APPENDIX 4C

Eastern Washington Design Storm Events

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Appendix 4C Eastern Washington Design Storm Events

Eastern Washington design storms are based on two parameters:

- Total rainfall volume (depth in inches)
- Rainfall distribution (dimensionless)

The design storm event is specified by return period (months and/or years) and duration. The following sections explain total rainfall depth and rainfall distribution associated with a design storm.

All storm event hydrograph methods require the input of a rainfall distribution or design storm hyetograph. Essentially, the design storm hyetograph is a plot of rainfall depth versus time for a given design period and duration. It is usually presented as a dimensionless plot of unit rainfall depth (incremental rainfall depth for each time interval divided by the total rainfall depth) versus time.

Design storm distribution for all eastern Washington Climatic Regions – 1, 2, 3, and 4:

- **Flow-Based BMPs:** The short-duration storm distribution.
- **Volume-Based BMPs:** The SCS Type 1A storm distribution (Regions 2 and 3) or the regional long-duration storm (Regions 1–4).

4C-1 SCS Type II and Type 1A Hyetographs

The Type II hyetograph is a standard SCS (NRCS) rainfall distribution that has a high-intensity peak. It has been used in eastern Washington since the 1970s and is also used throughout much of the United States. The Type IA hyetograph is also a standard NRCS rainfall distribution. It is applicable to western Washington and Climatic Regions 2 and 3 in eastern Washington. These are two of four 24-hour storm distribution types commonly used in SCS hydrograph methods.

For graphical representation of these two SCS hyetographs, see Figures 4C-1 and 4C-2. Tabular values of these hyetographs are in Tables 4C-3 and 4C-4.

4C-2 Custom Design Storm Hyetographs

When rainfall patterns during storms were analyzed in eastern Washington (see Appendix 4A), it was concluded that the SCS Type II rainfall distribution does not match the historical records for two storm types of interest for stormwater analyses in eastern Washington: the short-duration thunderstorm and the long-duration winter storm.

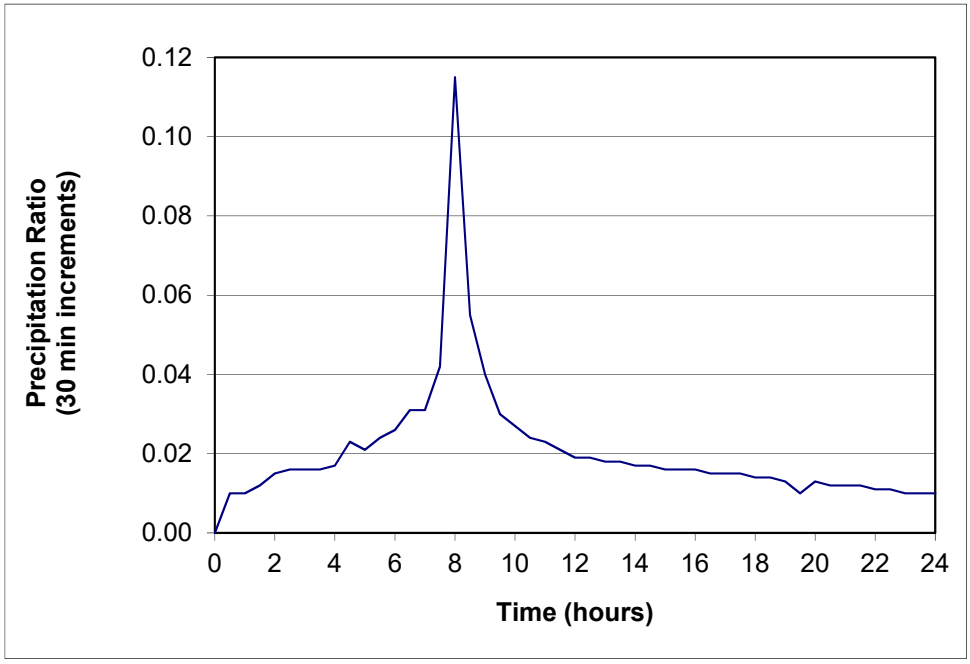


Figure 4C-1 SCS Type 1A hyetograph.

