A Method for Estimating Volume and Rate of Runoff in Small Watersheds

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ABSTRACT

The Soil Conservation Service (SCS) has developed charts ES-1026 and ES-1027 for estimating the instantaneous peak discharge expected from small areas. They provide the peak discharge rate for establishing conservation practices on individual farms and ranches and for the design of water-control measures in small watersheds. The graphs were prepared from computations made by automatic data processing (ADP). Each graph relates peak discharge to drainage area and rainfall depths for each of (1) a given set of watershed characteristics, (2) different rainfall time distributions and (3) three categories of average watershed slopes. Peak discharges range from 5 to 2,000 cubic feet per second (cfs), drainage areas range from 5 to 2,000 acres, and 24-hour rainfall depths range from 1 to 12 inches. Curve numbers (CN) are used to represent watershed characteristics that influence runoff. Each chart represents one of seven curve numbers ranging from 60 to 90 in increments of 5. Each group of seven charts represents one of the three average watershed slope factors (FLAT, MODERATE, and STEEP) making a total of 21 charts for each of two rainfall time distributions. The procedures for computation of peak discharges by ADP were based upon those in the SCS National Engineering Handbook, Section 4, Watershed Hydrology (NEH-4). The logic and procedures used for the ADP computation are described.

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INTRODUCTION

Ven Te Chow has described many methods which have been used for determining waterway areas and the design of drainage control structures in small watersheds (1). Some of these methods have been used by the Soil Conservation Service (SCS) for estimating peak discharge rates. These include the rational method (Ramser curves after C. E. Ramser), the Cook method after H. L. Cook, the modified Cook or ΣW method by M. M. Culp and others, and the method by Victor Mockus and others described in the National Engineering Handbook, Section 4, an inservice handbook of SCS, hereinafter referred to as NEH-4. SCS has used these methods primarily for the design of measures for individual farms and ranches.

The NEH-4 method provides for the development of a complete hydrograph and involves more detailed computations than the others. It is used primarily for planning and designing larger measures--larger than those for farms and ranches--in watersheds planned under the Watershed Protection and Flood Prevention Act (Public Law 566, 83d Cong.; Stat. 666), as amended.

Using different methods under similar conditions SCS obtained wide differences in the peak rates. These differences were mainly due to the choice of coefficients and factors inherent in each method rather than to the method itself. The method adopted by SCS is shown in charts ES-1026 and ES-1027 (Appendix). Guidelines have been established for selecting nationally applicable values for this method's parameters. This set of parameters is expected to provide adequate and more uniform estimates of peak discharges between areas having similar watershed characteristics.

A primary requirement was that the method be simple enough to be used by all grades of professional and subprofessional personnel on SCS work unit staffs. They all need to make quick, on-the-spot estimates of peak discharge rates for planning and designing of soil and water conservation measures.

It is further desirable for the method to be closely allied with those in NEH-4. The peak discharge for a small watershed with unusual characteristics can then be computed using the more detailed procedures in NEH-4 but with the same parameters. Specific values are computed for each parameter in contrast to the average values used in the charts.

The method described here is generally limited to drainage areas of 2,000 acres or less and to watersheds that have average slopes of less than 30 percent. The NEH-4 method is generally used for watersheds exceeding these limits or when the computed peak discharge exceeds 2,000 cfs. There are other circumstances where the method described here may not provide adequate estimates and the NEH-4 method should be used. These are described later under pertinent headings.

STORM RAINFALL

Stream-gage measurements are rarely available for small watersheds. Generalized rainfall data, however, are available nationally. Therefore it is desirable that the national SCS method for computing peak discharge rates and runoff volumes in small areas use rainfall for their basic input.

The Weather Bureau's Rainfall-Frequency Atlases covering the United States, Puerto Rico, and the Virgin Islands provide rainfall-frequency data for areas less than 400 square miles, for durations to 24 hours, and for frequencies from 1 to 100 years (6, 7, 8, 9).

Adjustment of rainfall with respect to area is not necessary in the method described here since this method includes only areas of less than 3 square miles. But the distribution of storm rainfall with respect to time is an important parameter. Two major regions were identified for this purpose. Time distributions for each are tabulated in table 1 and shown in figure 1. Type I represents Hawaii, Alaska, and the coastal side of the Sierra Nevada and Cascade Mountains in California, Oregon, and Washington. Type II distribution represents the rest of the United States, Puerto Rico, and the Virgin Islands. The type I and II distributions are based on the generalized rainfall depth-duration relationships shown in Weather Bureau Technical Papers (fig. 2).

The accumulative graphs which are the basis for type I and II distributions depart somewhat from a straight line plot on the Weather Bureau charts. They actually plot as straight lines on log-log paper. They are shown as dash lines along with the respective 25-year rainfall distributions from Weather Bureau atlases. The 25-year rainfall distribution is represented by a straight line of best fit to the values read from the atlases. Note in figure 2 that the type II distribution underestimates the 1-hour duration by about 0.6 inch at Lincoln, Nebr., overestimates it by about 0.5 inch at Mobile, Ala., and is within 0.1 inch on the northwest

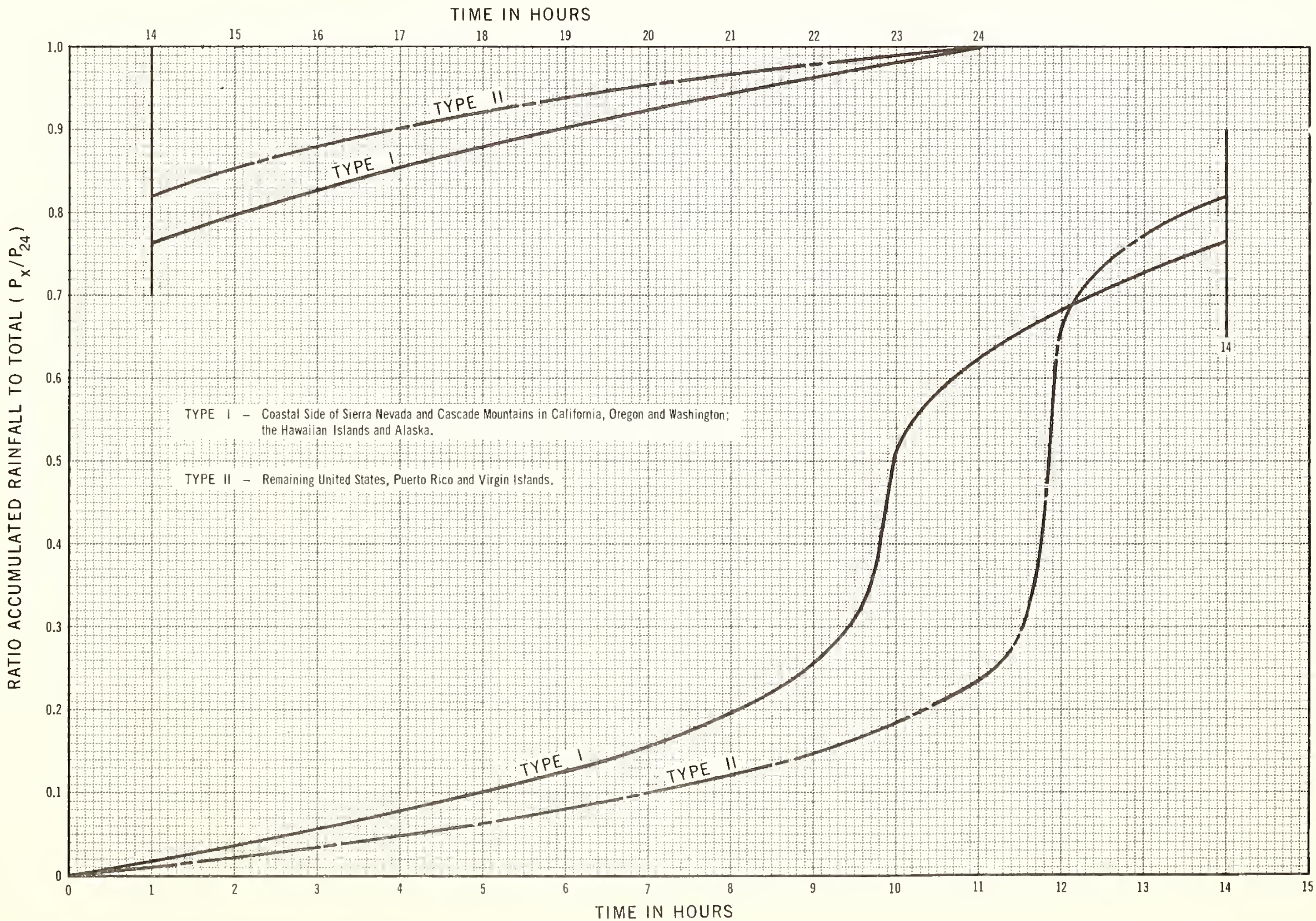


Figure 1.--Twenty-four hour rainfall distributions (SCS).

Table 1.--Accumulation of rainfall to 24 hours

Time (hours)	P_x/P_{24} [1/]	
	Type I	Type II
0	0	0
2.0	.035	.022
4.0	.076	.048
6.0	.125	.080
7.0	.156	-----
8.0	.194	.120
8.5	.219	-----
9.0	.254	.147
9.5	.303	.163
9.75	.362	-----
10.0	.515	.181
10.5	.583	.204
11.0	.624	.235
11.5	.654	.283
11.75	-----	.387
12.0	.682	.663
12.5	-----	.735
13.0	.727	.772
13.5	-----	.799
14.0	.767	.820
16.0	.830	.880
20.0	.926	.952
24.0	1.000	1.000

[1/] Ratio accumulated rainfall to total.

corner of Utah. The type I distribution underestimates the 6-hour duration by about 1 inch at Kahuka Point, Oahu, Hawaii. These variations are within the accuracy of rainfall amounts read from the Weather Bureau atlases.

The values for the dashed lines in figure 2 are rearranged to form the type I and II distributions in figure 1. They are arranged so that the greatest 30-minute depth is assumed to occur at about the middle of the 24-hour period, the second largest in the next 30 minutes, and the third largest in the preceding 30 minutes. This alternation continues with each decreasing order of magnitude until the smaller increments fall at the beginning and end of the 24-hour rainfall (fig. 1).

The effective storm period that contributes to an instantaneous peak rate of discharge varies with the time of concentration (T_c) of each small watershed. It is only a few minutes for a very short T_c and up to 24 hours for a long T_c. The effective period for most watersheds smaller than 2,000 acres is less than 6 hours. Because of the "built-in" range of 30-minute intensities the 24-hour duration is equally appropriate for a 5-acre watershed with less than a 30-minute

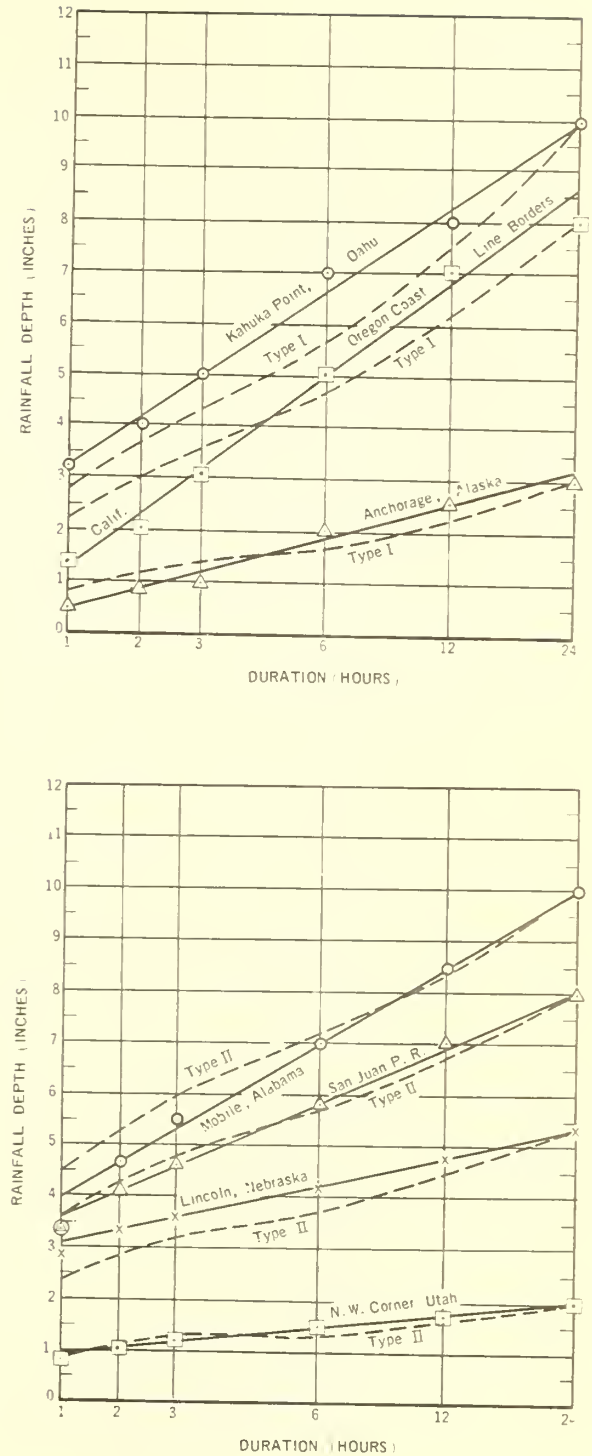


Figure 2.--Generalized 25-year frequency rainfall depth-duration relationships (U.S. Weather Bureau Rainfall Atlases).

effective storm period as it is for a 2,000-acre watershed where the effective periods may take up the entire 24 hours.

RAINFALL-RUNOFF EQUATION

The runoff equation used by SCS was developed by Victor Mockus and others about 1947 (5, 2). A relationship between accumulated rainfall and accumulated runoff was derived from experimental plots for numerous soils and vegetative cover conditions. Data for land-treatment measures, such as contouring and terracing, from experimental watersheds were included. The equation was developed mainly for small watersheds for which only daily rainfall and watershed data are ordinarily available. It was developed from recorded storm data that included total amount of rainfall in a calendar day but not its distribution with respect to time. The SCS runoff equation is therefore a method of estimating direct runoff from 24-hour or 1-day storm rainfall.

The equation is:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad (1)$$

Where:

Q = accumulated direct runoff.

P = accumulated rainfall (potential maximum runoff).

I_a = initial abstraction including surface storage, interception, and infiltration prior to runoff.

S = potential maximum retention.

The inset in figure 3 shows the initial abstraction (I_a) in a typical storm. The relationship between I_a and S was developed from experimental watershed data. It removes the necessity for estimating I_a for common usage. The empirical relationship used in the SCS runoff equation is:

$$I_a = 0.2S \qquad (2)$$

Substituting 0.2S for I_a in equation (1), the equation follows:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (3)$$

To show the rainfall-runoff relationship graphically, S values are transformed into curve numbers (CN) by the following equation (fig. 3):

$$CN = \frac{1000}{10 + S} \qquad (4)$$

The S values for CN's ranging from 0 to 100 are tabulated in NEH-4, table 10.1. Research data provided the association of CN's with various hydrologic soil-cover complexes as shown in table 2 for an average antecedent moisture condition. Soils are divided into four hydrologic soil groups: A, B, C, and D. The groups are included in NEH-4. Group A soils have a high infiltration rate even when thoroughly wet. When thoroughly wet, group B soils have a moderate infiltration rate, group C soils a slow infiltration rate, and group D soils a very slow infiltration rate. NEH-4 lists more than 3,000 soils and their hydrologic group.

The rainfall-runoff chart (fig. 3) is used mostly for estimating the runoff from watersheds for which composite CN's are obtained from listings like those in table 2. The curves can in turn be used to estimate a composite CN for an unlisted watershed characteristic with rainfall and runoff data for only a few years. The rainfall-runoff values for each storm in the short period can be plotted on a facsimile of figure 3. The curve in figure 3 equally dividing the plotted points can be assumed to represent the runoff CN for an average antecedent moisture condition in the watershed. The plotted points are usually widely scattered, representing a change in the value of S in equation (3) and hence a corresponding change in CN from one storm to the next. Most of this difference is the result of variations in soil moisture preceding each storm. Möckus based the antecedent moisture condition (AMC) on the total rainfall in the 5-day period preceding a storm and divided the AMC into three conditions (table 3). Figure 4 demonstrates how the plotted points usually fall between the CN's representing AMC I and AMC III with AMC II equally dividing them. This capability is an advantage to engineers working in foreign countries where, without experimental data on watershed characteristics unique to the local area, a minimum amount of measured data may suffice to establish CN's adequate for the design of small structures.

Changes in plant cover between seasons along with changes in land use from year to year can also affect the degree of scatter of plotted P and Q points. Furthermore, if rain gages are not spaced close enough to measure the true areal distribution of the storm, these inaccuracies will cause unrealistic scatter in the P and Q plotting.

The peak discharge computations in ES-1026 and ES-1027 are based on AMC-II.

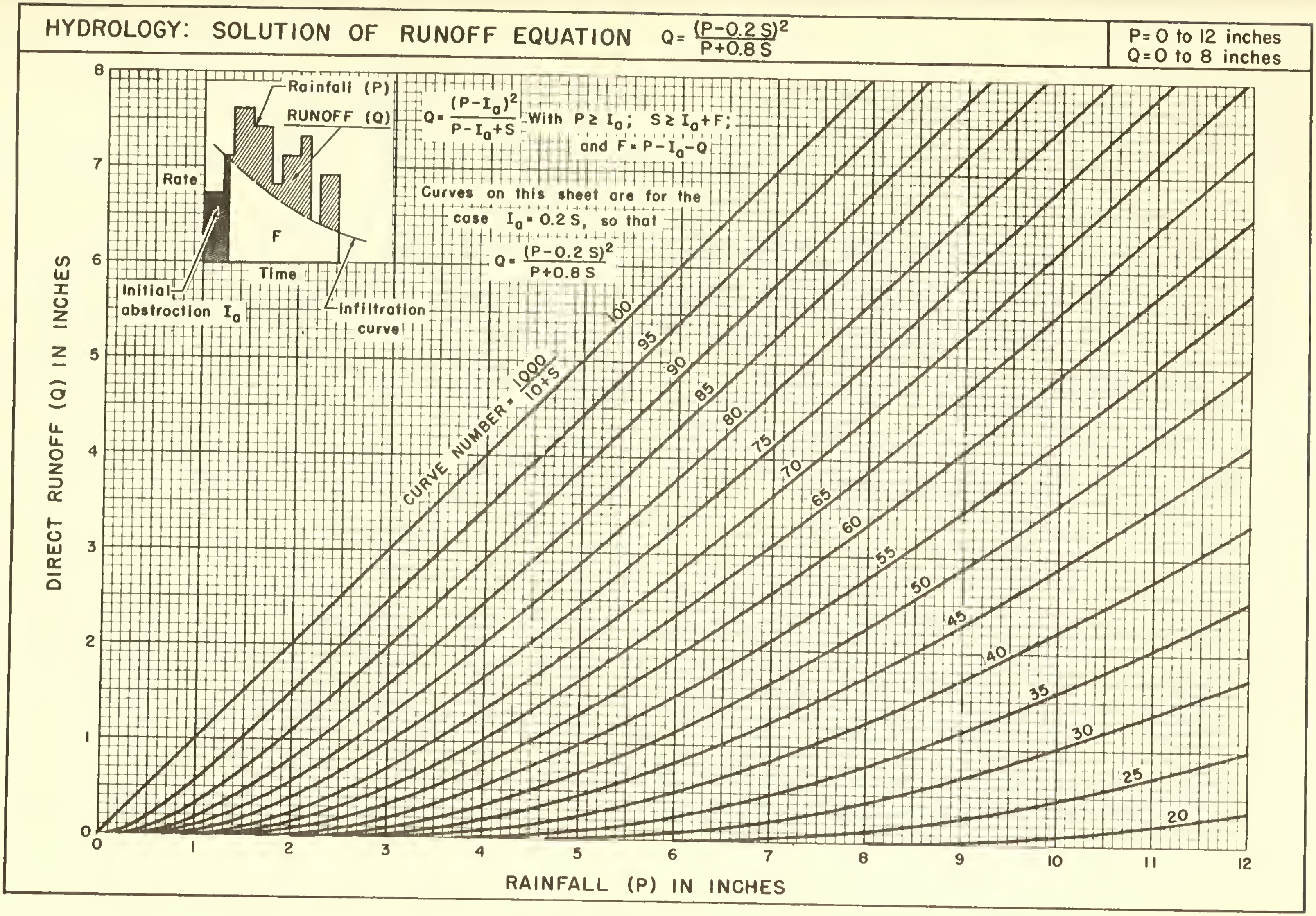


Figure 3.--Solution of the runoff equation, $Q = \frac{(P - 0.2S)^2}{P + 0.8S}$

Table 2.--Runoff curve numbers for hydrologic soil-cover complexes (Antecedent moisture condition II, and $I_a = 0.2\ S$)

Land use and treatment or practice	Hydrologic condition	Hydrologic soil group			
		A	B	C	D
Fallow					
Straight row	----	77	86	91	94
Row crops					
Straight row	Poor	72	81	88	91
Straight row	Good	67	78	85	89
Contoured	Poor	70	79	84	88
Contoured	Good	65	75	82	86
Contoured and terraced ..	Poor	66	74	80	82
Contoured and terraced ..	Good	62	71	78	81
Small grain					
Straight row	Poor	65	76	84	88
Straight row	Good	63	75	83	87
Contoured	Poor	63	74	82	85
Contoured	Good	61	73	81	84
Contoured and terraced ..	Poor	61	72	79	82
Contoured and terraced ..	Good	59	70	78	81
Close-seeded legumes or rotation meadow					
Straight row	Poor	66	77	85	89
Straight row	Good	58	72	81	85
Contoured	Poor	64	75	83	85
Contoured	Good	55	69	78	83
Contoured and terraced ..	Poor	63	73	80	83
Contoured and terraced ..	Good	51	67	76	80
Pasture or range					
No mechanical treatment	Poor	68	79	86	89
No mechanical treatment	Fair	49	69	79	84
No mechanical treatment	Good	39	61	74	80
Contoured	Poor	47	67	81	88
Contoured	Fair	25	59	75	83
Contoured	Good	6	35	70	79
Meadow	Good	30	58	71	78
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	25	55	70	77
Farmsteads	----	59	74	82	86
Roads[1/]					
Dirt	----	72	82	87	89
Hard surface	----	74	84	90	92

1/ Including rights-of-way.

