Massachusetts Department of Environmental Protection Wetlands Program

Standard Method to Convert Required Water Quality Volume to a Discharge Rate for Sizing Flow Based Manufactured Proprietary Stormwater Treatment Practices

Effective October 15, 2013, computations following the standardized method must be submitted with a Wetlands Notice of Intent (NOI) when a proprietary manufactured stormwater treatment device sized using a flow rate is proposed in connection with work proposed in a wetland resource area or associated buffer zone. The computational method will primarily affect the sizing of the proprietary manufactured stormwater treatment separators, and not other types of stormwater treatment practices that are volume based (such as extended detention basins) or proprietary stormwater treatment filters sized using the Water Quality Volume (WQV).

Stormwater Standard No. 4 requires structural stormwater management practices to be sized to capture the required WQV in accordance with the Massachusetts Stormwater Handbook (310 CMR 10.05(6)(k)(4) and 314 CMR 9.06(6)(a)(4)) . Stormwater Standard No. 4 requires that the full WQV be captured and treated to remove 80% of the Total Suspended Solid (TSS) load.

Since manufactured proprietary stormwater separators are sized using discharge rates and not volume, MassDEP is requiring the standardized method described below be used to convert the required WQV to a discharge rate (Q). No other methods are allowed to convert the WQV to the Q rate. This will ensure that flow rate based manufactured proprietary stormwater treatment practices are sized consistently from manufacturer to manufacturer. This section contains the following: caveats for method use, method description, examples of how to use the method, and documentation describing how the method was derived. This method will be incorporated into the Massachusetts Stormwater Handbook.

The following caveats apply to use of the method:

- Device sized using the Q rate must only be used as pretreatment practice.
- Device sized using this method shall be designed to be "offline", unless approved otherwise through written reciprocity granted by MassDEP to a final certification pursuant to the Technology Acceptance Reciprocity Partnership (TARP). This means the device must be sized at a minimum to fully treat the Q rate without any overflow, by-pass, surcharge of runoff, or scouring of sediments or oils previously trapped or entrained in the device.
- The computations described below must be provided in the Stormwater Report accompanying Wetlands Notice of Intent or application for 401 Water Quality Certification.
- MassDEP reserves ability to revise this method in the future as may be needed to reflect documented increases to precipitation intensity (Douglas 2011), updates to design intensity storms currently being considered by the National Weather Service or Northeast Climate Center (NECC)[1] to Technical Paper 40 (upon which this methodology is based), NRCS revisions to the WinTR55/TR20 methods,[2] or changes to the National Pollution Discharge Elimination System (NPDES) permits issued by EPA for Massachusetts.

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[1] On web, see precipitation intensities at http://precip.net

[2] On web, See MA-NRCS description at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_013763.pdf

METHOD

1. Determine if the WQV is the first ½-inch or 1-inch of runoff. If WQV is the first ½ -inch, go to STEP 2. If WQV is the first 1-inch of runoff, go to STEP 7.

FOR FIRST ½ INCH RUNOFF WQV

2. Use Curve Number (CN) 98 to represent the runoff potential for impervious surfaces (see Method Derivation section below for explanation regarding how CN 98 was obtained).

   Only use impervious surfaces for these computations. Runoff from pervious surfaces should not be included in the WQV computations for the Q rate. The WQV required by the Massachusetts Wetlands Protection (310 CMR 10.05(6)(k)(4)) and 401 Water Quality Certification (314 CMR 9.06(6)(a)(4)) regulations for Stormwater Standard No. 4 is based only on impervious surfaces.

3. Compute the time of concentration (tc) using the methods described in TR-55 1986, Chapter 3.

4. Refer to Figure 1, Ia/P Curve = 0.058

5. Determine unit peak discharge using Figure 1 or 2. Figure 2 is in tabular form so is preferred. Using the tc determined in STEP 3, read the unit peak discharge (qu) from Figure 1 or Table in Figure 2. qu is expressed in the following units: cfs/mi^2/watershed inches (csm/in).

6. Compute Q rate using the following equation:

$$Q_{0.5} = (qu)(A)(WQV)$$

   Where:

   $Q_{0.5}$ = flow rate associated with first ½ -inch of runoff

   qu = the unit peak discharge, in csm/in.

   A = impervious surface drainage area (in square miles)

   WQV = water quality volume in watershed inches (½ -inch in this case)

See Example 1, page 8 applying use of the method to convert first ½ -inch WQV to minimum $Q_{0.5}$ rate.

Figure 1: For First ½-inch Runoff, Ia/P Curve = 0.058, Relationship Between Unit Peak Discharge and Time of Concentration for NRCS Type III Storm Distribution.

