Engineering Field Handbook Chapter 2: Estimating Runoff and Peak Discharges

Pennsylvania Notice 34 Supplement

Introduction / Background

This Supplement to EFH-2 concerns use of rainfall data developed by the National Oceanic and Atmospheric Administration Atlas 14 (NOAA 14) and rainfall distributions based on the NOAA 14 data. These rainfall data and rainfall distributions will replace rainfall data from Weather Bureau Technical Paper 40 (TP-40) and the standard NRCS rainfall distributions Type II and Type III.

The EFH-2 computer program User Guide contains information, guidance, and examples concerning runoff curve number, average watershed slope, watershed length, input/output operations, and limitations. This supplement includes information related to rainfall data and rainfall distributions for use with the EFH-2 computer program in Pennsylvania. Additional technical information is available from the NOAA 14 web site (http://hdsc.nws.noaa.gov/hdsc/pfds/) and NRCS technical directives such as National Engineering Handbook Part 630 – Hydrology, Chapter 4, Storm Rainfall Depth and Distribution.

Implementation

The methods and data described in this supplement supersede any applicable methods and data not removed from NEH 650, Chapter 2 for Pennsylvania only. A specific example begins on Page PA2-14.C.

This supplement will be implemented by replacing the state/county rainfall database (**county.PA**) and rainfall distribution types (**type.rf**) used with the EFH-2 computer program.

Rainfall Data

NOAA completed Volume 2 of Atlas 14 precipitation-frequency analysis in 2004. This is the first comprehensive precipitation-frequency analysis for the Ohio Valley and neighboring states since TP-40 was completed in 1961. Data are available for specific locations from an interactive web site (http://hdsc.nws.noaa.gov/hdsc/pfds/). Alternatively, data for representative locations in Pennsylvania counties are included in a rainfall database **county.PA** for use with the EFH-2 computer program. The data contained in the database are included in Appendix 1 of this Supplement.

Rainfall Values

NOAA used periods of record for rainfall stations up through December 2000 to compute precipitation-duration-frequency values. The period of record for TP-40 ended in 1958. This additional 42 years of data gives different frequency-duration rainfall values than TP-40. These values have been updated in 2011 for Pennsylvania.

The preferred method to obtain site specific NOAA 14 rainfall values for EFH-2 is to:

1. Browse to http://hdsc.nws.noaa.gov/hdsc/pfds/ in a web browser.
2. Click on Pennsylvania on the national map.
3. In the map, navigate to drag the red cross hair icon to the project site location. Other options for selecting a location are to enter a latitude and longitude (from a GPS, for example) or select a rainfall station from a pull-down list. Typically choose the centroid of your drainage area.
4. Scroll down on the screen below the map. A table of precipitation-frequency data is shown for the selected location.
5. Scroll to the bottom of the screen. There is an option to save the data in a comma-separated-variable (csv) format.
6. Replace the default rainfall values on the EFH-2 Rainfall/Discharge data tab with the 24-hour duration NOAA values from the table.

The alternative method is to use representative county values that have been developed from the NOAA 14 study for use with EFH-2. These are the default values seen in EFH-2 computer program when the updated rainfall database (**county.PA**) is loaded. The data are also included in Appendix 1 of this Supplement.

The county data for Pennsylvania was chosen to be the maximum 1-year through 25-year 24-hour values in each county. Note, the maximum 1-year through 25-year 24-hour rainfalls do not necessarily occur at the same location.

The county data are good representative values when using a model with the precision of EFH-2 but it is not the average or minimum amount of rainfall found in any county. If a more precise rainfall estimate is desired, site specific data may be downloaded as described above.

Rainfall Type

Ideally, site specific rainfall distributions would be used to convert the runoff volume from the Curve Number calculations to a hydrograph. However the EFH-2 computer program cannot handle this type of input. Instead, EFH-2 uses equations to produce the unit peak discharge from the time of concentration and excess runoff volume.

The coefficients for these equations were developed from additional modeling by the NRCS for four new rainfall types (NOAA 14 A, B, C, & D) from the NOAA 14 data. The map of the state of Pennsylvania showing where to use each of the four types follows in Figure 1.

These new rainfall types replace the NRCS Type II in EFH-2 for Pennsylvania. The Type II should no longer be used and is only included to recreate old models.

The EFH-2 computer program uses equations to relate unit peak discharge (cubic feet per second per inch of runoff per square mile of drainage area) to time of concentration in hours. The equations and coefficients for the four NOAA 14 rainfall types, and former Type II are included in the **type.RF** file and

Appendix 2. Plots of the four rainfall distributions used to develop the coefficients are included in Appendix 3.

