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SECTION II

CHAPTER 5 - ESTIMATING PEAK DISCHARGES

(Urban Areas, Pages 5-38 to 5-53)

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CHAPTER 5 - ESTIMATING PEAK DISCHARGES

Introduction

Peak discharge, used in Soil Conservation Service design work, is the highest rate of runoff, expressed in cubic feet per second (cfs), that may be expected from a particular watershed for a specific recurrence interval.

The following material presents several methods for obtaining the peak of the hydrograph without plotting the hydrograph. The methods presented are the Time of Concentration Method (Pages 5-1 to 5-6) as derived from Section 4 of the SCS National Engineering Handbook; Peak Rate of Discharge for Small Watersheds (Pages 5-7 to 5-31) derived from SCS T. P. 149; Annual Peak Curve (Pages 5-23 to 5-33) derived from stream flow data collected by the U. S. Geological Survey; and Drainage Curves (Pages 5-34 to 5-36) from U.S.D.A. Drainage Handbooks.

With the exception of the drainage curves, these methods may be used for design of temporary storage structures. All storage type structures may also be routed with computer programs or longhand.

Procedures and sample problems for each method are contained in this chapter.

TIME OF CONCENTRATION METHOD

This method developed for use in North Dakota, is based on the unit hydrograph procedure as explained in Chapter 16 of Section 4, "Hydrology", National Engineering Handbook. This method is based upon a 24-hour duration Type I storm distribution (see Table 6-2).

Procedure Steps

1. From the 24-hour duration rainfall maps (Chapter 1) select the proper amount of rainfall for the required design.

2. Compute a weighted runoff curve number (Table 3-1 or Table 3-2) for the drainage area and determine the runoff (Table 3-5) from the 24-hour duration design storm.

3. Knowing the rainfall for the 24-hour duration storm and the runoff curve number, read the hydrograph family number from Figure 5-1 (Page 5-5) by interpolation to the nearest 0.1 value. When the point on Figure 5-1 falls below the 3.5 hydrograph family line, use hydrograph family 3.5. When the point on Figure 5-1 falls above the 1 hydrograph family, use hydrograph family 1.

4. Determine the time of concentration (Tc) using the procedure outlined in Chapter 4.

5. Having the time of concentration (Tc) and reading the hydrograph family, select the peak discharge (CSM/inch) from Figure 5-2 (Page 5-6). The abbreviation CSM/inch represents cubic feet per second from each square mile of drainage area for 1.0 inch of runoff. To obtain the peak discharge for a given watershed, multiply the value from Figure 5-2 by the drainage area in square miles and the inches of runoff as determined from step 2 above. Figure 5-2 is based upon a 0.25 time increment in the rainfall distribution table.

6. If the drainage area includes lakes, swamps and potholes, the ratio of these lakes, swamps and potholes to the total drainage area should be calculated. If the travel path for calculating the Tc passes through a given lake or swamp, this lake or swamp should <u>not</u> be included in the ratio of lakes, swamps and potholes to the total drainage area. From Figure 5-3, the lake and swamp adjustment factor can be read and then multiplied times the peak discharge from step 5 above. In a watershed with a significant degree of storage the only reliable method of estimating peak flows is by reservoir routing through the storage areas.

Examples of Determining Peak Discharges Using Figure 5-2

Example No. 1

Given: Watershed Drainage Area = 600 acres (0.938 sq. mi.)
Tc = 0.60 hour
P = 5.1" (24-hour Duration - 1% Chance)
Runoff Curve No. 71

Find: The peak discharge for the given conditions on the watershed:

1. Hydrograph Family No. 1.4 (Figure 5-1)
2. Q = 2.19" (Table 3-5)
3. Peak flow in CSM/inch = 230 (Figure 5-2)
4. Compute peak discharge:

$$q = 230 \text{ CSM/inch} \times 0.938 \text{ sq. mi.} \times 2.19''$$
$$= 472 \text{ cfs}$$

Example No. 2

Given: Drainage Area 1500 acres (2.34 sq. mi.)
Tc = 1.05 hours
P = 5.0" (24-hour Duration - 1% Chance)
Runoff Curve No. 82

Find: The peak discharge for the given conditions on the watershed:

1. Hydrograph Family No. 1.0 (Figure 5-1)
2. Q = 3.08" (Table 3-5)
3. Peak flow in CSM/inch = 180 (Figure 5-2)
4. Compute peak discharge

$$q = 180 \text{ CSM/inch} \times 2.34 \text{ sq. mi.} \times 3.08''$$
$$= 1297 \text{ cfs}$$

Example No. 3

Given: Drainage area of 2100 acres of which 100 acres are in deep depressions and is non-contributing and an additional 300 acres are in lakes and swamps. 50 of the 300 acres is a lake through which the travel path for calculating the Tc passes.

Tc = 4.3 hours
P = 4.4" (24-hour Duration)
Runoff Curve No. 65

Find: The peak discharge for the given conditions on the watershed:

1. Effective drainage area = $\frac{2100-100}{640}$ = 3.12 sq. mi.

2. Hydrograph Family No. 2.3 (Figure 5-1)

3. Q = 1.27" (Table 3-5)
4. Peak flow in CSM/inch = 63 (Figure 5-2)
5. Adjustment factor for lakes and swamps

$$\frac{300-50}{2100-100} = 12.5\% \text{ of the area is lakes and swamps}$$

Adjustment factor = 0.76 (Figure 5-3)

6. Computed peak discharge;

$$q = 63 \text{ CSM/inch} \times 3.12 \text{ sq. mi.} \times 1.27'' \times 0.76$$
$$= 190 \text{ cfs}$$

Example No. 4

Given: A 300-acre rural watershed is to be developed into an urban area. The runoff curve number for the proposed development is computed to be 80. Approximately 60 percent of the hydraulic length will be modified by the installation of street gutters and storm drains to the watershed outlet. The street gutters and storm drains will produce higher velocity runoff resulting in a shorter time of concentration of 0.35 hours. The time of concentration for present conditions is 0.5 hours. Compute the present-condition and anticipated future-condition peak discharge for the 50-year 24-hour storm event of 5 inches of rainfall. The present-condition runoff curve number is 75.

1. From Table 3-5 the runoff for present condition is 2.44 inches and for future condition is 2.89 inches.
2. Hydrograph Family for present-condition is 1.2 (Figure 5-1).
3. Peak flow for present-condition in CSM/inch = 260 (Figure 5-2).

$$q = 260 \text{ CSM/inch} \times \frac{300 \text{ acres}}{640 \text{ acres}} \times 2.44''$$

$$= 297 \text{ cfs}$$

4. Hydrograph Family No. 1.0 for future condition (Figure 5-1).
5. Peak flow for future condition in CSM/inch = 315 (Figure 5-2).

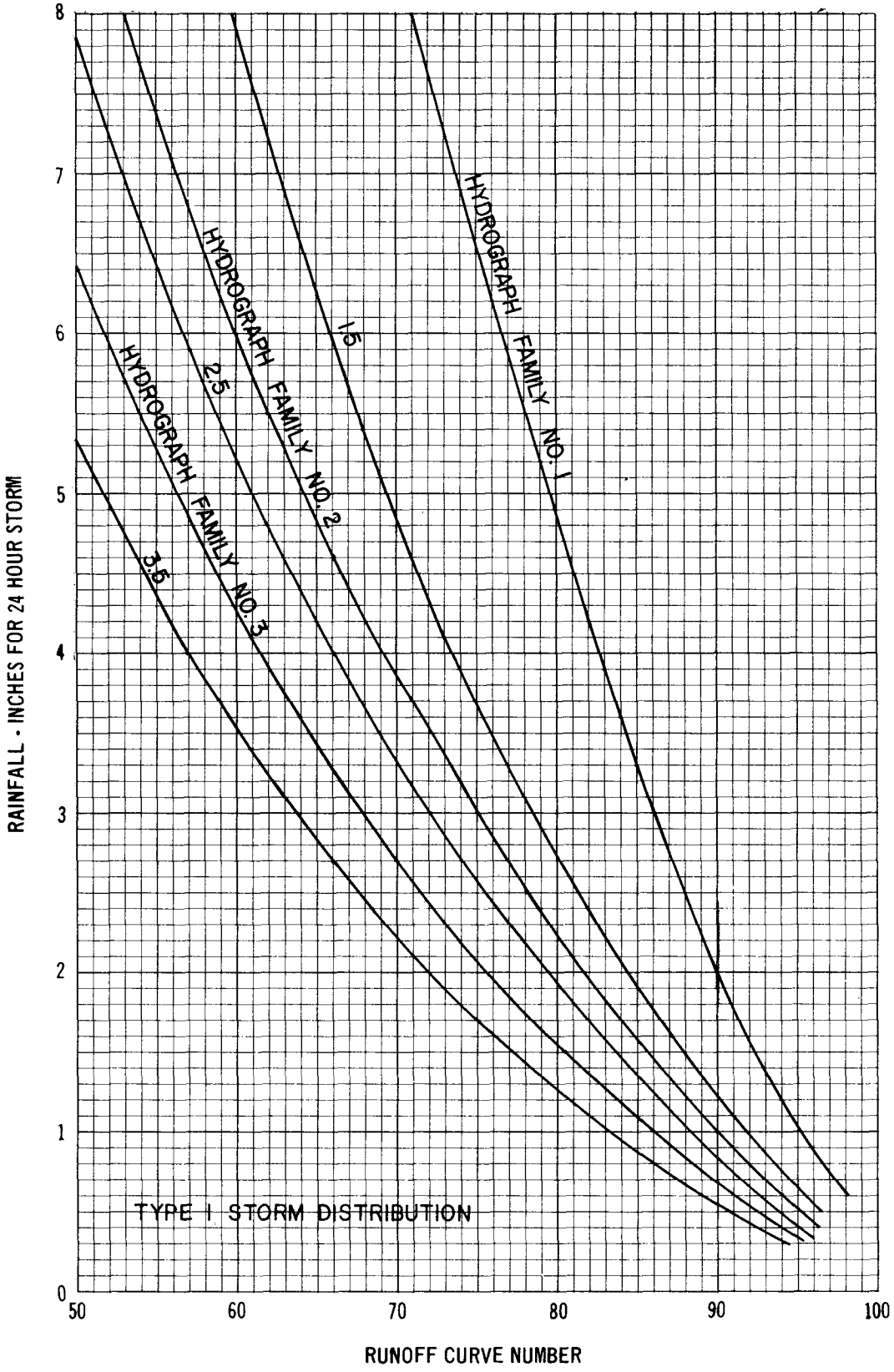
$$q = 315 \text{ CSM/inch} \times \frac{300 \text{ acres}}{640 \text{ acres}} \times 2.89''$$

$$= 427 \text{ cfs}$$

6. The effect of this proposed development is to increase the peak discharge from 207 cfs to 427 cfs.
7. Urban development will not always increase the peak discharge. Even if the runoff is at a higher velocity the hydraulic length may be increased enough to offset the higher velocity. Storage facilities may be included in the urban development which will reduce the peak discharge.