Table 3.--Curve numbers (CN) for wet (AMC III) and dry (AMC I) antecedent moisture conditions corresponding to an average antecedent moisture condition (AMC II)[1/].

CN for AMC II	Corresponding CN's AMC I	Corresponding CN's AMC III
100	100	100
95	87	98
90	78	96
85	70	94
80	63	91
75	57	88
70	51	85
65	45	82
60	40	78
55	35	74
50	31	70
45	26	65
40	22	60
35	18	55
30	15	50
25	12	43
20	9	37
15	6	30
10	4	22
5	2	13

1/ AMC I. Lowest runoff potential. Soils in the watershed are dry enough for satisfactory plowing or cultivation.
AMC II. The average condition.
AMC III. Highest runoff potential. Soils in the watershed are practically saturated from antecedent rains.

WATERSHED LAG AND TIME OF CONCENTRATION

The average slope within the watershed together with the overall length and retardance of overland flow are the major factors affecting the runoff rate through the watershed.

Time of concentration (T_c) is the time it takes for water to travel from the most hydraulically distant point in a watershed to its outlet. Lag (L) can be considered as a weighted time of concentration. When runoff from a watershed is nearly uniform it is usually sufficient to relate lag to time of concentration as follows:

$$L = 0.6\ T_c \qquad (5)$$

The lag for the runoff from an increment of excess rainfall can further be considered as the time between the center of mass of the excess

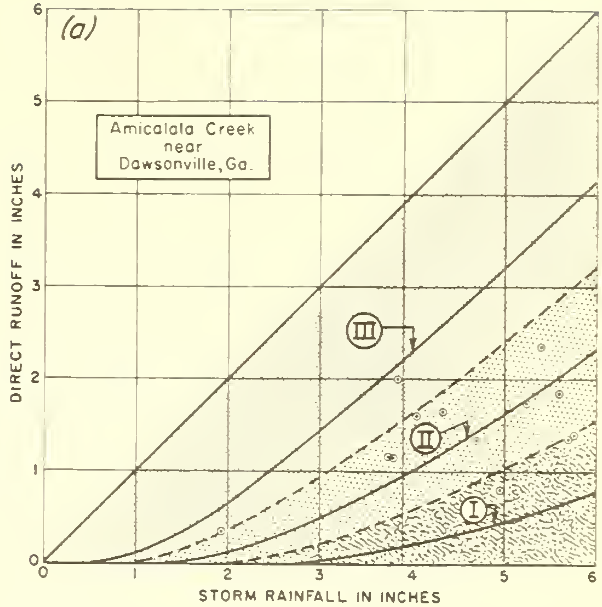


Figure 4.--Limited-gage data used to assign curve numbers to new and unmeasured watershed characteristics.

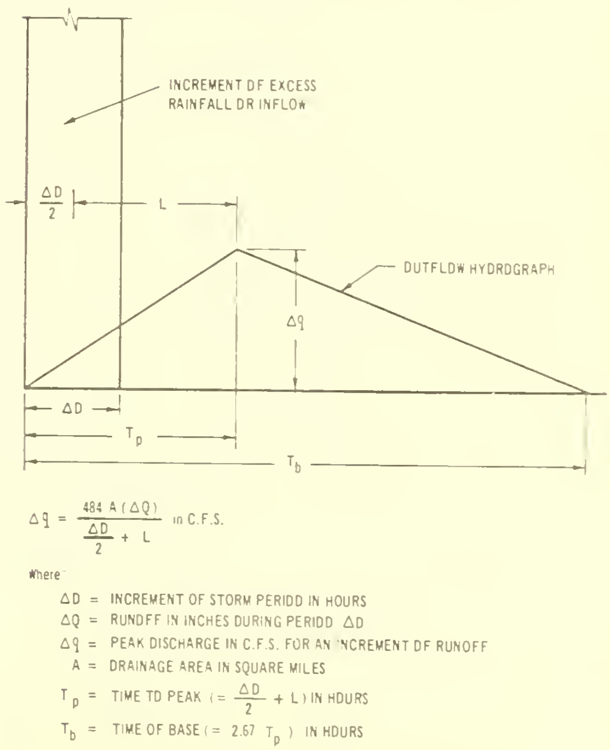


Figure 5.--Triangular hydrograph relationships.

rainfall increment and the peak of its incremental outflow hydrograph (fig. 5). A graph for estimating lag is shown in figure 6. The equation is:

$$L = \frac{\ell^{0.8}\,(S + 1)^{1.67}}{9000\,Y^{0.5}} \qquad (6)$$

Where:

L = lag in hours.

ℓ = length of mainstream to farthest divide in feet.

Y = average slope of watershed in percent.

$$S = \frac{1000}{CN} - 10$$

CN = curve number representing the watershed's hydrologic soil-cover complex.

Watershed Shape Factor

The length (ℓ) of the mainstream to the farthest divide was measured on ARS maps of the small experimental watersheds (3, 4). The hydraulic length and area of these watersheds are plotted in figure 7. The relationship is represented by the equation:

$$\ell = 209\,a^{0.6} \qquad (7)$$

Where:

ℓ = hydraulic length in feet.

a = drainage area in acres.

The ratio of length (ℓ) to average width (w) of a watershed may be referred to as a "shape factor." It follows from equation (7) that the shape factor varies with drainage area.

$$\ell = 43{,}560\,a/w \qquad (8)$$

Where:

w = average width of watershed in feet.

Substituting the value of ℓ in equation (7) for ℓ in equation (8):

$$w = (43{,}560\,a)/(209\,a^{0.6})$$

and:

$$w = 208.4\,a^{0.4} \qquad (9)$$

Combining equations (7) and (9):

$$\ell/w = Ka^{0.2} \qquad (10)$$

Where:

K = 209/208.4 (or 1 for practical purposes).

ℓ/w = watershed shape factor.

Variation in shape factor with respect to drainage area based on equation (10) is shown in the following tabulation.

Drainage area (acres)	ℓ/w 1/ Ratio
10	1.58
100	2.51
1000	3.98

1/ w is average width of watershed, area/length.

There are small watersheds that do not conform to the shape factor in equation (10); some deviate considerably. In the example shown in figure 8, the diversion terrace along one side changes the shape in reference to the hydraulic length and average width relationship. Here the ℓ/w factor is 3.75 as compared to a factor of 1.69 based on the general equation (7) used for ES-1026 and ES-1027 solutions. Example 2 under the heading "Basic Procedure for Estimating Peak Discharge Without Developing a Hydrograph" computes the peak discharge for this watershed to be 43 cfs as compared to 50 cfs obtained from the solution in ES-1027. The ES-1026 and ES-1027 solution provides a higher peak discharge estimate for all watersheds that have diversions or terraces and will result in a greater capacity requirement for the design of a structure. This is generally acceptable and often desirable for the installation of smaller measures. Where the economy of a structure requires close adherence to the lesser design capacity, the peak discharge can be determined manually as shown later in example 2. No attempt has been made to modify the precomputed estimates in ES-1026 and ES-1027 for special watershed shape factors since those used change with each change in drainage area as shown by equation (10) and the tabulation following it.

Use of Curve Numbers to Reflect Overland Retardance

The chart for estimating watershed lag in figure 6 uses CN's to reflect the retardance effect of surface conditions on the rate at which runoff moves down the slope. A hay meadow or a thick mulch in a forest is associated with

HYDROLOGY: WATERSHED LAG

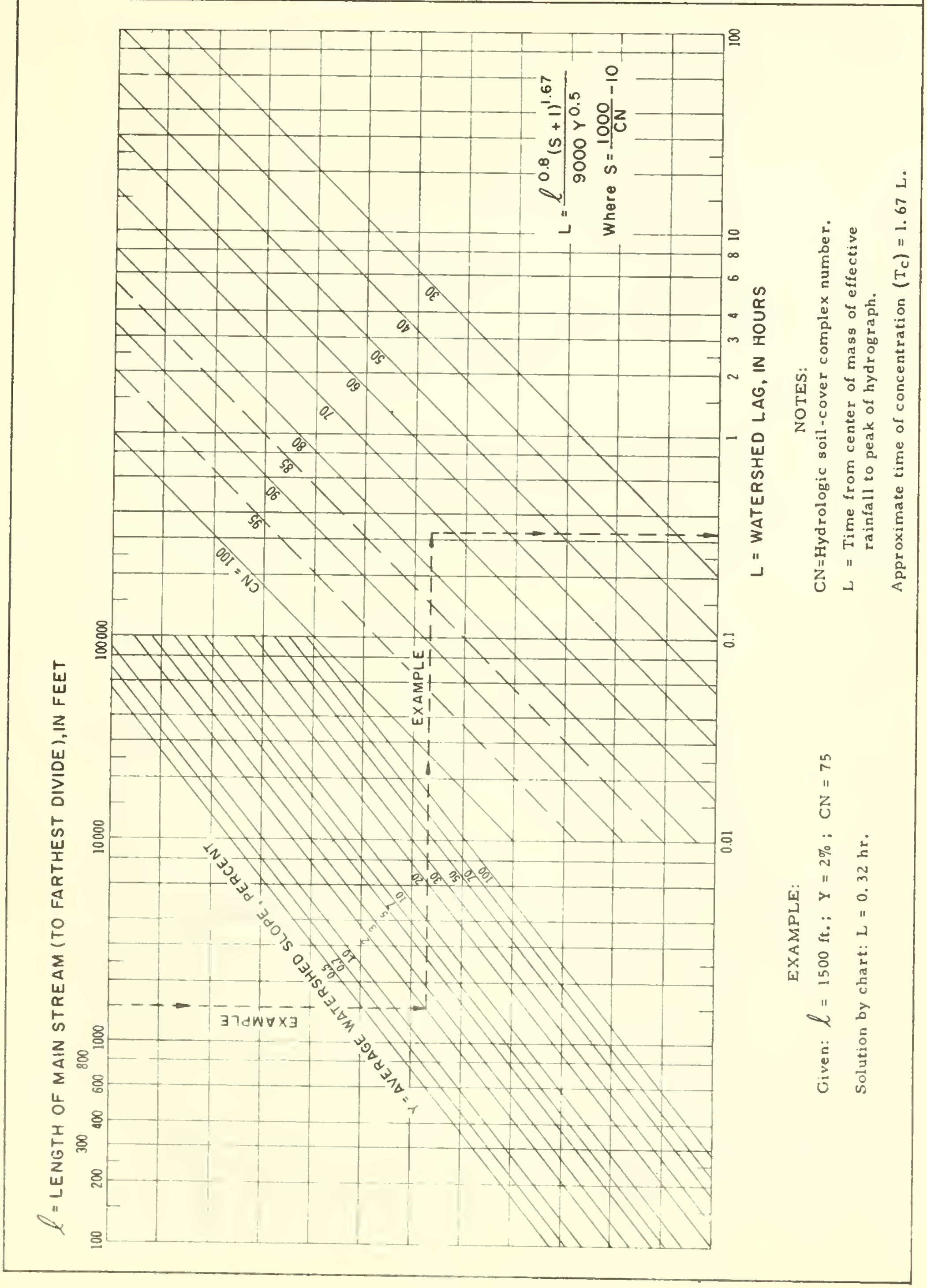


Figure 6.--Watershed lag.

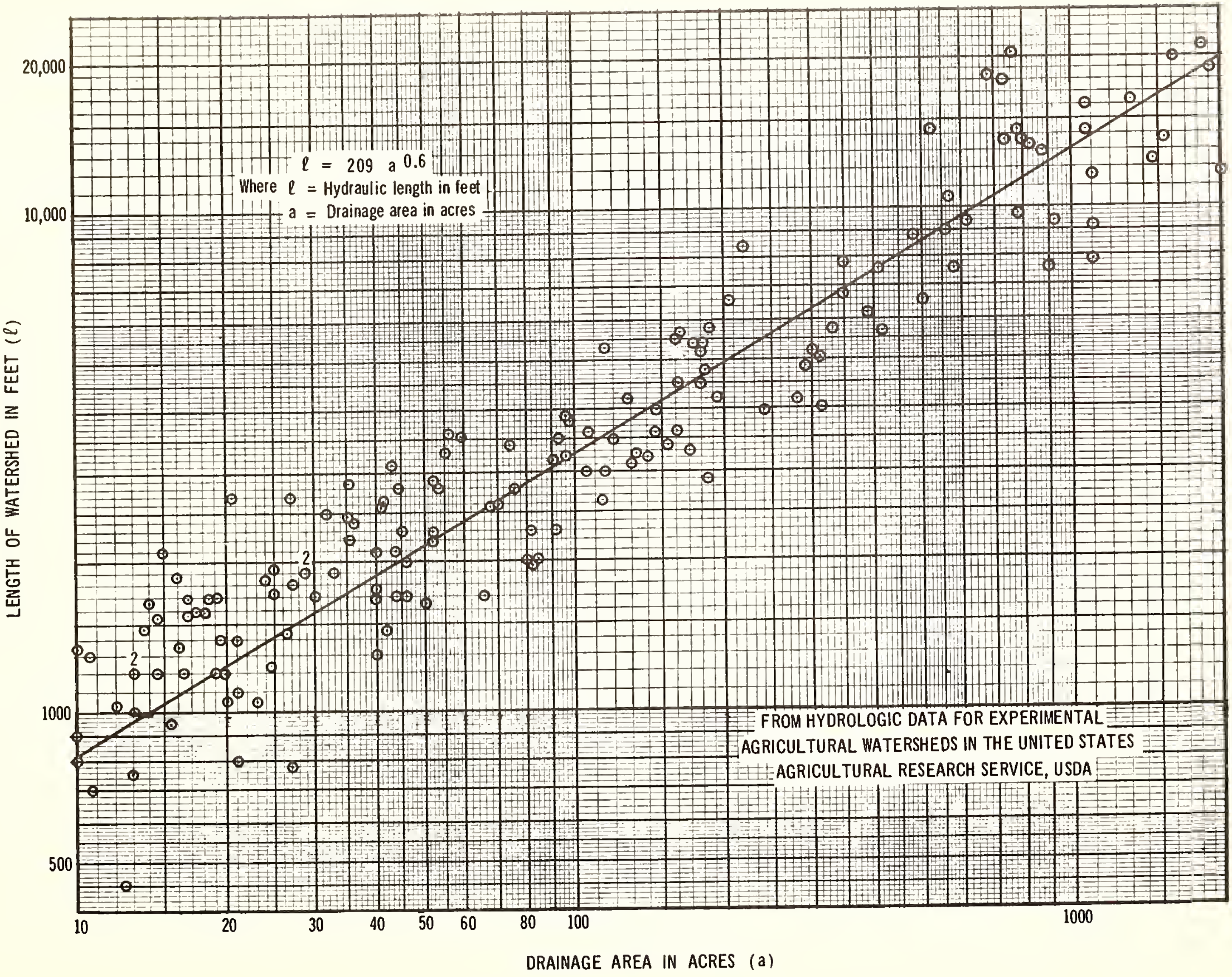


Figure 7.--Hydraulic length and drainage area relationship.

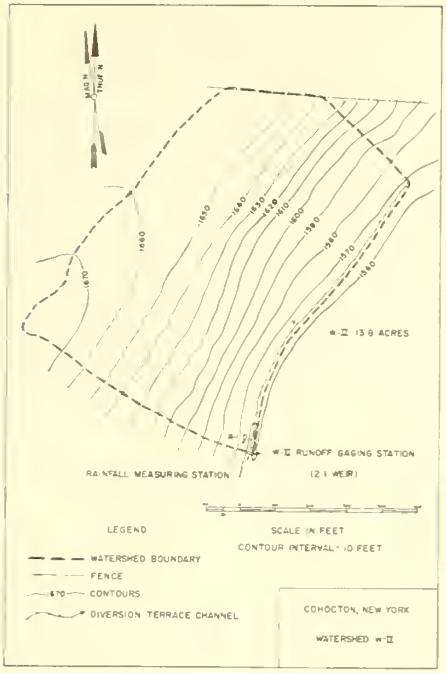


Figure 8.--Natural watershed shape factor altered by a diversion terrace.

low CN's and high retardance. Conversely, a bare surface is associated with high CN's and low retardance. The CN's denoting retardance are the same as those used for estimating the depth of runoff from rainfall (table 2).

The ADP solutions for charts ES-1026 and ES-1027 used the same CN for computing both depth of runoff and watershed lag in equations (3) and (6) respectively.

There are unusual situations for which a common CN will not provide an adequate estimate of peak discharge. One example would be a watershed in which the soils have a high infiltration rate (hydrologic soil group A or B) but no surface cover and are on rather steep slopes. Here the CN for estimating depth of runoff would be small because of the hydrologic-soil-group class. Once the soil was saturated and runoff had commenced, however, the overland retardance for the bare surface would not be adequately represented by the CN in figure 6. In special cases where it is believed that a closer approximation of lag or time of concentration can be made and where a closer peak discharge determination is warranted, the manual solution described later should be made and compared with the results in ES-1026 or ES-1027.

Average Watershed Slope

Slope as used in this method for computing peak discharge means primarily average watershed slope in the direction of overland flow. Slope is readily available at most locations from existing soil survey data. On larger watersheds the gradient of the stream channel becomes an additional consideration in estimating time of concentration. An estimate of one average slope for all the land within watersheds of less than 2,000 acres is adequate for the slope parameter (Y) in equation (6).

Average slope is defined under three broad categories for the peak discharge charts ES-1026 and ES-1027 (table 4). Peak discharges were computed for the slopes shown in the second column and assigned to the broad categories of the first and third columns. Ordinarily the peak discharge values given for one of the three slope categories in ES-1026 and ES-1027 are adequate for most uses without interpolating between slope categories.

Table 4.--Slope factors for peak discharge computations in charts ES-1026 and ES-1027.

Slope factor	Slope for which computations were made	Average slope range
	Percent	Percent
FLAT[1/]	1	0 to 3
MODERATE	4	3 to 8
STEEP	16	8 or more

1/ Level to nearly level.

Interpolation for Intermediate Slopes

If a closer estimate of peak discharge is needed than that provided in ES-1026 and ES-1027 for the three slope categories, the value can be determined by a curvilinear interpolation between 1 percent (FLAT), 4 percent (MODERATE), and 16 percent (STEEP). The estimate is made simpler by interpolating along a straight-line plot of peak against slope on log-log paper (fig. 9). The straight-line plot on log-log paper can also be used to extrapolate peak discharge values for slopes steeper than 16 percent. But other parameters than those in equation (6) may need to be considered for average watershed slopes steeper than 30 percent.