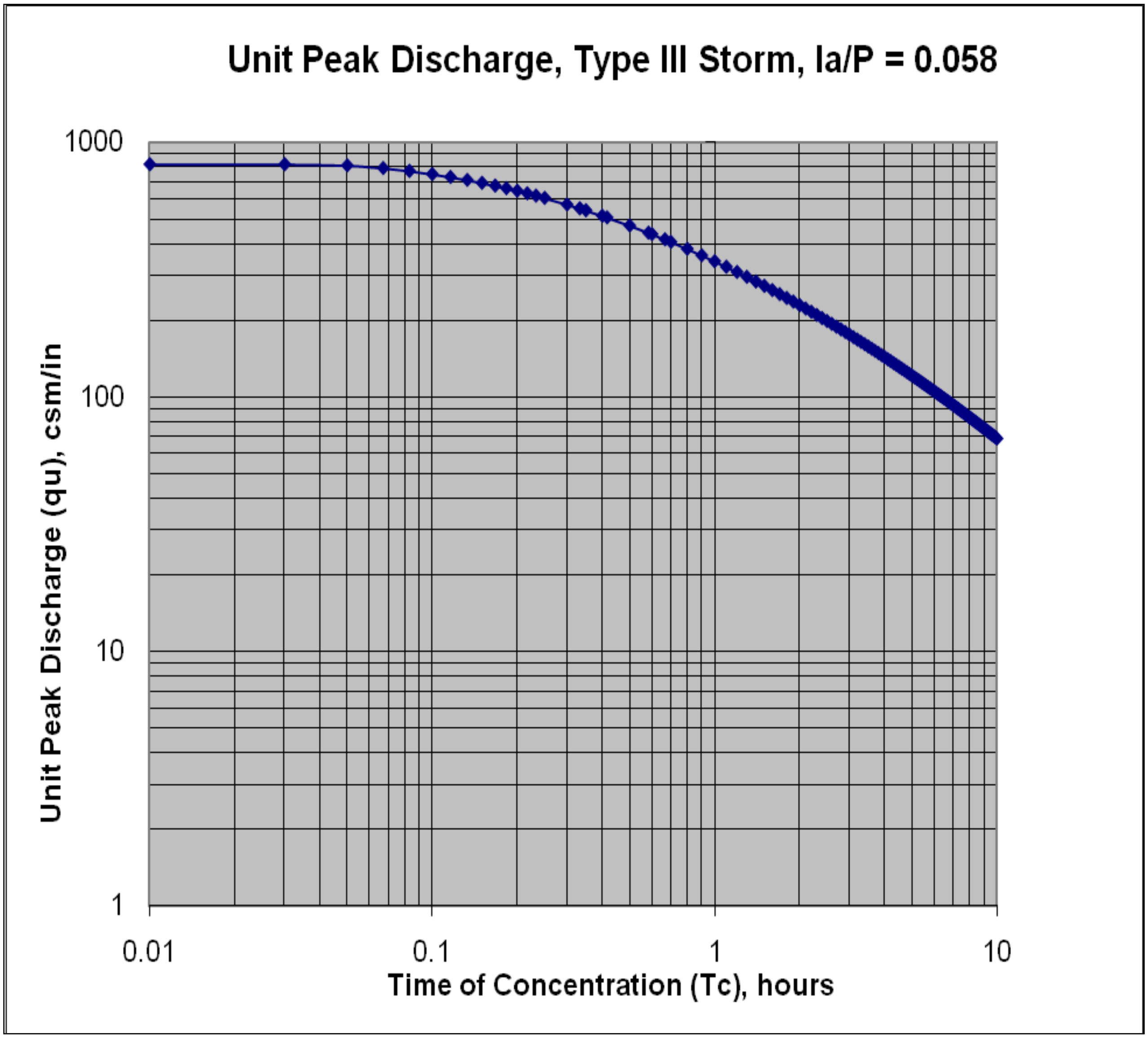

Figure 2: For First ½-inch of Runoff, Table of qu values for Ia/P Curve = 0.0.058, listed by tc, for Type III Storm Distribution

Tc (Hours)	qu (csm/in)
0.01	821
0.03	821
0.05	813
0.067	794
0.083	773
0.1	752
0.116	733
0.133	713
0.15	694
0.167	677
0.183	662
0.2	646
0.217	632
0.233	619
0.25	606
0.3	572
0.333	552
0.35	542
0.4	516
0.416	508
0.5	472
0.583	443
0.6	437
0.667	417
0.7	408
0.8	383
0.9	361
1	342
1.1	325
1.2	311
1.3	297
1.4	285
1.5	274
1.6	264
1.7	254

Tc (Hours)	qu (csm/in)
1.8	246
1.9	238
2	230
2.1	223
2.2	217
2.3	211
2.4	205
2.5	200
2.6	194
2.7	190
2.8	185
2.9	181
3	176
3.1	173
3.2	169
3.3	165
3.4	162
3.5	158
3.6	155
3.7	152
3.8	149
3.9	147
4	144
4.1	141
4.2	139
4.3	136
4.4	134
4.5	132
4.6	130
4.7	128
4.8	126
4.9	124
5	122
5.1	120
5.2	118

Tc (Hours)	qu (csm/in)
5.3	116
5.4	115
5.5	113
5.6	112
5.7	110
5.8	109
5.9	107
6	106
6.1	104
6.2	103
6.3	102
6.4	100
6.5	99
6.6	98
6.7	97
6.8	96
6.9	94
7	93
7.1	92
7.2	91
7.3	90
7.4	89
7.5	88
7.6	87
7.7	86
7.8	85
7.9	84
8	84
8.1	83
8.2	82
8.3	81
8.4	80
8.5	79
8.6	79
8.7	78

Tc (Hours)	qu (csm/in)
8.8	77
8.9	76
9	76
9.1	75
9.2	74
9.3	74
9.4	73
9.5	72
9.6	72
9.7	71
9.8	70
9.9	70
10	69

FOR FIRST 1-INCH RUNOFF WQV

7. Use Curve Number (CN) 98 to represent the runoff potential for impervious surfaces (see Method Derivation section below for explanation regarding how CN 98 was obtained).

   Only use impervious surfaces for these computations. Runoff from pervious surfaces should not be included in the WQV computations for peak WQF. The WQV required by the Massachusetts Wetlands Protection (310 CMR 10.05(6)(k)(4)) and 401 Water Quality Certification (314 CMR 9.06(6)(a)(4)) regulations for Stormwater Standard No. 4 is based only on impervious surfaces.