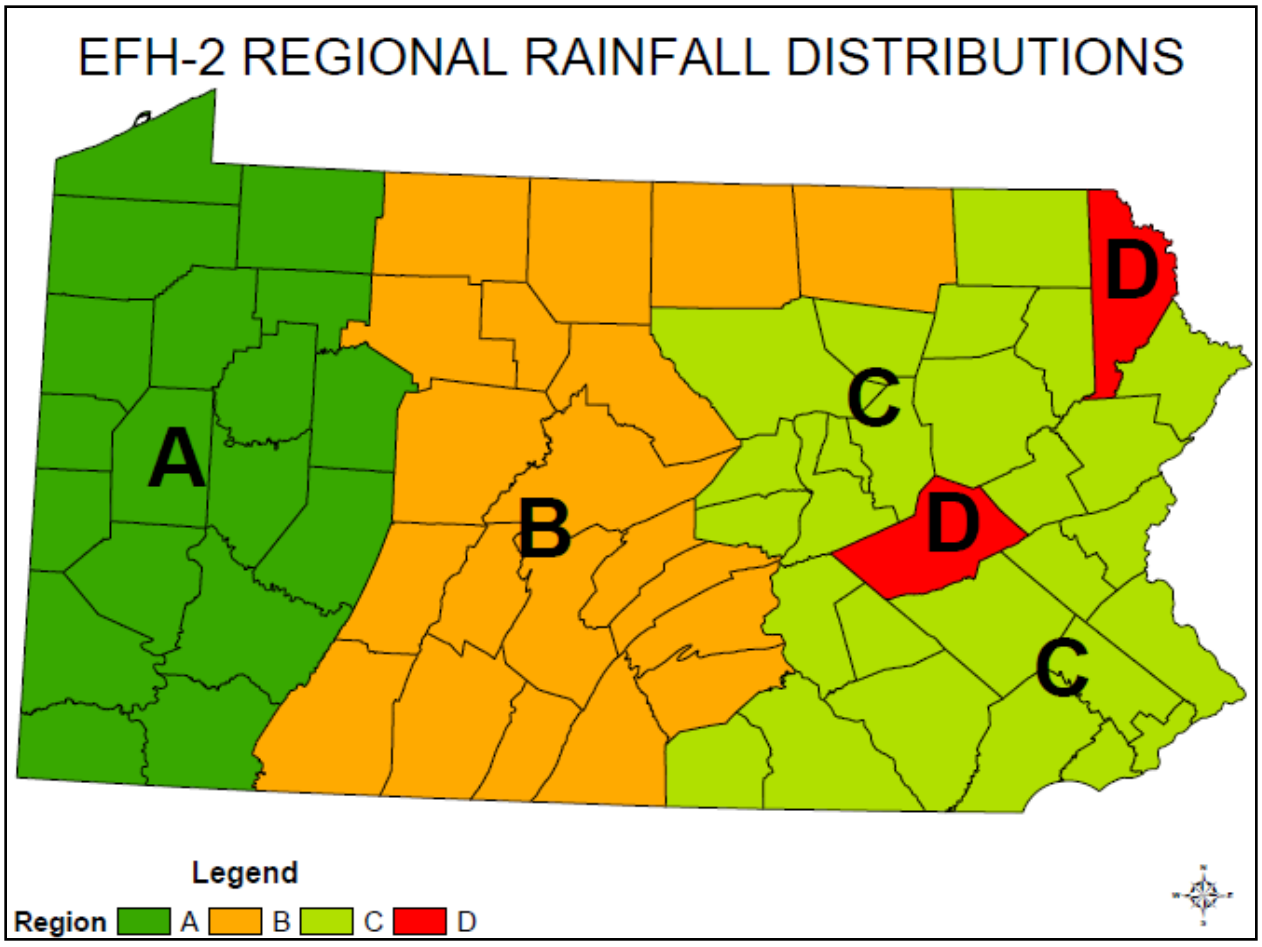
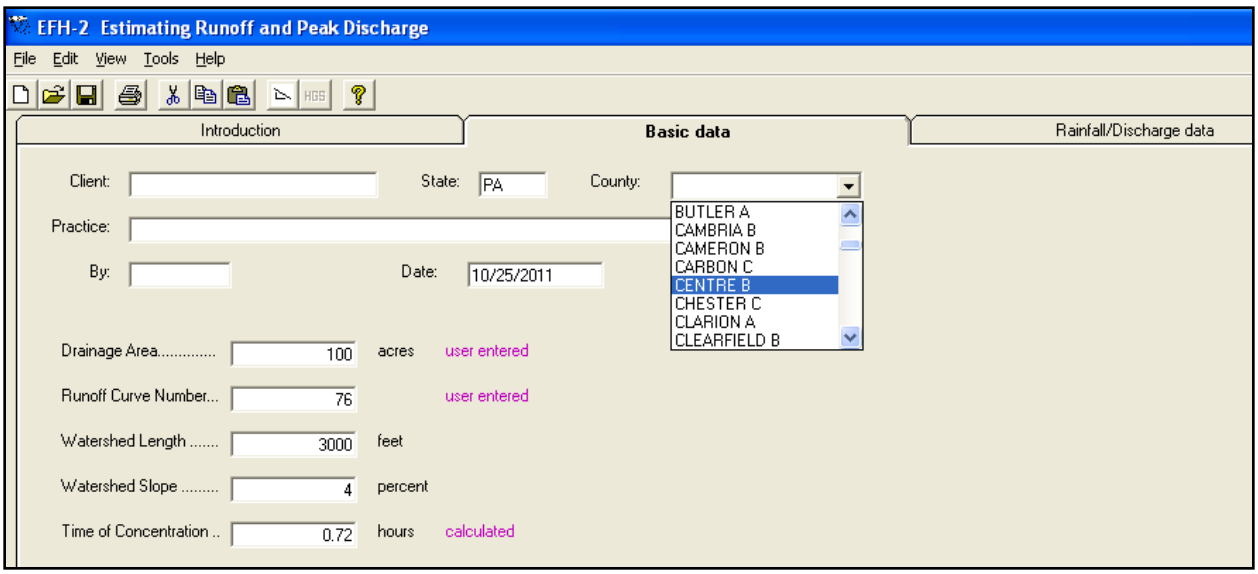


Figure 1 Map showing designated rainfall distribution for Pennsylvania Counties.

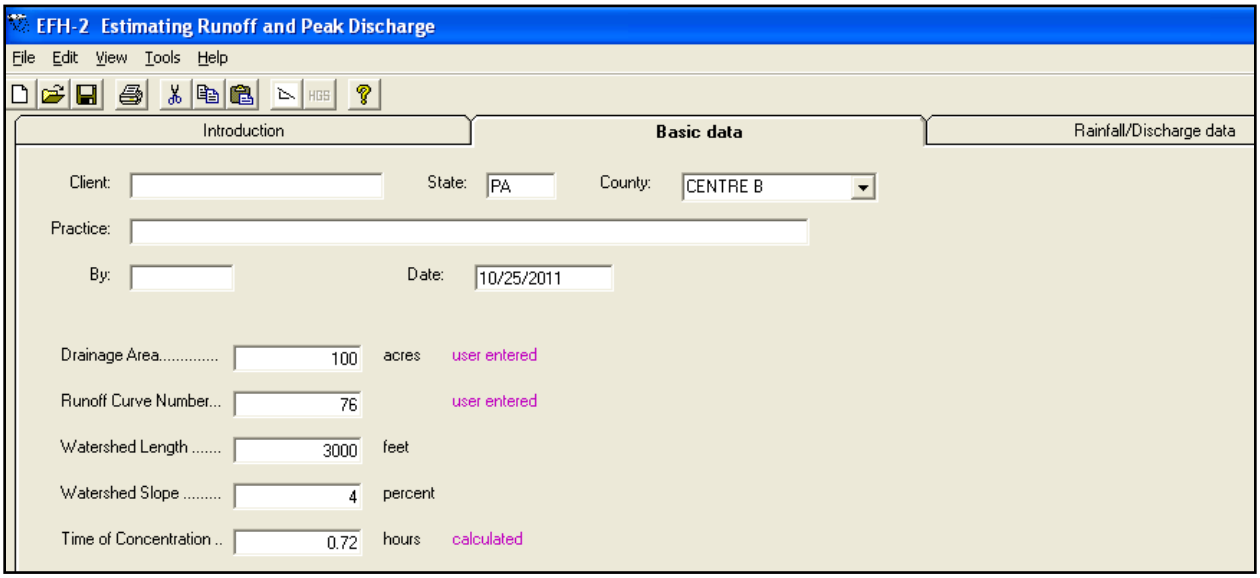
Example Application of the EFH-2 Computer Program in Pennsylvania

For this example, we select a small watershed in Centre County. The drainage area is 100 acres, the curve number is 76, length is 3000 feet, and average watershed slope is 4 percent. From the rainfall distribution map above, the rainfall distribution region is "B".