FIGURE 5-1

CHART FOR SELECTING A HYDROGRAPH FAMILY FOR A 24 HOUR RAINFALL AND RUNOFF CURVE NUMBER



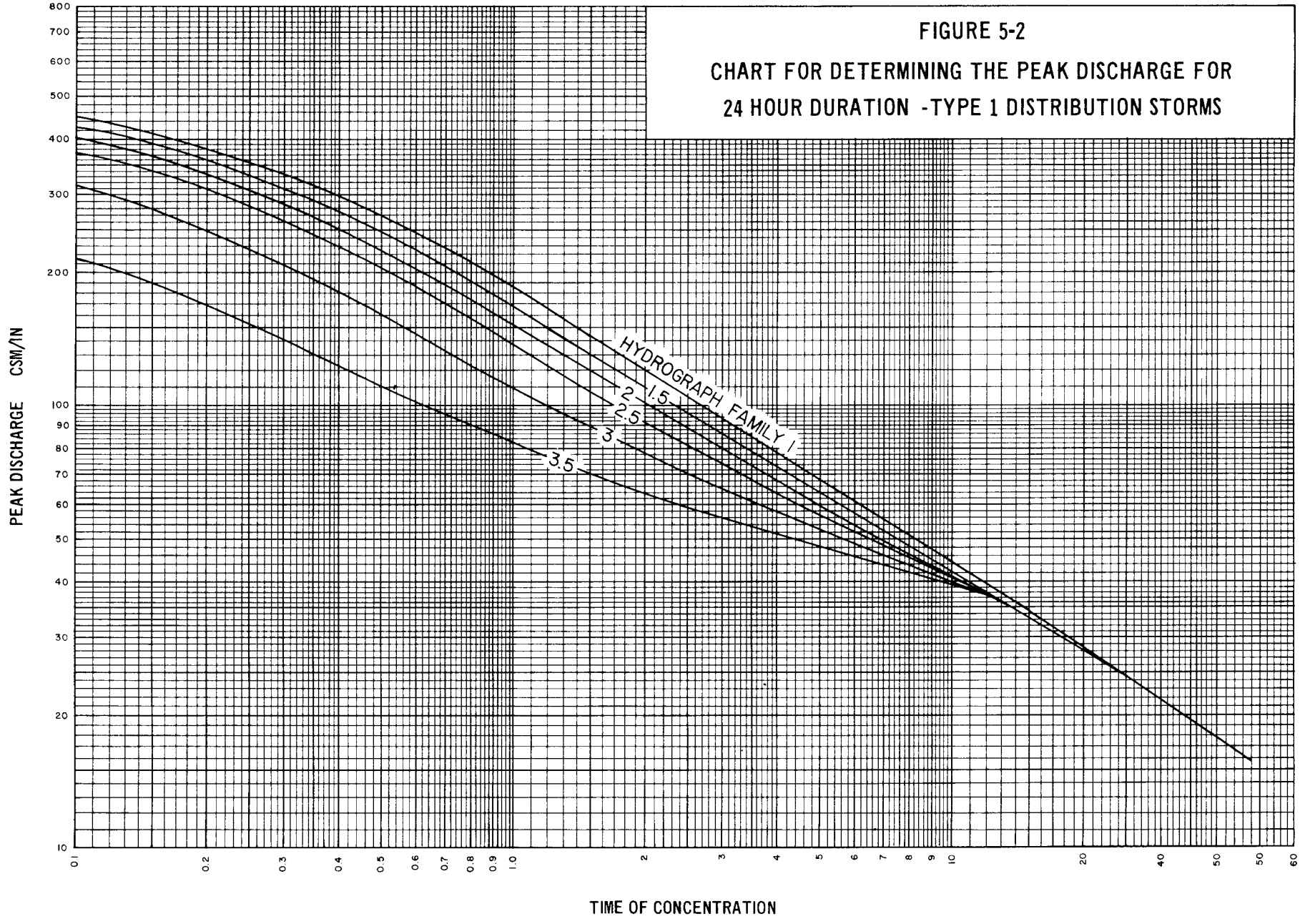
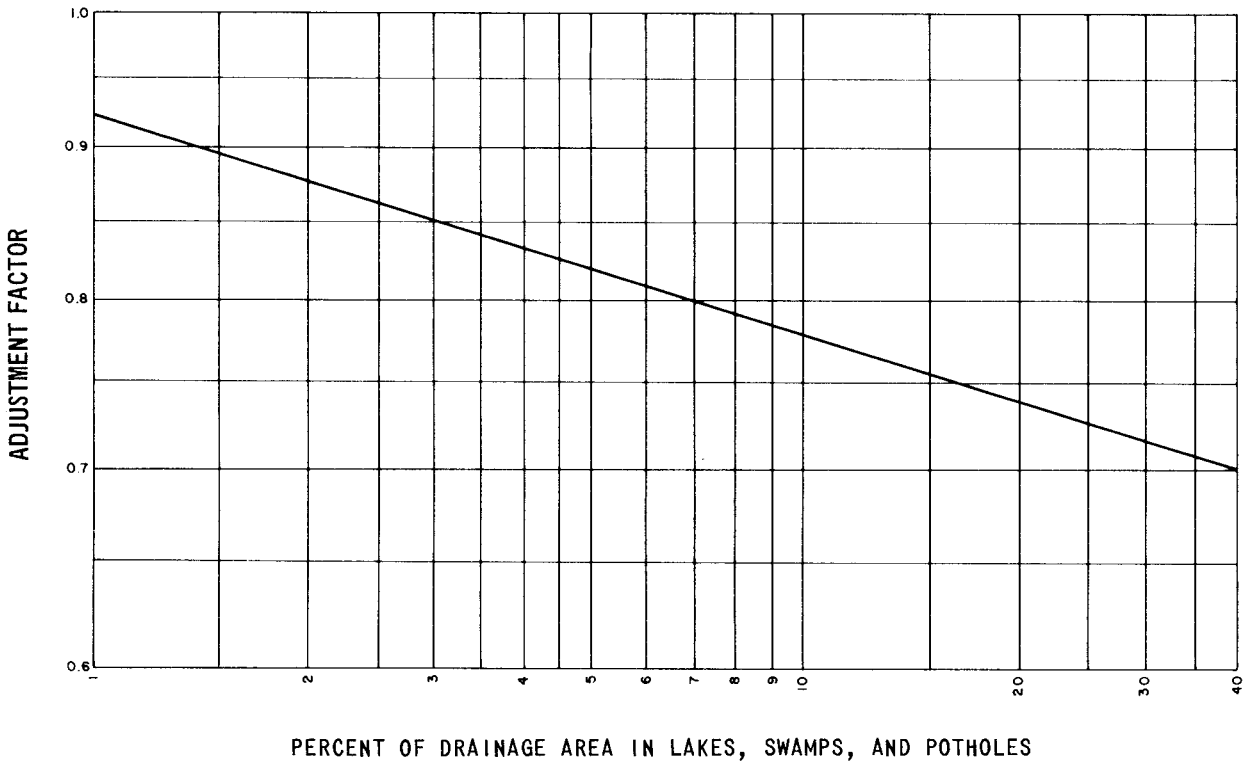


FIGURE 5-2

CHART FOR DETERMINING THE PEAK DISCHARGE FOR 24 HOUR DURATION -TYPE 1 DISTRIBUTION STORMS

FIGURE 5-3

ADJUSTMENT FACTOR FOR PERCENT LAKES, SWAMPS, AND POTHOLES



$$q_{MOD} = q * (\text{Factor}_{LS})$$

where

q_{MOD} = Modified discharge due to adjustment for lakes, swamps, and potholes

q = Discharge before adjustment

Factor_{LS} = Adjustment factor for percent of drainage area in lakes, swamps, and potholes through which the travel path for calculating t_c <u>does not</u> pass

PEAK DISCHARGES USING 24-HOUR RAINFALL
TYPE I DISTRIBUTION
FOR DRAINAGE AREAS FROM .01 TO 3.13 SQ. MILES

Peak discharges from 24-hour rainfall, with a Type I distribution can be obtained from the following charts on Pages 5-10 to 5-30, depending on whether the slope is flat, moderate or steep. Flat slopes are usually in the range of 0% to 3%. Moderate slopes range from 3% to 8% and steep slopes range from 8% or more. Most SCS work is generally confined to flat slopes. Procedures for computing average slope can be found on pages 5-36 and 5-37.

Corrections for slope, lakes, swamps and potholes shall be made when using Figures 5-4, Page 5-10 through 5-30. Slope correction factors are found at the top of Figure 5-4. The lake, swamp and pothole correction is found on Figure 5-3, Page 5-7.