8. Compute the time of concentration (tc) using the methods described in TR-55 1986, Chapter 3.

9. Refer to Ia/P Curve = 0.034 (Figure 3)

10. Determine unit peak discharge using Figure 3 or 4. Figure 4 is in tabular form so is preferred. Using the tc determined in STEP 8, read the unit peak discharge (qu) from Figure 2 or from Table in Figure 4. qu is expressed in the following units: cfs/mi^2/watershed inches (csm/in).

11. Compute the water quality flow (WQF) using the following equation:

$$Q_1 = (qu)(A)(WQV)$$

Where:

Q_1 = peak flow rate associated with first 1-inch of runoff

qu = the unit peak discharge, in csm/in.

A = impervious surface drainage area (in square miles)

WQV = water quality volume in watershed inches (1.0-inches in this case)

See Example 2, page 8 applying use of the method to convert first 1-inch WQV to minimum Q_1 rate.

Figure 3: For First 1-inch Runoff, Ia/P Curve = 0.034, Relationship Between Unit Peak Discharge and Time of Concentration for NRCS Type III Storm Distribution

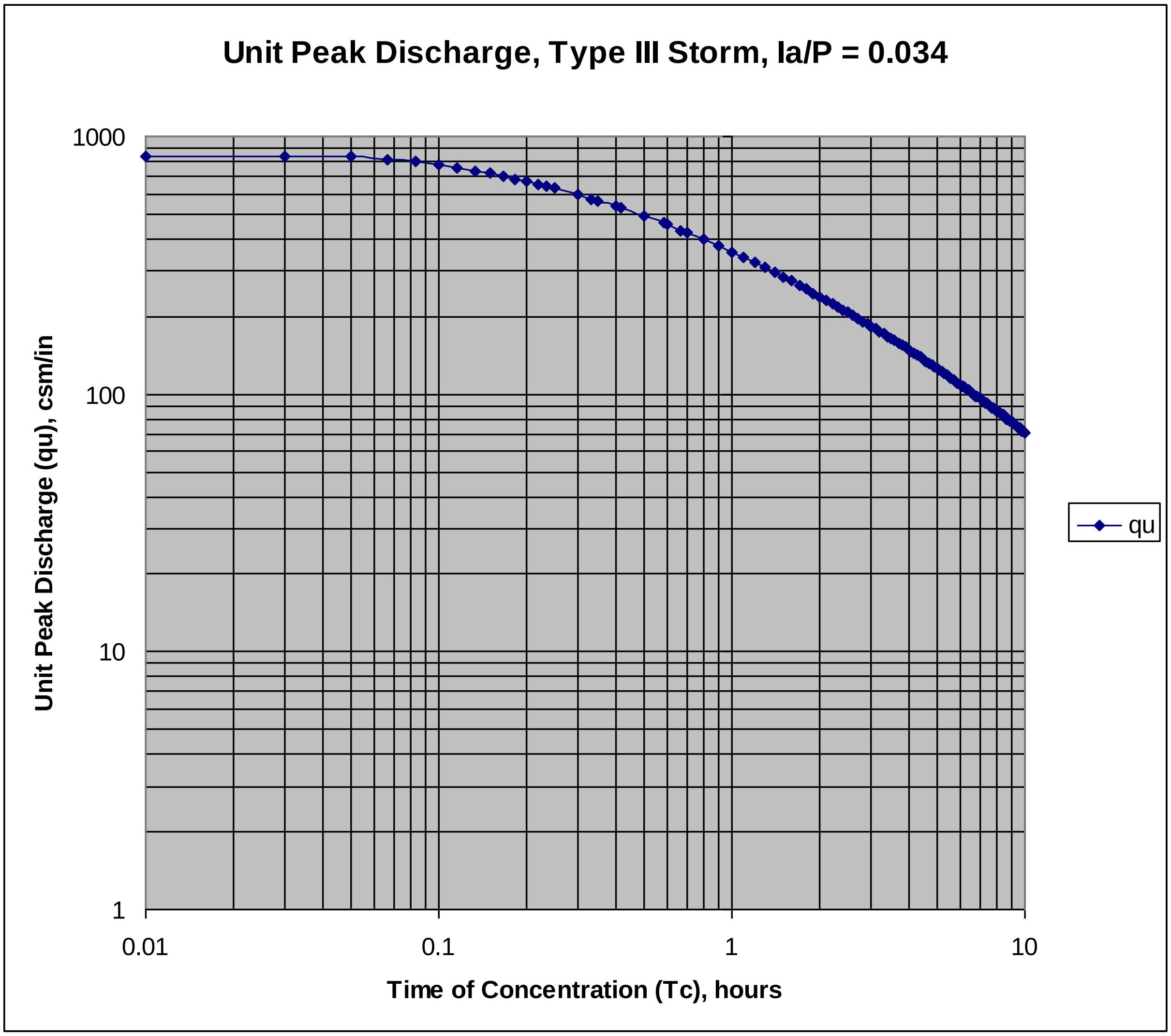

Figure 4: for First 1-inch Runoff, Table of qu values for Ia/P Curve = 0.034, listed by tc, for Type III Storm Distribution