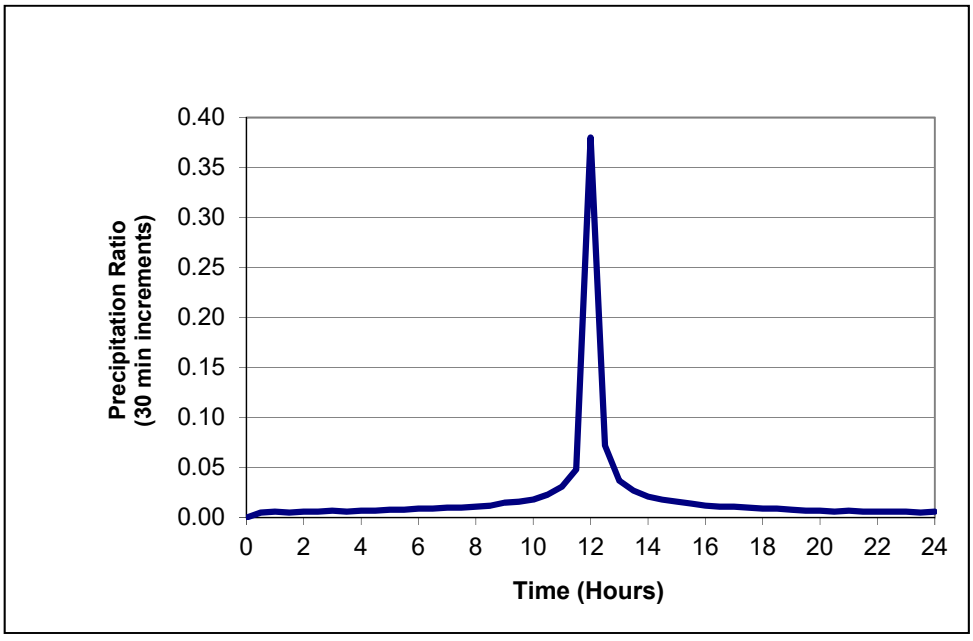
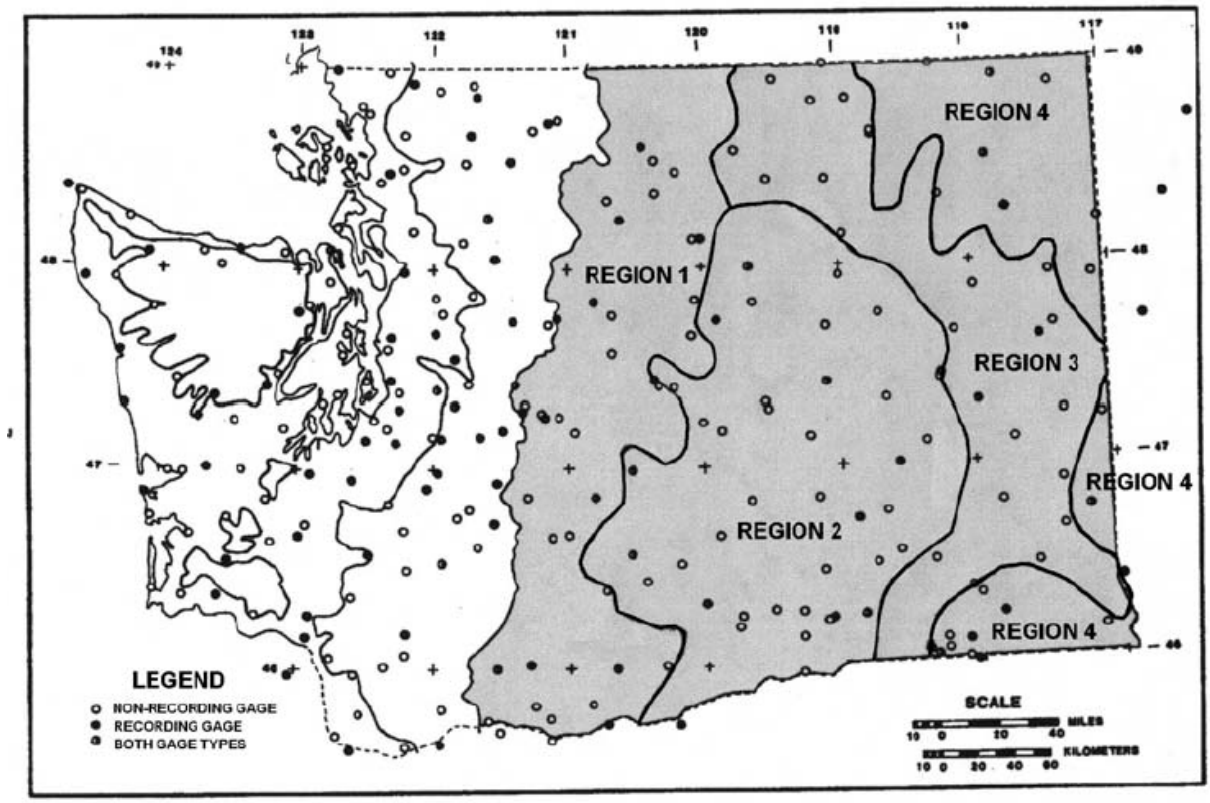


Figure 4C-2 SCS Type II hyetograph.

Short-duration thunderstorms can occur in late spring through early fall and are characterized by high intensities for short periods of time over localized areas. These types of storms can produce high rates of runoff and flash flooding in urban areas and are important where flood peak discharge and/or erosion are design considerations.

Long-duration general storms can occur at any time of the year, but are more common in late fall through winter and in late spring and early summer. General storms in eastern Washington are characterized by sequences of storms and intervening dry periods, often occurring over several days. Low- to moderate-intensity precipitation is typical during the periods of storm activity. These types of events can produce floods with moderate peak discharge and large runoff volumes. The runoff volume can be augmented by snowmelt when precipitation falls on snow during winter and early spring storms. These types of storm events are important where both runoff volume and peak discharge are design considerations.

When using the custom design storms, it is necessary to note that eastern Washington has been divided into four climatic regions to reflect the differences in storm characteristics and the seasonality of storms. The four climatic regions are shown as follows:



Region 1 – East Slopes of the Cascade Mountains

This region is composed of mountain areas on the east slopes of the Cascade Mountains. It is bounded on the west by the Cascade crest and generally bounded to the east by the contour line of 16 inches mean annual precipitation.

Region 2 – Central Basin

The Central Basin Region is composed of the Columbia Basin and adjacent low elevation areas in central Washington. It is generally bounded on the west by the contour line of 16 inches mean annual precipitation at the base of the east slopes of the Cascade Mountains. The region is bounded on the north and east by the contour line of 12 inches mean annual precipitation. Most of this region receives about 8 inches of mean annual precipitation. Many of the larger cities in eastern Washington are in this region, including Ellensburg, Kennewick, Moses Lake, Pasco, Richland, Wenatchee, and Yakima.

Region 3 – Okanogan, Spokane, and the Palouse

This region is composed of intermountain areas and includes areas near Okanogan, Spokane, and the Palouse. It is bounded on the northwest by the contour line of 16 inches mean annual precipitation at the base of the east slopes of the Cascade Mountains. It is bounded on the south and west by the contour line of 12 inches mean annual precipitation at the eastern edge of the Central Basin. It is bounded on the northeast by the Kettle River Range and Selkirk Mountains at approximately the contour line of 22 inches mean annual precipitation. It is bounded on the southeast by the Blue Mountains; also at the contour line of 22 inches mean annual precipitation.

Region 4 – Northeastern Mountains and Blue Mountains

This region is composed of mountain areas in the easternmost part of Washington State. It includes portions of the Kettle River Range and Selkirk Mountains in the northeast and the Blue Mountains in the southeast corner of eastern Washington. Mean annual precipitation ranges from a minimum of 22 inches to over 60 inches. The western boundary of this region is the contour line of 22 inches mean annual precipitation.

4C-3 Storm Analysis

Based on analyses of historical storms in eastern Washington, it has been concluded that the short-duration summer thunderstorm typically generates the greatest peak discharges for small urban watersheds. Use of short-duration thunderstorms is therefore appropriate for designing conveyance structures and biofiltration swales. Analyses also indicate that the long-duration winter storm typically generates the greatest runoff volume. Long-duration design storms are therefore appropriate for designing stormwater detention and runoff treatment facilities where runoff volume is the primary concern. Use the Type 1A storm distribution for volume-based BMPs in Climatic Regions 2 and 3, or use the regional long-duration distribution in Climatic Regions 1–4.

Based on these analyses, synthetic design storms were developed for the short-duration thunderstorm and long-duration winter storm. The design storms were developed in a manner that replicated temporal characteristics observed in storms from areas climatologically similar to eastern Washington.

- **Short-Duration Storm**

  Short duration, high intensity, and smaller volumes characterize summer thunderstorms. The short-duration storm was selected to be 3 hours in duration. The storm temporal pattern is shown in Figure 4C-3 as a unit hyetograph. Tabular values are listed in Table 4C-5. Total precipitation is 1.06 times the 2-year, 2-hour precipitation amount to derive the 2-year, 3 hour storm. (See Table 4C-12 for further guidance.) There is one short-duration storm for all climatic regions in eastern Washington.