TRIANGULAR HYDROGRAPH EQUATION

The triangular hydrograph is a practical representation of excess runoff with only one rise, one peak, and one recession. It has been

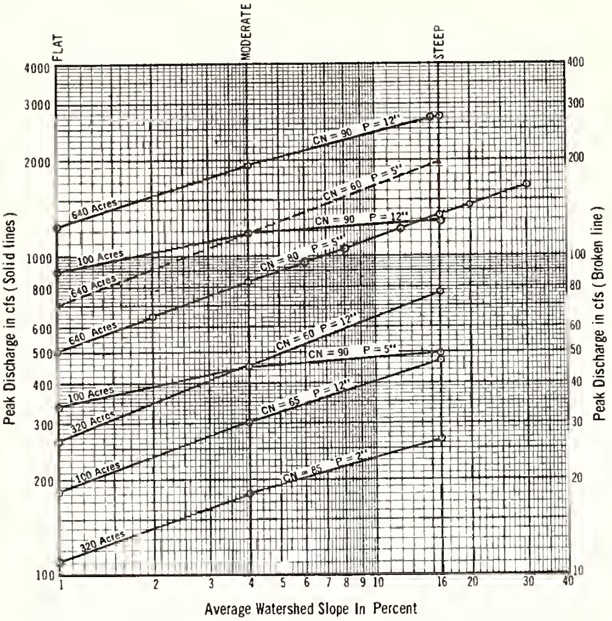


Figure 9.--Logarithmic interpolation of peak discharge for intermediate slopes.

very useful in the design of soil and water conservation measures. Its geometric makeup can be easily described mathematically, which makes it very useful in the processes of estimating discharge rates.

SCS developed the following equation to estimate the peak rate of discharge for spillway and channel capacities for conservation measures and water-control structures:

$$q_p = (KAQ)/T_p \qquad (11)(\underline{5},\underline{2})$$

Where:

q_p = peak rate of discharge.

A = drainage area contributing to the peak rate.

Q = storm runoff.

K = a constant.

T_p = time to peak.

Time to peak (T_p) is expressed as:

$$T_p = \frac{D}{2} + L$$

Where:

D = storm duration.

L = drainage area lag.

INCREMENTAL HYDROGRAPHS

Total storm rainfall rarely if ever occurs uniformly with respect to time. Because rainfall gage data and the variation of rainfall with time are lacking in most small watersheds, it is desirable that variations in rainfall with respect to time be standardized for the design of soil and water conservation measures. To use equation (11) for other than uniform storm rainfall, it is necessary to divide the storm into increments of duration (ΔD) and compute corresponding increments of runoff (ΔQ) (fig. 5). The peak discharge equation for an increment of runoff is:

$$\Delta q_p = \frac{484A\ (\Delta Q)}{\frac{\Delta D}{2} + L} \qquad (12)$$

Where:

A is in square miles.

ΔQ is in inches.

ΔD and L are in hours.

Δq_p is in cfs.

The constant, K, in equation (11) becomes 484 when the units are used to compute the peak discharge for the triangular hydrograph. The ordinates of the combined triangular hydrographs for each Δq_p are added to develop a composite hydrograph (fig. 10). Note how each incremental hydrograph is displaced a ΔD to the right for each succeeding time increment.

BASIC PROCEDURE FOR ESTIMATING PEAK DISCHARGE WITHOUT DEVELOPING A HYDROGRAPH

The plotting and summation of unit hydrograph ordinates (fig. 10) require more time than desirable or necessary to obtain only the peak discharge (q_p) for a design storm. The peak discharge, without the further development of the entire composite hydrograph, is all that is required for most SCS applications. For these the solution can be reduced to the period of runoff or of excess rainfall that directly affects the peak rate corresponding to a given watershed lag (L). A relationship between ΔD and L can be chosen that enables the summation of only a single ordinate from each incremental hydrograph within the effective runoff period to compute the peak discharge. The usual choice is to make ΔD equal to one-third the time to peak (T_p) (fig. 11). If ΔD is taken to equal $T_p/3$ then the equation for ΔD is:

$$\Delta D = 0.4L \qquad (13)$$

Where:

$$T_p = (\Delta D/2) + L \text{ (fig. 5)}$$

and

$$T_p = 3\,\Delta D$$

The effective peak-producing runoff period is $7\Delta D$ with the fifth increment ΔD_5 being the most intense runoff increment (fig. 12). The peak discharge for each increment (Δq_p) can be computed by equation (12) using:

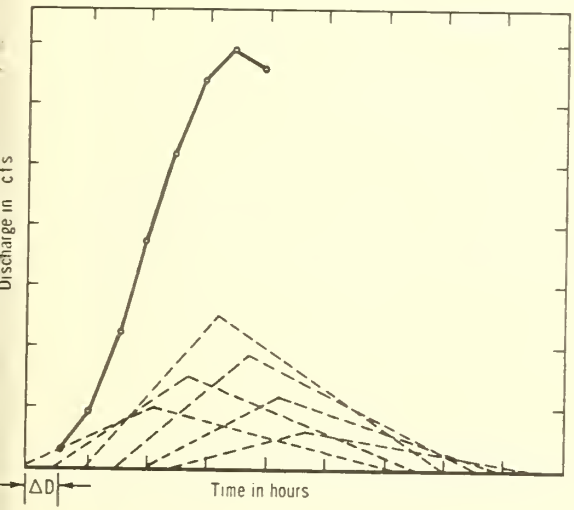


Figure 10.--Composite hydrograph from hydrographs for storm increments ΔD.

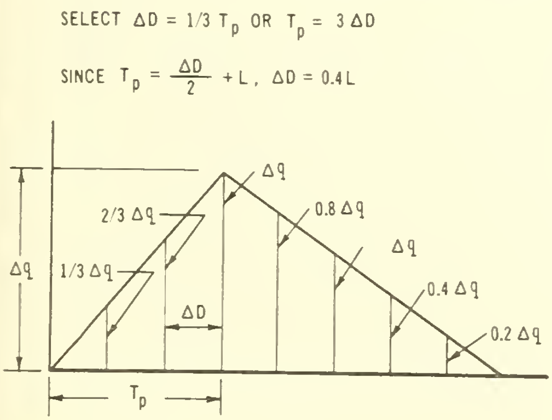


Figure 11.--Making ΔD equal to one-third the time to peak.

$$\Delta Q_1 = \text{Mass } Q_2 - \text{Mass } Q_1$$

$$\Delta Q_2 = \text{Mass } Q_3 - \text{Mass } Q_2 \qquad (14)$$

etc.

The y values in figure 13 are the proportional parts of Δq_{p1}, Δq_{p2}, etc., contributing to the composite peak q_p, Δq_p having been obtained for each by equation (12). The product $(y)\Delta q_p$ for each of the seven increments of runoff are added to obtain the composite peak rate (q_p). The summation equation is:

$$q = \Sigma\ 0.2\Delta q_{(1)} + 0.4\Delta q_{(2)} + 0.6\Delta q_{(3)} + 0.8\Delta q_{(4)} + 1.0\Delta q_{(5)} + \frac{2}{3}\Delta q_{(6)} + \frac{1}{3}\Delta q_{(7)} \qquad (15)$$

The equations were solved by ADP to get the peak-discharge rates for ES-1026 and ES-1027. These equations can be solved manually by following the examples given here.

Example 1.--Given a 100-acre watershed with runoff characteristics represented by CN 80 in table 2. The average slope of the watershed is 1 percent. The peak discharge is required for a 10-inch rain in 24 hours. The watershed is located in the area covered by the type II curve in figure 1.

Step 1.--Estimate the hydraulic length of the watershed by equation (7):

$$\ell = 209a^{0.6}$$
$$\ell = 209(100)^{0.6}$$
$$\therefore \ell = 3{,}300 \text{ feet}$$

Step 2.--Read watershed lag from figure 6 for ℓ = 3,300 feet; Y = 1 percent and CN 80:

$$L = 0.6 \text{ hour}$$

Step 3.--Compute ΔD from equation (13), assuming $\Delta D = T_p/3$:

$$\Delta D = 0.4\ L$$
$$\Delta D = 0.4(0.6)$$
$$\therefore \Delta D = 0.24 \text{ hour}$$

Step 4.--Compute the effective peak-producing runoff period for $7\Delta D$:

$$7\Delta D = 7(0.24) \text{ hours}$$
$$7\Delta D = 1.68 \text{ hours}$$

Step 5.--Prepare a tabulation based on a type II distribution in table 1; P_{24} = 10 inches and runoff (Q) for CN 80 from figure 3:

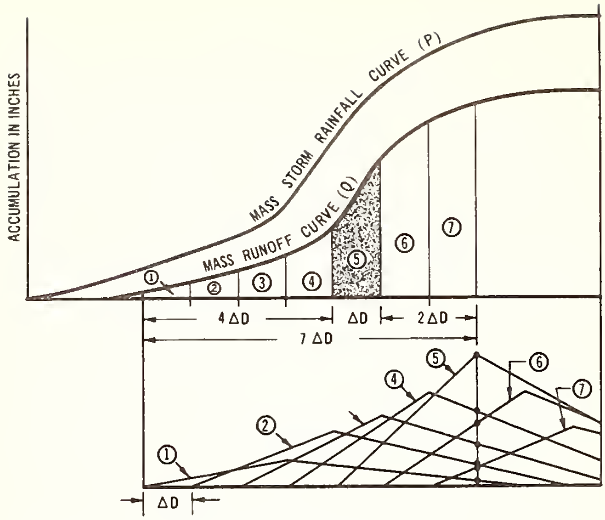
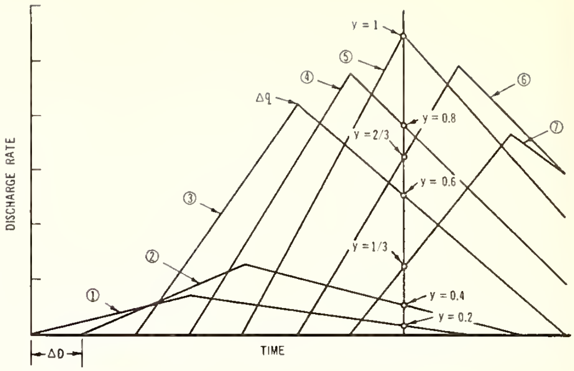


Figure 12.--Effective peak-producing period and most effective increment.



$$\Delta q = \frac{484\, A\,(\Delta Q)}{\frac{\Delta D}{2} + L}$$

$$q = \sum 0.2\,\Delta q_{①} + 0.4\,\Delta q_{②} + 0.6\,\Delta q_{③} + 0.8\,\Delta q_{④} + 1.0\,\Delta q_{⑤} + 2/3\,\Delta q_{⑥} + 1/3\,\Delta q_{⑦}$$

Figure 13.--Proportional parts of incremental hydrographs that contribute to the composite peak.

Time (hours)	P_x/P_{24}	Mass P (inches)	Mass Q (inches)
10.5	0.204	2.04	0.58
11.0	0.235	2.35	0.75
11.5	0.283	2.83	1.12
11.75	0.387	3.87	1.92
12.0	0.663	6.63	4.35
12.5	0.735	7.35	5.02
13.0	0.772	7.72	5.40

Step 6.--Prepare working curve. Plot mass Q versus time (fig. 14). Select midpoint of maximum increment of runoff (11.88 hours). This will be the same for most type II distributions, but it will occur later where initial abstraction (I_a = 0.2S) has not been satisfied prior to 11.75 hours. Mark the curve with the 7ΔD beginning at 10.8 hours for the selected midpoint minus 4.5ΔD.

$$11.88 - 4.5(0.24) = 10.8$$

Step 7.--Prepare computations for instantaneous peak discharge (table 5). The increment in

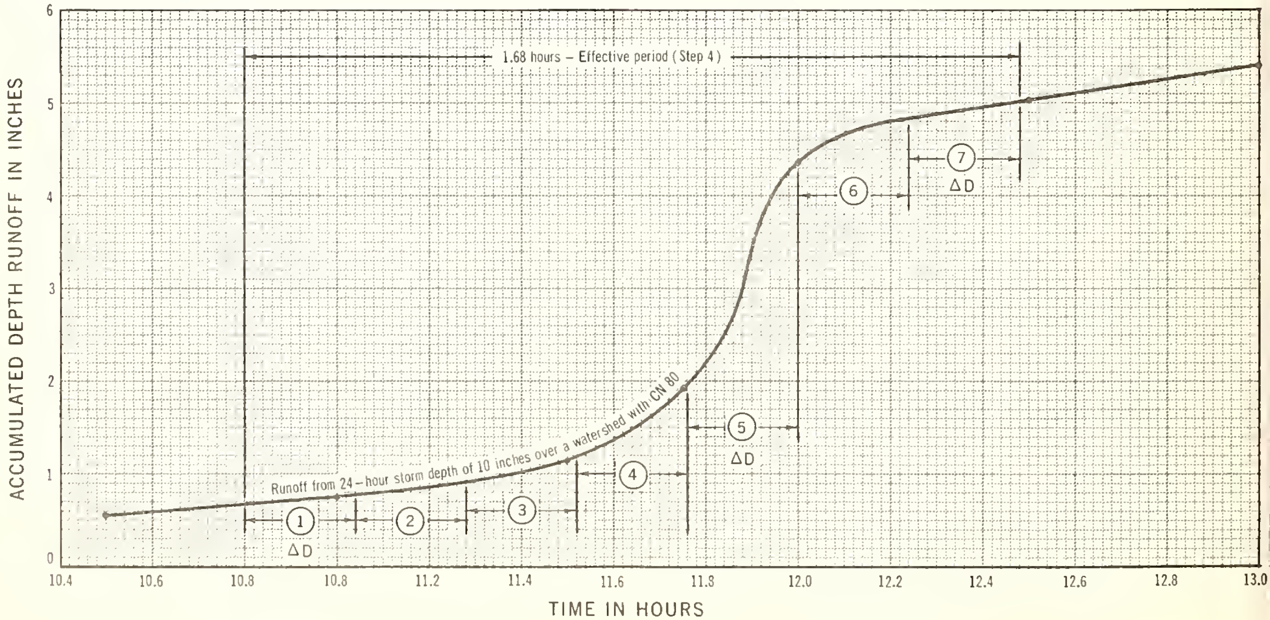


Figure 14.--Working curve for manual computation from type II storm distribution, table 1.

Table 5.--Example 1, computations for instantaneous peak discharge

(1) Increment	(2) Time	(3) Mass runoff	(4) ΔQ	(5) Δq[1/]	(6) Y[2/]	(7) Y(Δq)
	Hours	Inches	Inches	Cfs		Cfs
	10.80	0.70				
ΔD_1			0.07	7	0.2	1.4
	11.04	0.77				
ΔD_2			0.08	8	0.4	3.2
	11.28	0.85				
ΔD_3			0.33	35	0.6	21.0
	11.52	1.18				
ΔD_4			0.80	84	0.8	67.2
	11.76	1.98				
ΔD_5			2.37	249	1.0	249.0
	12.00	4.35				
ΔD_6			0.49	51	2/3	34.0
	12.24	4.84				
ΔD_7			0.18	19	1/3	6.3
	12.48	5.02				
					q_p =	382.1[3/]

1/ From equation (12).
2/ See figure 13.
3/ q_p = 380 (approximately) from ES-1027, sheet 5.

column 1 and the time in column 2 correspond with the beginning and end of each incremental period, ΔD, in figure 14. The runoff (Q) in column 3 is read from the curve in figure 14. Column 4 is the incremental runoff for each ΔD. Peak discharge for each increment of runoff is computed by equation (12) and tabulated in column 5. Column 6 lists the proportion of incremental peak that contributes to the total peak as shown in figure 13. Column 7 is the summation of proportionate parts of each incremental peak in equation (15).

Example 2.--Given watershed W-II, 13.8 acres located at Cohocton, N. Y. The watershed is in cultivation with good conservation treatment in effect; its soils are predominantly in hydrologic soil group C. The average watershed slope is 20 percent and hydraulic length ℓ is measured as 1,500 feet following the course of the diversion terrace (fig. 8). The peak discharge for a 25-year frequency storm is desired for AMC II.

Step 1.--Select CN from table 2 based on the watershed description: CN = 82

Step 2.--Compute S from equation (4):

$$S = \frac{1000}{CN} - 10$$

$$S = \frac{1000}{82} - 10$$

$$\therefore S = 2.2$$

Step 3.--Read watershed lag (L) from figure 6:

$$L = 0.06$$

Step 4.--The 24-hour, 25-year frequency rainfall for Cohocton, N. Y., in the Weather Bureau Atlas is 4.3 inches. Use type II distribution.

Step 5.--Compute ΔD from equation (13) assuming $\Delta D = T_p/3$:

$$\Delta D = 0.4L$$

$$\Delta D = 0.4(0.06) = 0.024 \text{ hour}$$

Step 6.--Compute the effective peak-producing runoff period for 7ΔD:

$$7\Delta D = 7(0.024) \text{ hours}$$

$$7\Delta D = 0.168 \text{ hour}$$

Step 7.--Prepare a tabulation from data in steps 1 and 4 for the period in step 6, solving for Q by using equation (3) or by reading Q from figure 3:

P = 4.3 inches; S = 2.2 inches.

Time (hours)	P_x/P_{24}[1/]	Mass P (inches)	Mass Q (inches)
11.5	0.283	1.22	0.20
11.75	0.387	1.66	0.44
12.0	0.663	2.85	1.26

1/ From table 1, type II distribution.

Step 8.--Prepare working curve (fig. 15) from data in step 7.

Step 9.--Prepare computations for instantaneous peak discharge (table 6).

The peak discharge for this example is rounded to 46 cfs, as computed manually, and by estimating lag (L) on the actual hydraulic length (ℓ) along the diversion terrace. The peak discharge obtained from ES-1027 (sheets 19 and 20), with ℓ based on equation (7) and not the measured length along the diversion terrace, is:

q for STEEP, CN 80, 13.8 acres, and P = 4.3 inches is 46 cfs.

q for STEEP, CN 85, 13.8 acres, and P = 4.3 inches is 56 cfs.

By interpolation,

q for STEEP, CN 82, 13.8 acres, and P = 4.3 inches is 51 cfs.

Converting from the 16-percent slope for STEEP to a 20-percent slope would not add more than 1

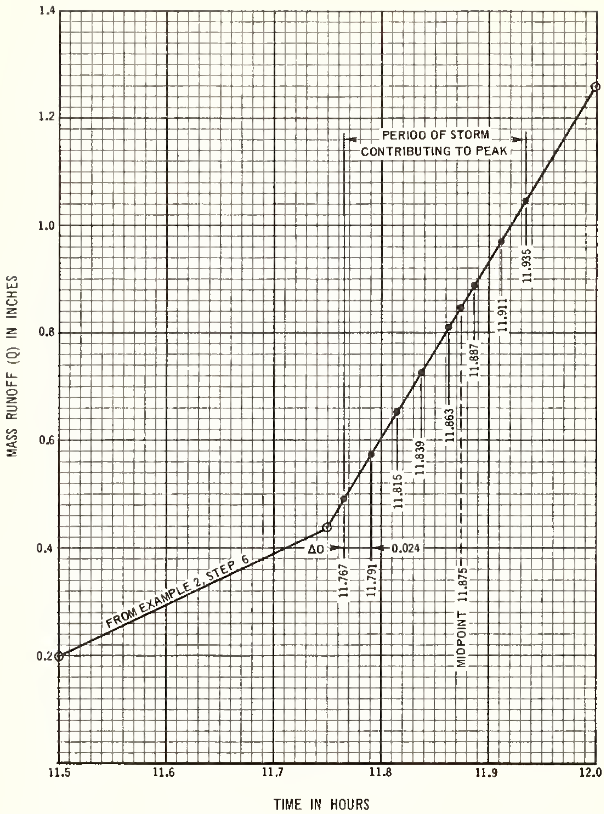


Figure 15.--Working curve for example 2.

or 2 cfs by extrapolation on log-log paper as was suggested for special cases (fig. 9).

It may be concluded that the ES-1027 charts overestimate the peak discharge in this example by about 6 cfs or 13 percent. This is due mainly to the alteration of the watershed shape factor by the diversion terrace.

Example 3.--This example demonstrates the need for making ΔD smaller than 0.4L as used in the previous two examples. To keep it less than 0.25 hour and commensurate with the increment of maximum storm intensity in table 1, it is set equal to 1/6 T_p instead of 1/3 T_p and it follows that:

$$\Delta D = 0.182L \qquad (16)$$

Given a 2,000-acre watershed with CN 83 and an average slope of 3 percent located on Kahuka Point, Oahu. An estimate of the peak discharge for a 25-year frequency rainstorm is desired.