Tc (Hours)	qu (csm/in)
0.01	835
0.03	835
0.05	831
0.067	814
0.083	795
0.1	774
0.116	755
0.133	736
0.15	717
0.167	700
0.183	685
0.2	669
0.217	654
0.233	641
0.25	628
0.3	593
0.333	572
0.35	563
0.4	536
0.416	528
0.5	491
0.583	460
0.6	454
0.667	433
0.7	424
0.8	398
0.9	376
1	356
1.1	339
1.2	323
1.3	309
1.4	296
1.5	285
1.6	274
1.7	264
1.8	255
1.9	247
2	239
2.1	232
2.2	225
2.3	219
2.4	213
2.5	207
2.6	202
2.7	197
2.8	192
2.9	187
3	183
3.1	179
3.2	175
3.3	171
3.4	168
3.5	164
3.6	161
3.7	158
3.8	155
3.9	152
4	149
4.1	146
4.2	144
4.3	141
4.4	139
4.5	137
4.6	134
4.7	132
4.8	130
4.9	128
5	126
5.1	124
5.2	122
5.3	120
5.4	119
5.5	117
5.6	115
5.7	114
5.8	112
5.9	111
6	109
6.1	108
6.2	106
6.3	105
6.4	104
6.5	102
6.6	101
6.7	100
6.8	99
6.9	98
7	96
7.1	95
7.2	94
7.3	93
7.4	92
7.5	91
7.6	90
7.7	89
7.8	88
7.9	87
8	86
8.1	85
8.2	84
8.3	84
8.4	83
8.5	82
8.6	81
8.7	80
8.8	79
8.9	79
9	78
9.1	77
9.2	76
9.3	76
9.4	75
9.5	74
9.6	74
9.7	73
9.8	72
9.9	72
10	71

Examples

Example 1: 2.28-acre asphalt parking lot (impervious surface), with time of concentration equal to 0.25 hours. The proposed parking lot drains to a wetland resource area, which is not a critical area, nor is the site located "near" a critical area. A proprietary separator is proposed to pretreat runoff to be directed to an Extended Detention Basin.

Because site does not drain to or located near a critical area, WQV = ½ -inch

1-acre = 0.0015625 mi^2

Step 1: Use CN = 98 to represent the 2.28-acre impervious surface.

Step 2: Determine tc

tc = 0.25 hours (given).

Step 3: Determine qu using Figure 2

With tc = 0.25 hours, qu is determined to be 606 csm/inch using Table in Figure 2.

Step 4 (Final Step): Determine $Q_{0.5}$

$$Q_{0.5} = (qu)(A)(WQV)$$

$$Q_{0.5} = (606 \text{ csm/in})(2.28\text{-acre})(0.0015625 \text{ mi}^2/\text{acre})(\tfrac{1}{2}\text{-inch})$$

$$Q_{0.5} \approx 1.1 \text{ CFS}$$

Example 2: One-acre site composed entirely of impervious surfaces, with time of concentration equal to 6 minutes. The proposed impervious surfaces are to be drained to a stream located in Zone II of a public drinking water supply. A proprietary separator is proposed to pretreat runoff to be directed to an Infiltration Basin.

Because site drains to a critical area, WQV = 1-inch

1-acre = 0.0015625 mi^2

Step 1: Use CN = 98 to represent the 1-acre impervious surface.

Step 2: Determine tc

tc = 6 minutes (given).

Convert minutes to hours

tc = (6 minutes) /(60 minutes/hr) = 0.1 hours

Step 3: Determine qu using Table in Figure 4

Using the tc column, read down to find tc = 0.1 hours. Read to the right of tc = 0.1 hours to find the qu value which is 774 csm/inch.

Alternatively, you may use Figure 3 (Ia/P curve = 0.034). Find tc = 0.1 hours, read up to the Ia/P curve, then follow intersecting line to the left to interpolate the qu value. You'll note that using Figure 4 is quicker in so far as no interpolation is required. In cases where the tc is not listed in Figure 4, you may need to use Figure 3. In such instances, Figure 4 may still assist you in bracketing the qu values to interpolate.

Step 4 (Final Step): Determine Q_1

$$Q_1 = (qu)(A)(WQV)$$

$$Q_1 = (774 \text{ csm/in})(1\text{-acre})(0.0015625 \text{ mi}^2\text{/acre})(1\text{-inch})$$

$$Q_1 \approx 1.2 \text{ CFS}$$

If the conversion factor to convert acres to square miles is not included, the result will not be correct. As different units are used in the computations, double check your units to ensure the result is correct.

Method Derivation

The Stormwater Advisory Committee convened to assist MassDEP with the 2008 stormwater revisions to the Wetlands and 401 Water Quality Certification regulations. The Advisory Committee tabled a method proposed at that time and asked its Proprietary BMP subcommittee to study the issue further. Subsequently, the Proprietary BMP subcommittee met from 2008 to 2011, examining multiple methods. Among the methods reviewed included the Rational Method used by New Jersey DEP, Ahlfeld et al 2004, Winkler et al 2001, Claytor and Scheuler 1996, Imbrium PCSWMM, and Bryant. The Ahlfeld and Winkler methods were funded by MassDEP through 319 funds and developed using Massachusetts precipitation data. The Claytor method is based on SCS TR-55 graphical methods. The PCSWMM method is a proprietary version of the EPA SWMM method, based on Mannings equation. The Bryant method was based on precipitation data compiled in the Ahlfeld and Winkler methods.

To assist in selecting a method, Rees and Schoen 2009 conducted third party review of the different approaches. Rees and Schoen found that the various methods produced different peak rate flows.

Differences were also found between peak flow rates in coastal and inland areas. With some methods, the precipitation intensity associated with the ½-inch water quality volume produced a greater flow rate than the 1-inch water quality volume. The study concluded that the Claytor and Schueler 1996 method was the most complete in attempting to transform the Water Quality Volume to a flow rate.

Subsequent to the study, flow rate results from the Claytor and Schueler method were adapted for use in Massachusetts using both the first ½ - inch and 1-inch Water Quality Volumes. Flow rates were found to bypass a portion of the Water Quality Volume for the both the first ½ -inch and 1-inch of runoff depending on drainage area and treatment device size. As bypassed runoff is not treated, the Proprietary BMP Subcommittee agreed on meeting held in March 2011 that practices sized using the flow conversion method must be restricted to pretreatment only and directed to stormwater treatment practices. The Proprietary BMP Subcommittee subsequently recommended the Claytor and Schueler 1996 method be used, as adapted for use in Massachusetts, to the Stormwater Advisory Committee in May 2011.