- **Long-Duration Storm (varies by region)**

  The long-duration storm varies by region and is composed of a series of storm events separated by a dry intervening period, occurring during a 72-hour period of time. A sample 72-hour long-duration storm hyetograph is shown in Figure 4C-4.

The smaller event (from 6 to 21 hours, above) is insufficient to generate the runoff that is present when the larger precipitation commences. For that reason, it is not necessary to directly model the smaller precipitation event. Only the larger portion (commencing at 36 hours, as shown above) is necessary to directly model.

The larger portion is similar to the 24-hour SCS Type 1A storm. For Climatic Regions 2 and 3, the SCS Type IA storm is sufficiently similar to the four regional long-duration storm hyetographs to use directly.

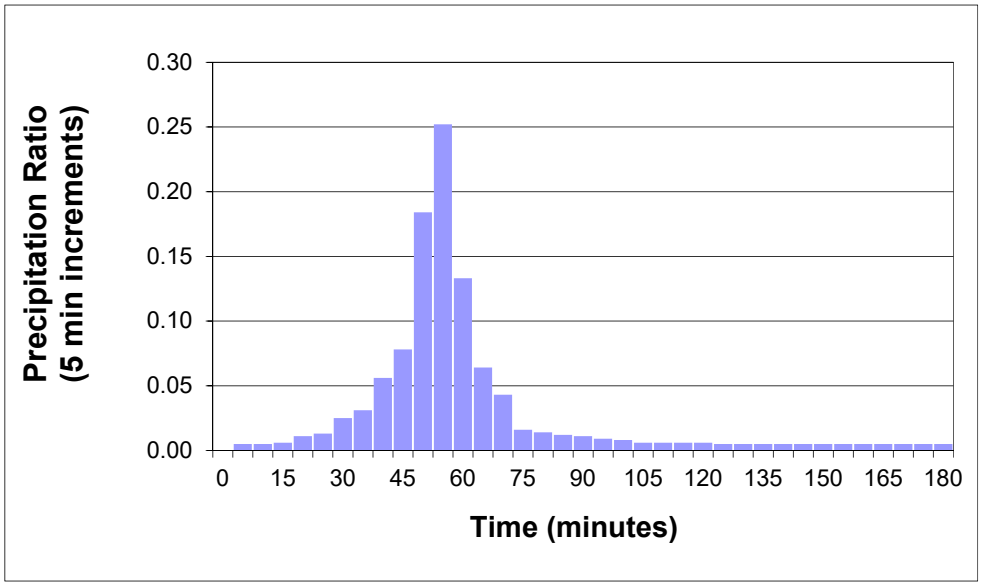


Figure 4C-3 Short-duration storm unit hyetograph.

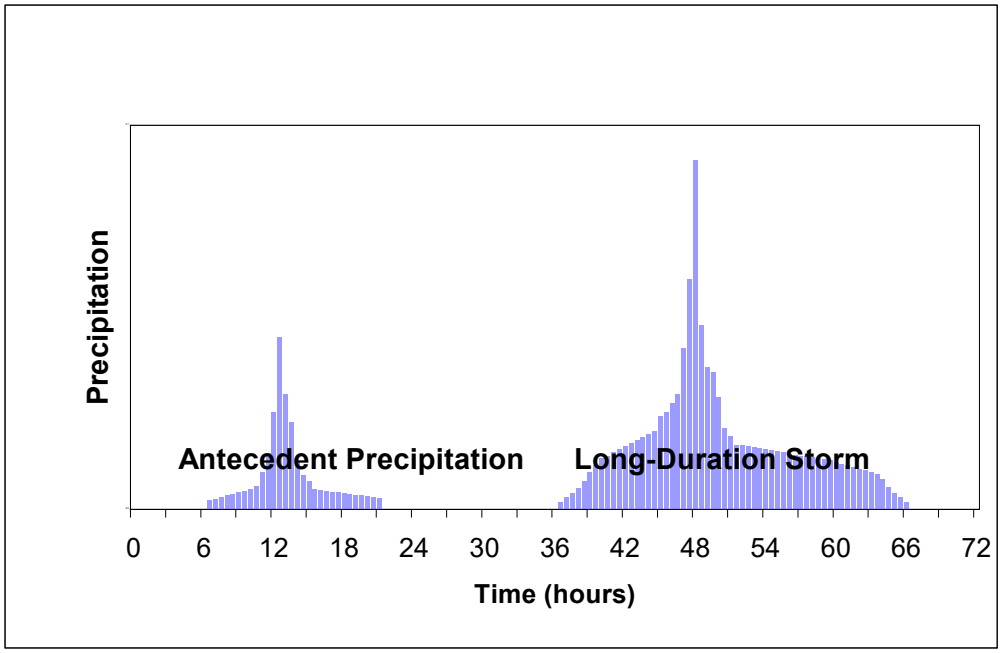


Figure 4C-4 Sample long-duration storm hyetograph.

Tabular values of the regional long-duration storm hyetographs are listed in Tables 4C-8 to 4C-11.

If you use the 24-hour SCS Type 1A storm for the long-duration storm, the precipitation totals are the 24-hour amounts without adjustment. If you use the regional long-duration hyetographs, adjust the precipitation totals as indicated for Regions 1 and 4, using Table 4C-11.

4C-4 Antecedent Moisture Condition

Regardless whether you use the 24-hour SCS Type 1A or regional hyetographs for long-duration storm modeling, you need to account for the prior soil wetting produced by the smaller storm event (from 6 hours to 21 hours, above) that is not modeled. You can express the amount of antecedent precipitation as a percentage of the total precipitation modeled, as shown in Table 4C-3.

Consider curve number adjustments, based on engineering analysis and judgment of the antecedent precipitation, soils characteristics, and surface conditions. The Antecedent Moisture Condition (AMC) is one basis for adjustment. Another is use of the Soil Conservation Service county surveys that include estimates of permeability and/or infiltration rates.

Following is an example of the AMC:

For a 25-year Type 1A storm in Spokane (2.2"), determine whether AMC adjustments need to be considered in the analysis. If so, take the following steps:

1. From Table 4C-1, multiply 2.2" by 27% (Region 3), which equals 0.7". This is the amount of precipitation from the first hump of the long-duration storm.

Table 4C-1 Antecedent precipitation prior to long-duration storm.