This section can be used for drainage areas of 5 to 2000 acres or .01 to 3.13 square miles.

Example 1:

Given an 80-acre watershed in Walsh County using the Type I storm distribution. The soil scientist has classified the soils as belonging to hydrologic soil group B. The average watershed slope is estimated to be 5%. (See pages 5-36 or 5-37) The land use is fallow with 15% potholes. The peak discharge rate from a 4% chance (25-year) 24-hour rainfall is desired for the design of an emergency spillway.

1. Curve number 85 is determined. (Use table 3-1, Page 3-3).

2. Storm rainfall for the location of the watershed is obtained from the rainfall maps, Chapter 1. For this example, the storm rainfall is 3.9 inches.

3. From peak discharge curve for Curve No. 85, Fig. 5-4, (Page 5-22) read 80 cfs for the peak discharge from the 3.9 inch rainfall on the 80 acre watershed.

4. Slope correction for 5% slope, from table (Page 5-22) is 1.08. 80 cfs X 1.08 = 86 cfs.

5. Pothole correction for 15% potholes is: (from Fig. 5-3, Page 5-7) .76 (pothole correction) X 86 cfs = 62 cfs.

Example 2:

Given a 1,000 acre watershed in Billings County. About 600 acres of the watershed is in hydrologic soil group B, within which two-thirds of the area has a CN of 71 and the other on-third has a CN of 61. The remaining 400 acres of the watershed is in hydrologic soil group C, with a CN of 78. The average watershed slope is about 5 percent. (See pages 5-36 and 5-37) The peak discharge rate for a 10% chance (10 year) 24-hour flood is desired for the design of a diversion channel at the outlet.

1. A weighted CN is required:

   2/3 of 600 Ac = 400 ac @ CN 71 and (400/1000) 71=28.4
   1/3 of 600 Ac = 200 ac @ CN 61 and (200/1000) 61=12.2
   400 ac @ CN 78 and (400/1000) 78=31.2
   weighted CN 71.8
   (Round to 72)

2. The storm rainfall 3.01 inches is from rainfall maps, Chapter 1.

3. The peak discharge for a 5% slope for a 3 inch rainfall and CN 72 is calculated as follows:

   CN 70 (Fig. 5-5) = 84 cfs
   CN 75 (Fig. 5-5) = 138 cfs
   CN 72 = 84 + 2/5 (138-84) = 105 cfs

4. Slope correction:

   105 cfs x 1.08 = 113 cfs

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
0.2	.52
0.5	.76
1.0	1.00
2.0	1.31

SLOPES - FLAT

CURVE NUMBER - 60

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

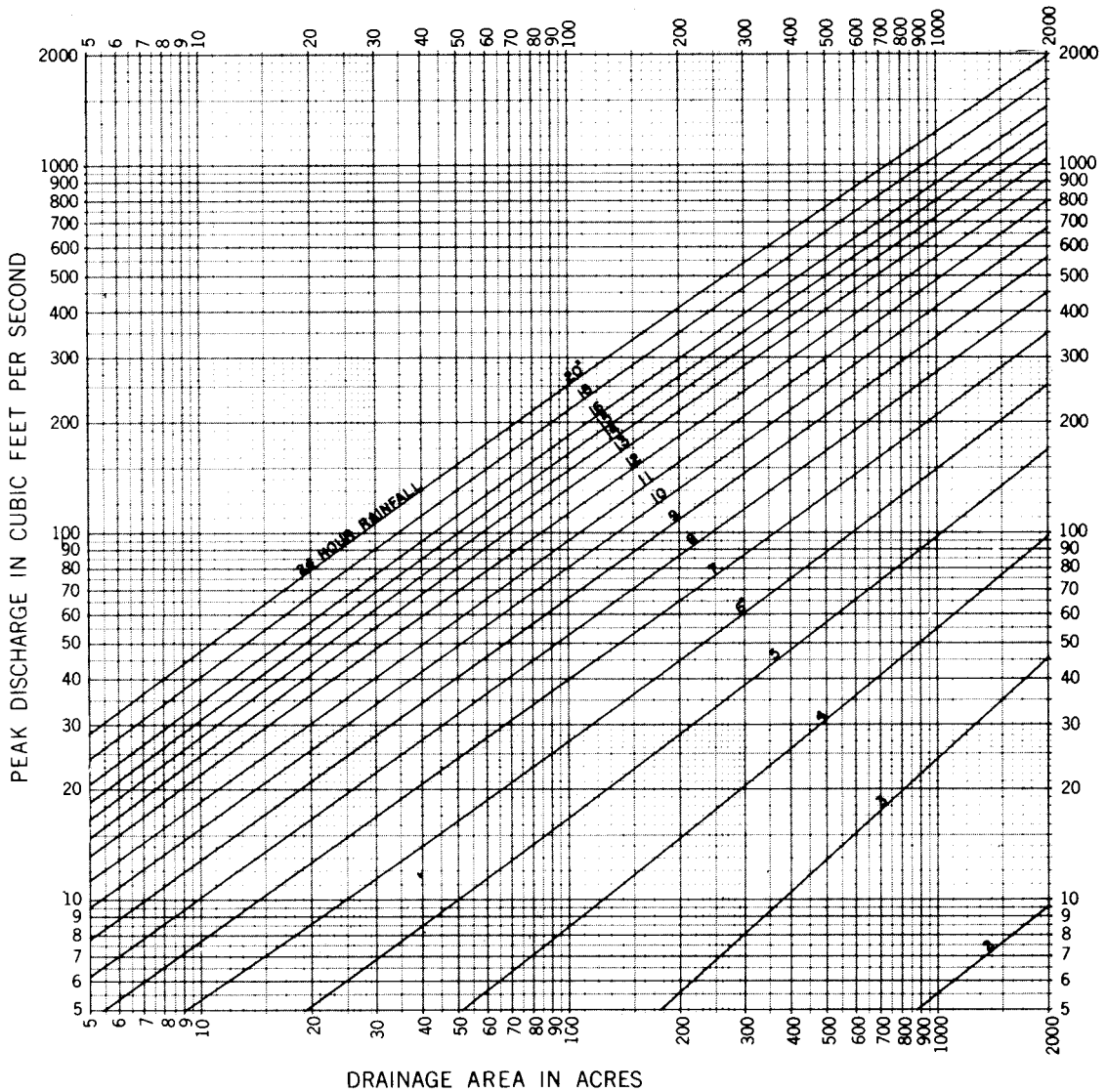


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
0.2	.52
0.5	.76
1.0	1.00
2.0	1.31

SLOPES - FLAT

CURVE NUMBER - 65

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

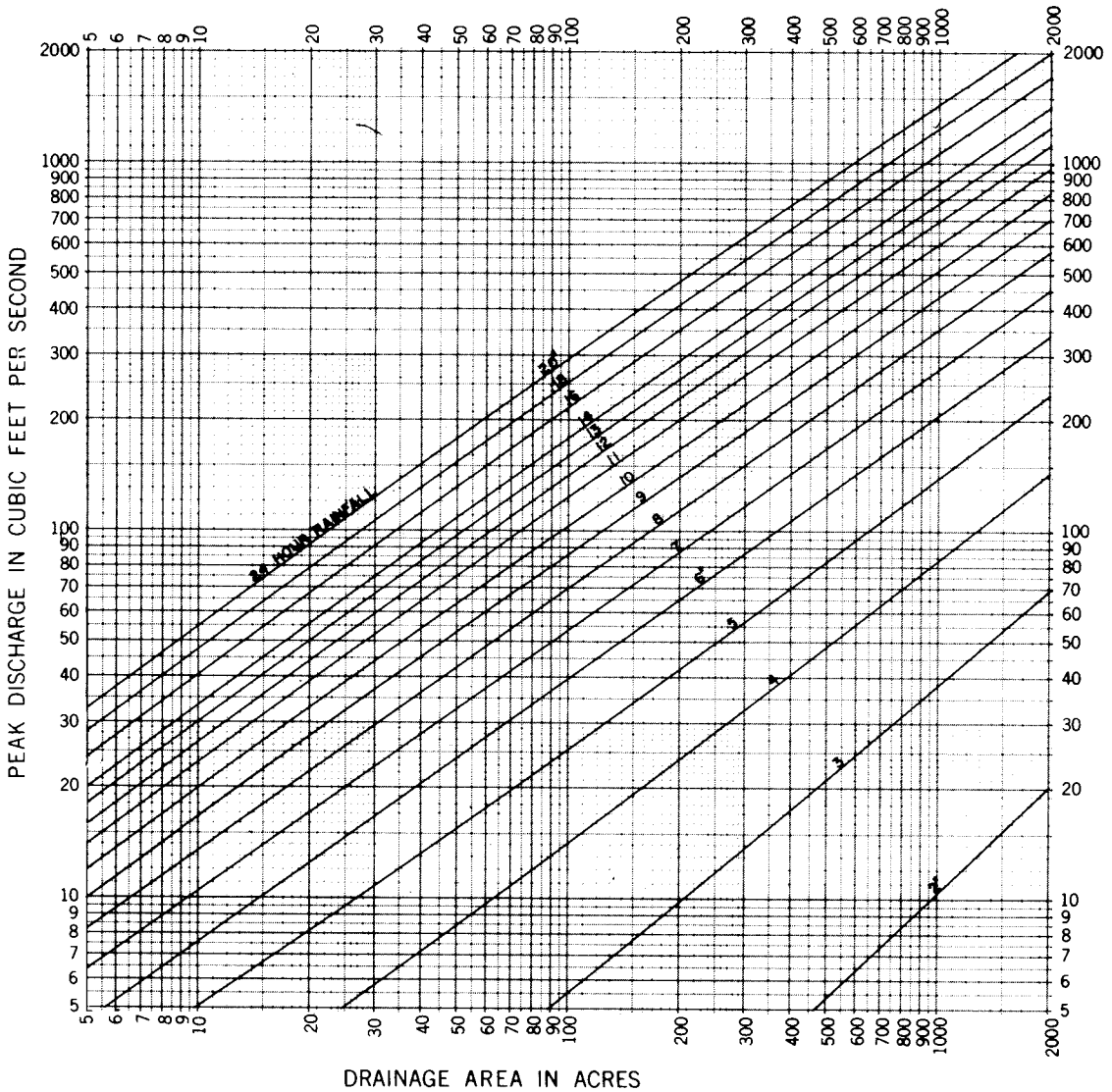


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
0.2	.52
0.5	.76
1.0	1.00
2.0	1.31