The Claytor and Schueler 1996 approach in part utilizes the U.S. Natural Resource and Conservation Service Technical Release 55 (TR-55) Graphical Peak Discharge Method (NRCS / SCS 1986), adapted for small storm hydrology (Pitt 1999). It was adapted for use in Massachusetts by determining the precipitation values that generate the first ½ -inch and 1-inch of runoff, using the NRCS / SCS 1986 equations as described below.

1. The Massachusetts Stormwater Standard No. 4 sets the required WQV equal to 0.5-inch or 1.0- inch, depending if the discharge is to or near a critical area, Land Use with Higher Potential Pollutant Load (LUHPPL), or soil with rapid infiltration rate.
2. The Claytor and Scheuler 1996 method requires a Curve Number (CN) be determined to represent the ability of a surface to effectively convey runoff. CN 98 was derived for impervious surfaces using small storm hydrology using the following equation (NRCS / SCS 1986). The precipitation depth associated with the first 1.0-inch of runoff is 1.2 watershed inches based on Figure 4 (NRCS 1986 Table 2-1) and Figure 5 (NRCS 1986 Figure 2-1). The precipitation depth associated with the first ½ -inch of runoff is 0.7 watershed inches.

½-inch WQV Derivation:

Solve for P_t

$$CN = \frac{1000}{10 + 5P_t + 10Q_{WQV} - 10(Q_{WQV}{}^2 + 1.25Q_{WQV}P_t)^{0.5}}$$

Where:

CN = Runoff Curve Number = 98 for runoff impervious surfaces

P_t = Precipitation depth

Q_{WQV} = Runoff depth related to Water Quality Volume = 0.5 watershed inches

This equation produces the result **P_t = 0.7** inches, when CN = 98 and Q_{WQV} = 0.5 inches.

1-inch WQV Derivation

$$CN = \frac{1000}{10 + 5P_t + 10Q_{WQV} - 10(Q_{WQV}{}^2 + 1.25Q_{WQV}P_t)^{0.5}}$$

Where:

CN = Runoff Curve Number = 98 for runoff from impervious surfaces

P_t = Precipitation depth

Q_{WQV} = Runoff depth related to Water Quality Volume = 1.0 watershed inches

This equation produces the result **P_t = 1.2** inches, when CN = 98 and Q_{WQV} = 1.0 inches

3. Potential maximum retention (S) in inches was derived using the following equation (NRCS 1986):

½-inch WQV Derivation / 1-inch WQV Derivation (result same for both):

$$S = (1000/CN) – 10$$

This equation produces the result S = 0.204 when the CN = 98

4. The initial abstraction (Ia) was derived using the following equation (NRCS 1986):

½-inch WQV Derivation / 1-inch WQV Derivation (result same for both):

$$Ia = 0.2S$$

This equation produces the result Ia = 0.041, when S = 0.204

Also See Figure 6 (NRCS 1986, Table 4-1), where Ia = 0.041, for CN = 98

5. The Ia/P Ratio was derived using the following equation (NRCS 1986):

½-inch WQV Derivation

Solve for Ia/P Ratio using the following equation (NRCS 1986):

$$Ia/P \text{ Ratio} = Ia/ P_t$$

Where:

Ia = 0.041 (for CN = 98)

P_t = 0.7 watershed inches

$$Ia/P \text{ Ratio} = 0.041/ 0.7 = 0.058$$

1-inch WQV Derivation

$$Ia/P \text{ Ratio} = Ia/\ P_t$$

Where:

$Ia = 0.041$ (for CN = 98)

$P_t = 1.2$ watershed inches

$$Ia/P \text{ Ratio} = 0.041/\ 1.2 = 0.034$$

6. For the first ½ -inch runoff, Ia/P curve for 0.058 ratio (Figure 1) and corresponding table (Figure 2) were generated using coefficients C_0, C_1 and C_2 derived from regression of coefficients published in Appendix F in NRCS / SCS TR-55 1986.
7. For the first 1-inch runoff, Ia/P curve for 0.034 ratio (Figure 3) and corresponding table (Figure 4) were generated using coefficients C_0, C_1 and C_2 derived from regression of coefficients published in Appendix F in NRCS / SCS TR-55 1986.