Region #	Region Name	Antecedent Precipitation as Percentage of 24-Hour SCS Type 1A Storm Precipitation
1	East Slope Cascades	33%
2	Central Basin	19%
3	Okanogan, Spokane, Palouse	27%
4	NE & Blue Mountains	36%

Region #	Region Name	Antecedent Precipitation as Percentage of Regional Long-Duration Storm Hyetograph Precipitation
1	East Slope Cascades	28%
2	Central Basin	19%
3	Okanogan, Spokane, Palouse	25%
4	NE & Blue Mountains	34%

2. Next, determine whether the AMC will affect the CN values using Table 4C-2. If the precipitation from the first storm is over 1.1 or less than 0.5, adjust the CN value using Appendix 4B. CN values are generally assumed to be AMC II.

Table 4C-2 Total 5-day antecedent rainfall (inches).

AMC	Dormant Season	Growing Season
I	Less than 0.5	Less than 1.4
II	0.5 to 1.1	1.4 to 2.1
III	Over 1.1	Over 2.1

4C-5 Precipitation Magnitude/Frequency Analysis

The current source for precipitation magnitude/frequency estimates is National Oceanic and Atmospheric Administration (NOAA) Atlas II, which is based on data collected from about 1940 through 1966, and NOAA Technical Report Number 36, which uses data through the late 1970s. In both of these studies, precipitation statistics were computed for each gage and used to produce point precipitation estimates at each site. The accuracy of the estimates was strongly related to the length of record at each site. Better estimates were obtained for more common events, with lesser accuracy for more rare events.

NOAA published the total depth of rainfall (in tenths of an inch) for storms of 24-hour duration and 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals. The information is presented in the form of "isopluvial" maps for each state. Isopluvial maps are contour maps where the contours represent total inches of rainfall for a specific duration.

- The web link to the isopluvial map for eastern Washington for the 2-year recurrence interval for the 2-hour duration storm event is in Appendix 4A. This map is from the Dam Safety Guidelines, Technical Note 3, Design Storm Construction, Washington State Department of Ecology, Water Resources Program, Report 92-55G, April 1993. This map is used for designs based on the short-duration storm.
- Web links to the isopluvial maps for eastern Washington for the 2-, 10-, 25-, 50- and 100-year recurrence interval for 24-hour duration storm events are in Appendix 4A. These are excerpted from NOAA Atlas 2. The 24-hour isopluvial maps are used for designs based on the long-duration storm and 24-hour storms.

Table 4C-3 SCS Type 1A storm hyetograph values.

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall	Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall	Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.000	0.000	4.5	0.004	0.135	9.0	0.007	0.520
0.1	0.002	0.002	4.6	0.004	0.139	9.1	0.007	0.527
0.2	0.002	0.004	4.7	0.004	0.143	9.2	0.006	0.533
0.3	0.002	0.006	4.8	0.004	0.147	9.3	0.006	0.539
0.4	0.002	0.008	4.9	0.005	0.152	9.4	0.006	0.545
0.5	0.002	0.010	5.0	0.004	0.156	9.5	0.005	0.550
0.6	0.002	0.012	5.1	0.005	0.161	9.6	0.006	0.556
0.7	0.002	0.014	5.2	0.004	0.165	9.7	0.005	0.561
0.8	0.002	0.016	5.3	0.005	0.170	9.8	0.006	0.567
0.9	0.002	0.018	5.4	0.005	0.175	9.9	0.005	0.572
1.0	0.002	0.020	5.5	0.005	0.180	10.0	0.005	0.577
1.1	0.003	0.023	5.6	0.005	0.185	10.1	0.005	0.582
1.2	0.003	0.026	5.7	0.005	0.190	10.2	0.005	0.587
1.3	0.003	0.029	5.8	0.005	0.195	10.3	0.005	0.592
1.4	0.003	0.032	5.9	0.005	0.200	10.4	0.004	0.596
1.5	0.003	0.035	6.0	0.006	0.206	10.5	0.005	0.601
1.6	0.003	0.038	6.1	0.006	0.212	10.6	0.005	0.606
1.7	0.003	0.041	6.2	0.006	0.218	10.7	0.004	0.610
1.8	0.003	0.044	6.3	0.006	0.224	10.8	0.005	0.615
1.9	0.003	0.047	6.4	0.007	0.231	10.9	0.005	0.620
2.0	0.003	0.050	6.5	0.006	0.237	11.0	0.004	0.624
2.1	0.003	0.053	6.6	0.006	0.243	11.1	0.004	0.628
2.2	0.003	0.056	6.7	0.006	0.249	11.2	0.005	0.633
2.3	0.004	0.060	6.8	0.006	0.255	11.3	0.004	0.637
2.4	0.003	0.063	6.9	0.006	0.261	11.4	0.004	0.641
2.5	0.003	0.066	7.0	0.007	0.268	11.5	0.004	0.645
2.6	0.003	0.069	7.1	0.007	0.275	11.6	0.004	0.649
2.7	0.003	0.072	7.2	0.008	0.283	11.7	0.004	0.653
2.8	0.004	0.076	7.3	0.008	0.291	11.8	0.004	0.657
2.9	0.003	0.079	7.4	0.009	0.300	11.9	0.003	0.660
3.0	0.003	0.082	7.5	0.010	0.310	12.0	0.004	0.664
3.1	0.003	0.085	7.6	0.021	0.331	12.1	0.004	0.668
3.2	0.003	0.088	7.7	0.024	0.355	12.2	0.003	0.671
3.3	0.003	0.091	7.8	0.024	0.379	12.3	0.004	0.675
3.4	0.004	0.095	7.9	0.024	0.403	12.4	0.004	0.679
3.5	0.003	0.098	8.0	0.022	0.425	12.5	0.004	0.683
3.6	0.003	0.101	8.1	0.014	0.439	12.6	0.004	0.687
3.7	0.004	0.105	8.2	0.013	0.452	12.7	0.003	0.690
3.8	0.004	0.109	8.3	0.010	0.462	12.8	0.004	0.694
3.9	0.003	0.112	8.4	0.010	0.472	12.9	0.003	0.697
4.0	0.004	0.116	8.5	0.008	0.480	13.0	0.004	0.701
4.1	0.004	0.120	8.6	0.009	0.489	13.1	0.004	0.705
4.2	0.003	0.123	8.7	0.009	0.498	13.2	0.003	0.708
4.3	0.004	0.127	8.8	0.007	0.505	13.3	0.004	0.712
4.4	0.004	0.131	8.9	0.008	0.513	13.4	0.004	0.716

Table 4C-3. SCS Type IA storm hyetograph values (continued).

