine the distance between check dams:

- Per Table 4.7 → At a 3% slope, the distance between check dams is 33 ft.

iv. Determine total number of check dams:

$$Total\ \#\ of\ dams = \frac{430}{33} = 13$$

* Depending on the location of the swale, a geotechnical report may need to be submitted and approval from LADBS may be required.

Design for: Planter Box

Givens:

- Soil media infiltration rate: 5 in/hr *(Table 4.5)*
- T_{Fill} = 3 ft *(Table 4.5)*
- Drawdown time, T (hr) = 48 hrs *(Table 4.5)*

i. Determine the design volume:

$$V_{Design}(ft^3) = 1.5 \bullet 0.0625(ft) \bullet Catchment\ Area(ft^2)$$

$$Catchment\ area\ (ft^2) = (impervious\ area \bullet 0.9) + [(pervious\ area + undeveloped\ area) \bullet 0.1]$$

$$V_{Design}(ft^3) = 1.5 \bullet 0.0625\, ft \bullet 43{,}560\, ft^2 \bullet [(1 \bullet 0.9) + [(0.15 + 0) \bullet 0.1]\ ]$$

$$V_{Design} = 3{,}737\, ft^3$$

ii. Determine the design infiltration rate, $K_{Sat,Design}$:

$$K_{Sat,Design} = \frac{K_{Sat,Media}}{FS} = \frac{5\ in/hr}{2} = 2.5\ in/hr$$

iii. Determine the BMP ponding depth, d_p:

$$d_p(ft) = \frac{(k_{sat,design(in/hr)} \bullet T(hr))}{12\, in/ft} = \frac{(2.5\ in/hr\ \bullet 48\ hr)}{12\, in/hr} = 10\, ft$$

Per Table 4.5, maximum ponding depth (d_p) allowed is 1.0 ft
Therefore use d_p = 1.0 ft

iv. Calculate the BMP Surface Area, A_{min}*:

$$A_{min}(ft^2) = \frac{V_{Design}}{\left[\left(\frac{T_{Fill} \bullet k_{Sat,Design}}{12\ in/ft}\right) + d_p\right]} = \frac{3{,}737\ ft^3}{\left[\left(\frac{3\ ft \bullet 2.5\ in/hr}{12\ in/hr}\right) + 1\, ft\right]} = 2{,}300\, ft^2$$

**** Rule of thumb: With a max ponding depth of 1 ft, area needed is 5 - 6% of impervious area***