Figures Used for Method Derivation

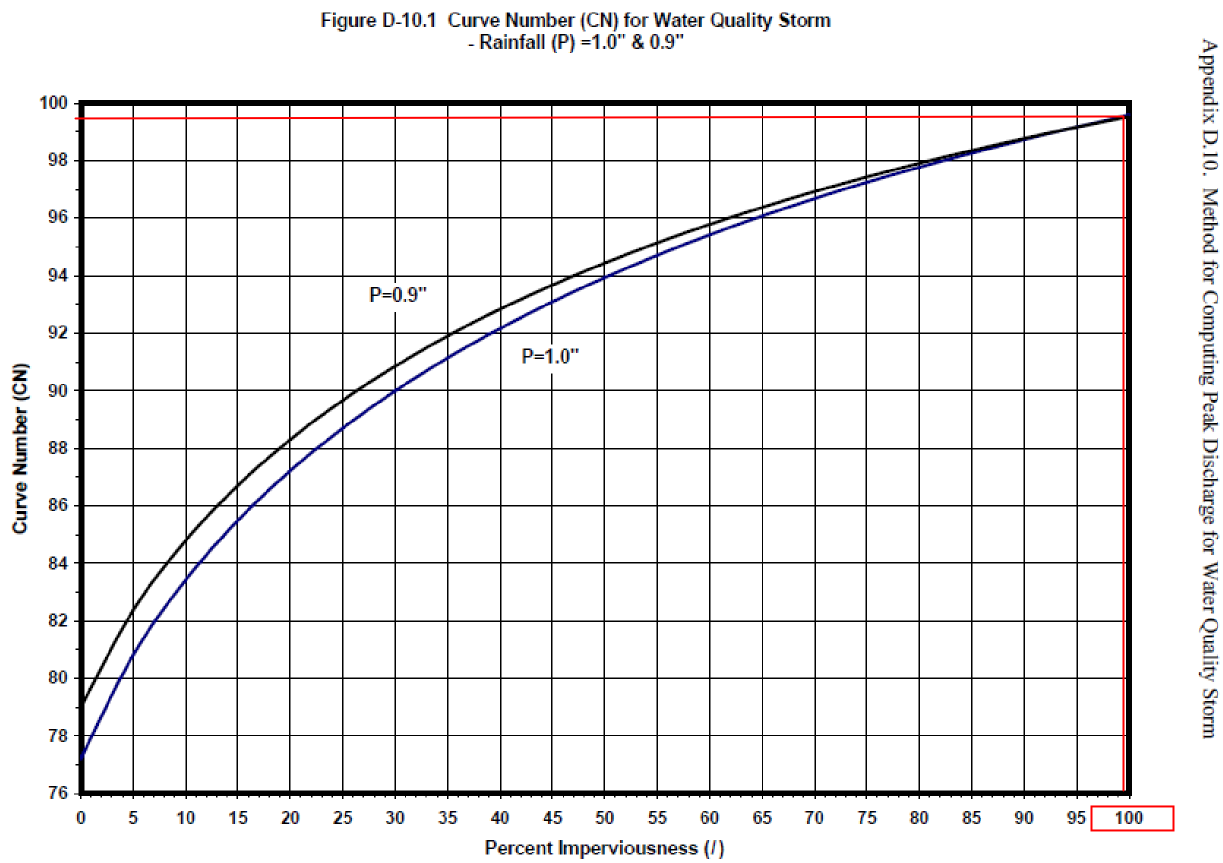

Figure 5: Graph Depicting CN to Percent Impervious Relationship by Precipitation Depth (MD 2000, Figure D-10.1). Note at 100% imperviousness, precipitation depths coincide, making corresponding Runoff CN greater than 98.

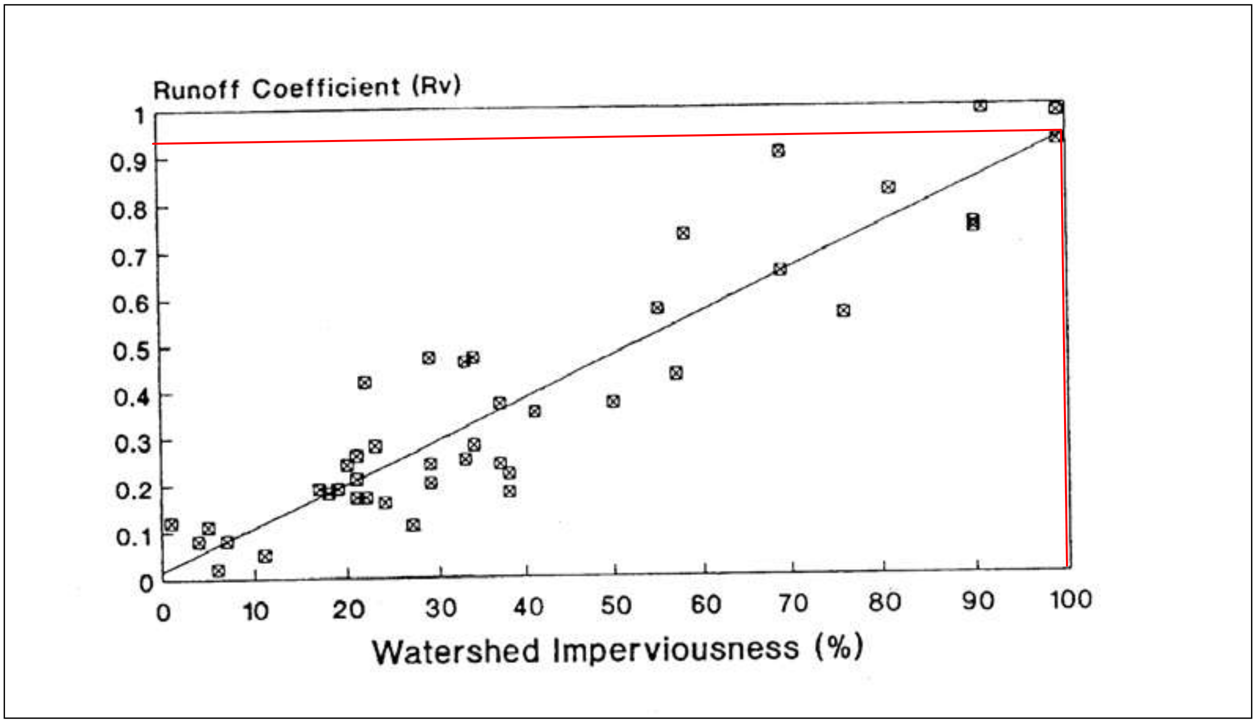

Figure 6: Relationship Between Impervious Cover & Runoff Coefficient (Vermont 2002, from Schueler, 1987). Note at 100% imperviousness, Rv is between 0.9 and 1, meaning that most of the precipitation effectively becomes runoff.