Step 1.--Estimate the hydraulic length of the watershed by equation (7) or read from figure 7:

$$\ell = 20,000 \text{ feet}$$

Table 6.--Example 2, computations for instantaneous peak discharge

Increment	Time	Mass runoff	ΔQ	Δq[1/]	Y	Y(Δq)
	Hours	Inches	Inches	Cfs		Cfs
	11.767[2/]	0.49				
ΔD_1			0.08	11.6	0.2	2.3
	11.791[3/]	0.57				
ΔD_2			0.08	11.6	0.4	4.6
	11.815	0.65				
ΔD_3			0.08	11.6	0.6	7.0
	11.839	0.73				
ΔD_4			0.08	11.6	0.8	9.3
	11.863	0.81				
ΔD_5			0.08	11.6	1.0	11.6
	11.887	0.89				
ΔD_6			0.08	11.6	2/3	7.7
	11.911	0.97				
ΔD_7			0.08	11.6	1/3	3.9
	11.935	1.05				
					TOTAL =	46.4

1/ $\Delta q = \dfrac{484\ A\ (\Delta Q)}{\frac{\Delta D}{2} + L} = \dfrac{(484)\ (13.8)\ \Delta Q}{(.012 + 0.060)\ 640} = 145\ \Delta Q$

2/ 11.875 - 4.5 ΔD = 11.875 - 4.5 (0.024) = 11.767 hours

3/ 11.767 + 0.024 = 11.791 hours (etc.)

Step 2.--Read watershed lag from figure 6 for ℓ = 20,000 feet; Y = 3 percent and CN 83:

$$L = 1.1 \text{ hours}$$

Step 3.--Compute ΔD from equation (16), assuming ΔD = $T_p/6$:

$$\Delta D = 0.2 \text{ hour}$$

Step 4.--Compute the effective peak-producing runoff period for 15ΔD:

$$15\Delta D = 15(0.2) \text{ hours}$$

$$15\Delta D = 3.0 \text{ hours}$$

Step 5.--Prepare a tabulation based on a type I distribution in table 1; P_{24} = 10 inches and CN 83:

Time (hours)	P_x/P_{24}	Mass P (inches)	Mass Q (inches)
8.00	0.194	1.94	0.66
8.50	0.219	2.19	0.83
9.00	0.254	2.54	1.09
9.50	0.303	3.03	1.47
9.75	0.362	3.62	1.96
10.00	0.515	5.15	3.30
10.50	0.583	5.83	3.93
11.00	0.624	6.24	4.32
11.50	0.654	6.54	4.59

Step 6.--Prepare working curve (fig. 16) from data in step 5.

Step 7.--Prepare computations for instantaneous peak discharge (table 7).

EQUATIONS AND ASSUMPTIONS USED IN COMPUTER SOLUTIONS FOR CHARTS ES-1026 AND ES-1027

Storm Rainfall

Fifteen- and 30-minute increments of accumulated-to-total ratios of rainfall were used with both type I and II distributions shown in figure 1. The 15-minute increments extended through the most intense 1-hour period of each distribution. Twenty-four hour storms were generated accordingly for each distribution for those rainfall depths shown in the ES charts.

Rainfall-Runoff Equations

Runoff (Q) was computed accumulatively from the two accumulated rainfall distributions and their increments described. This solution was made for all rainfall depths and for each of the seven CN's included in the ES charts by the following equations:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (3)$$

and

$$S = \frac{1000}{CN} - 10 \qquad (17)$$

Watershed Lag

Lag time (L) was computed for 1-, 4-, and 16-percent slopes (Y) for each of the seven CN's in the ES charts and for each of the following drainage areas (a):

5 acres
10 to 100 acres by 10-acre increments
100 to 1,000 acres by 20-acre increments
1,000 to 2,000 acres by 50-acre increments

The programmed equations were:

$$L = \frac{\ell^{0.8} (S + 1)^{1.67}}{9000\ Y^{0.5}} \qquad (6)$$

$$\ell = 209\ a^{0.6} \qquad (7)$$

$$S = \frac{1000}{CN} - 10 \qquad (17)$$

The same CN and hence the same S value was used for computing L as was used in the corresponding runoff solution.

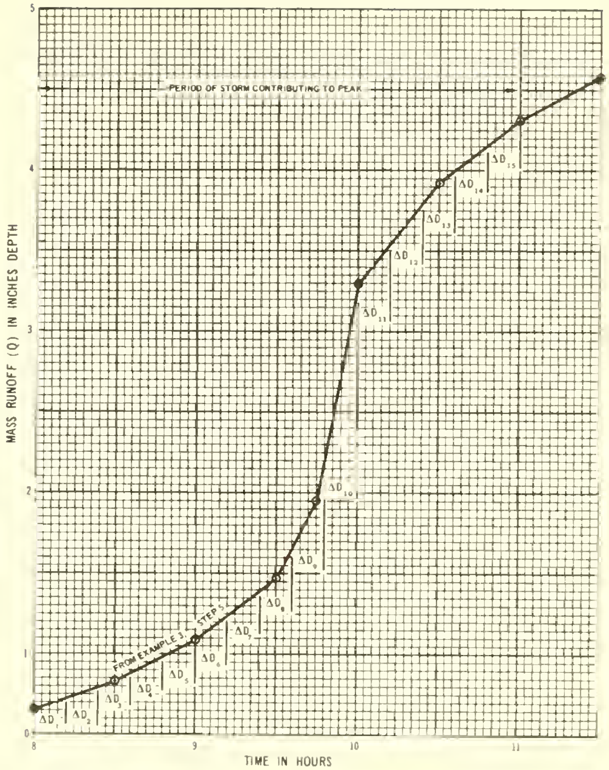


Figure 16.--Working curve for example 3.

Period of Runoff Affecting Peak Discharge

The computer program related the incremented periods (ΔD) of storm runoff to lag (L) as follows (example 3):

$$\Delta D = 0.182\ L \qquad (16)$$

The peak producing storm period for this relationship is 15 ΔD (table 7, example 3).

The computer solution determined the time at which the midperiod of the most intense 15-minute increment of accumulated runoff occurred. This was at 9.875 hours for the type I distribution and 11.875 hours for the type II distribution. It computed the time at the beginning of the effective period (15ΔD) as:

9.875 - 9.5 ΔD for type I
11.875 - 9.5 ΔD for type II

Incremental Peak Discharge

The instantaneous peak discharge was computed for each increment of runoff (ΔQ) within the

Table 7.--Example 3, computations for instantaneous peak discharge

Increment	Time	Mass Q	ΔQ	Δq[1/] [2/]	Y	Y(Δq)[2/]
	Hours	Inches	Inches	Cfs		Cfs
	8.0	0.66				
ΔD_1			.07	88	0.1	9
	8.2	0.73				
ΔD_2			.07	88	0.2	18
	8.4	0.80				
ΔD_3			.09	113	0.3	34
	8.6	0.89				
ΔD_4			.10	126	0.4	50
	8.8	0.99				
ΔD_5			.10	126	0.5	63
	9.0	1.09				
ΔD_6			.15	189	0.6	113
	9.2	1.24				
ΔD_7			.16	202	0.7	141
	9.4	1.40				
ΔD_8			.27	340	0.8	272
	9.6	1.67				
ΔD_9			.55	692	0.9	623
	9.8	2.22				
ΔD_{10}			1.08	1360	1.0	1360
	10.0	3.30				
ΔD_{11}			0.25	315	5/6	262
	10.2	3.55				
ΔD_{12}			0.25	315	4/6	210
	10.4	3.80				
ΔD_{13}			0.20	252	3/6	126
	10.6	4.00				
ΔD_{14}			0.16	202	2/6	67
	10.8	4.16				
ΔD_{15}			0.16	202	1/6	34
	11.0	4.32				
					Total, q =	3416 cfs

1/ $\Delta q = 0.692 \frac{a}{L} \Delta Q$ ($\Delta q = 1260 \Delta Q$) where a = 2,000 acres and L = 1.1 hours

2/ Slide rule computations, rounded to nearest whole number

effective period (15ΔD) described according to the following equation:

$$\Delta q = \frac{0.692a}{L}(\Delta Q) \qquad (18)$$

Combined Peak Discharge

The incremental peaks (Δq's) were combined in the computer program in a manner similar to the manual solution shown in table 7, example 3.

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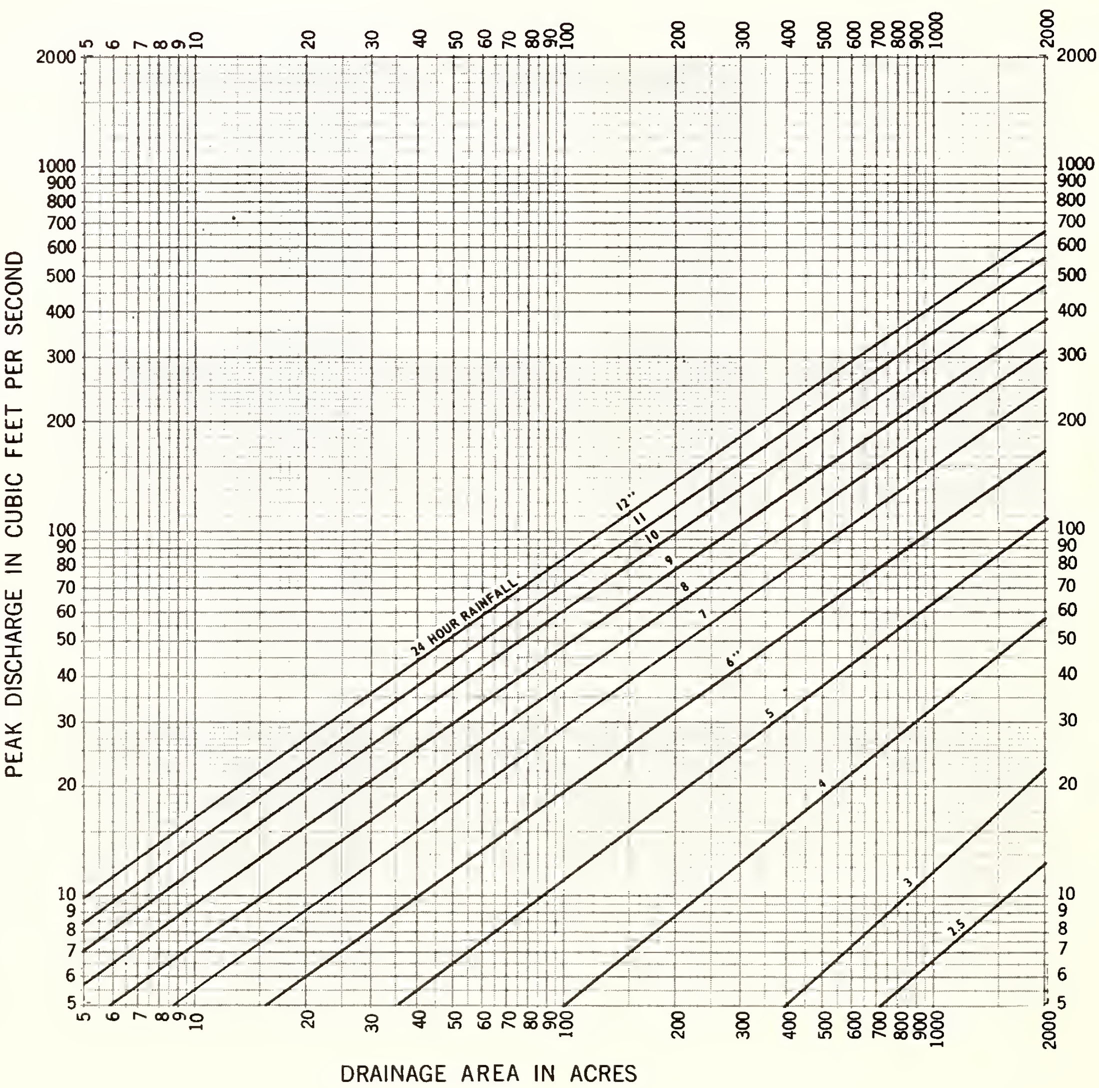
1961. Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years. Tech. Paper 40, 115 pp.

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - FLAT
CURVE NUMBER - 60

24 HOUR RAINFALL FROM US WB TP-40

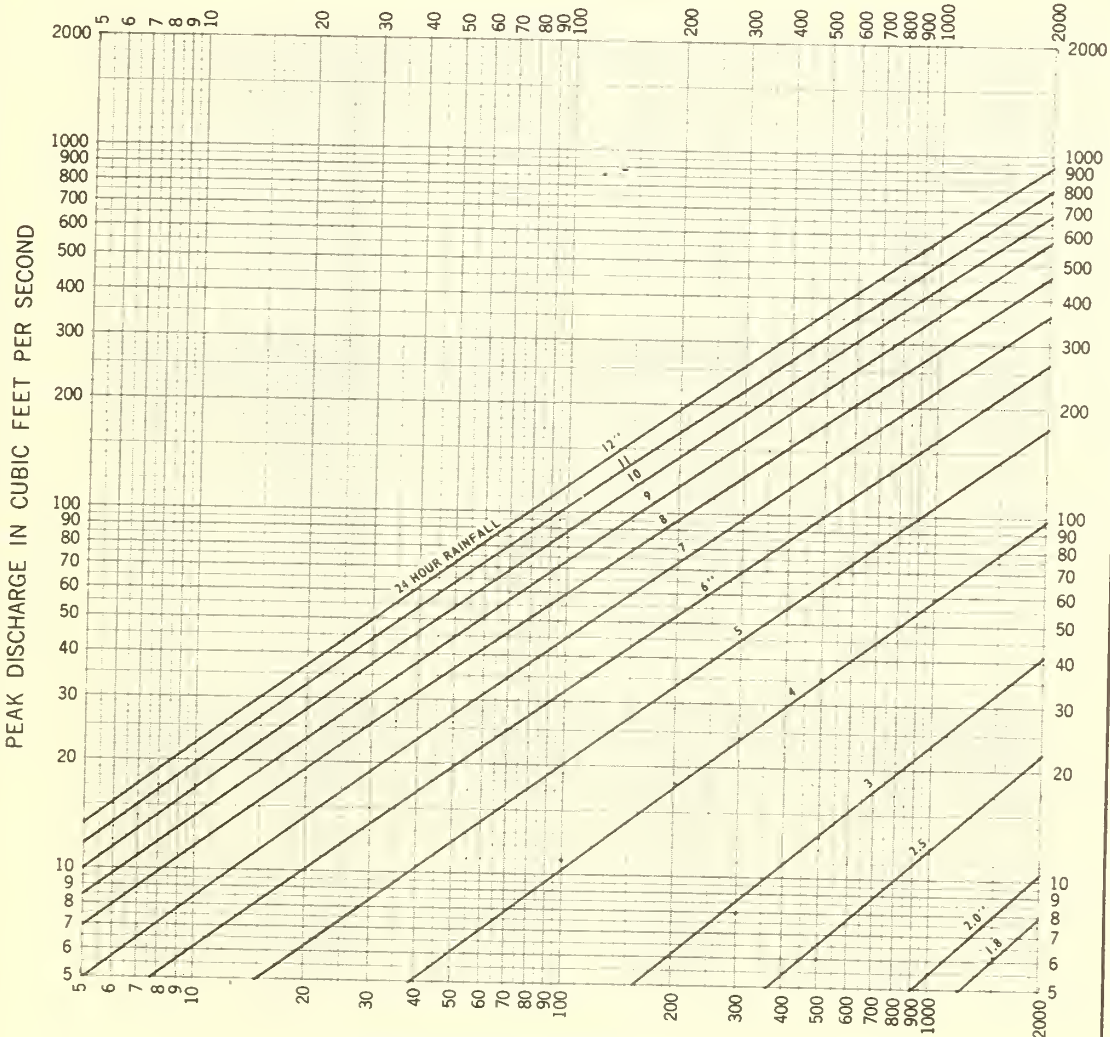


ES- 1026
SHEET 1 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES – FLAT
CURVE NUMBER – 65

24 HOUR RAINFALL FROM US WB TP-40

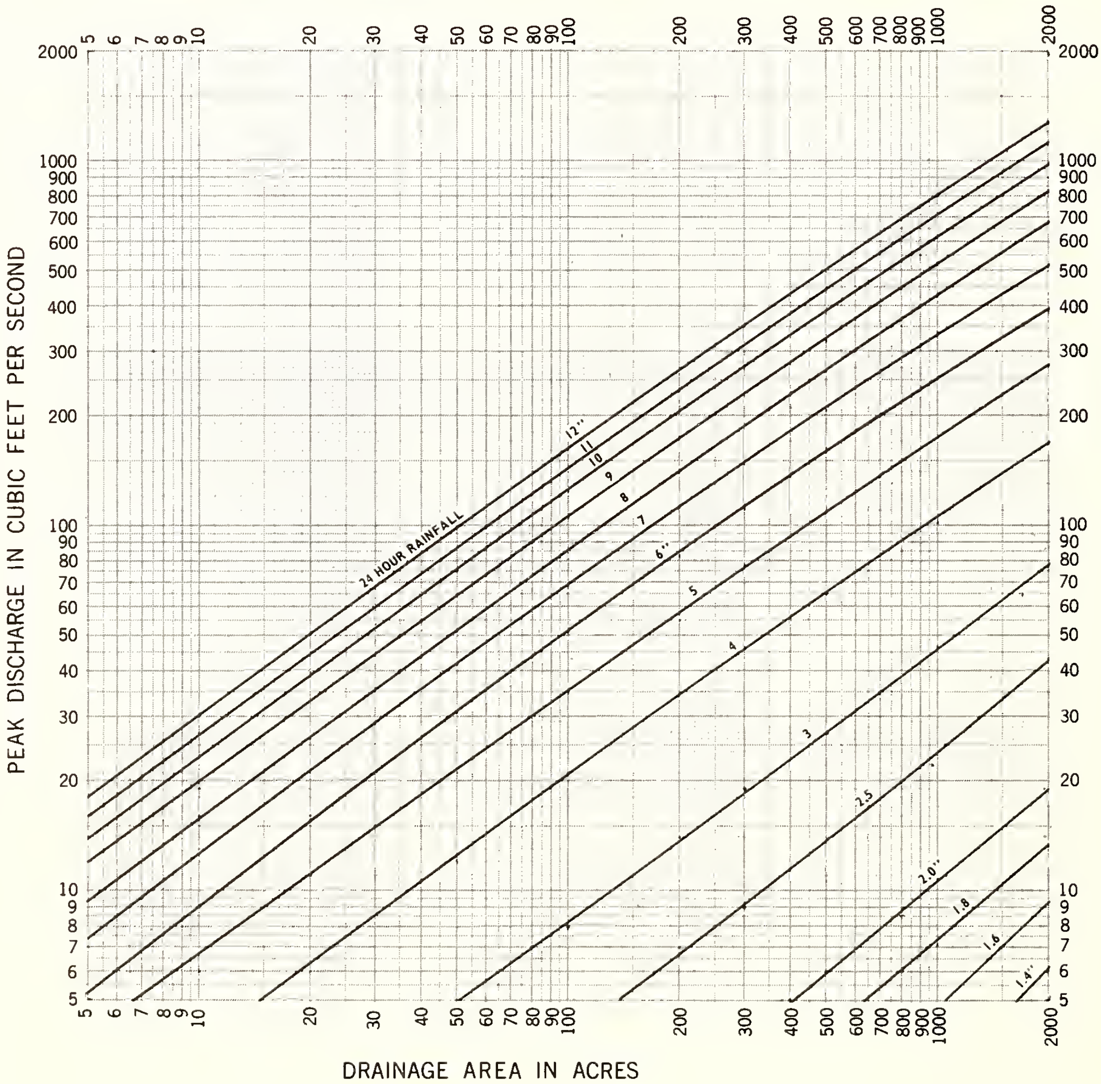


ES- 1026
SHEET 2 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES – FLAT
CURVE NUMBER – 70