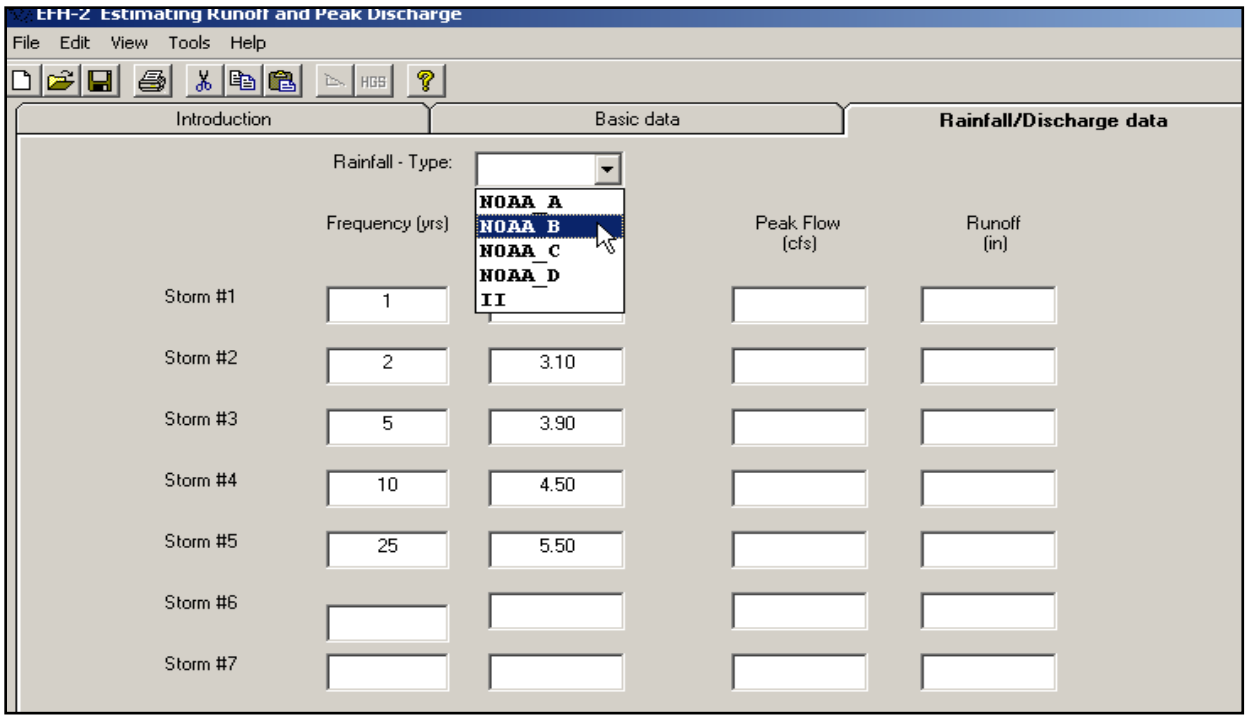
1. Open the EFH-2 computer program and open the Basic Data tab. Enter State: PA and use the pull-down menu to select Centre County. The letter "B" next to the county name designates this county is in Distribution Region B.



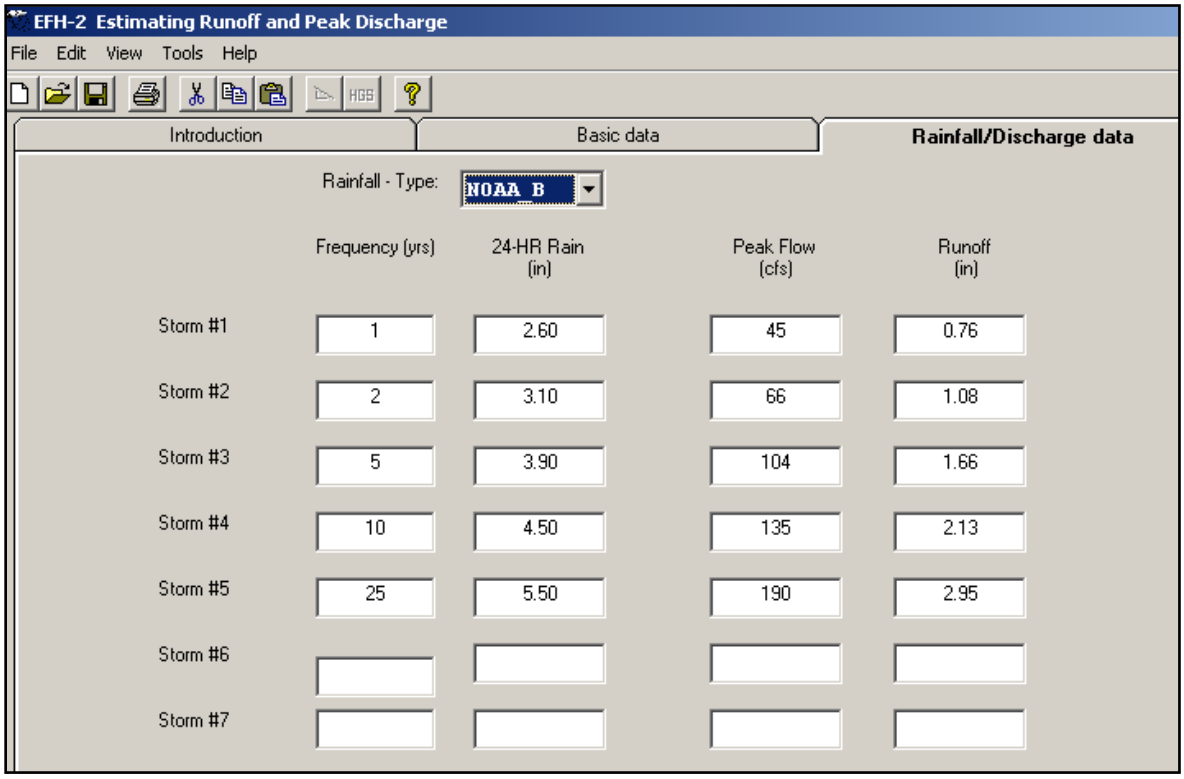
2. Enter the remaining data on this window. The Drainage Area and Runoff Curve Number could alternatively have been entered by opening the RCN tab (far right side of Basic data window). Open the Rainfall/Discharge data tab.