Table 2-1 Runoff depth for selected CN's and rainfall amounts [1]

Rainfall	Runoff depth for curve number of—												
	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

Figure 7: Table Depicting Relationship Between Precipitation (P) and Direct Runoff (Q) by Curve Number (NRCS 1986, Table 2-1). 1.2 inches of precipitation effectively becomes 0.99-inch of runoff.

Figure 2-1 Solution of runoff equation.

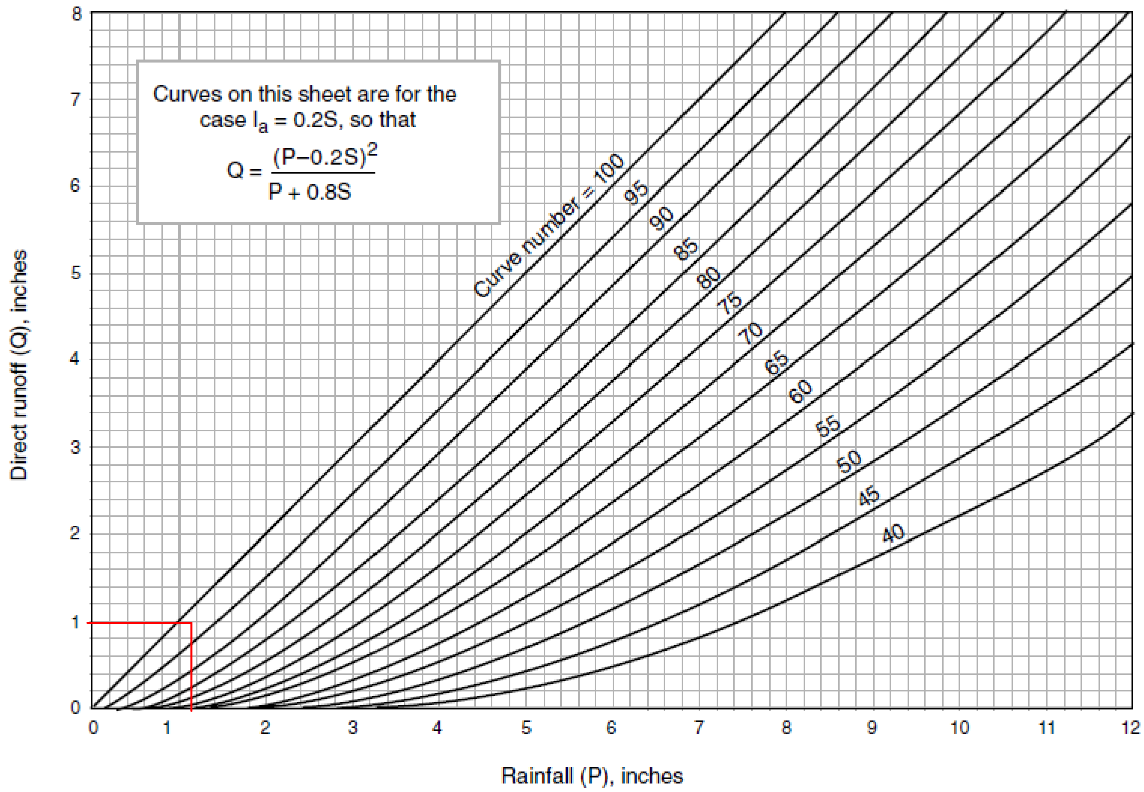

Figure 8: Graph Depicting Relationship Between Precipitation (P) and Direct Runoff (Q) by Curve Number (NRCS 1986, Figure 2-1). This indicates that for a CN 98 (representing impervious surfaces), 1.2 inches of precipitation effectively equals 1-inch of direct runoff.

Table 4-1 I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Figure 9: Table Listing Ia by CN (NRCS 1986, Table 4-1). This indicates Initial Abstraction (Ia) for CN 98 = 0.041