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
13.5	0.003	0.719
13.6	0.003	0.722
13.7	0.004	0.726
13.8	0.003	0.729
13.9	0.004	0.733
14.0	0.003	0.736
14.1	0.003	0.739
14.2	0.004	0.743
14.3	0.003	0.746
14.4	0.003	0.749
14.5	0.004	0.753
14.6	0.003	0.756
14.7	0.003	0.759
14.8	0.004	0.763
14.9	0.003	0.766
15.0	0.003	0.769
15.1	0.003	0.772
15.2	0.004	0.776
15.3	0.003	0.779
15.4	0.003	0.782
15.5	0.003	0.785
15.6	0.003	0.788
15.7	0.004	0.792
15.8	0.003	0.795
15.9	0.003	0.798
16.0	0.003	0.801
16.1	0.003	0.804
16.2	0.003	0.807
16.3	0.003	0.810
16.4	0.003	0.813
16.5	0.003	0.816
16.6	0.003	0.819
16.7	0.003	0.822
16.8	0.003	0.825
16.9	0.003	0.828
17.0	0.003	0.831
17.1	0.003	0.834
17.2	0.003	0.837
17.3	0.003	0.840
17.4	0.003	0.843
17.5	0.003	0.846
17.6	0.003	0.849
17.7	0.002	0.851
17.8	0.003	0.854
17.9	0.003	0.857
18.0	0.003	0.860
18.1	0.003	0.863
18.2	0.002	0.865
18.3	0.003	0.868
18.4	0.003	0.871
18.5	0.003	0.874
18.6	0.002	0.876
18.7	0.003	0.879
18.8	0.003	0.882
18.9	0.002	0.884
19.0	0.003	0.887
19.1	0.003	0.890
19.2	0.002	0.892
19.3	0.003	0.895
19.4	0.002	0.897
19.5	0.003	0.900
19.6	0.003	0.903
19.7	0.002	0.905
19.8	0.003	0.908
19.9	0.002	0.910
20.0	0.003	0.913
20.1	0.002	0.915
20.2	0.003	0.918
20.3	0.002	0.920
20.4	0.002	0.922
20.5	0.003	0.925
20.6	0.002	0.927
20.7	0.003	0.930
20.8	0.002	0.932
20.9	0.002	0.934
21.0	0.003	0.937
21.1	0.002	0.939
21.2	0.002	0.941
21.3	0.003	0.944
21.4	0.002	0.946
21.5	0.002	0.948
21.6	0.003	0.951
21.7	0.002	0.953
21.8	0.002	0.955
21.9	0.002	0.957
22.0	0.002	0.959
22.1	0.003	0.962
22.2	0.002	0.964
22.3	0.002	0.966
22.4	0.002	0.968
22.5	0.002	0.970
22.6	0.002	0.972
22.7	0.002	0.974
22.8	0.002	0.976
22.9	0.002	0.978
23.0	0.002	0.980
23.1	0.002	0.982
23.2	0.002	0.984
23.3	0.002	0.986
23.4	0.002	0.988
23.5	0.002	0.990
23.6	0.002	0.992
23.7	0.002	0.994
23.8	0.002	0.996
23.9	0.002	0.998
24.0	0.002	1.000

Table 4C-4 SCS Type II storm hyetograph values.

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.000	0.000
0.1	0.001	0.001
0.2	0.001	0.002
0.3	0.001	0.003
0.4	0.001	0.004
0.5	0.001	0.005
0.6	0.001	0.006
0.7	0.001	0.007
0.8	0.001	0.008
0.9	0.001	0.009
1.0	0.002	0.011
1.1	0.001	0.012
1.2	0.001	0.013
1.3	0.001	0.014
1.4	0.001	0.015
1.5	0.001	0.016
1.6	0.001	0.017
1.7	0.001	0.018
1.8	0.002	0.020
1.9	0.001	0.021
2.0	0.001	0.022
2.1	0.001	0.023
2.2	0.001	0.024
2.3	0.002	0.026
2.4	0.001	0.027
2.5	0.001	0.028
2.6	0.001	0.029
2.7	0.002	0.031
2.8	0.001	0.032
2.9	0.001	0.033
3.0	0.002	0.035
3.1	0.001	0.036
3.2	0.001	0.037
3.3	0.001	0.038
3.4	0.002	0.040
3.5	0.001	0.041
3.6	0.001	0.042
3.7	0.002	0.044
3.8	0.001	0.045
3.9	0.002	0.047
4.0	0.001	0.048
4.1	0.001	0.049
4.2	0.002	0.051
4.3	0.001	0.052
4.4	0.002	0.054
4.5	0.001	0.055
4.6	0.002	0.057
4.7	0.001	0.058
4.8	0.002	0.060
4.9	0.001	0.061
5.0	0.002	0.063
5.1	0.002	0.065
5.2	0.001	0.066
5.3	0.002	0.068
5.4	0.002	0.070
5.5	0.001	0.071
5.6	0.002	0.073
5.7	0.002	0.075
5.8	0.001	0.076
5.9	0.002	0.078
6.0	0.002	0.080
6.1	0.002	0.082
6.2	0.002	0.084
6.3	0.001	0.085
6.4	0.002	0.087
6.5	0.002	0.089
6.6	0.002	0.091
6.7	0.002	0.093
6.8	0.002	0.095
6.9	0.002	0.097
7.0	0.002	0.099
7.1	0.002	0.101
7.2	0.002	0.103
7.3	0.002	0.105
7.4	0.002	0.107
7.5	0.002	0.109
7.6	0.002	0.111
7.7	0.002	0.113
7.8	0.003	0.116
7.9	0.002	0.118
8.0	0.002	0.120
8.1	0.002	0.122
8.2	0.003	0.125
8.3	0.002	0.127
8.4	0.003	0.130
8.5	0.002	0.132
8.6	0.003	0.135
8.7	0.003	0.138
8.8	0.003	0.141
8.9	0.003	0.144
9.0	0.003	0.147
9.1	0.003	0.150
9.2	0.003	0.153
9.3	0.004	0.157
9.4	0.003	0.160
9.5	0.003	0.163
9.6	0.003	0.166
9.7	0.004	0.170
9.8	0.003	0.173
9.9	0.004	0.177
10.0	0.004	0.181
10.1	0.004	0.185
10.2	0.004	0.189
10.3	0.005	0.194
10.4	0.005	0.199
10.5	0.005	0.204
10.6	0.005	0.209
10.7	0.006	0.215
10.8	0.006	0.221
10.9	0.007	0.228
11.0	0.007	0.235
11.1	0.008	0.243
11.2	0.008	0.251
11.3	0.010	0.261
11.4	0.010	0.271
11.5	0.012	0.283
11.6	0.024	0.307
11.7	0.047	0.354
11.8	0.077	0.431
11.9	0.137	0.568
12.0	0.095	0.663
12.1	0.019	0.682
12.2	0.017	0.699
12.3	0.014	0.713
12.4	0.012	0.725
12.5	0.010	0.735
12.6	0.008	0.743
12.7	0.008	0.751
12.8	0.008	0.759
12.9	0.007	0.766
13.0	0.006	0.772
13.1	0.006	0.778
13.2	0.006	0.784
13.3	0.005	0.789
13.4	0.005	0.794

Table 4C-4. SCS Type II storm hyetograph values (continued).