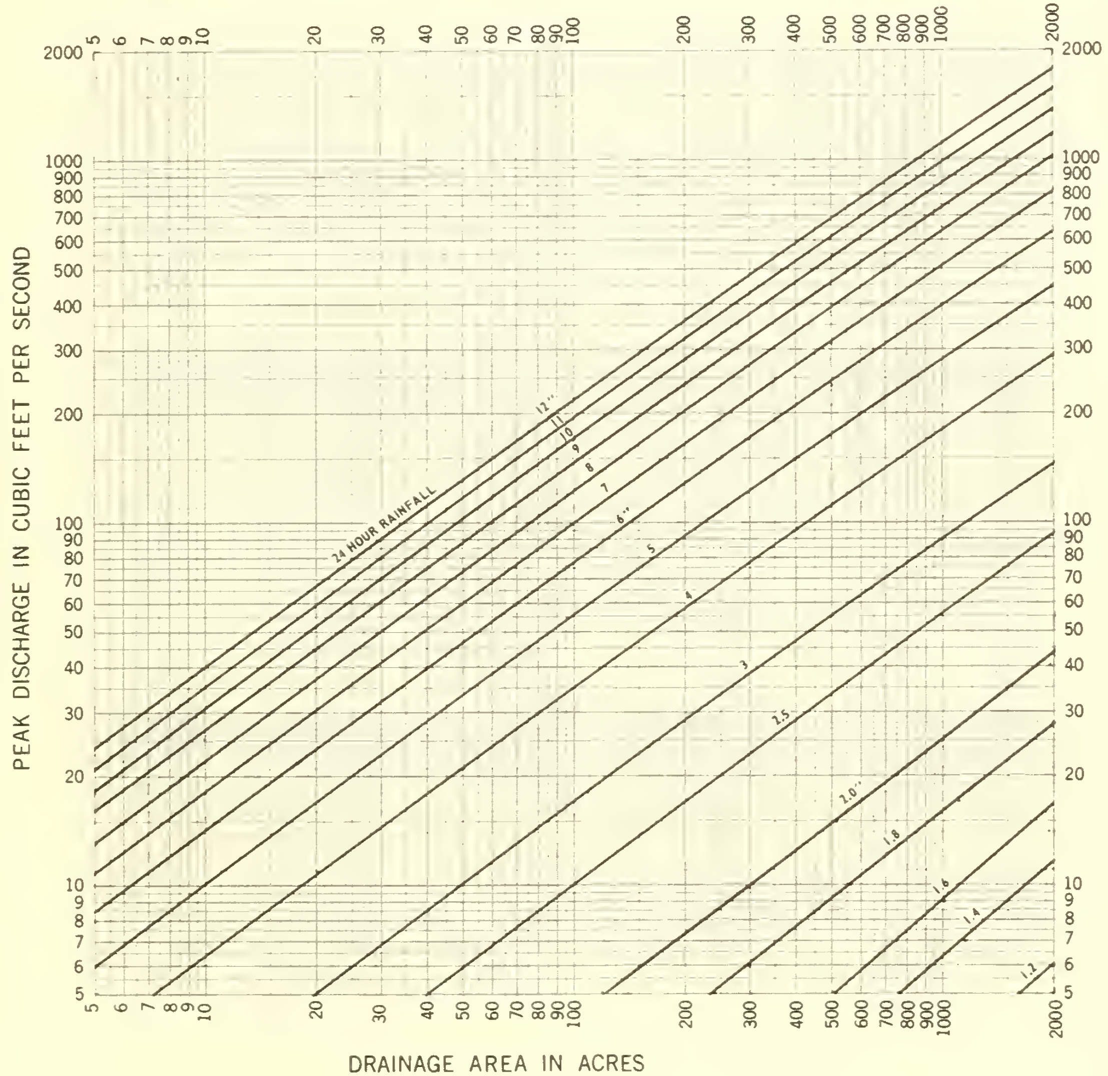
24 HOUR RAINFALL FROM US WB TP-40



PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - FLAT
CURVE NUMBER - 75

24 HOUR RAINFALL FROM US WB TP-40

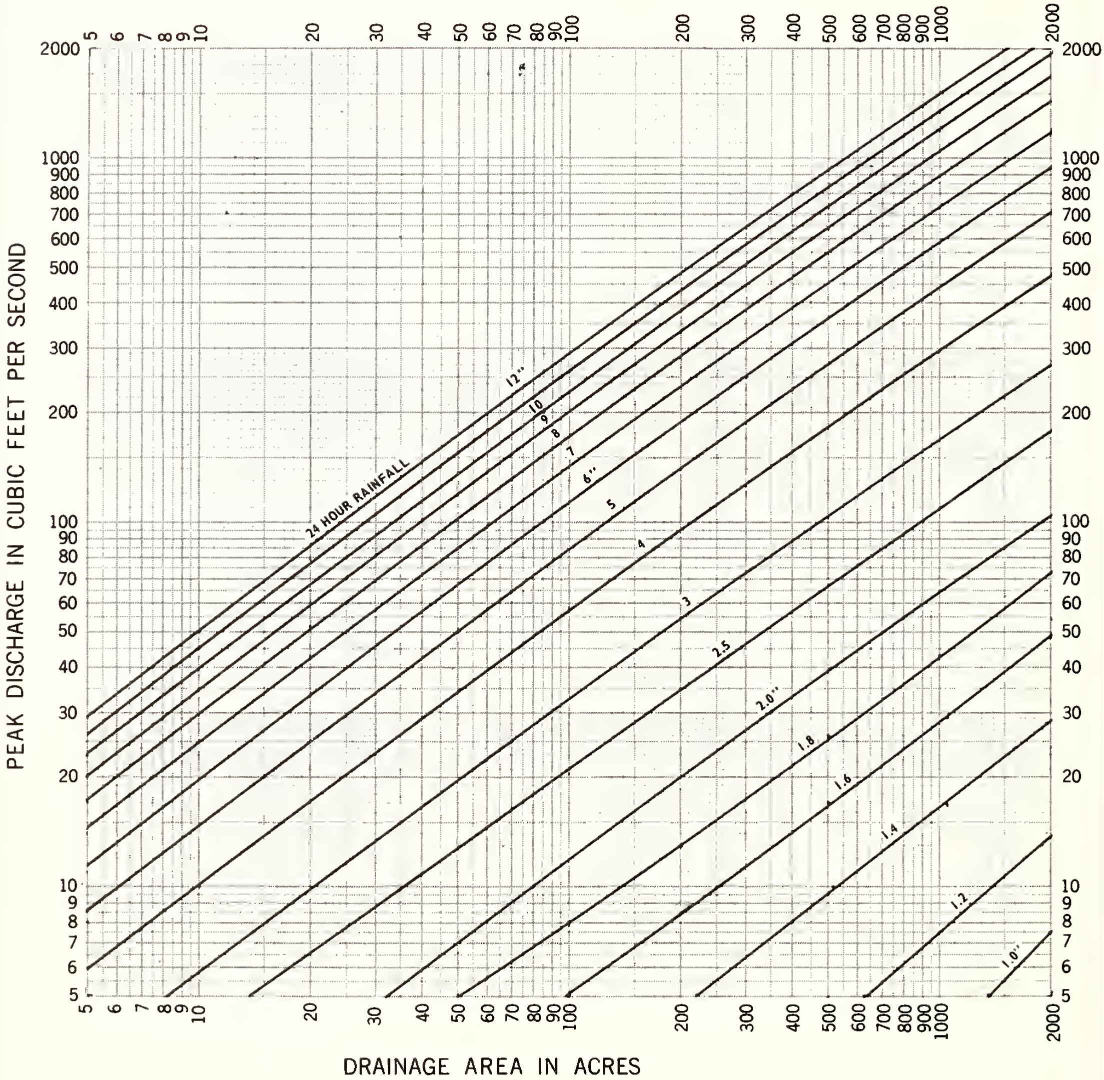


ES- 1026
SHEET 4 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - FLAT
CURVE NUMBER - 80

24 HOUR RAINFALL FROM US WB TP-40

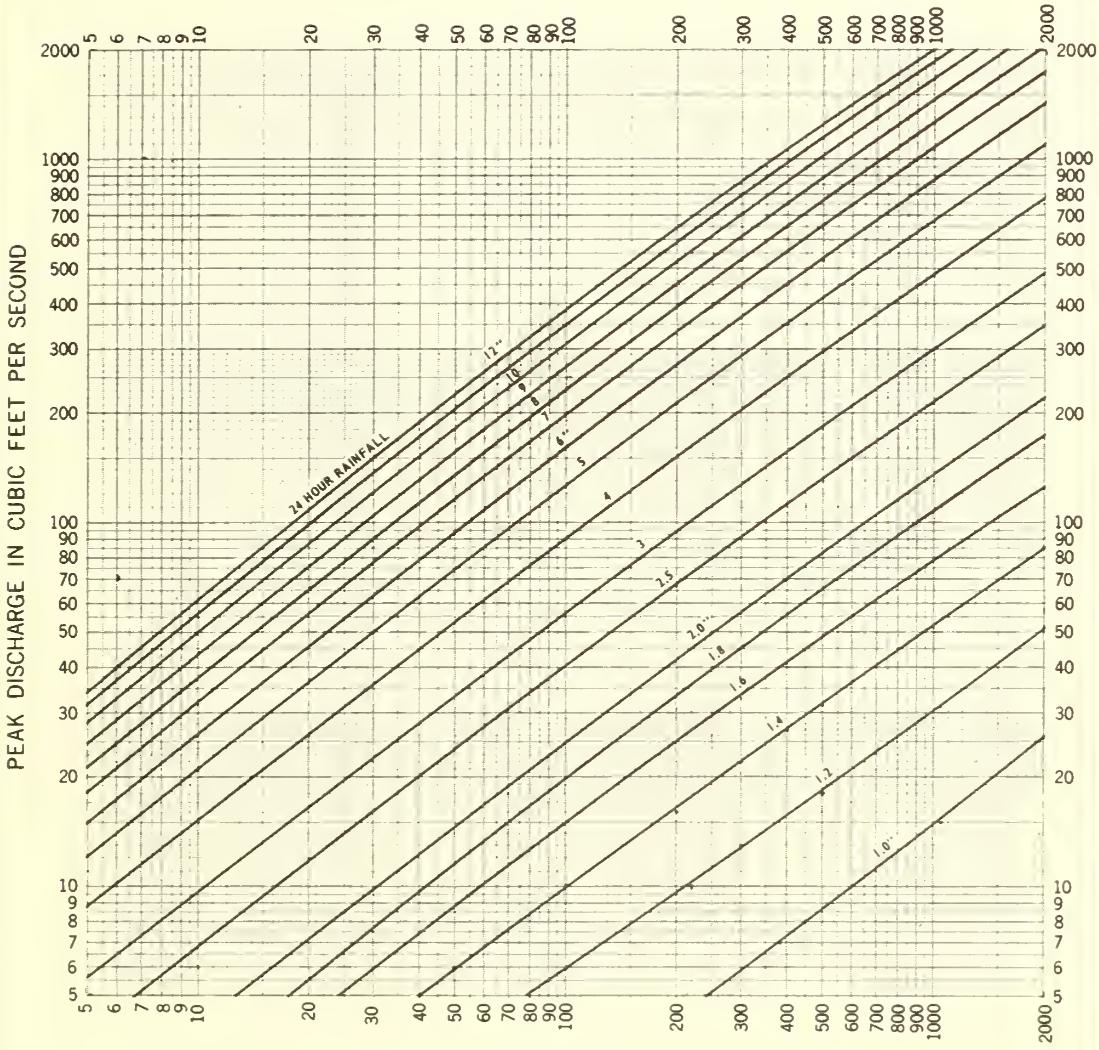


ES- 1026
SHEET 5 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - FLAT
CURVE NUMBER - 85

24 HOUR RAINFALL FROM US WB TP-40

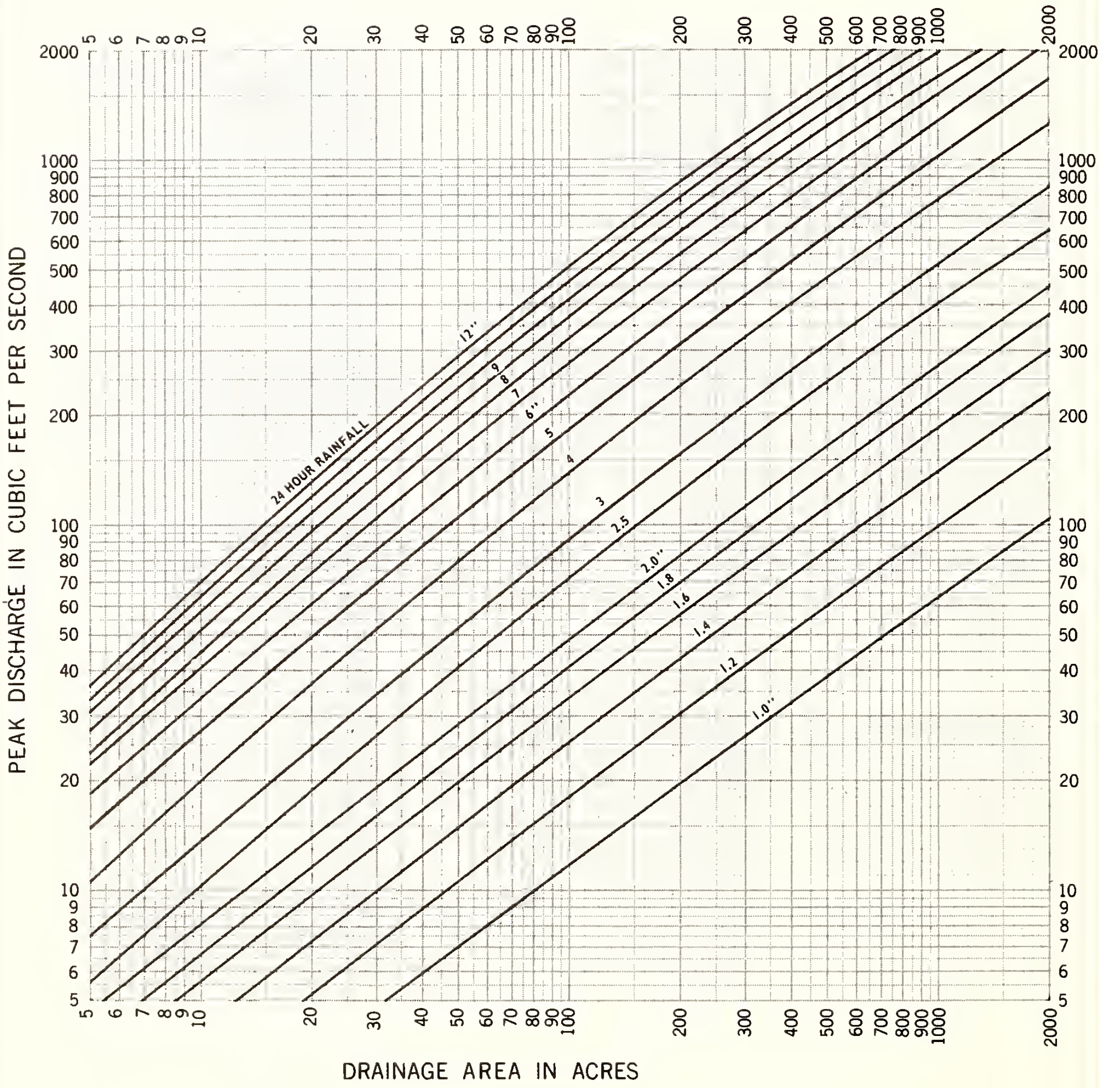


ES- 1026
SHEET 6 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - FLAT
CURVE NUMBER - 90

24 HOUR RAINFALL FROM US WB TP-40

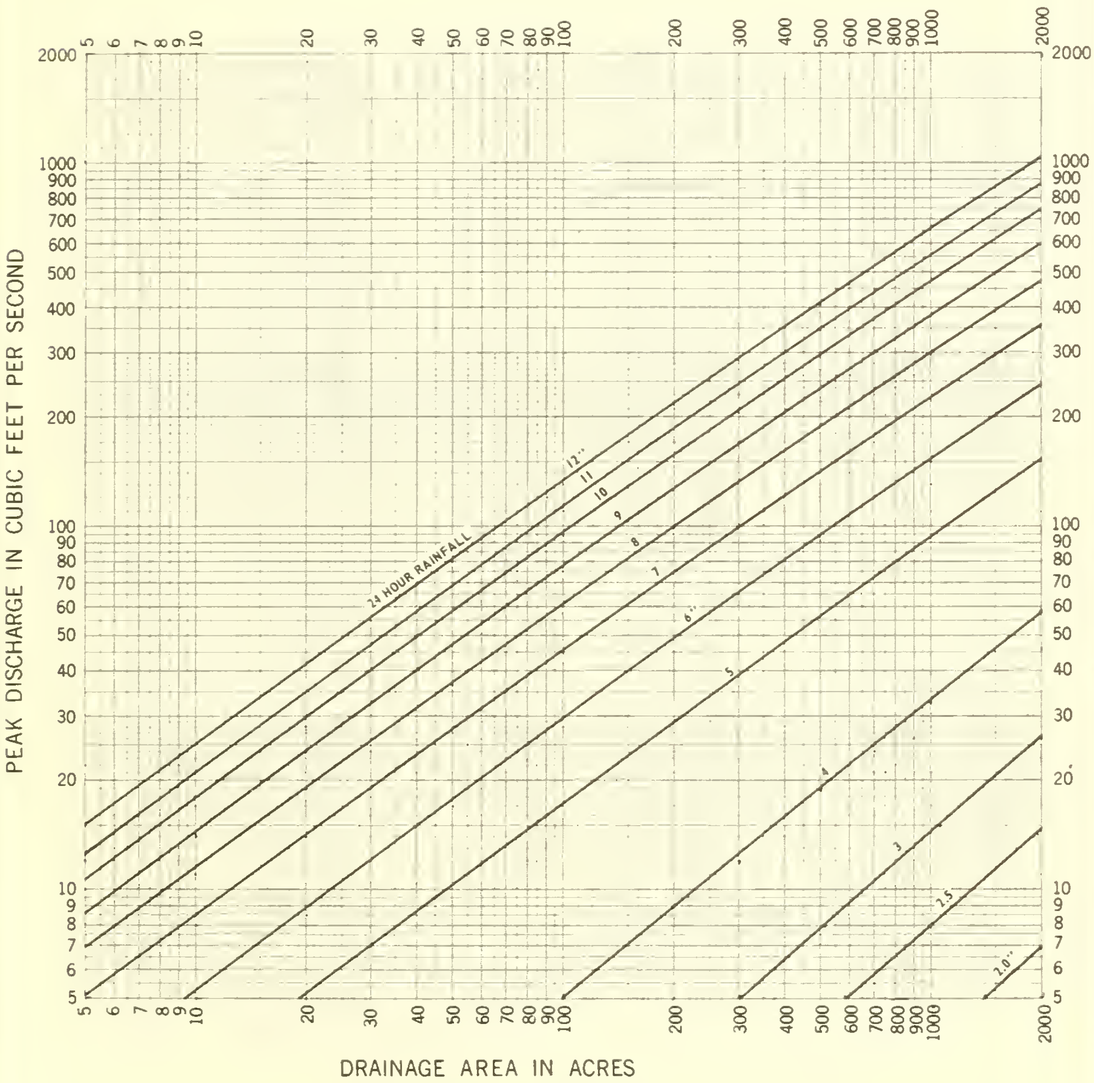


ES- 1026
SHEET 7 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - MODERATE
CURVE NUMBER - 60