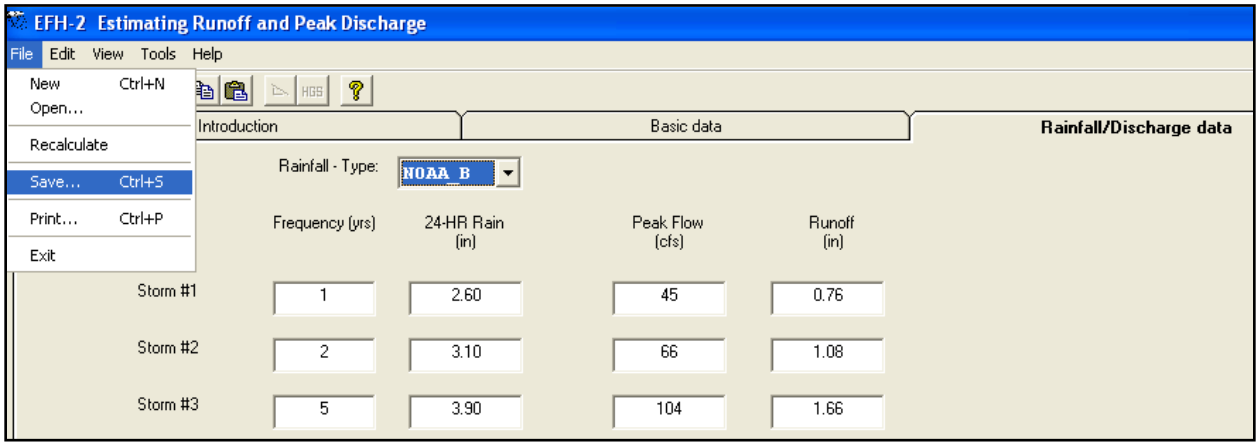
3. The 24-hour rainfall data for Centre County has automatically been entered. At this point you may replace these county values with site specific data from http://hdsc.nws.noaa.gov/hdsc/pfds/ if desired.
4. Use the Rainfall Type: pull-down menu to select NOAA_B.



5. Upon choosing the rainfall type, the peak discharges and runoff depths are calculated.



To complete the project, click File and Save. Print output if desired. Close EFH-2.



Appendix 1. County rainfall database (county.PA) Notes: Rainfall distribution for each county and zone are shown with the county name (Region A, B, C, or D). The 24-hour rainfall duration values are in units of inches.

Table PA A1-1 NRCC Rainfall Values and Regional Codes for Pennsylvania Counties

COUNTY	REGION	1-year	2-year	5-year	10-year	25-year
ADAMS	C	2.8	3.4	4.2	4.9	6.0
ALLEGHENY	A	2.0	2.4	2.9	3.4	4.0
ARMSTRONG	A	2.1	2.5	3.1	3.5	4.2
BEAVER	A	2.0	2.4	2.9	3.4	4.0
BEDFORD	B	2.3	2.8	3.5	4.0	4.8
BERKS	C	2.8	3.4	4.2	4.9	6.0
BLAIR	B	2.3	2.8	3.5	4.0	4.8
BRADFORD	B	2.2	2.6	3.2	3.7	4.3
BUCKS	C	2.8	3.4	4.3	5.0	6.2
BUTLER	A	2.0	2.4	3.0	3.4	4.1
CAMBRIA	B	2.3	2.8	3.5	4.0	4.8
CAMERON	B	2.2	2.6	3.2	3.7	4.4
CARBON	C	2.9	3.5	4.4	5.1	6.3
CENTRE	B	2.6	3.1	3.9	4.5	5.5
CHESTER	C	2.7	3.3	4.1	4.9	6.0
CLARION	A	2.1	2.5	3.1	3.5	4.2
CLEARFIELD	B	2.2	2.6	3.2	3.7	4.4
CLINTON	B	2.6	3.1	3.8	4.4	5.4
COLUMBIA	C	2.7	3.2	3.9	4.6	5.7
CRAWFORD	A	2.1	2.5	3.1	3.6	4.3
CUMBERLAND	B	2.8	3.3	4.1	4.9	5.9
DAUPHIN	C	2.6	3.1	3.9	4.6	5.6
DELAWARE	C	2.7	3.3	4.1	4.9	6.0
ELK	B	2.2	2.6	3.2	3.7	4.4
ERIE	A	2.2	2.6	3.2	3.7	4.5
FAYETTE	A	2.1	2.6	3.1	3.6	4.3
FOREST	A	2.1	2.5	3.0	3.5	4.1
FRANKLIN	B	2.8	3.4	4.2	4.9	6.0
FULTON	B	2.4	2.9	3.7	4.2	5.1
GREENE	A	2.1	2.5	3.1	3.5	4.1
HUNTINGDON	B	2.3	2.8	3.5	4.1	4.9
INDIANA	A	2.2	2.6	3.2	3.7	4.5
JEFFERSON	A	2.1	2.5	3.1	3.6	4.3
JUNIATA	B	2.6	3.1	3.9	4.5	5.6
LACKAWANNA	C	2.7	3.2	4.0	4.7	5.8