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
13.5	0.005	0.799
13.6	0.005	0.804
13.7	0.004	0.808
13.8	0.004	0.812
13.9	0.004	0.816
14.0	0.004	0.820
14.1	0.004	0.824
14.2	0.003	0.827
14.3	0.004	0.831
14.4	0.003	0.834
14.5	0.004	0.838
14.6	0.003	0.841
14.7	0.003	0.844
14.8	0.003	0.847
14.9	0.003	0.850
15.0	0.004	0.854
15.1	0.002	0.856
15.2	0.003	0.859
15.3	0.003	0.862
15.4	0.003	0.865
15.5	0.003	0.868
15.6	0.002	0.870
15.7	0.003	0.873
15.8	0.002	0.875
15.9	0.003	0.878
16.0	0.002	0.880
16.1	0.002	0.882
16.2	0.003	0.885
16.3	0.002	0.887
16.4	0.002	0.889
16.5	0.002	0.891
16.6	0.002	0.893
16.7	0.002	0.895
16.8	0.003	0.898
16.9	0.002	0.900
17.0	0.002	0.902
17.1	0.002	0.904
17.2	0.002	0.906
17.3	0.002	0.908
17.4	0.002	0.910
17.5	0.002	0.912
17.6	0.002	0.914
17.7	0.001	0.915
17.8	0.002	0.917
17.9	0.002	0.919
18.0	0.002	0.921
18.1	0.002	0.923
18.2	0.002	0.925
18.3	0.001	0.926
18.4	0.002	0.928
18.5	0.002	0.930
18.6	0.001	0.931
18.7	0.002	0.933
18.8	0.002	0.935
18.9	0.001	0.936
19.0	0.002	0.938
19.1	0.001	0.939
19.2	0.002	0.941
19.3	0.001	0.942
19.4	0.002	0.944
19.5	0.001	0.945
19.6	0.002	0.947
19.7	0.001	0.948
19.8	0.001	0.949
19.9	0.002	0.951
20.0	0.001	0.952
20.1	0.001	0.953
20.2	0.002	0.955
20.3	0.001	0.956
20.4	0.001	0.957
20.5	0.001	0.958
20.6	0.002	0.960
20.7	0.001	0.961
20.8	0.001	0.962
20.9	0.002	0.964
21.0	0.001	0.965
21.1	0.001	0.966
21.2	0.001	0.967
21.3	0.001	0.968
21.4	0.002	0.970
21.5	0.001	0.971
21.6	0.001	0.972
21.7	0.001	0.973
21.8	0.002	0.975
21.9	0.001	0.976
22.0	0.001	0.977
22.1	0.001	0.978
22.2	0.001	0.979
22.3	0.002	0.981
22.4	0.001	0.982
22.5	0.001	0.983
22.6	0.001	0.984
22.7	0.001	0.985
22.8	0.001	0.986
22.9	0.002	0.988
23.0	0.001	0.989
23.1	0.001	0.990
23.2	0.001	0.991
23.3	0.001	0.992
23.4	0.001	0.993
23.5	0.001	0.994
23.6	0.002	0.996
23.7	0.001	0.997
23.8	0.001	0.998
23.9	0.001	0.999
24.0	0.001	1.000

Table 4C-5 Short-duration storm hyetograph values: All regions.

Use 2-hour precipitation value times 1.06 to determine 3-hour total precipitation amount.

Time (minutes)	Time (hours)	Incremental Rainfall	Cumulative Rainfall
0	0	0.0000	0.0000
5	0.08	0.0047	0.0047
10	0.17	0.0047	0.0094
15	0.25	0.0057	0.0151
20	0.33	0.0104	0.0255
25	0.42	0.0123	0.0378
30	0.50	0.0236	0.0614
35	0.58	0.0292	0.0906
40	0.67	0.0528	0.1434
45	0.75	0.0736	0.2170
50	0.83	0.1736	0.3906
55	0.92	0.2377	0.6283
60	1.00	0.1255	0.7538
65	1.08	0.0604	0.8142
70	1.17	0.0406	0.8548
75	1.25	0.0151	0.8699
80	1.33	0.0132	0.8831
85	1.42	0.0113	0.8944
90	1.50	0.0104	0.9048
95	1.58	0.0085	0.9133
100	1.67	0.0075	0.9208
105	1.75	0.0057	0.9265
110	1.83	0.0057	0.9322
115	1.92	0.0057	0.9379
120	2.00	0.0057	0.9436
125	2.08	0.0047	0.9483
130	2.17	0.0047	0.9530
135	2.25	0.0047	0.9577
140	2.33	0.0047	0.9624
145	2.42	0.0047	0.9671
150	2.50	0.0047	0.9718
155	2.58	0.0047	0.9765
160	2.67	0.0047	0.9812
165	2.75	0.0047	0.9859
170	2.83	0.0047	0.9906
175	2.92	0.0047	0.9953
180	3.00	0.0047	1.0000

Table 4C-6 Long-duration storm hyetograph values: Region 1 – Cascade Mountains.