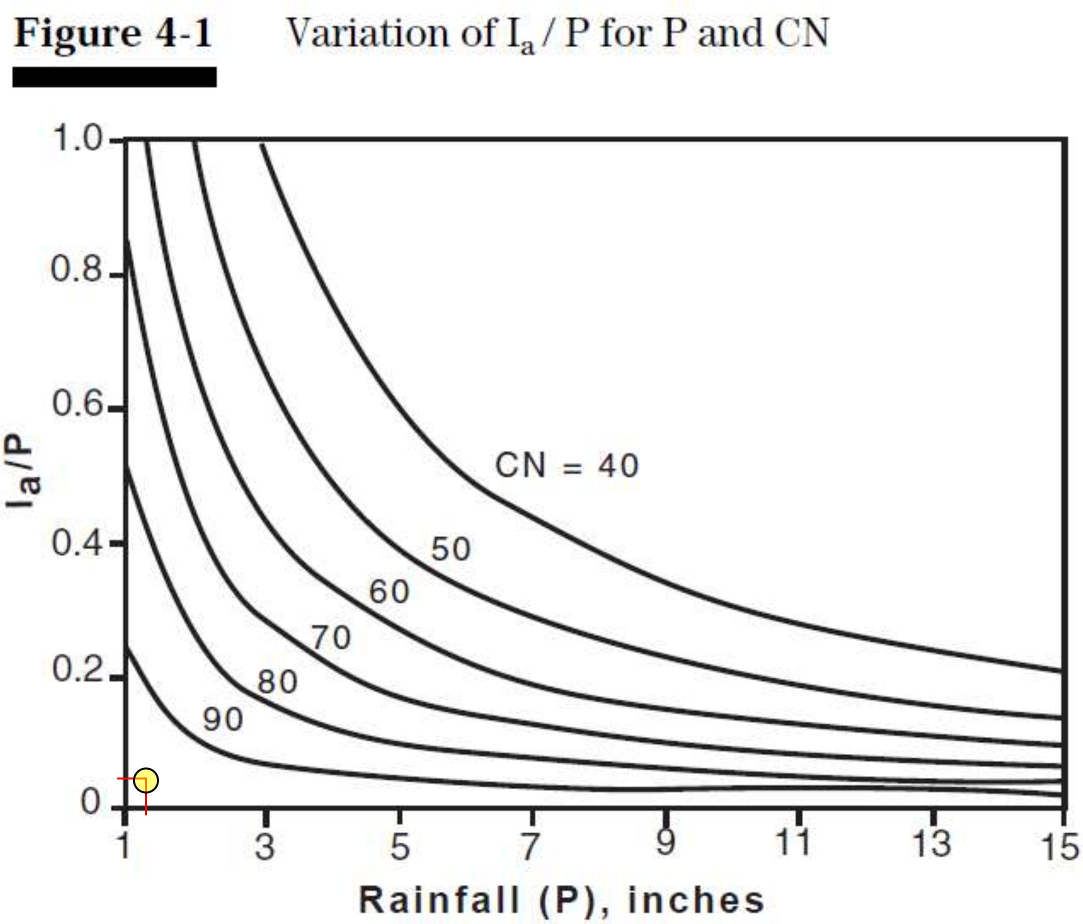

Figure 10: Graph Depicting Ia/P to Precipitation Relationship by CN (NRCS 1986, Figure 4-1). Ia/P ratio of 0.034 corresponding to 1.2 inches of precipitation added. Ia/P ratio determined for CN 98, using Ia = 0.041, P = 1.2

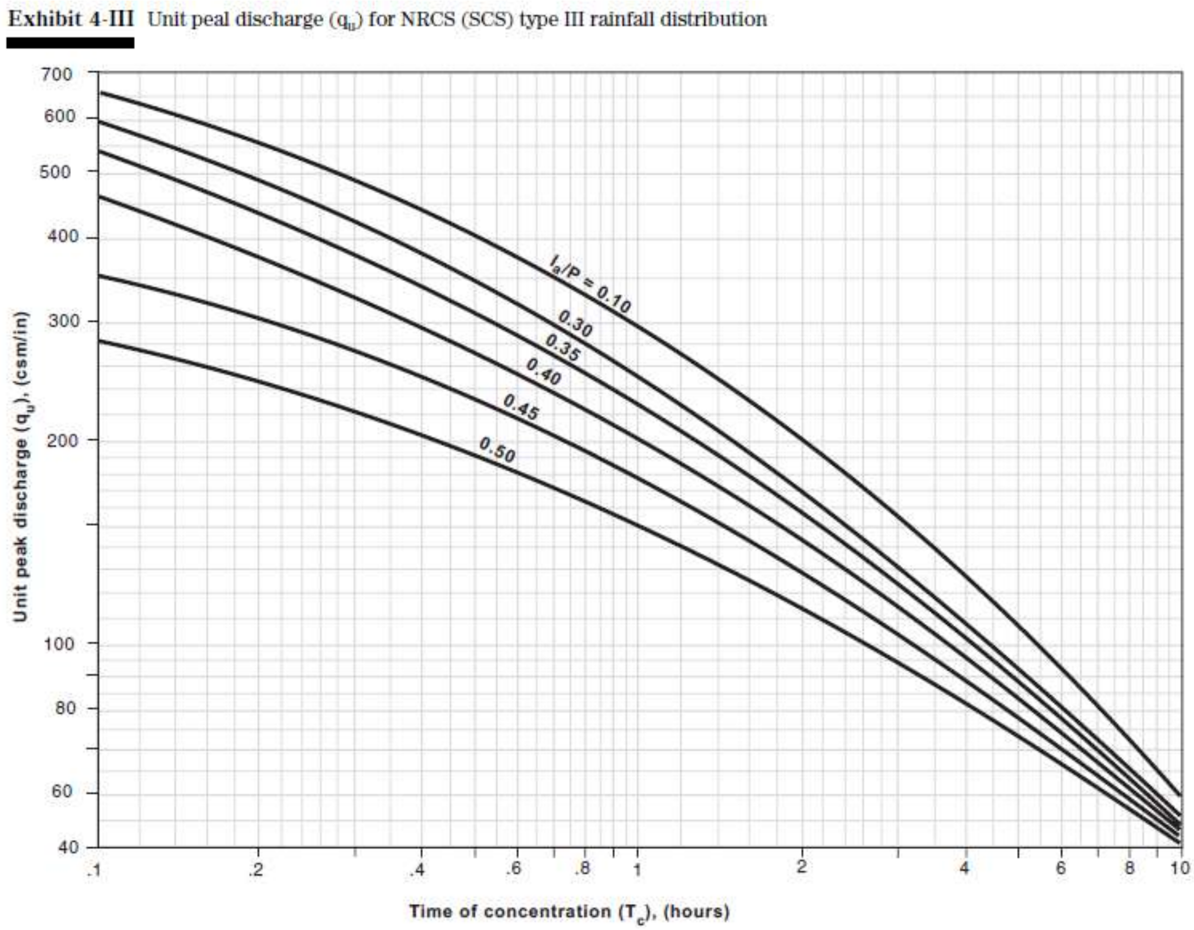

Figure 11: Relationship Between Time of Concentration and Unit Peak Discharge for Ia/P Ratios from 0.10 to 0.50 for NRCS Type III Storm Distribution (NRCS 1986, Exhibit 4-III). NRCS / SCS 1986 specifies Type III storm distribution (tropical influenced storms) for Massachusetts. See Figure 3 and 4 for Ia/P Ratio = 0.034

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