SLOPES - FLAT

CURVE NUMBER - 70

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

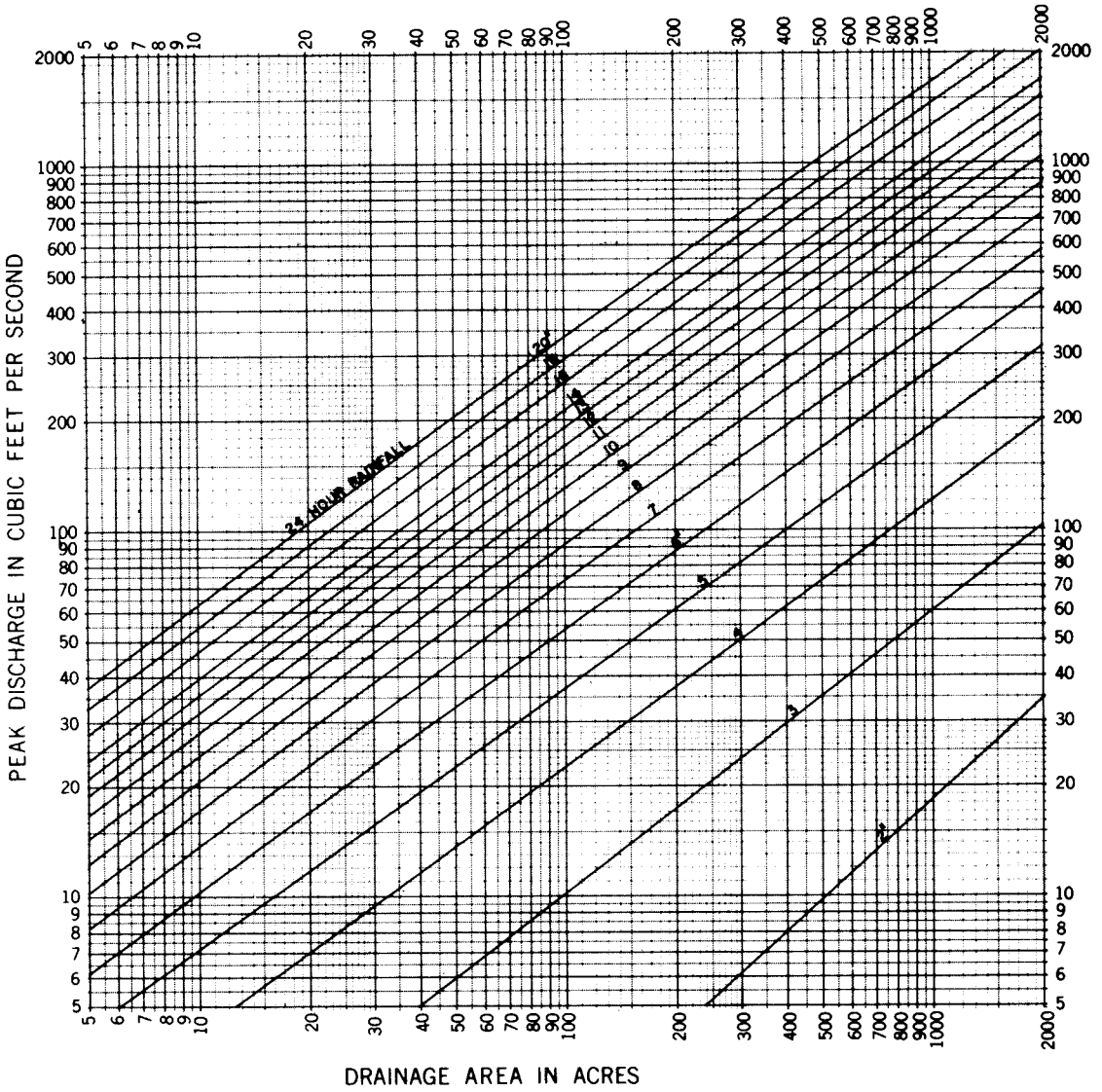


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
0.2	.52
0.5	.76
1.0	1.00
2.0	1.31

SLOPES - FLAT

CURVE NUMBER - 75

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

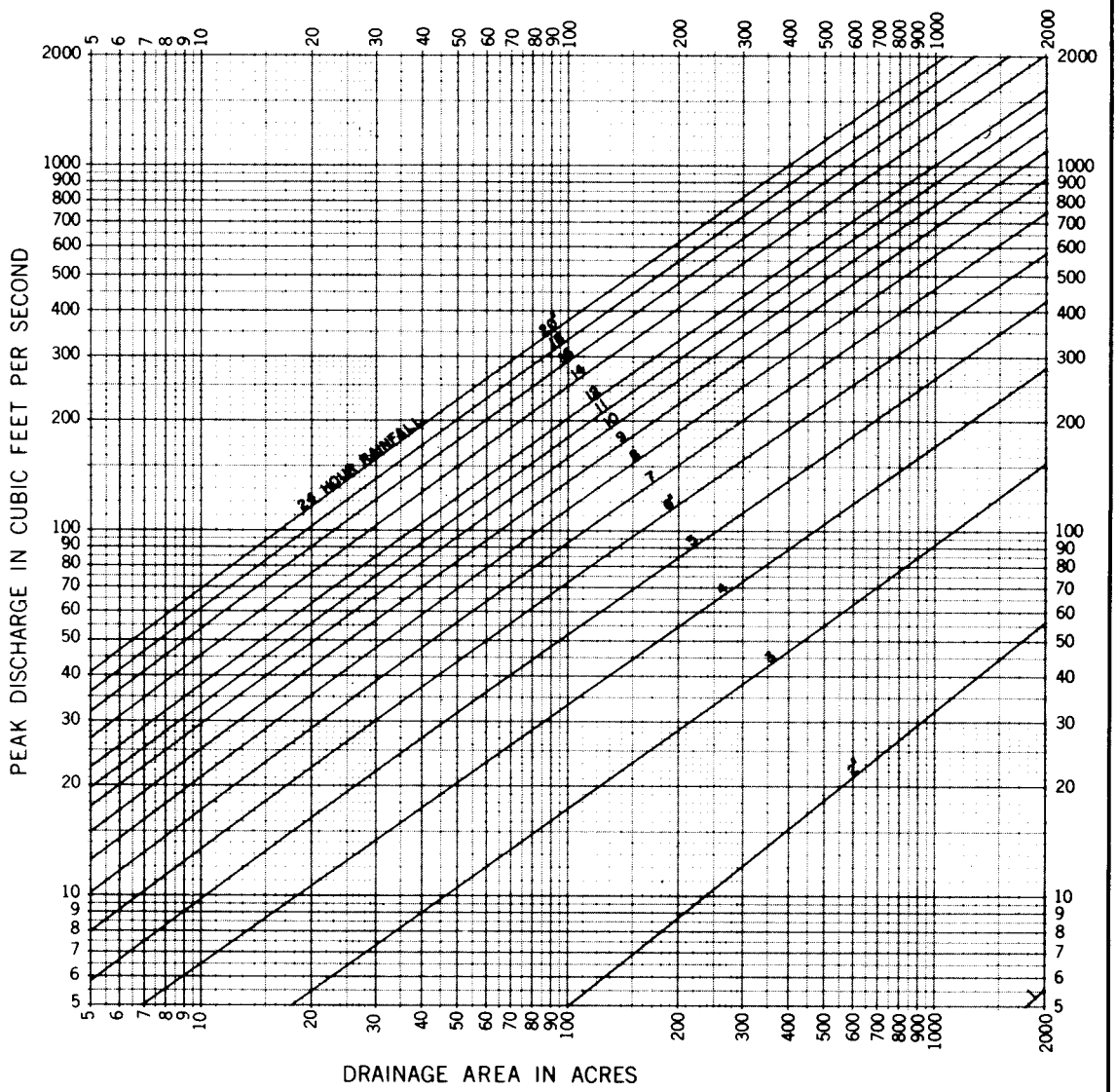


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
0.2	.52
0.5	.76
1.0	1.00
2.0	1.31