COUNTY	REGION	1-year	2-year	5-year	10-year	25-year
LANCASTER	C	2.7	3.2	4.1	4.8	6.0
LAWRENCE	A	2.0	2.4	3.0	3.4	4.0
LEBANON	C	2.6	3.2	4.0	4.6	5.7
LEHIGH	C	2.8	3.3	4.2	4.9	6.0
LUZERNE	C	2.9	3.4	4.3	5.0	6.2
LYCOMING	C	2.6	3.1	3.8	4.4	5.4
McKEAN	B	2.1	2.5	3.1	3.6	4.3
MERCER	A	2.1	2.5	3.0	3.5	4.1
MIFFLIN	B	2.5	3.0	3.8	4.4	5.3
MONROE	C	2.8	3.3	4.1	4.9	6.0
MONTGOMERY	C	2.8	3.3	4.2	5.0	6.1
MONTOUR	C	2.4	2.9	3.6	4.2	5.1
NORTHAMPTON	C	2.8	3.3	4.1	4.8	5.9
NORTHUMBERLAND	C	2.6	3.1	3.8	4.5	5.5
PERRY	B	2.5	2.9	3.7	4.3	5.3
PHILADELPHIA	C	2.8	3.3	4.2	5.0	6.1
PIKE	C	2.6	3.1	3.9	4.6	5.7
POTTER	B	2.2	2.6	3.2	3.7	4.5
SCHUYLKILL	D	2.9	3.5	4.4	5.1	6.3
SNYDER	C	2.7	3.2	4.0	4.7	5.7
SOMERSET	B	2.2	2.7	3.3	3.9	4.7
SULLIVAN	C	2.7	3.2	3.9	4.6	5.5
SUSQUEHANNA	C	2.5	3.0	3.7	4.3	5.3
TIOGA	B	2.2	2.6	3.2	3.7	4.4
UNION	C	2.6	3.1	3.9	4.5	5.5
VENANGO	A	2.1	2.5	3.0	3.5	4.1
WARREN	A	2.1	2.5	3.1	3.6	4.3
WASHINGTON	A	2.0	2.4	3.0	3.4	4.0
WAYNE	D	2.6	3.2	3.9	4.6	5.7
WESTMORELAND	A	2.2	2.6	3.2	3.8	4.6
WYOMING	C	2.5	3.0	3.7	4.3	5.2
YORK	C	2.6	3.2	4.1	4.9	6.1

Appendix 2. Rainfall Type Equations

Since EFH-2 cannot use actual rainfall distributions, alternative methods of estimating peak discharges are needed as described below. Also, since NRCS Type II does not match the NOAA 14 data, new distributions and peak flow coefficients were also created.

Extents of Rainfall Types

Four rainfall types (NOAA 14 A, B, C, & D) were developed from the NOAA 14 data to replace the NRCS Type-II rainfall distribution and EFH-2 coefficients. The four rainfall types were developed for the NOAA Atlas 14 Volume 2 region which includes 13 states from New Jersey west to Illinois and southeast to South Carolina. The extent of each region was based on the 60-minute/24-hour ratio of the 25-year NOAA 14 data. The thresholds for the 4 regions are as follows.

A > 0.48
B 0.43 to 0.48
C 0.38 to 0.43
D < 0.38

Peak Equation Coefficients

Rainfall distributions were created for each region and used in WinTR20 models to develop peak flow equation coefficients for use in EFH-2. To simplify the estimation of peak discharge, WinTR-20 was run for times of concentration of 0.1 to 10.0 hours and I_a/P ratios of 0.1, 0.2, 0.3, 0.4 and 0.5. I_a is initial abstraction in units of inches. Initial abstraction includes all losses before runoff begins (interception, depression storage, early storm infiltration, etc). P is the storm rainfall with units of inches.

$$I_a = 0.2 * ((1000 / CN) – 10) \quad \text{Eq. PA2-1}$$

where CN = NRCS runoff curve number.

Equations to relate time of concentration to unit peak discharge were then developed. The equation used to compute the unit peak discharge (q) for the EFH-2 computer program is:

$$q = 10 \text{ ^ } (Coeff\_1 + Coeff\_2 * LOG(T_c) + Coeff\_3 * (LOG(T_c))\text{^}2) \quad \text{Eq. PA2-2}$$

The coefficients to be used with each rainfall distribution are tabulated below. For example, the equation applicable to the Region C rainfall distribution region of Pennsylvania and I_a/P ratio of 0.1 is:

$$q = 10^{(2.4928 – 0.585 * LOG(T_c) – 0.137 * (LOG(T_c))^2)} \quad \text{Eq. PA2-3}$$

For a time of concentration of 0.5 hours and I_a/P ratio of 0.1, the unit peak discharge is q = 453.41 cfs / inch / sq mile. If the drainage area is 200 acres (0.31 square miles) and there is 1.5 inches of runoff, the peak discharge, Q, is:

$$Q = 453.41 * 0.31 * 1.5 = 210 \text{ cfs} \quad \text{Eq. PA2-4}$$

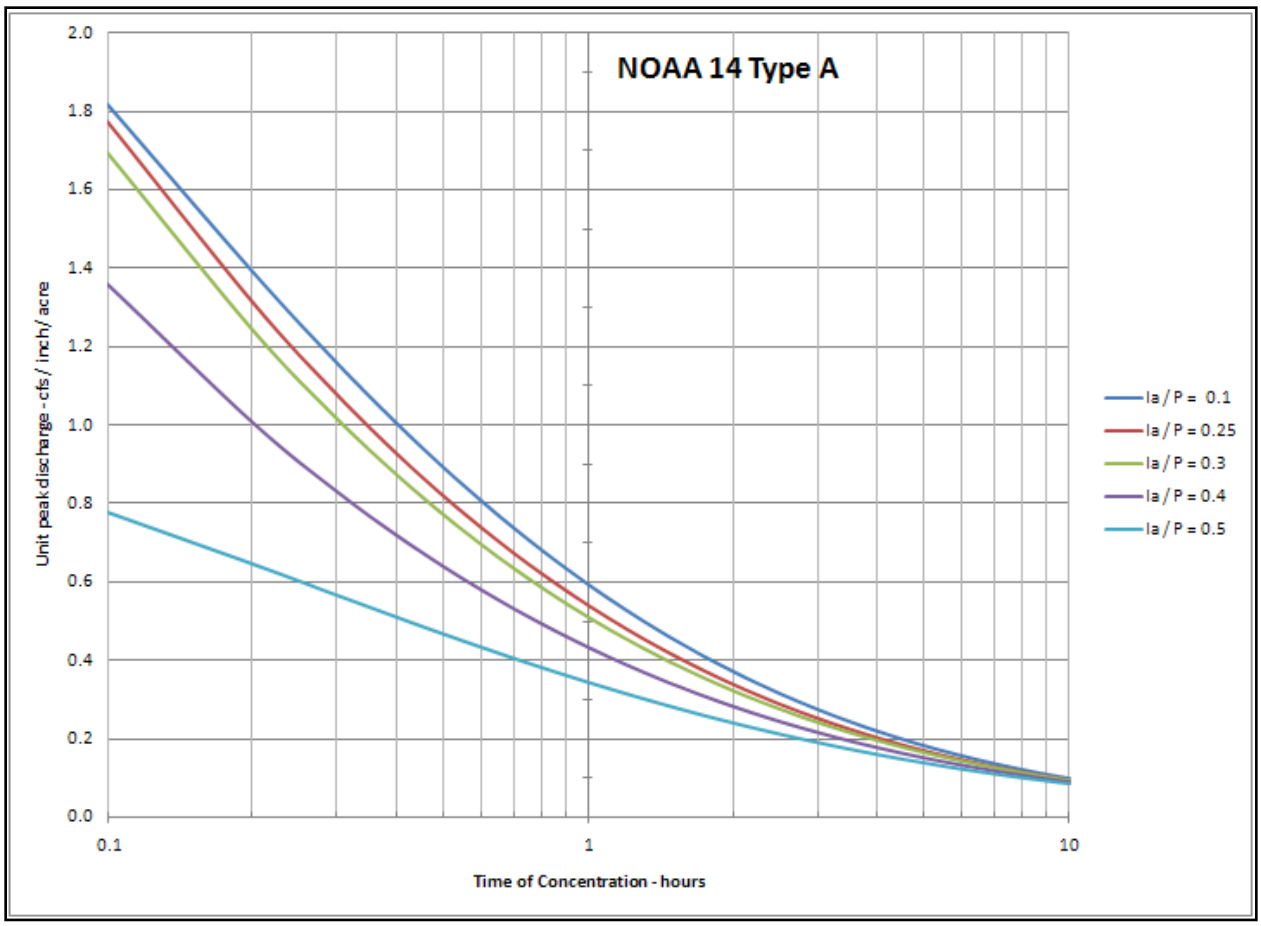


Figure A2-1, EFH-2 Peak Discharge Curves for Region A

Table A2-1, EFH-2 Peak Discharge Equation Coefficients for Region A

I_a/P	Coeff_1	Coeff_2	Coeff_3
0.1	2.5796	-0.6312	-0.1451
0.2	2.539	-0.6368	-0.1203
0.3	2.5126	-0.6315	-0.1087
0.4	2.4423	-0.5887	-0.0921
0.5	2.3435	-0.4789	-0.1246

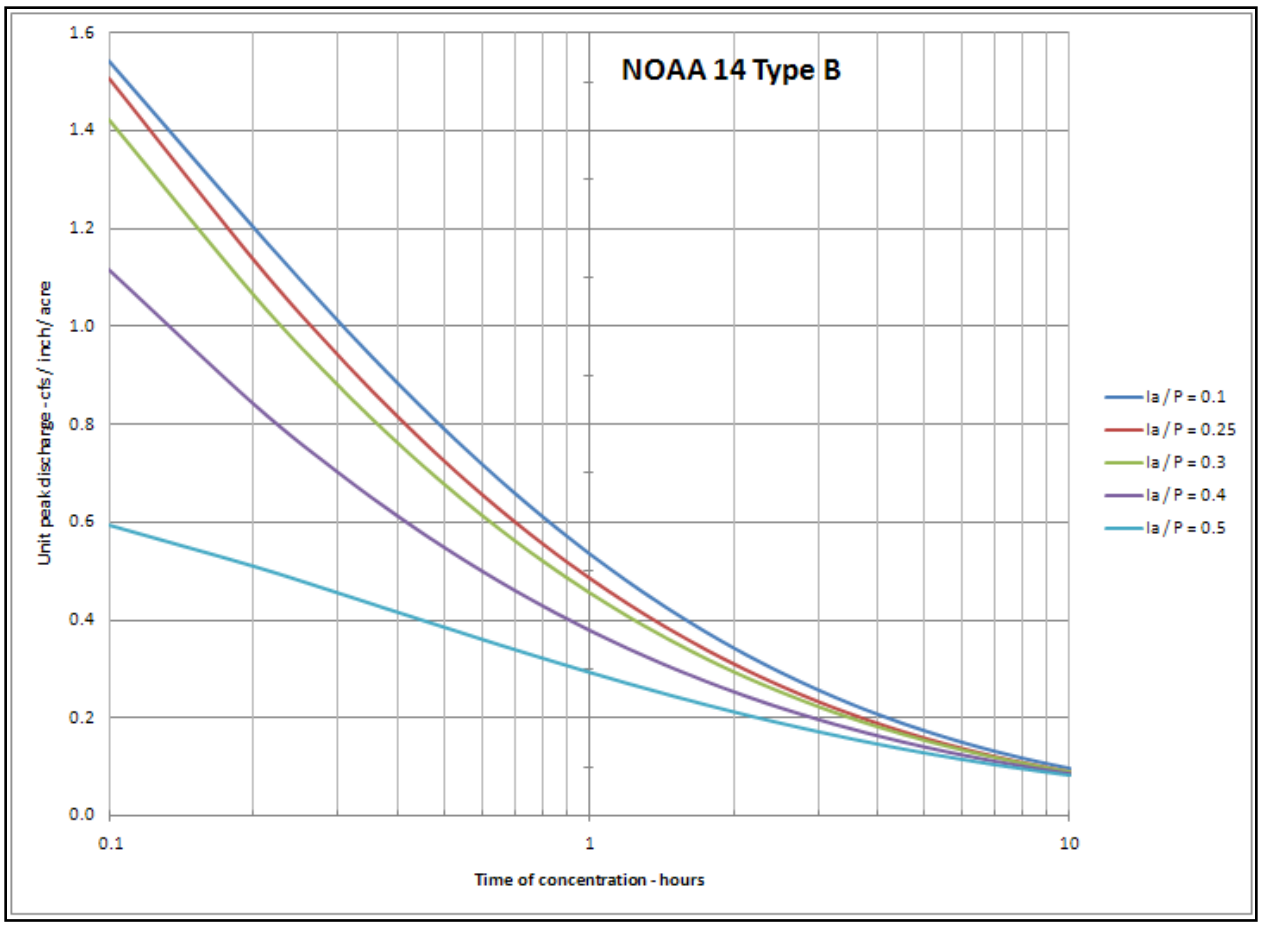


Figure A2-2, EFH-2 Peak Discharge Curves for Region B

Table A2-2, EFH-2 Peak Discharge Equation Coefficients for Region B

I_a/P	Coeff_1	Coeff_2	Coeff_3
0.1	2.5352	-0.603	-0.1433
0.2	2.4928	-0.6109	-0.1197
0.3	2.4646	-0.6035	-0.1085
0.4	2.3852	-0.5578	-0.0886
0.5	2.2713	-0.4318	-0.124