24 HOUR RAINFALL FROM US WB TP-40

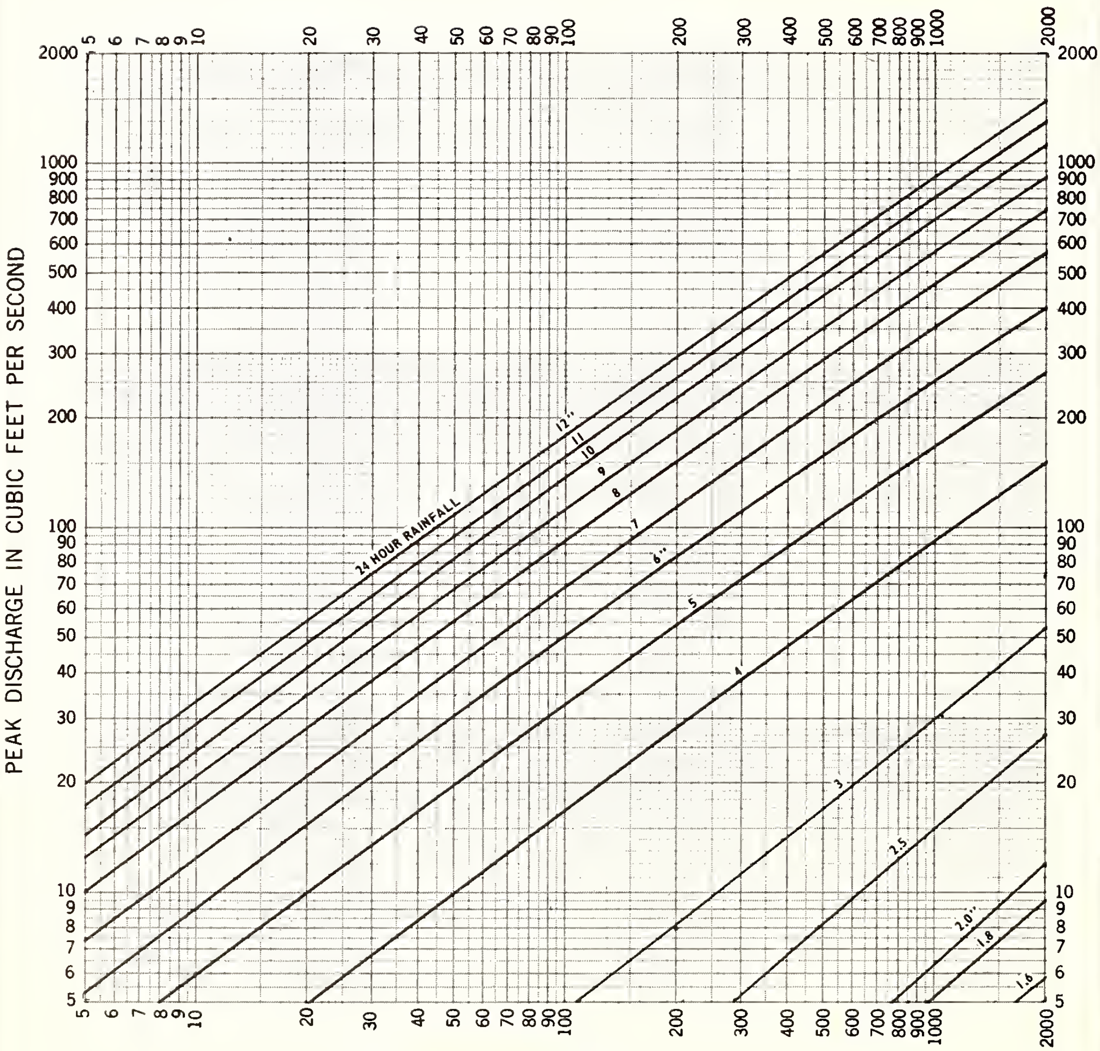


ES- 1026
SHEET 8 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - MODERATE
CURVE NUMBER - 65

24 HOUR RAINFALL FROM US WB TP-40

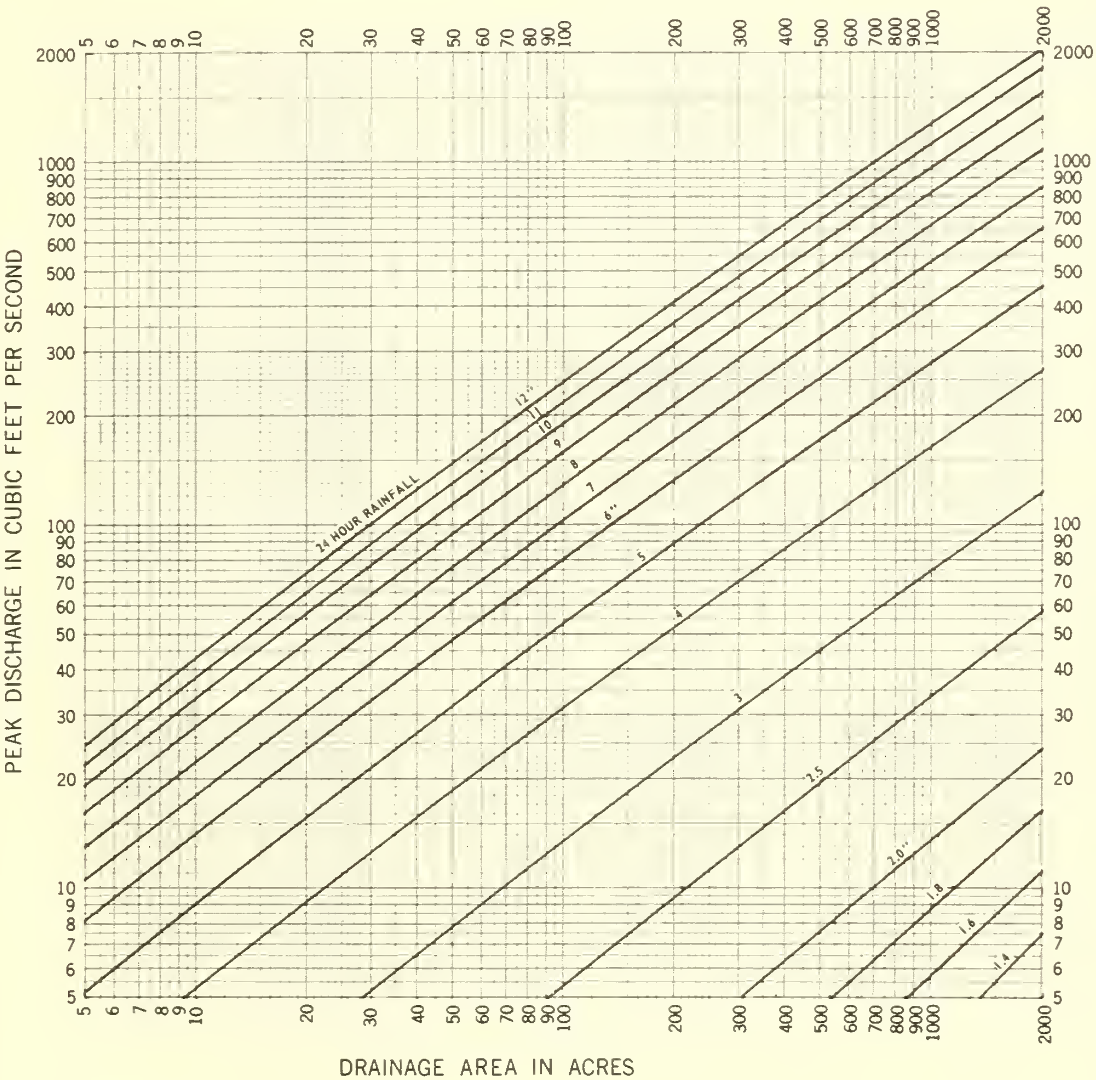


ES- 1026
SHEET 9 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - MODERATE
CURVE NUMBER - 70

24 HOUR RAINFALL FROM US WB TP-40

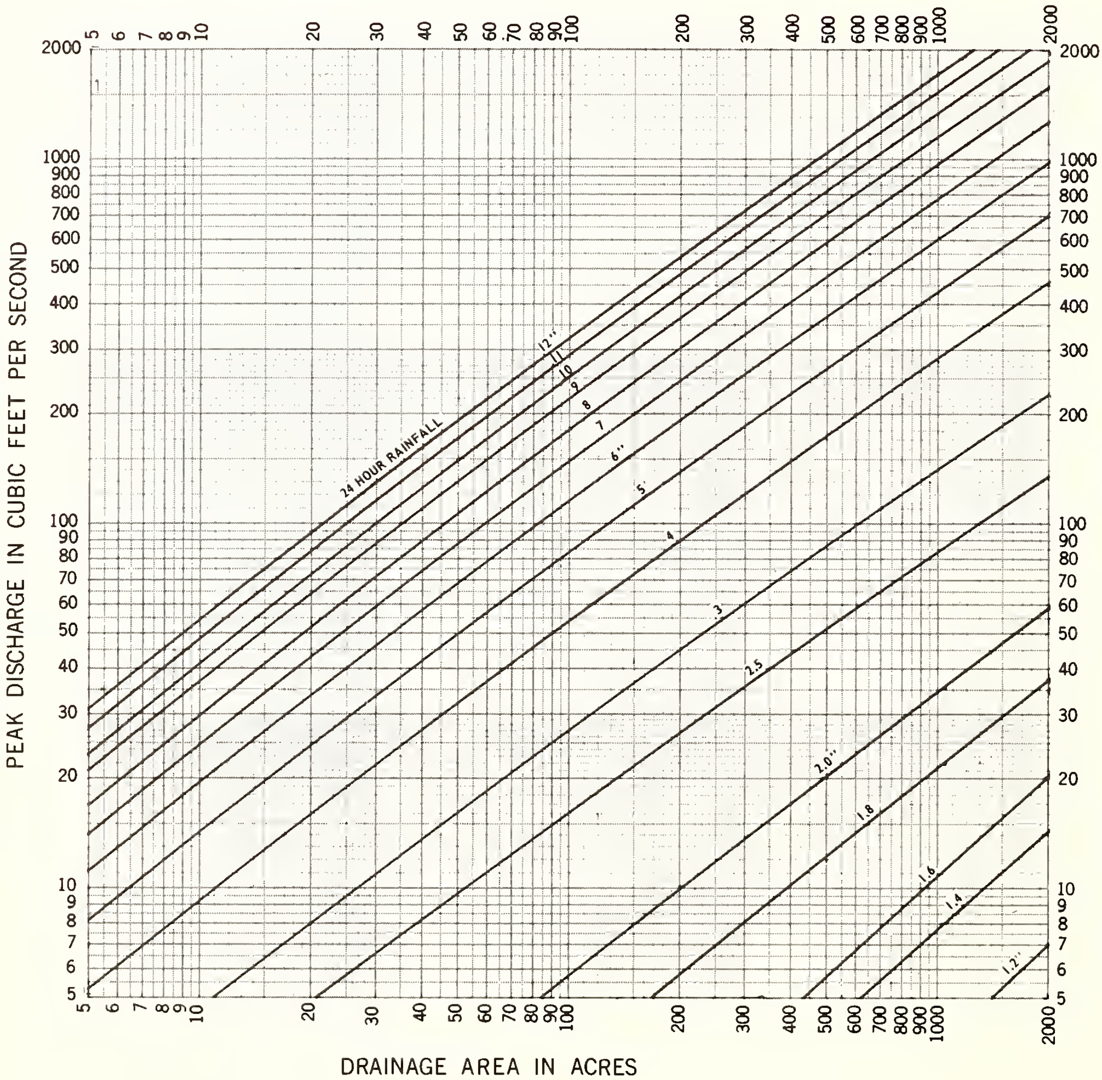


ES- 1026
SHEET 10 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - MODERATE
CURVE NUMBER - 75

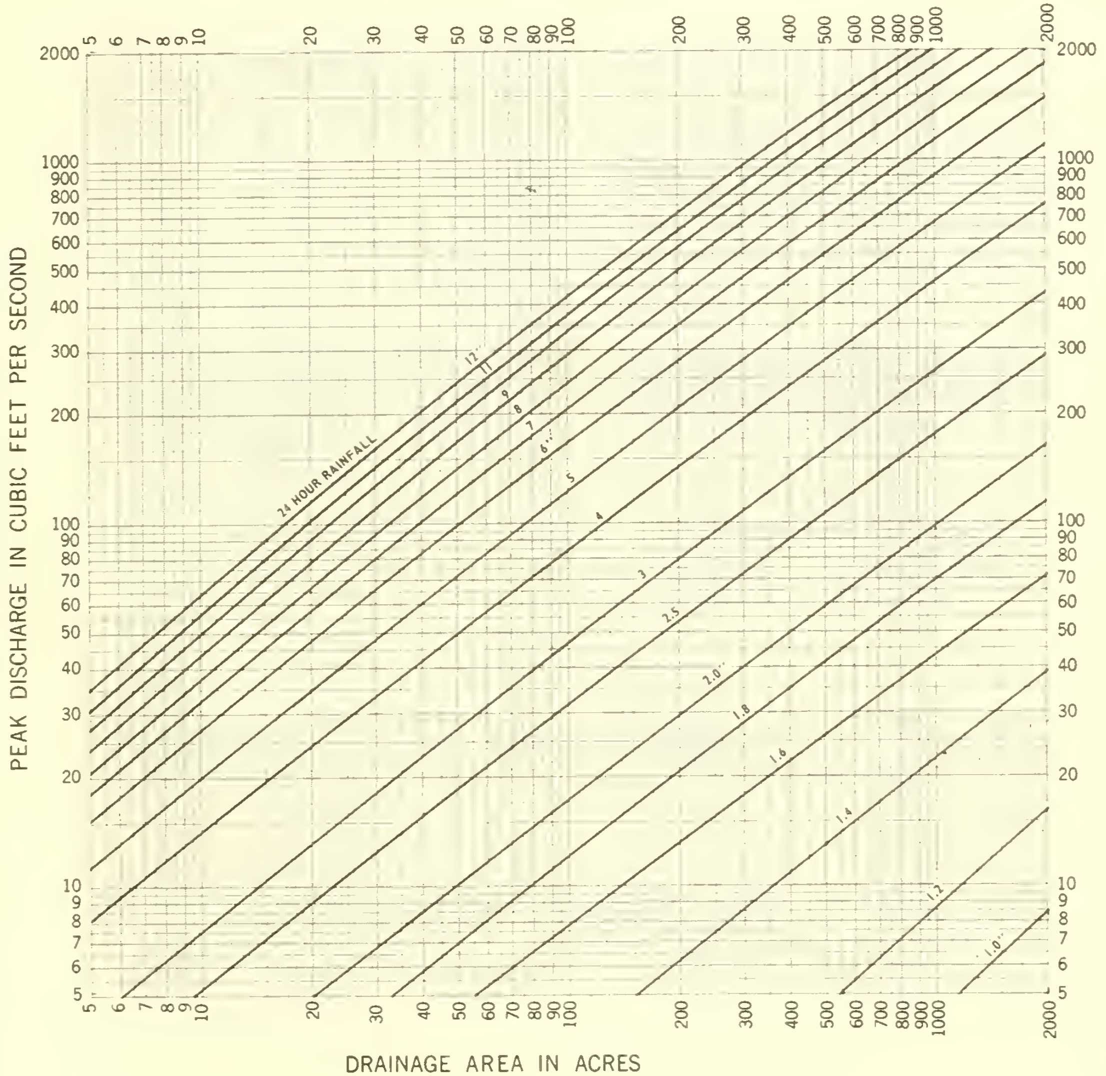
24 HOUR RAINFALL FROM US WB TP-40



PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - MODERATE
CURVE NUMBER - 80

24 HOUR RAINFALL FROM US WB TP-40

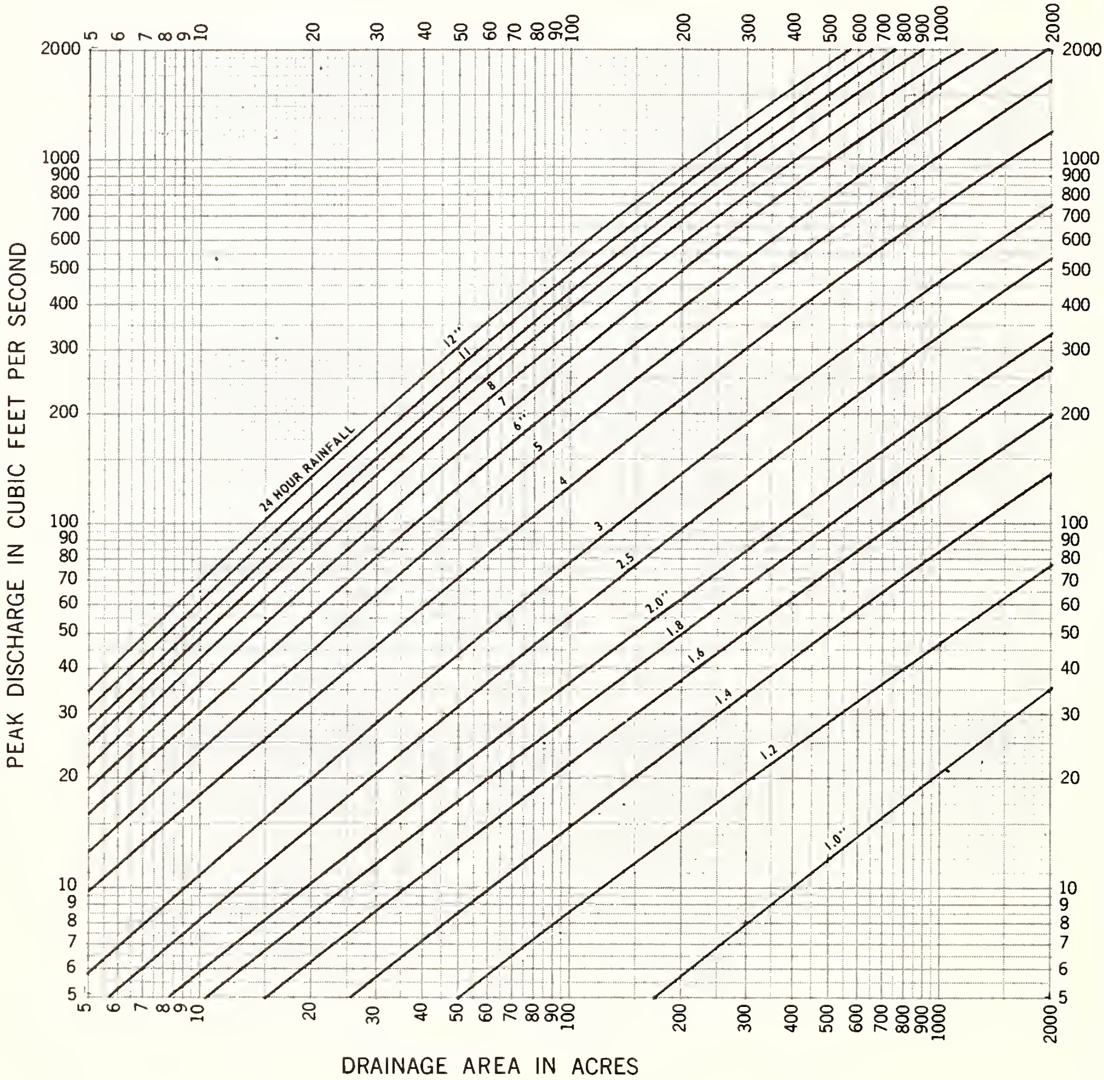


ES- 1026
SHEET 12 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - MODERATE
CURVE NUMBER - 85

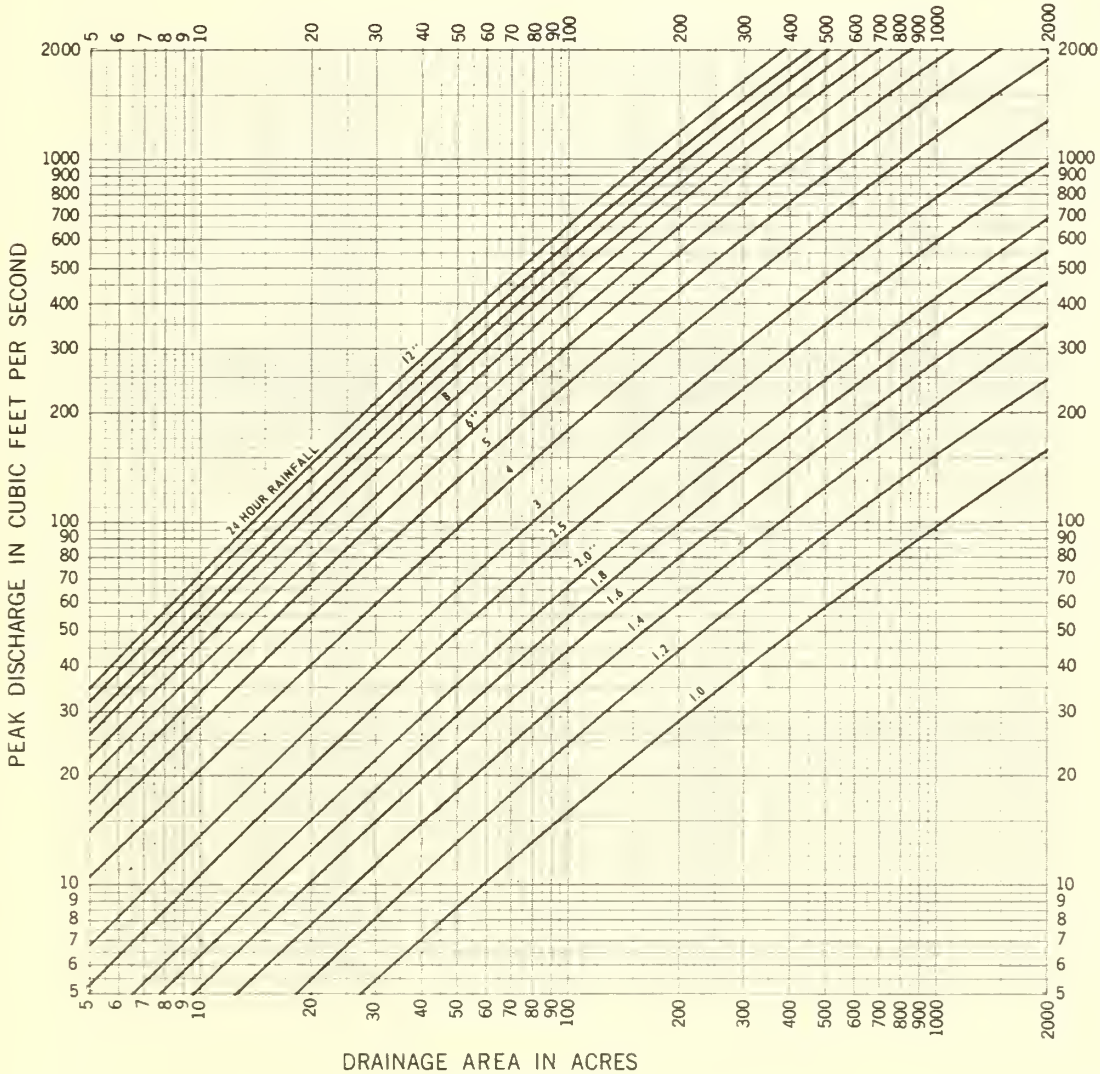
24 HOUR RAINFALL FROM US WB TP-40



PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPFS - MODERATE
CURVE NUMBER - 90