SLOPES - FLAT

CURVE NUMBER - 80

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

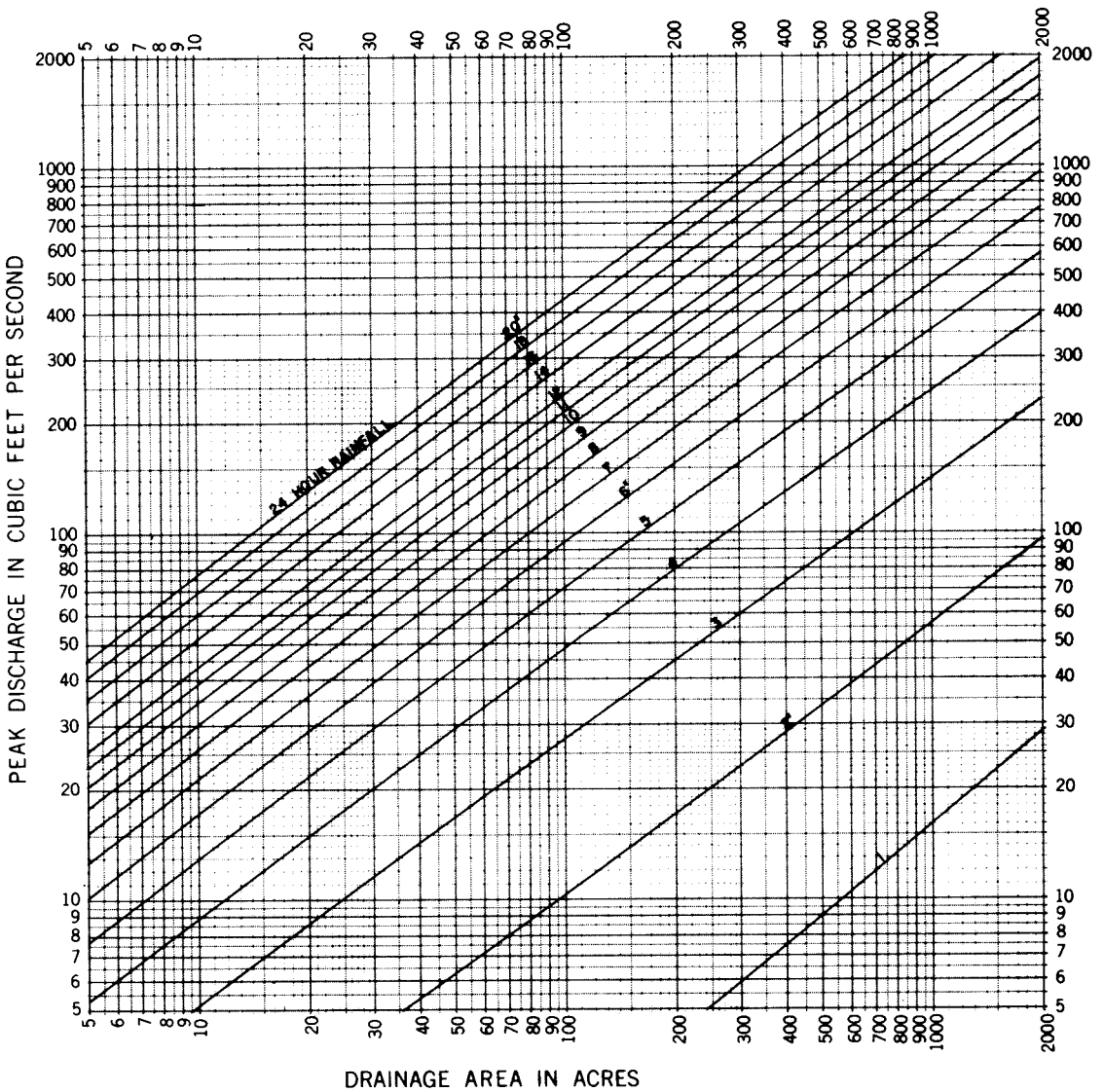


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
0.2	.52
0.5	.76
1.0	1.00
2.0	1.31

SLOPES - FLAT

CURVE NUMBER - 85

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

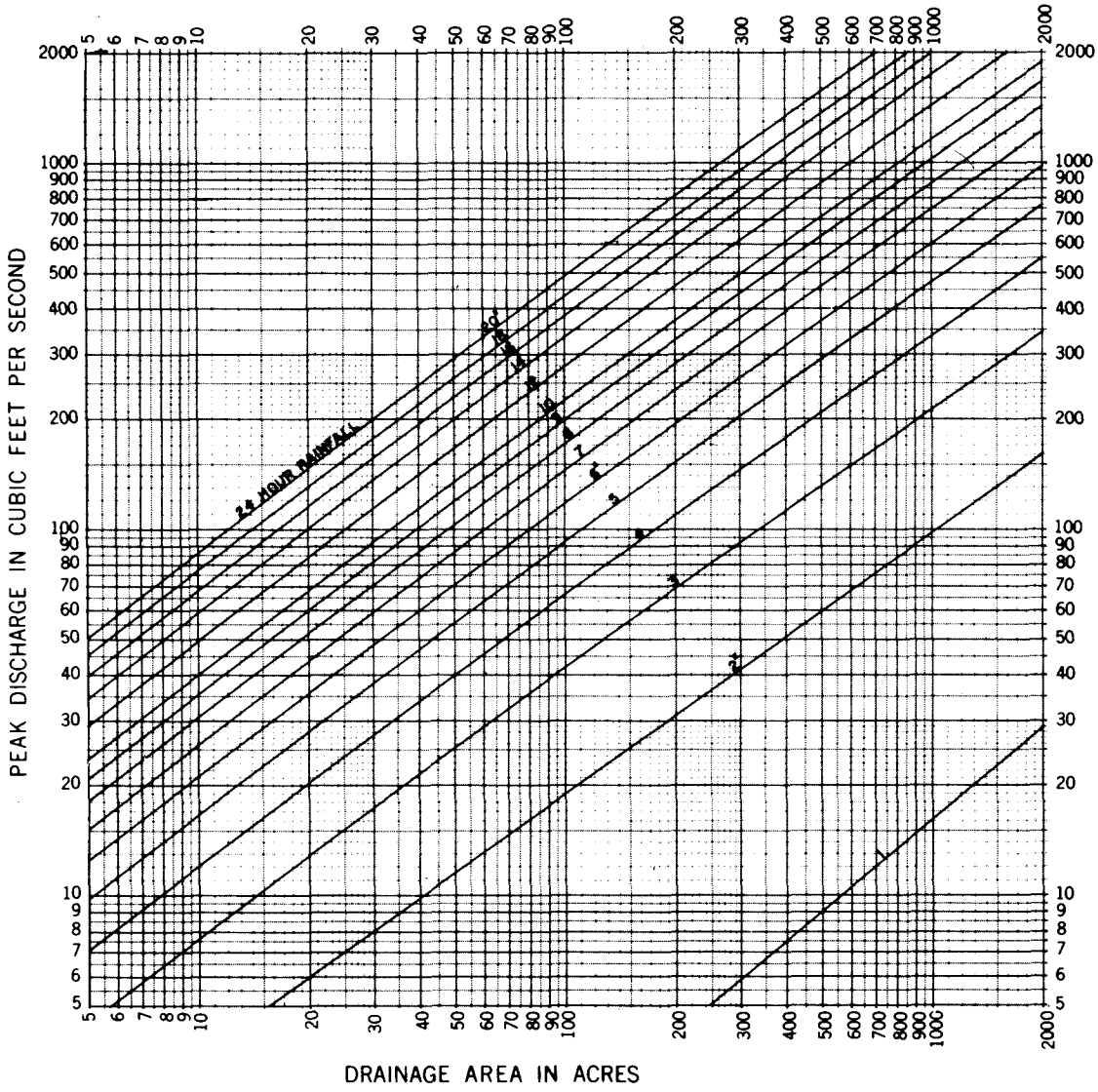


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
0.2	.52
0.5	.76
1.0	1.00
2.0	1.31

SLOPES - FLAT

CURVE NUMBER - 90

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

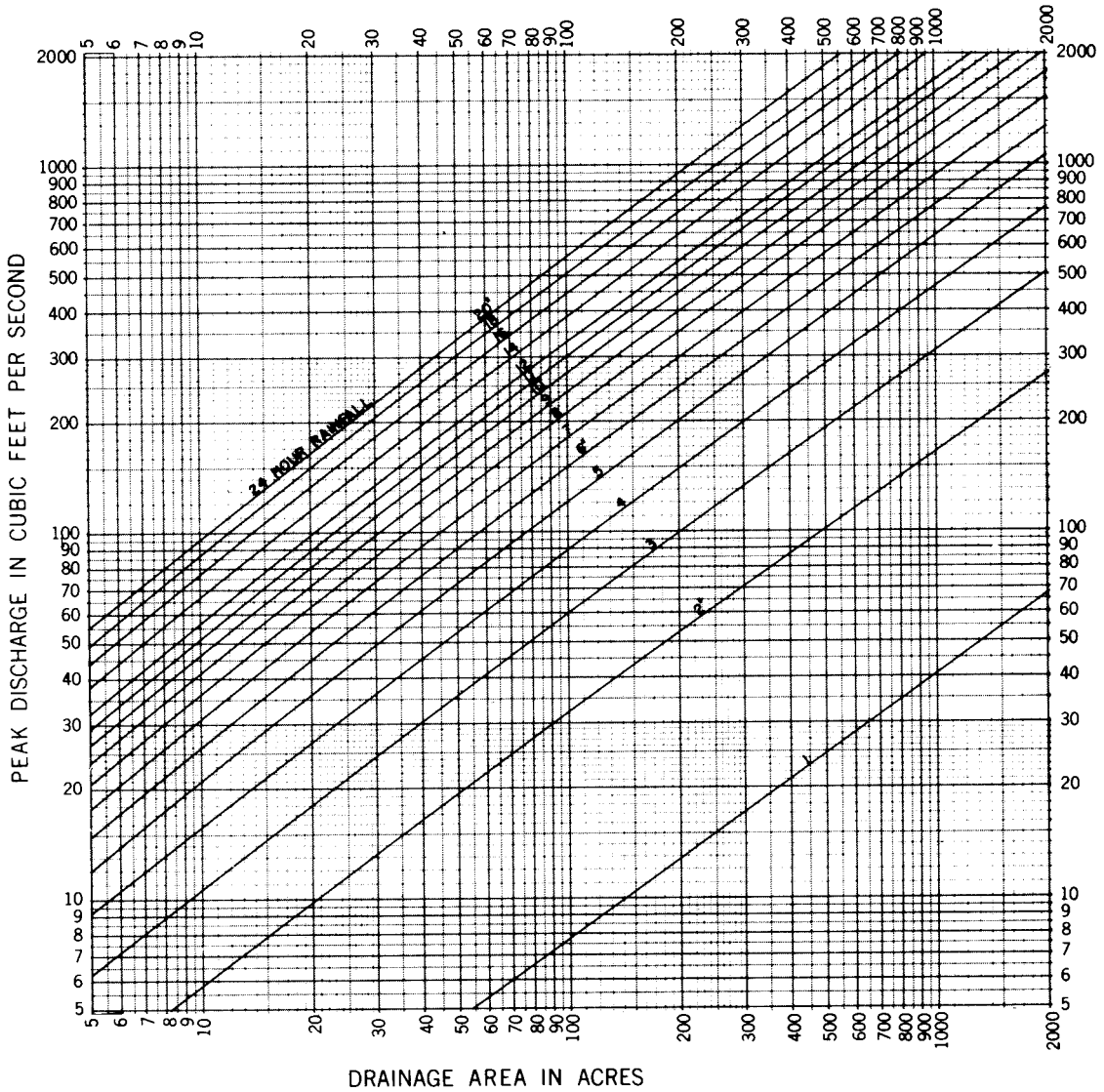


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
3.0	.90
4.0	1.00
5.0	1.08
6.0	1.14
7.0	1.21