Use 24-hour precipitation value times 1.16 to determine long-duration storm precipitation total.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000
0.5	0.0024	0.0024
1.0	0.0036	0.0060
1.5	0.0040	0.0101
2.0	0.0047	0.0148
2.5	0.0051	0.0199
3.0	0.0054	0.0253
3.5	0.0058	0.0311
4.0	0.0062	0.0374
4.5	0.0066	0.0439
5.0	0.0078	0.0517
5.5	0.0096	0.0614
6.0	0.0120	0.0733
6.5	0.0138	0.0871
7.0	0.0150	0.1022
7.5	0.0157	0.1179
8.0	0.0164	0.1343
8.5	0.0171	0.1513
9.0	0.0178	0.1691
9.5	0.0185	0.1876
10.0	0.0192	0.2067
10.5	0.0198	0.2266
11.0	0.0205	0.2471
11.5	0.0212	0.2683
12.0	0.0220	0.2904
12.5	0.0226	0.3130
13.0	0.0235	0.3364
13.5	0.0243	0.3608
14.0	0.0297	0.3905
14.5	0.0338	0.4243
15.0	0.0507	0.4750
15.5	0.0315	0.5066
16.0	0.0283	0.5349
16.5	0.0257	0.5606
17.0	0.0231	0.5837
17.5	0.0214	0.6051
18.0	0.0183	0.6234
18.5	0.0168	0.6402
19.0	0.0165	0.6566
19.5	0.0161	0.6728
20.0	0.0158	0.6886
20.5	0.0154	0.7040
21.0	0.0151	0.7191
21.5	0.0148	0.7339
22.0	0.0144	0.7483
22.5	0.0141	0.7623
23.0	0.0137	0.7761
23.5	0.0134	0.7894
24.0	0.0130	0.8025
24.5	0.0127	0.8151
25.0	0.0123	0.8275
25.5	0.0120	0.8395
26.0	0.0117	0.8512
26.5	0.0115	0.8627
27.0	0.0112	0.8739
27.5	0.0110	0.8849
28.0	0.0107	0.8956
28.5	0.0104	0.9060
29.0	0.0102	0.9162
29.5	0.0099	0.9261
30.0	0.0097	0.9358
30.5	0.0088	0.9446
31.0	0.0079	0.9525
31.5	0.0071	0.9596
32.0	0.0063	0.9659
32.5	0.0058	0.9717
33.0	0.0054	0.9772
33.5	0.0050	0.9822
34.0	0.0047	0.9869
34.5	0.0043	0.9912
35.0	0.0039	0.9950
35.5	0.0030	0.9981
36.0	0.0019	1.0000

Table 4C-7 Long-duration storm hyetograph values: Region 2 – Central Basin.

Use 24-hour precipitation value times 1.00 to determine long-duration storm precipitation total.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000
0.5	0.0054	0.0054
1.0	0.0086	0.0140
1.5	0.0100	0.0240
2.0	0.0120	0.0360
2.5	0.0130	0.0490
3.0	0.0140	0.0630
3.5	0.0150	0.0780
4.0	0.0160	0.0940
4.5	0.0170	0.1110
5.0	0.0187	0.1297
5.5	0.0228	0.1525
6.0	0.0283	0.1808
6.5	0.0305	0.2113
7.0	0.0335	0.2448
7.5	0.0365	0.2813
8.0	0.0484	0.3297
8.5	0.0622	0.3919
9.0	0.0933	0.4852
9.5	0.0527	0.5380
10.0	0.0402	0.5782
10.5	0.0372	0.6154
11.0	0.0348	0.6502
11.5	0.0331	0.6833
12.0	0.0289	0.7122
12.5	0.0252	0.7374
13.0	0.0219	0.7593
13.5	0.0191	0.7783
14.0	0.0167	0.7950
14.5	0.0148	0.8098
15.0	0.0134	0.8232
15.5	0.0123	0.8355
16.0	0.0116	0.8471
16.5	0.0110	0.8581
17.0	0.0105	0.8686
17.5	0.0103	0.8789
18.0	0.0103	0.8892
18.5	0.0104	0.8996
19.0	0.0105	0.9100
19.5	0.0105	0.9205
20.0	0.0104	0.9309
20.5	0.0102	0.9412
21.0	0.0100	0.9512
21.5	0.0097	0.9609
22.0	0.0093	0.9702
22.5	0.0087	0.9789
23.0	0.0083	0.9872
23.5	0.0078	0.9950
24.0	0.0050	1.0000

Table 4C-8 Long-duration storm hyetograph values: Region 3 – Okanogan, Spokane, Palouse.

Use 24-hour precipitation value times 1.06 to determine long-duration storm precipitation total.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000
0.5	0.0017	0.0017
1.0	0.0030	0.0047
1.5	0.0041	0.0088
2.0	0.0053	0.0141
2.5	0.0068	0.0209
3.0	0.0092	0.0301
3.5	0.0108	0.0409
4.0	0.0126	0.0535
4.5	0.0132	0.0667
5.0	0.0139	0.0806
5.5	0.0147	0.0952
6.0	0.0154	0.1106
6.5	0.0162	0.1268
7.0	0.0169	0.1437
7.5	0.0177	0.1614
8.0	0.0184	0.1798
8.5	0.0192	0.1990
9.0	0.0228	0.2219
9.5	0.0238	0.2457
10.0	0.0260	0.2717
10.5	0.0282	0.2999
11.0	0.0395	0.3394
11.5	0.0564	0.3958
12.0	0.0855	0.4813
12.5	0.0451	0.5265
13.0	0.0348	0.5612
13.5	0.0335	0.5948
14.0	0.0276	0.6223
14.5	0.0199	0.6422
15.0	0.0179	0.6601
15.5	0.0158	0.6759
16.0	0.0156	0.6915
16.5	0.0154	0.7069
17.0	0.0152	0.7221
17.5	0.0150	0.7372
18.0	0.0148	0.7519
18.5	0.0145	0.7664
19.0	0.0142	0.7806
19.5	0.0139	0.7945
20.0	0.0136	0.8081
20.5	0.0133	0.8215
21.0	0.0131	0.8346
21.5	0.0130	0.8475
22.0	0.0128	0.8603
22.5	0.0126	0.8729
23.0	0.0123	0.8852
23.5	0.0120	0.8972
24.0	0.0116	0.9088
24.5	0.0112	0.9200
25.0	0.0108	0.9308
25.5	0.0104	0.9412
26.0	0.0100	0.9512
26.5	0.0096	0.9607
27.0	0.0092	0.9699
27.5	0.0086	0.9785
28.0	0.0074	0.9859
28.5	0.0054	0.9913
29.0	0.0040	0.9953
29.5	0.0030	0.9983
30.0	0.0017	1.0000

Table 4C-9 Long-duration storm hyetograph values: Region 4 – Northeastern Mountains and Blue Mountains.