24 HOUR RAINFALL FROM US WB TP-40

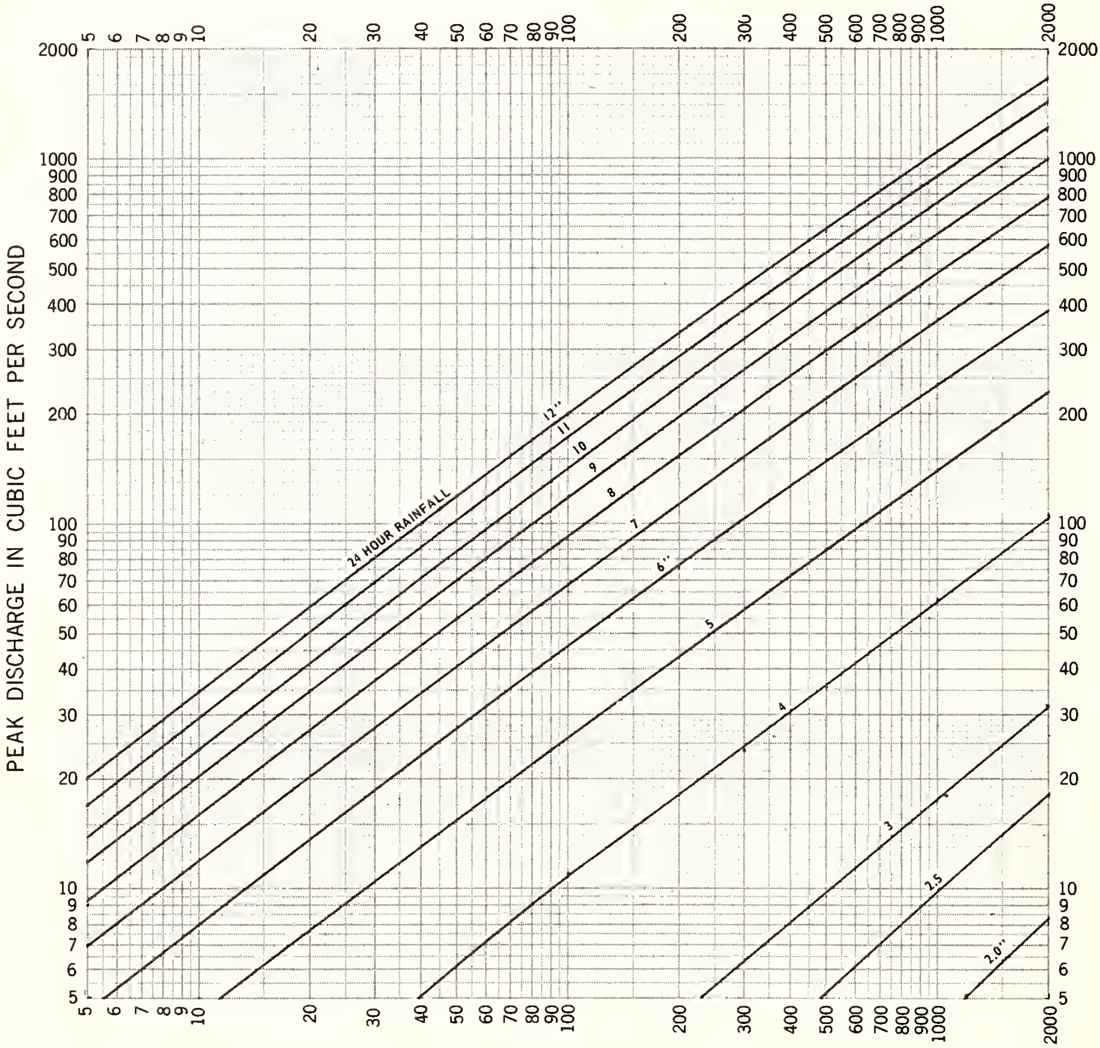


ES- 1026
SHEET 14 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - STEEP
CURVE NUMBER - 60

24 HOUR RAINFALL FROM US WB TP-40

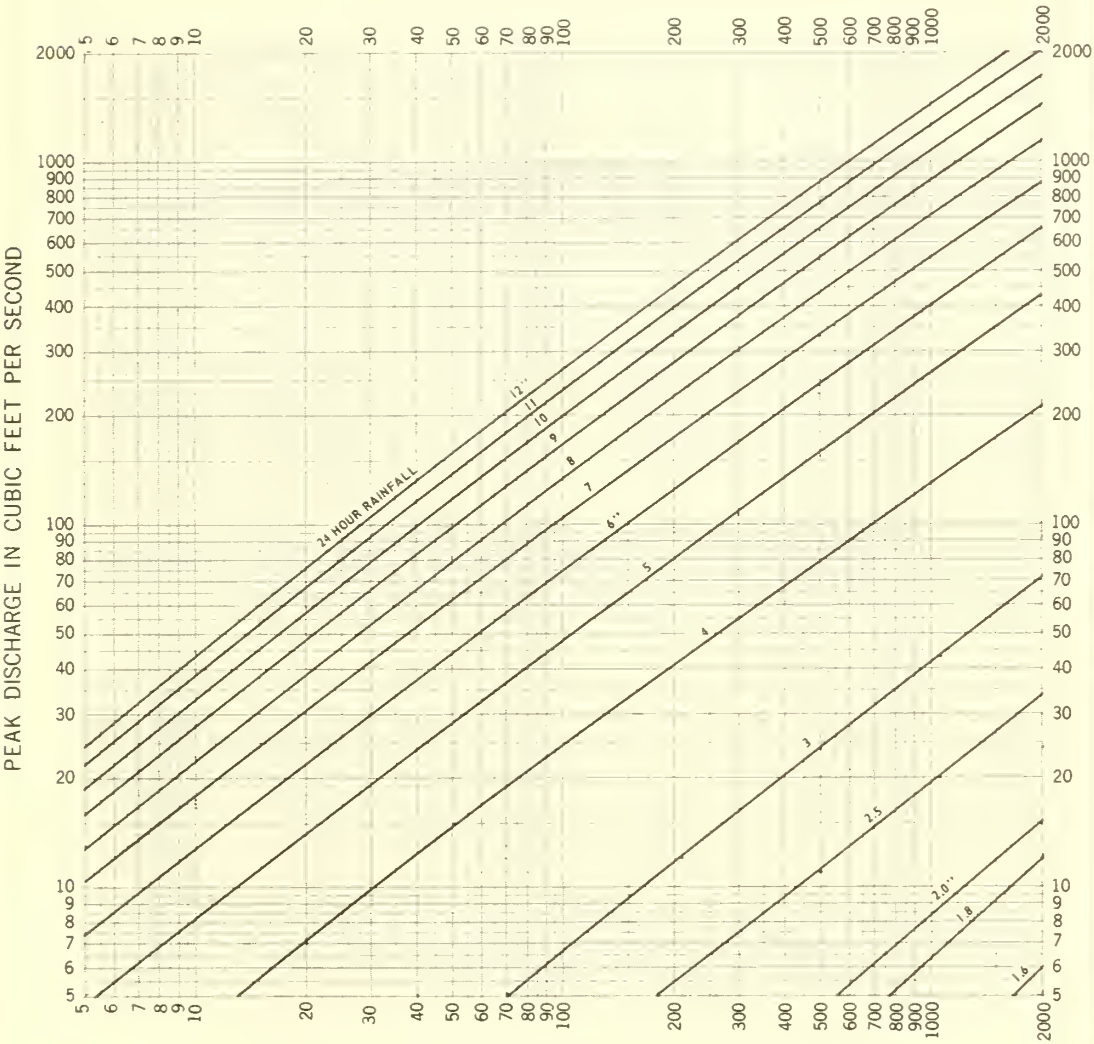


ES- 1026
SHEET 15 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - STEEP
CURVE NUMBER - 65

24 HOUR RAINFALL FROM US WB TP-40

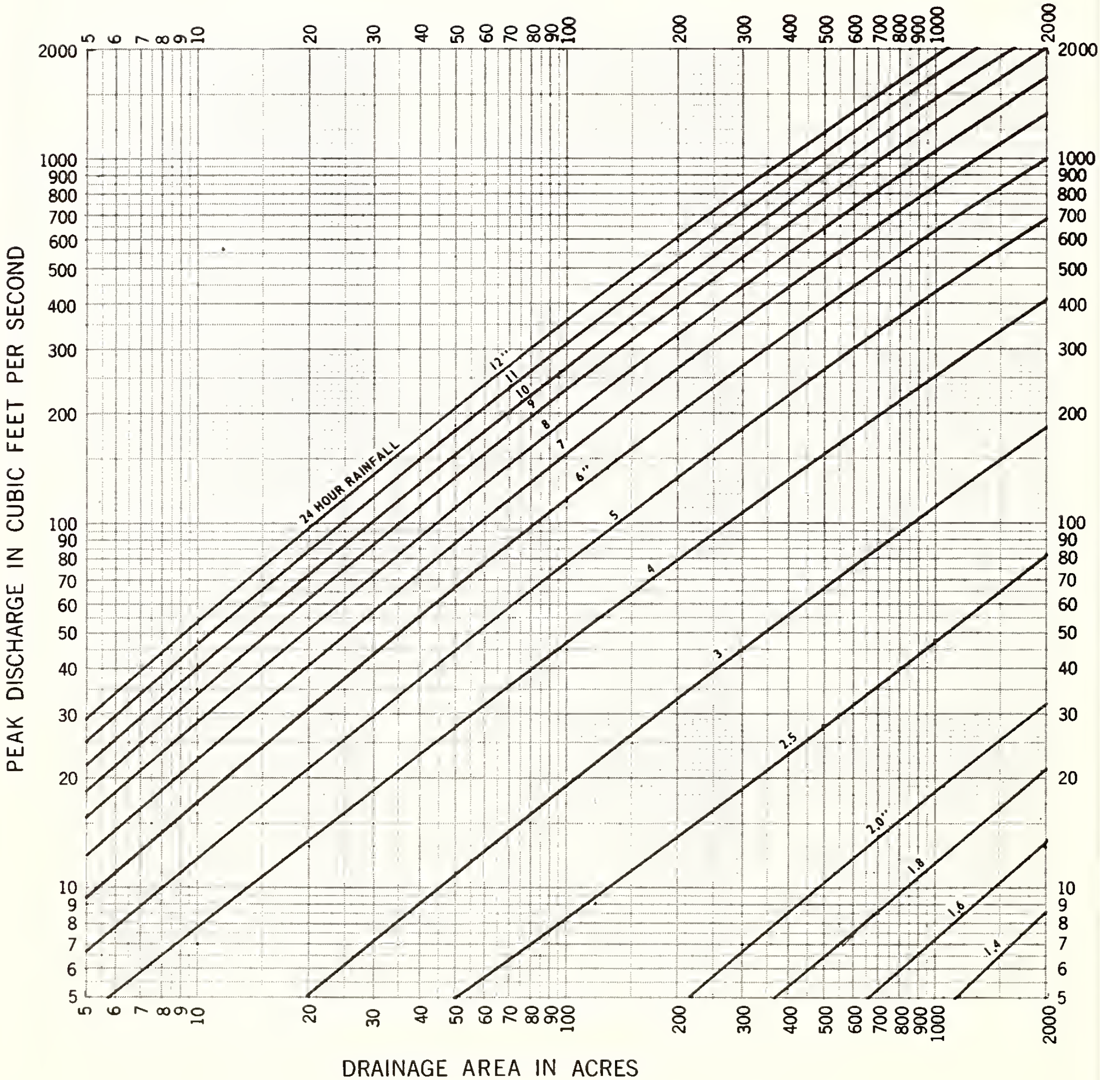


ES- 1026
SHEET 16 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - STEEP
CURVE NUMBER - 70

24 HOUR RAINFALL FROM US WB TP-40

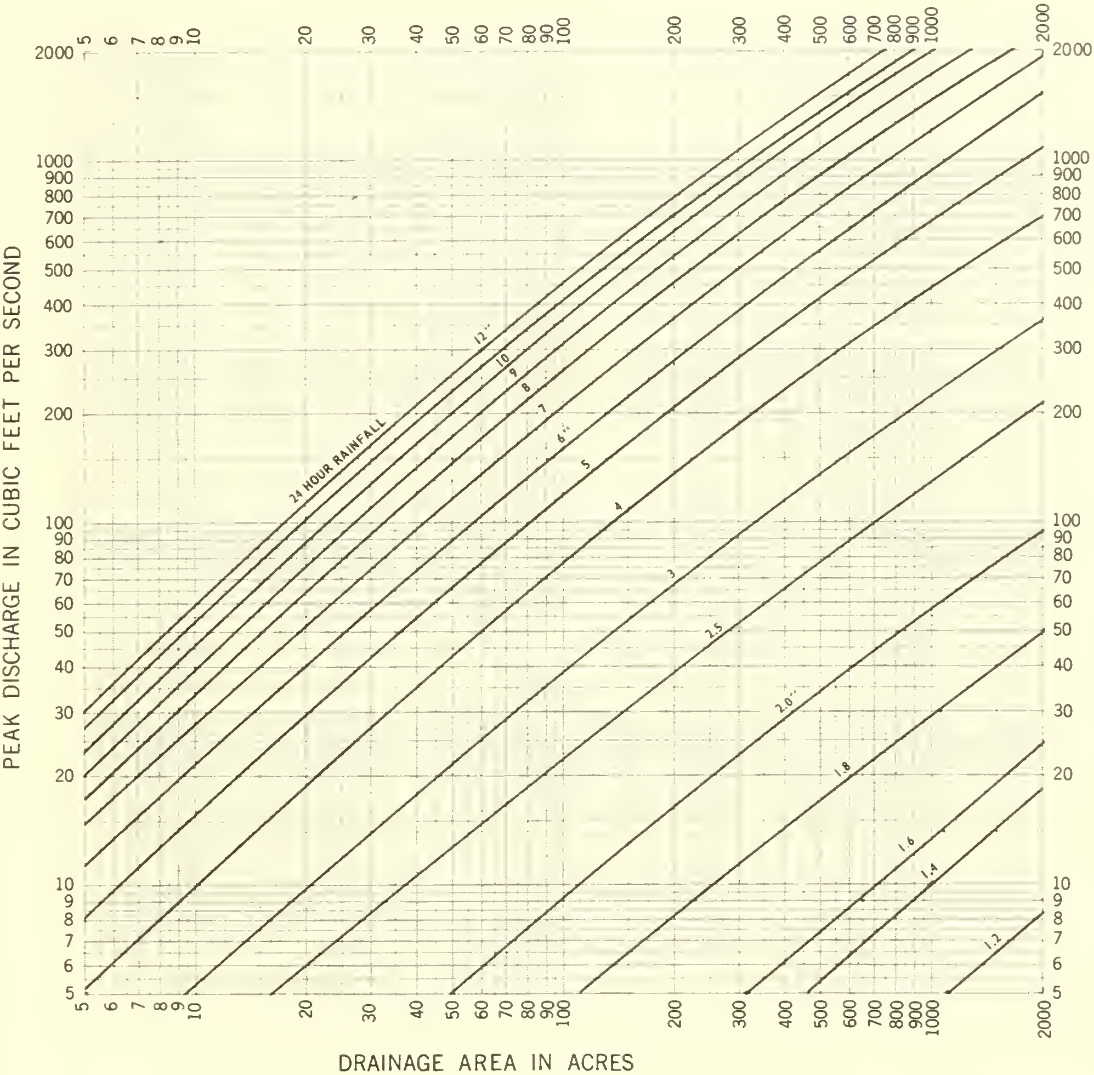


ES- 1026
SHEET 17 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - STEEP
CURVE NUMBER - 75

24 HOUR RAINFALL FROM US WB TP-40



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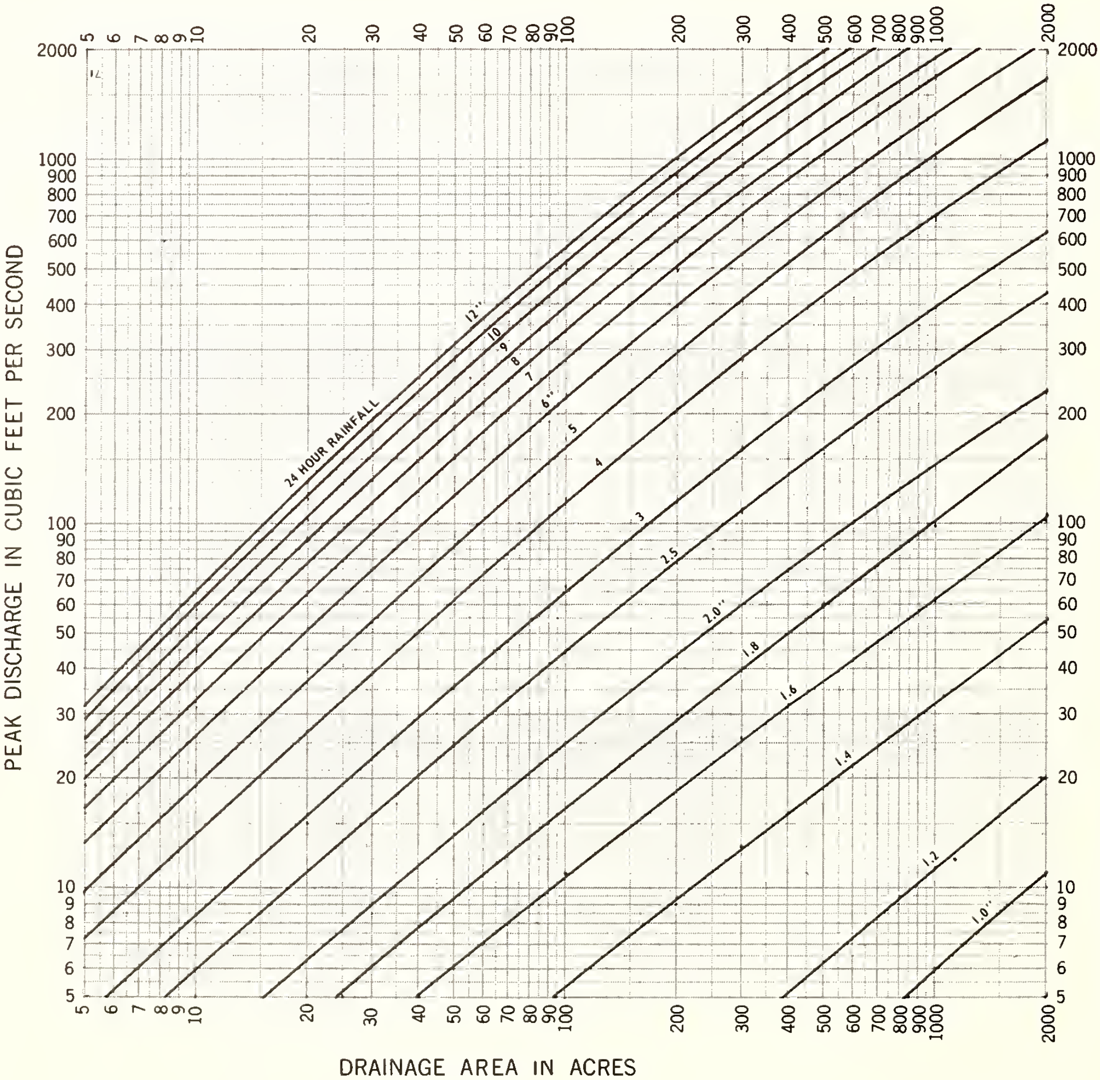
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - STEEP
CURVE NUMBER - 80