SLOPES - MODERATE

CURVE NUMBER - 60

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

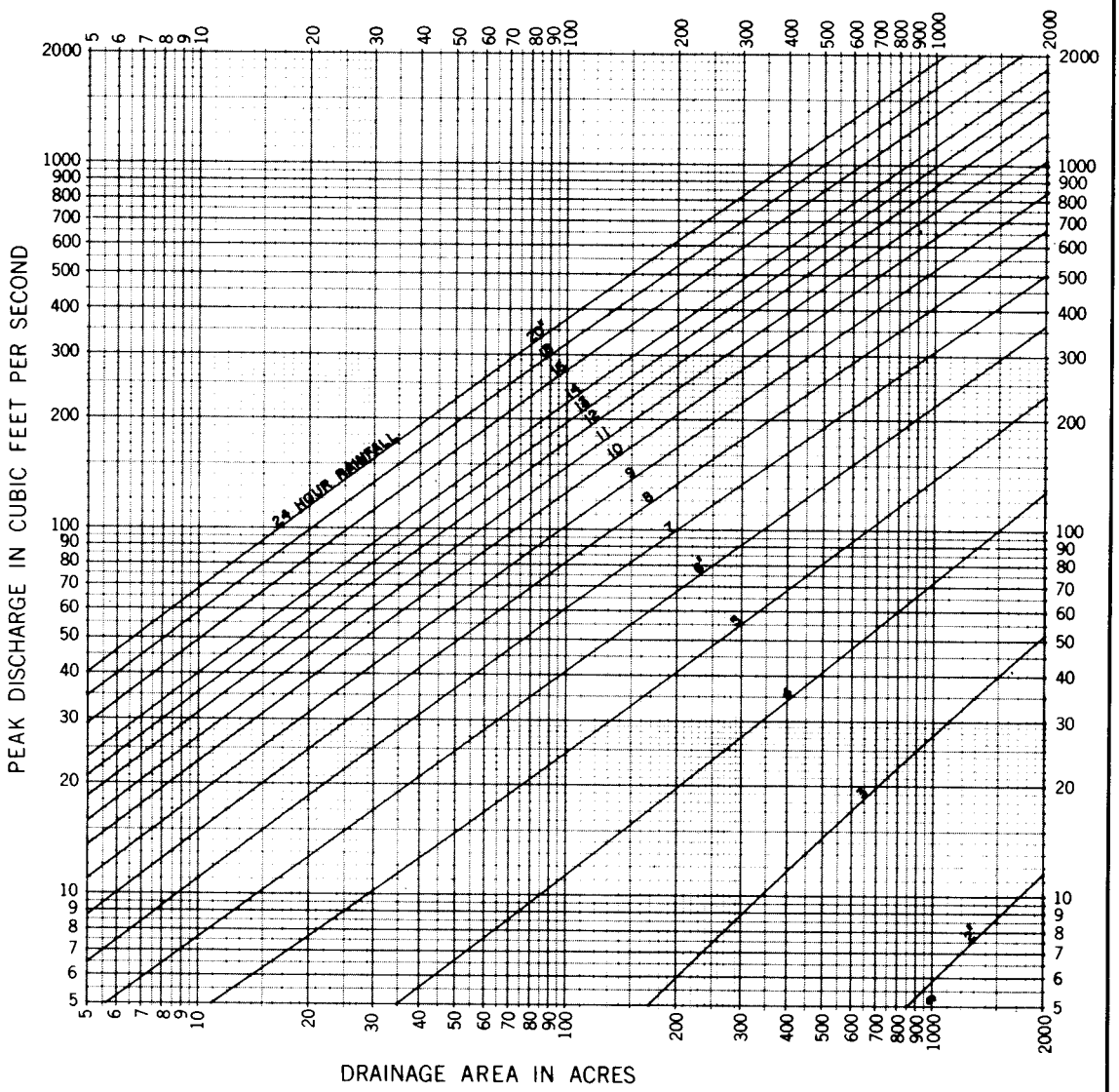


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
3.0	.90
4.0	1.00
5.0	1.08
6.0	1.14
7.0	1.21

SLOPES – MODERATE

CURVE NUMBER – 65

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

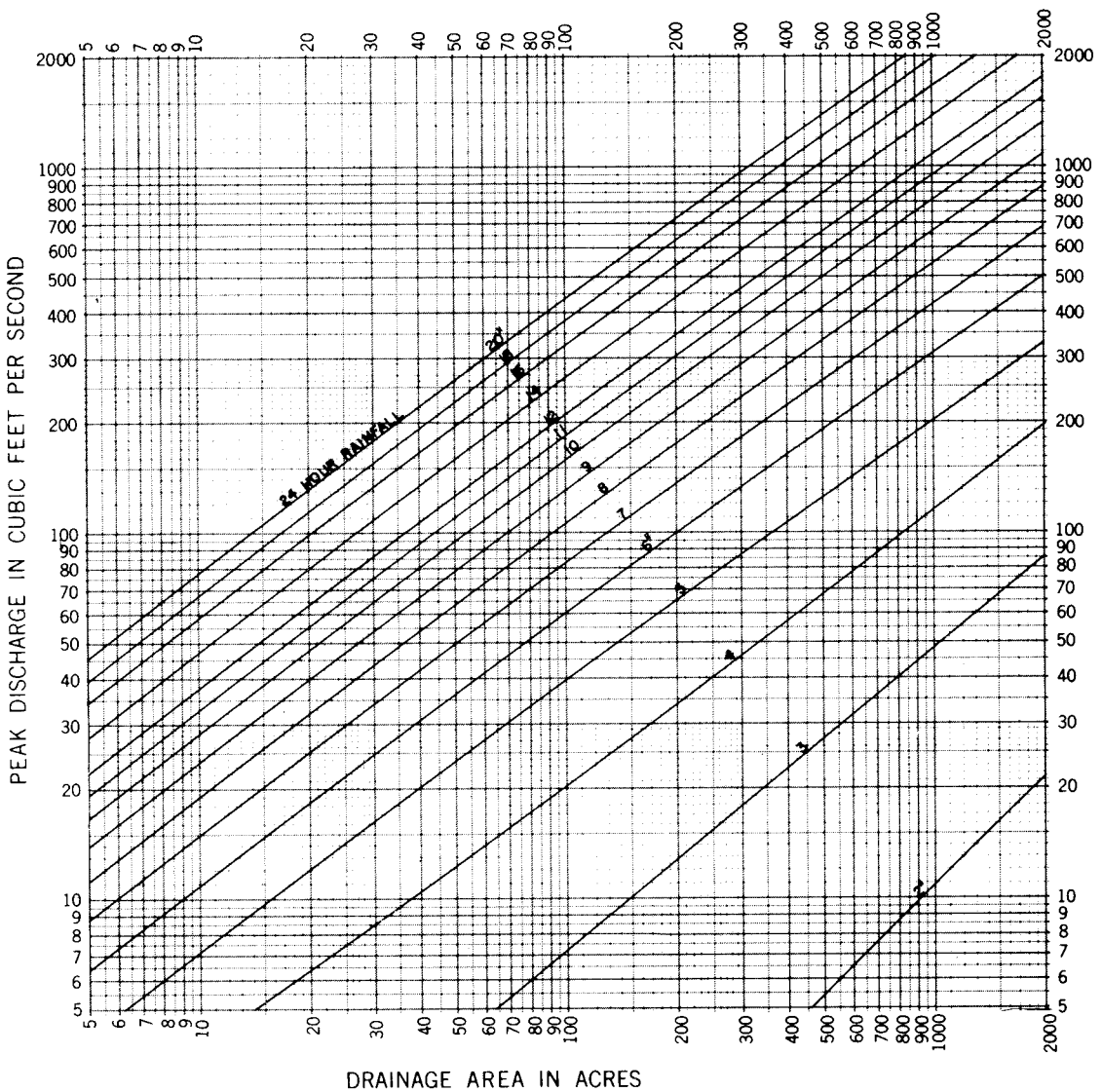


FIGURE 5–4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
3.0	.90
4.0	1.00
5.0	1.08
6.0	1.14
7.0	1.21