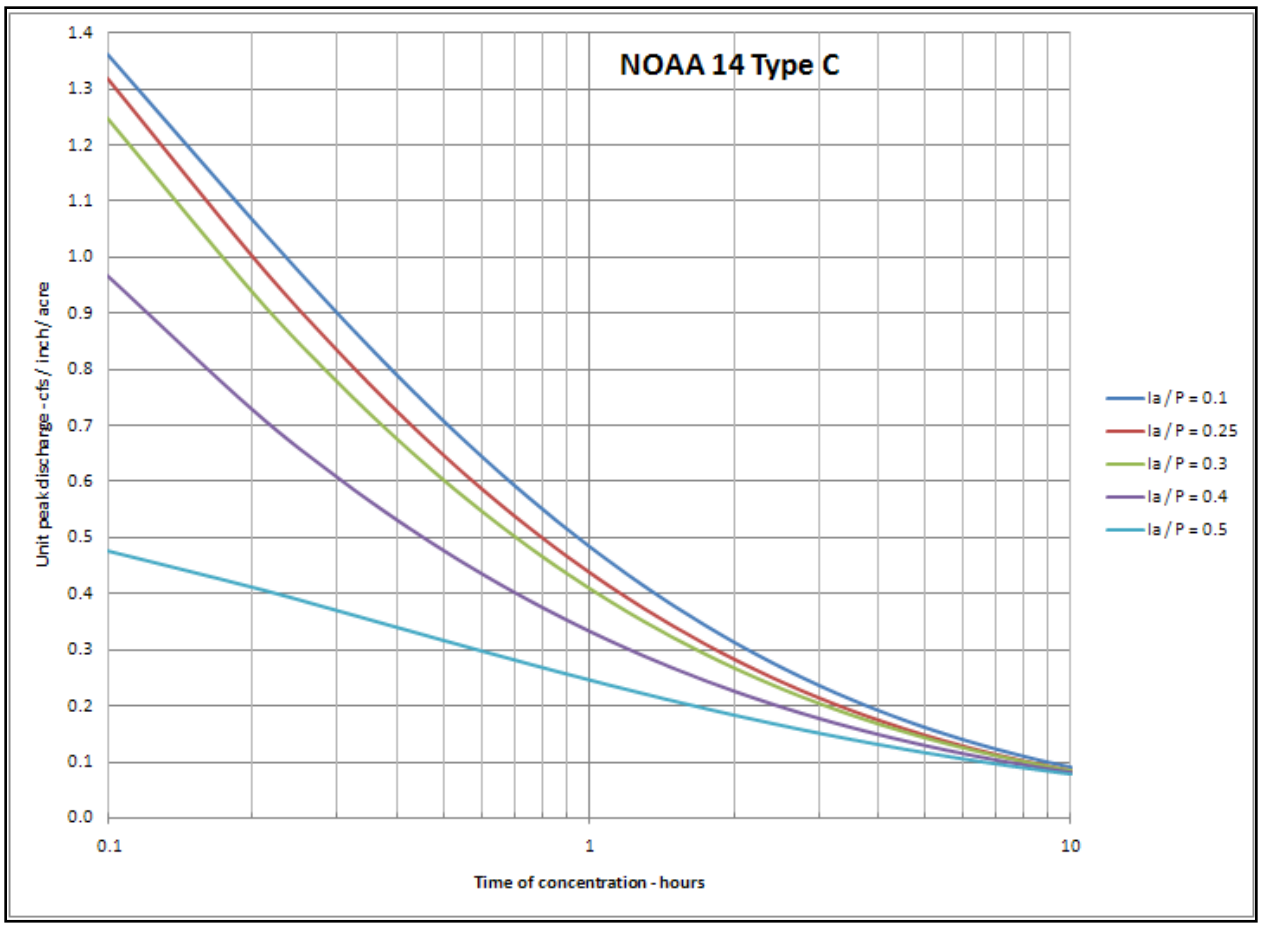


Figure A2-3, EFH-2 Peak Discharge Curves for Region C

Table A2-3, EFH-2 Peak Discharge Equation Coefficients for Region C

I_a/P	Coeff_1	Coeff_2	Coeff_3
0.1	2.4928	-0.585	-0.137
0.2	2.4494	-0.5928	-0.1154
0.3	2.4182	-0.5857	-0.1018
0.4	2.3289	-0.5381	-0.0754
0.5	2.1955	-0.3952	-0.1077