Use 24-hour precipitation value times 1.07 to determine long-duration storm precipitation total.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000
0.5	0.0015	0.0015
1.0	0.0031	0.0046
1.5	0.0047	0.0094
2.0	0.0064	0.0158
2.5	0.0082	0.0239
3.0	0.0104	0.0343
3.5	0.0115	0.0458
4.0	0.0123	0.0581
4.5	0.0130	0.0711
5.0	0.0137	0.0848
5.5	0.0145	0.0993
6.0	0.0152	0.1145
6.5	0.0160	0.1305
7.0	0.0167	0.1472
7.5	0.0174	0.1646
8.0	0.0182	0.1828
8.5	0.0190	0.2019
9.0	0.0207	0.2226
9.5	0.0232	0.2458
10.0	0.0260	0.2717
10.5	0.0278	0.2996
11.0	0.0399	0.3394
11.5	0.0531	0.3925
12.0	0.0796	0.4722
12.5	0.0441	0.5162
13.0	0.0329	0.5492
13.5	0.0303	0.5795
14.0	0.0291	0.6086
14.5	0.0199	0.6284
15.0	0.0166	0.6451
15.5	0.0155	0.6606
16.0	0.0153	0.6759
16.5	0.0151	0.6910
17.0	0.0149	0.7059
17.5	0.0148	0.7207
18.0	0.0146	0.7353
18.5	0.0144	0.7496
19.0	0.0142	0.7639
19.5	0.0140	0.7779
20.0	0.0137	0.7915
20.5	0.0134	0.8049
21.0	0.0132	0.8181
21.5	0.0131	0.8312
22.0	0.0129	0.8441
22.5	0.0129	0.8570
23.0	0.0128	0.8697
23.5	0.0127	0.8825
24.0	0.0127	0.8951
24.5	0.0126	0.9077
25.0	0.0124	0.9201
25.5	0.0121	0.9322
26.0	0.0116	0.9438
26.5	0.0109	0.9547
27.0	0.0101	0.9647
27.5	0.0090	0.9738
28.0	0.0077	0.9814
28.5	0.0061	0.9875
29.0	0.0051	0.9926
29.5	0.0045	0.9971
30.0	0.0029	1.0000

4C-6 Precipitation Magnitude for 24-Hour and Long- and Short-Duration Runoff Treatment Storm

The frequency of the long-duration runoff treatment storm is a 6-month recurrence interval or twice per year return period. Unfortunately, the NOAA Atlas 2 maps require the conversion of 2-year, 24-hour precipitation to 6-month, 24-hour precipitation.

Use the following equation to determine the 6-month precipitation:

$$P_{wqs} = C_{wqs} (P_{2yr24hr})$$

where: P_{wqs} is the 24-hour precipitation (inches) for the 6-month storm recurrence interval; this precipitation is used with the long-duration storm hyetograph or 24-hour SCS (NRCS) Type IA or Type II hyetographs, depending on the design storm option selected by the jurisdiction;

C_{wqs} is a coefficient from Table 4C-10 for computing the 6-month, 24-hour precipitation based on the climatic region; and

$P_{2yr24hr}$ is the 2-year, 24-hour precipitation in Appendix 4A.

Values of the coefficient C_{wqs} are shown in Table 4C-10 for all four regions.

Table 4C-10 Coefficients C_{wqs} for computing 6-month, 24-hour precipitation.

Region #	Region Name	C_{wqs}
1	East Slope Cascades	0.70
2	Central Basin	0.66
3	Okanogan, Spokane, Palouse	0.69
4	NE & Blue Mountains	0.70

4C-7 Precipitation Magnitude for Long-Duration Storms

Table 4C-11 provides the multipliers, by region, for the conversion of the 24-hour precipitation to the regional long-duration storm precipitation. Using the precipitation values from the isopluvial maps and the conversion factor in Table 4C-11, the precipitation can be adjusted for the long-duration hyetograph. The design of volume-based BMPs requires the regional long-duration storm in Regions 1 and 4. For Regions 2 and 4, designers can choose either the SCS Type 1A storm distribution or the regional long-duration storm. When the Type 1A storm distribution is used, the conversion factors in Table 4C-11 do not apply.

Table 4C-11 Conversion factor for 24-hour to regional long-duration storm precipitation.

Region #	Region Name	Conversion Factor
1	East Slope Cascades	1.16
2	Central Basin	1.00
3	Okanogan, Spokane, Palouse	1.06
4	NE & Blue Mountains	1.07

Use the following equation to determine the long-duration precipitation for a selected return period:

$$P_{sds} = C_F \, (P_{N\text{-yr } 24\text{-hr}})$$

where: P_{sds} is the precipitation (inches) adjusted for a selected long-duration hyetograph;

C_F is a conversion factor from Table 4C-11, by region, for converting the 24-hour precipitation to the regional long-duration storm precipitation; and

$P_{N\text{-yr } 24\text{-hr}}$ is the precipitation from the isopluvial maps for N years and 24 hours, Appendix 4A.

4C-8 Precipitation Magnitude for Short-Duration Storms

The only mapped frequency of the short-duration storm is a 2-year, 2-hour recurrence interval. The design of flow-based treatment BMPs using the Single Event Hydrograph Model requires conversion of the 2-year, 2-hour precipitation to the 6-month, 2-hour precipitation. The design of other BMPs or conveyance elements based on the short-duration storm could also require the conversion of the 2-year, 2-hour precipitation to a different recurrence interval.

Use the following equation to determine the 3-hour precipitation for a selected return period:

$$P_{sds} = C_{sds} \, (P_{2yr2hr})$$

where: P_{sds} is the 3-hour precipitation (inches) for a selected return period for the short-duration storm;

C_{sds} is a coefficient from Table 4C-12 for computing the 2-hour precipitation for a selected return period based on the 2-year, 2-hour precipitation; and

P_{2yr2hr} is the 2-year, 2-hour precipitation in Appendix 4A.

Values of the coefficient C_{sds} are based on the Generalized Extreme Value (GEV) distribution, whose distribution parameters can be expressed as a function of mean annual precipitation for eastern Washington. Table 4C-12 lists values of the coefficient C_{sds} for selected return periods for various magnitudes of mean annual precipitation. The web link for an isopluvial map of mean annual precipitation is in Appendix 4A (use the map to determine the mean annual precipitation for the site).

Table 4C-12 Precipitation for selected return periods (C_{sds}).

Region #	Mean Annual Precipitation (in.)	6-Month	1-Year	2-Year	10-Year	25-Year	50-Year	100-Year
	6-8	0.65	0.84	1.06	1.73	2.30	2.84	3.49
	8-10	0.66	0.85	1.06	1.70	2.22	2.70	3.28
2	10-12	0.68	0.86	1.06	1.65	2.14	2.59	3.10
2, 3	12-16	0.70	0.87	1.06	1.60	2.01	2.40	2.82
3	16-22	0.71	0.88	1.06	1.56	1.93	2.26	2.63
	22-28	0.73	0.89	1.06	1.52	1.84	2.13	2.45
	28-40	0.74	0.90	1.06	1.48	1.78	2.04	2.32
	40-60	0.76	0.91	1.06	1.44	1.71	1.93	2.17
1, 4	60-120	0.78	0.92	1.06	1.41	1.64	1.84	2.05