SLOPES - MODERATE

CURVE NUMBER - 70

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

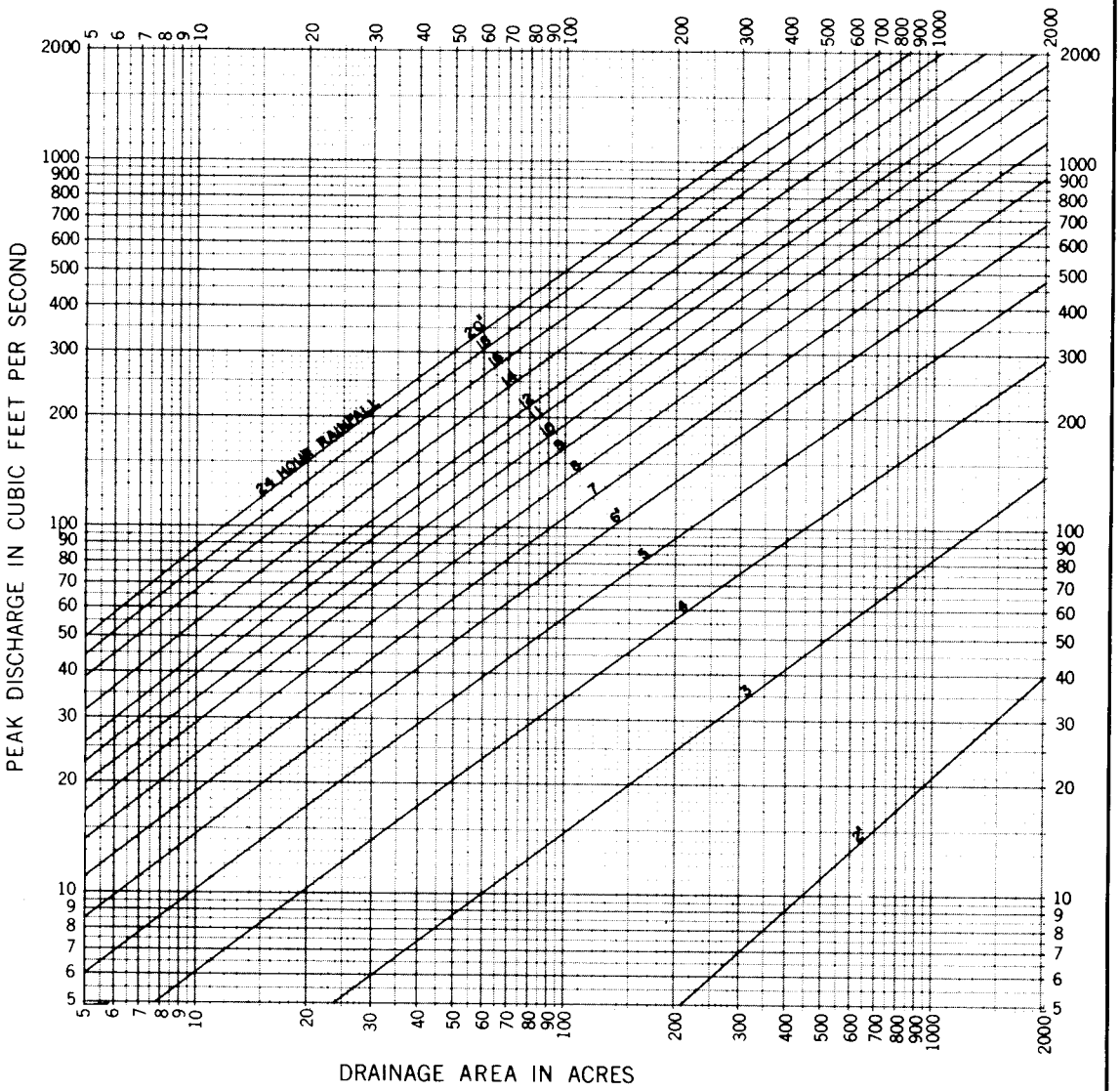


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
3.0	.90
4.0	1.00
5.0	1.08
6.0	1.14
7.0	1.21

SLOPES - MODERATE

CURVE NUMBER - 75

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

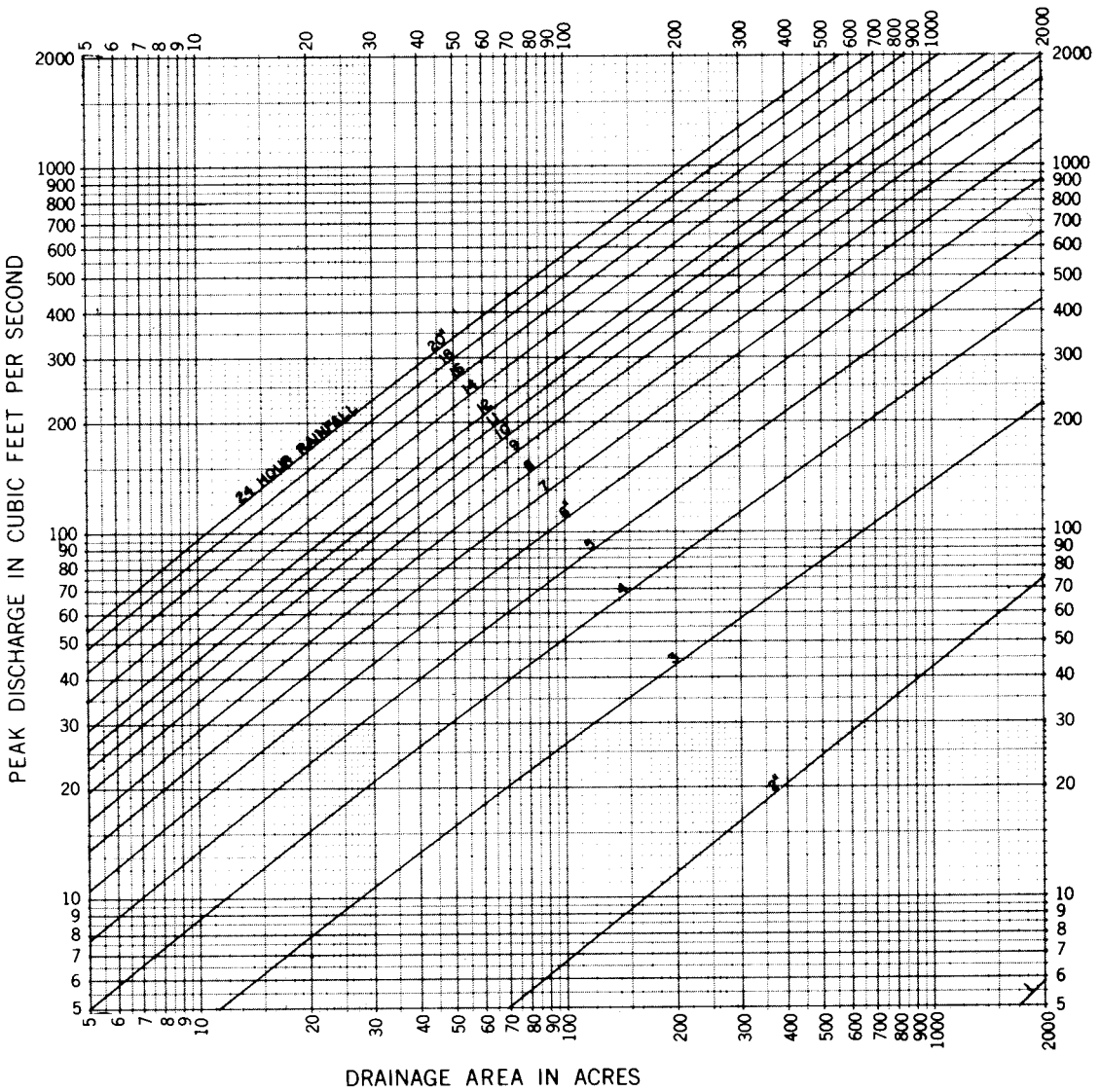


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
3.0	.90
4.0	1.00
5.0	1.08
6.0	1.14
7.0	1.21