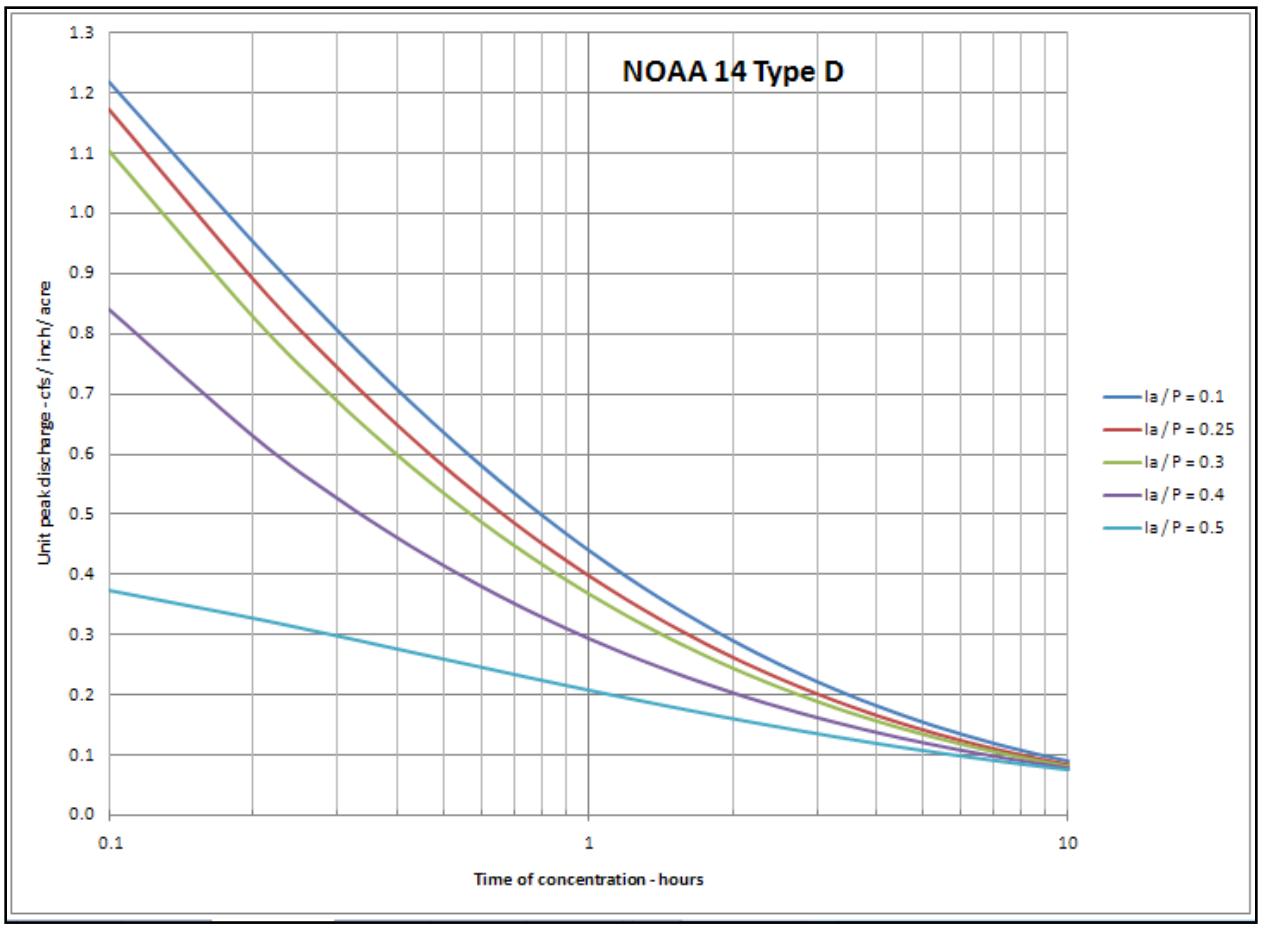


Figure A2-4, EFH-2 Peak Discharge Curves for Region D

Table A2-4, EFH-2 Peak Discharge Equation Coefficients for Region D

I_a/P	Coeff_1	Coeff_2	Coeff_3
0.1	2.4504	-0.5651	-0.1233
0.2	2.4067	-0.5713	-0.1024
0.3	2.3736	-0.5624	-0.0866
0.4	2.2763	-0.5109	-0.056
0.5	2.1265	-0.3442	-0.0908

Table A2-5, EFH-2 Peak Discharge Equation Coefficients for Type II Rainfall Distribution

I_a/P	Coeff_1	Coeff_2	Coeff_3
0.1	2.55323	-0.61512	-0.16403
0.3	2.46532	-0.62257	-0.11657
0.35	2.41896	-0.61594	-0.0882
0.4	2.36409	-0.59857	-0.05621
0.45	2.29238	-0.57005	-0.02281
0.5	2.20282	-0.51599	0.01259

Appendix 3. Plots of the Ohio Valley and neighboring states rainfall distributions.

The following plots are for use with 24-hour design storms. They represent the accumulated rainfall during the 24-hour storm duration on a non-dimensional basis. The maximum accumulated rainfall in the plot is 1.0 which represents the total storm 24-hour rainfall.

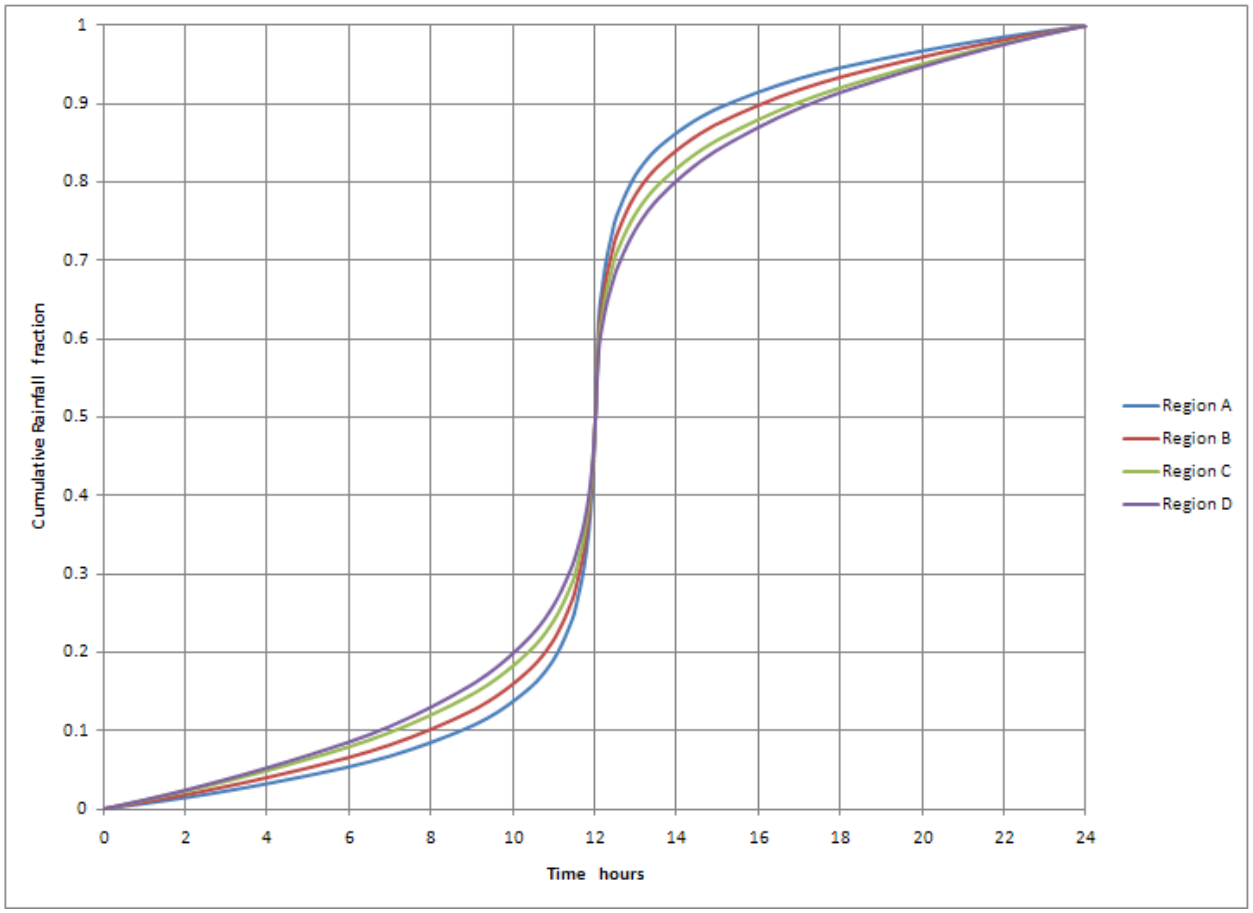


Figure A3-1, Plots of the Ohio Valley and neighboring states rainfall distributions.

These rainfall distributions are represented in WinTR-20 in tabular format at a time interval of 0.1 hour.