SLOPES - MODERATE

CURVE NUMBER - 80

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

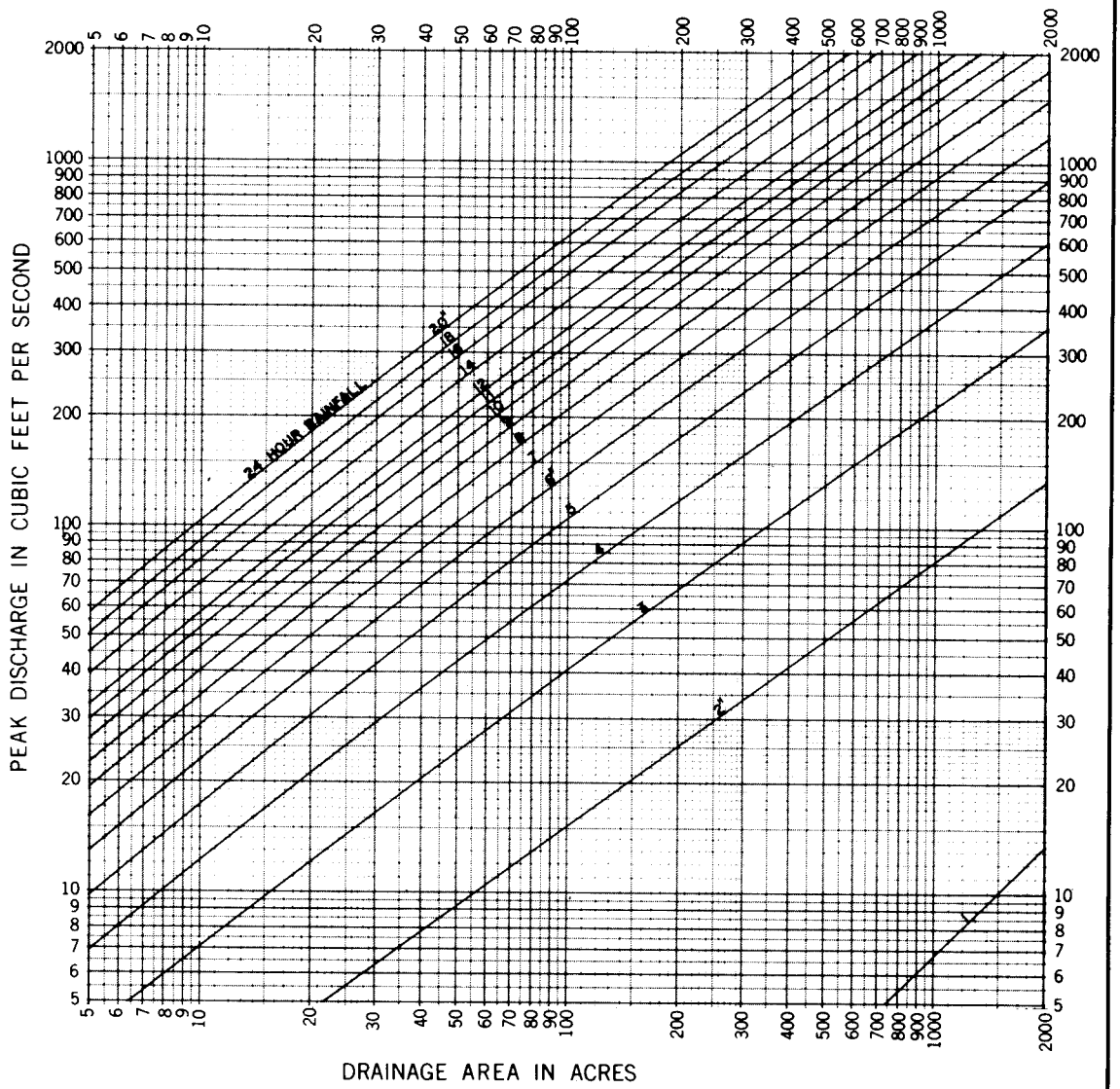


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
3.0	.90
4.0	1.00
5.0	1.08
6.0	1.14
7.0	1.21

SLOPES - MODERATE

CURVE NUMBER - 85

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

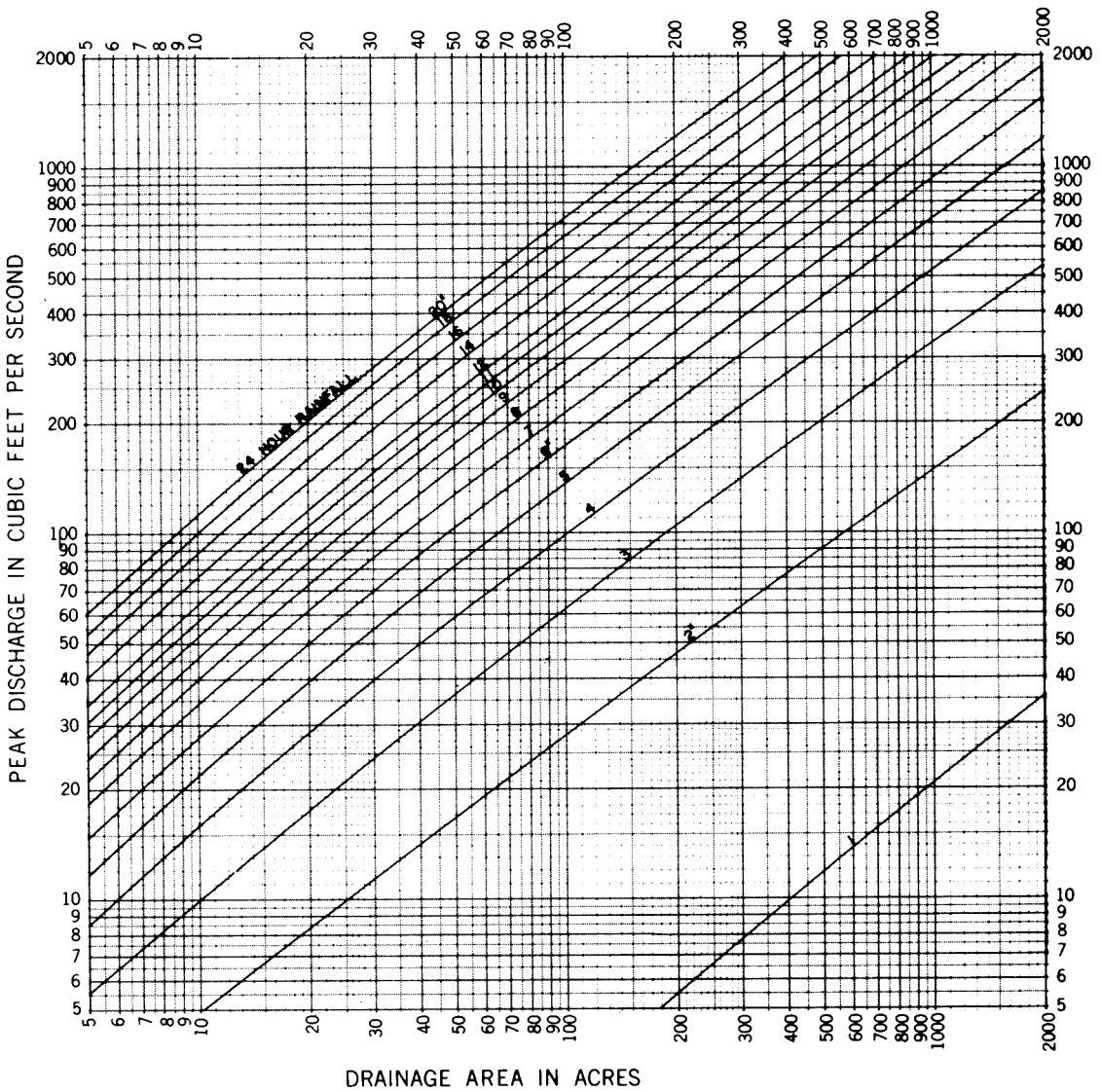


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
3.0	.90
4.0	1.00
5.0	1.08
6.0	1.14
7.0	1.21

SLOPES - MODERATE

CURVE NUMBER - 90

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

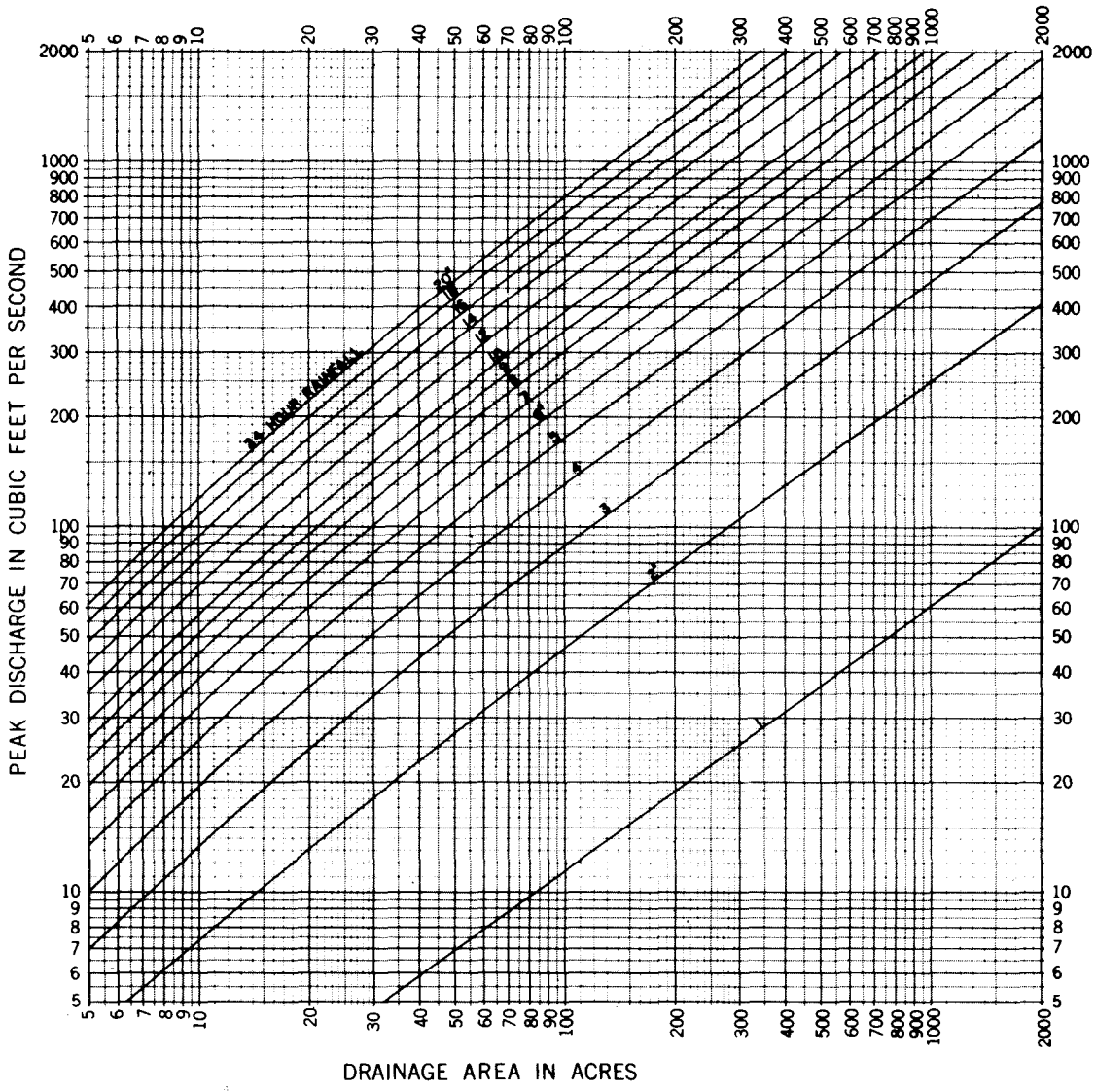


FIGURE 5-4