24 HOUR RAINFALL FROM US WB TP-40



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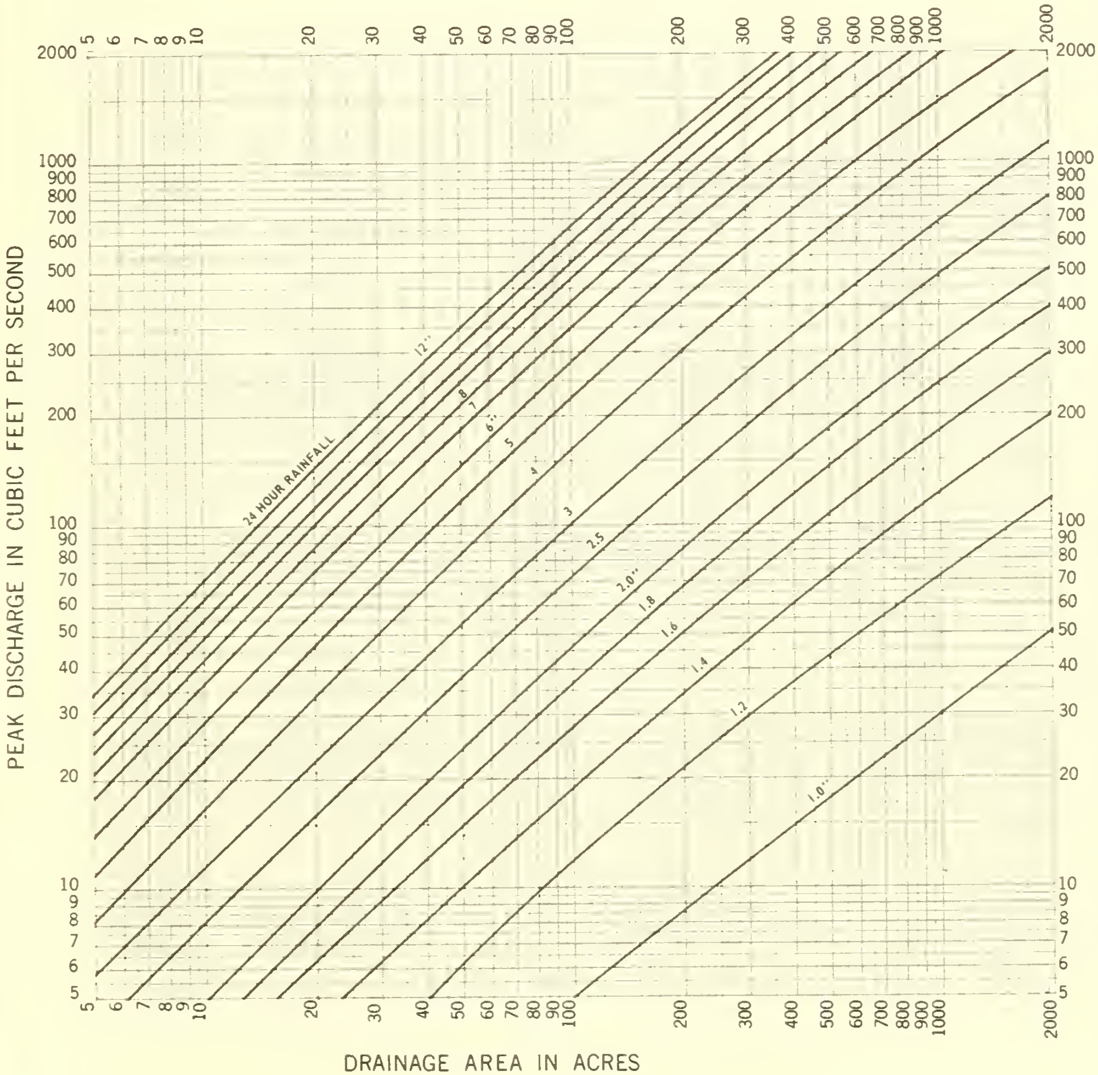
SHEET 19 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - STEEP
CURVE NUMBER - 85

24 HOUR RAINFALL FROM US WB TP-40



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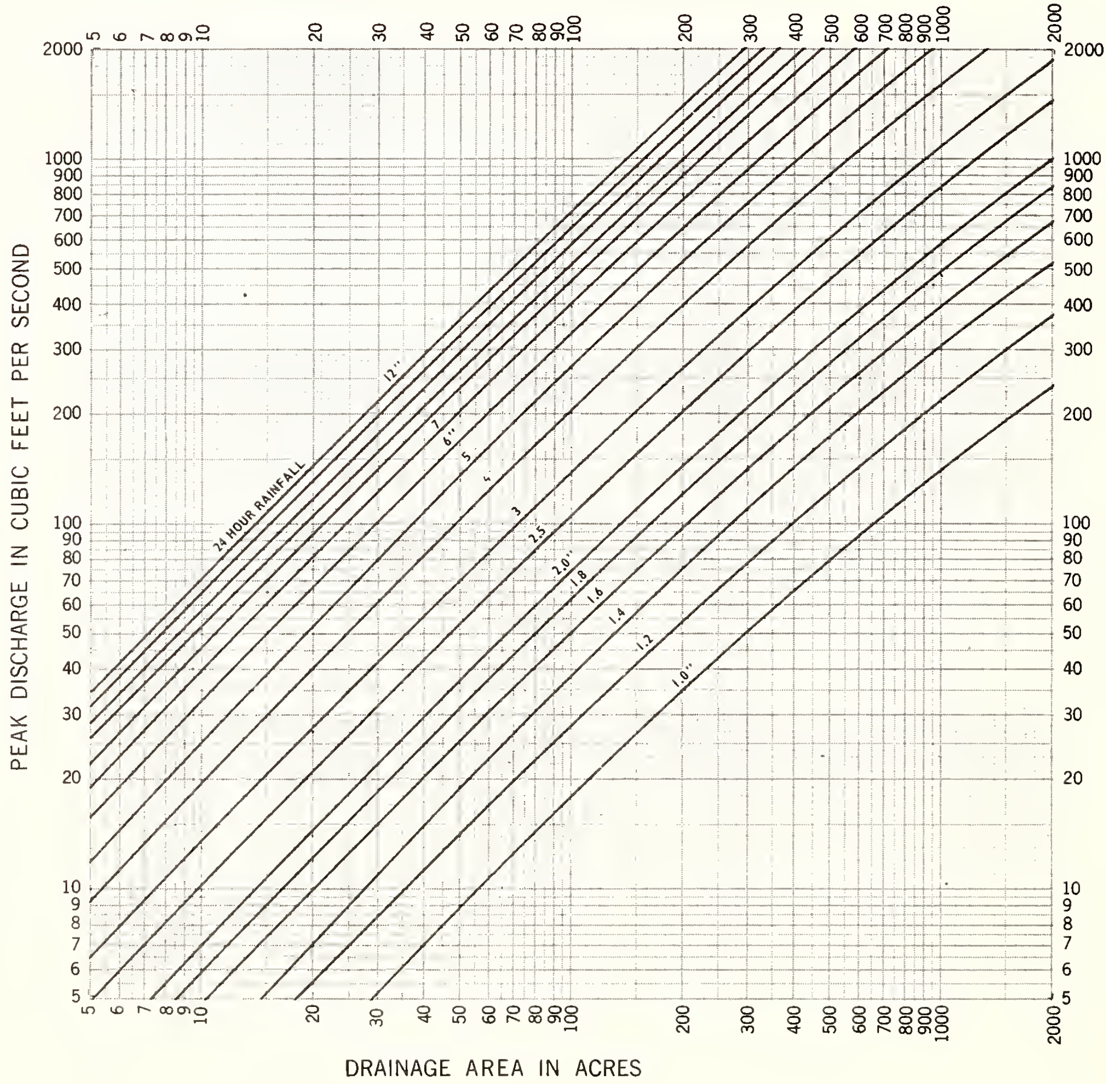
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPES - STEEP
CURVE NUMBER - 90

24 HOUR RAINFALL FROM US WB TP-40



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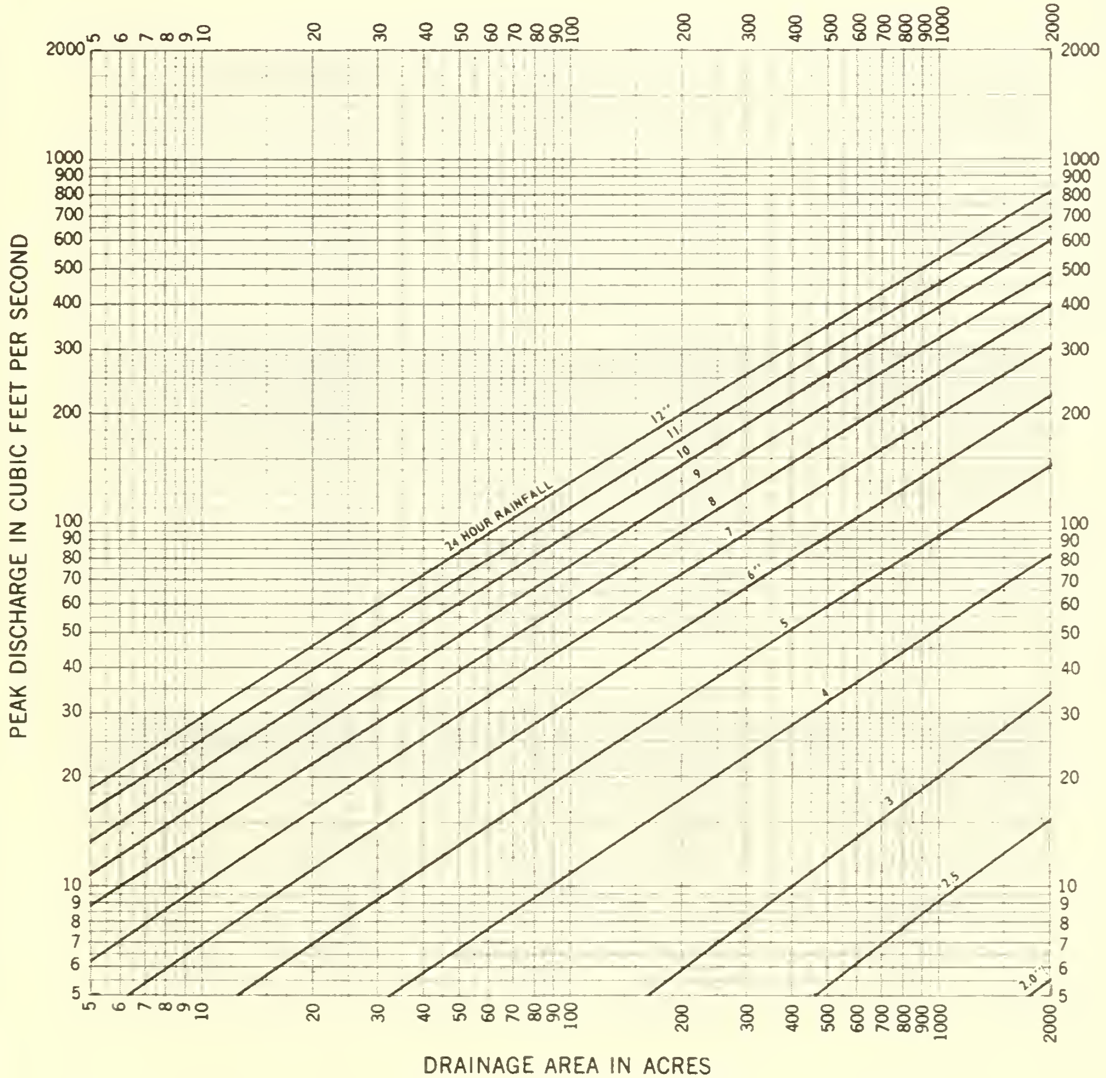
SHEET 21 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - FLAT
CURVE NUMBER - 60

24 HOUR RAINFALL FROM US WB TP-40



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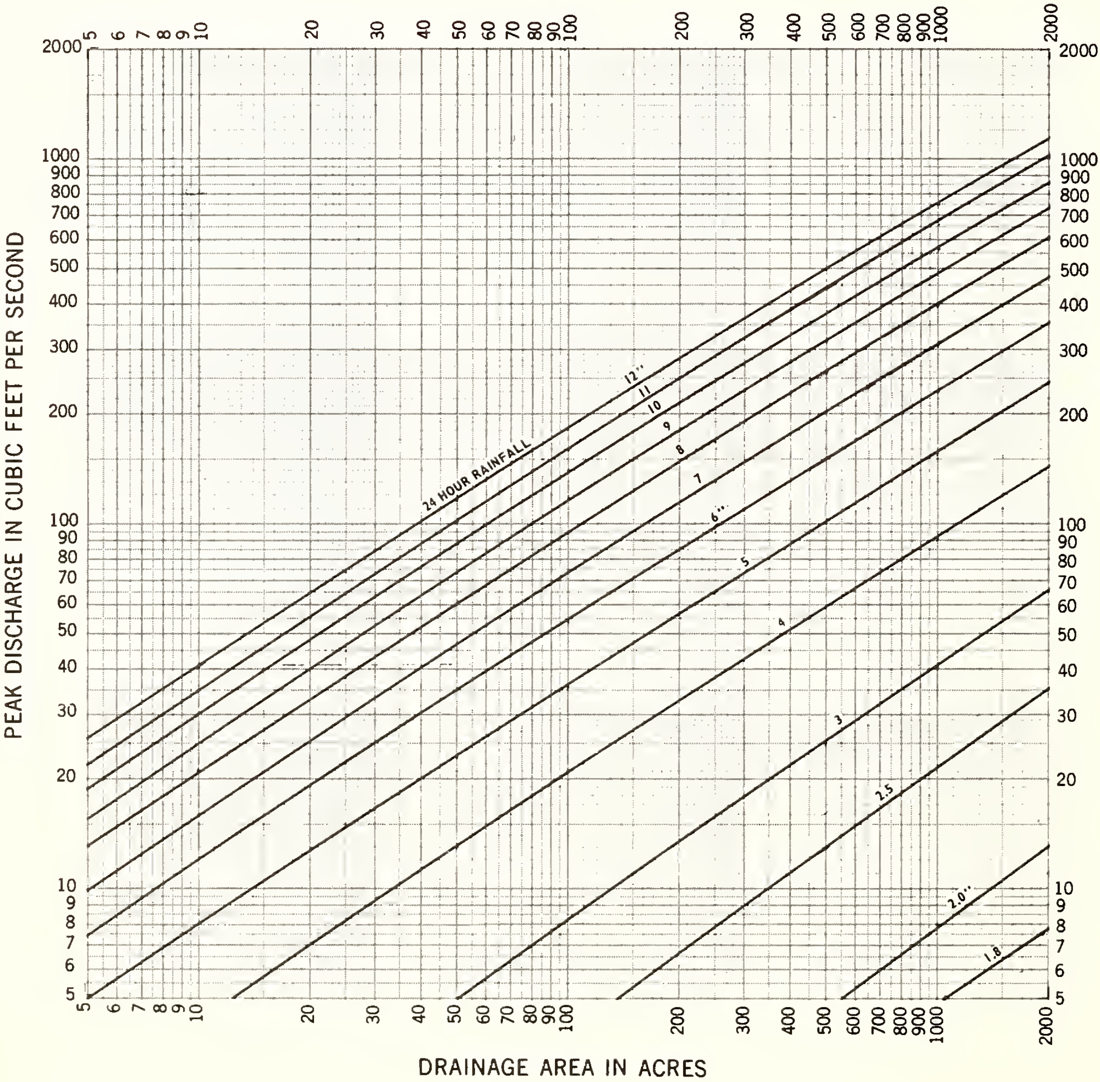
SHEET 1 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - FLAT
CURVE NUMBER 65

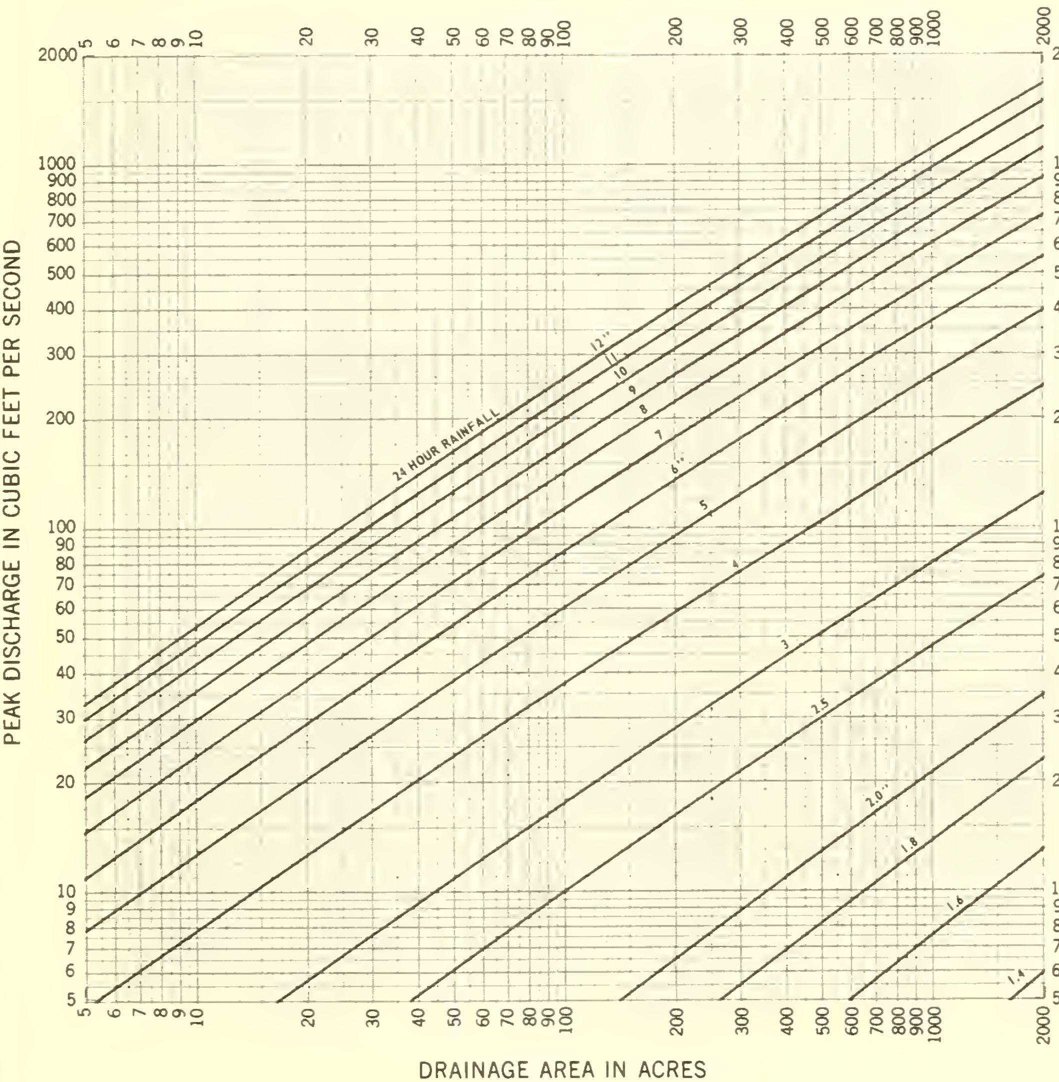
24 HOUR RAINFALL FROM US WB TP-40



PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - FLAT
CURVE NUMBER - 70

24 HOUR RAINFALL FROM US WB TP-40



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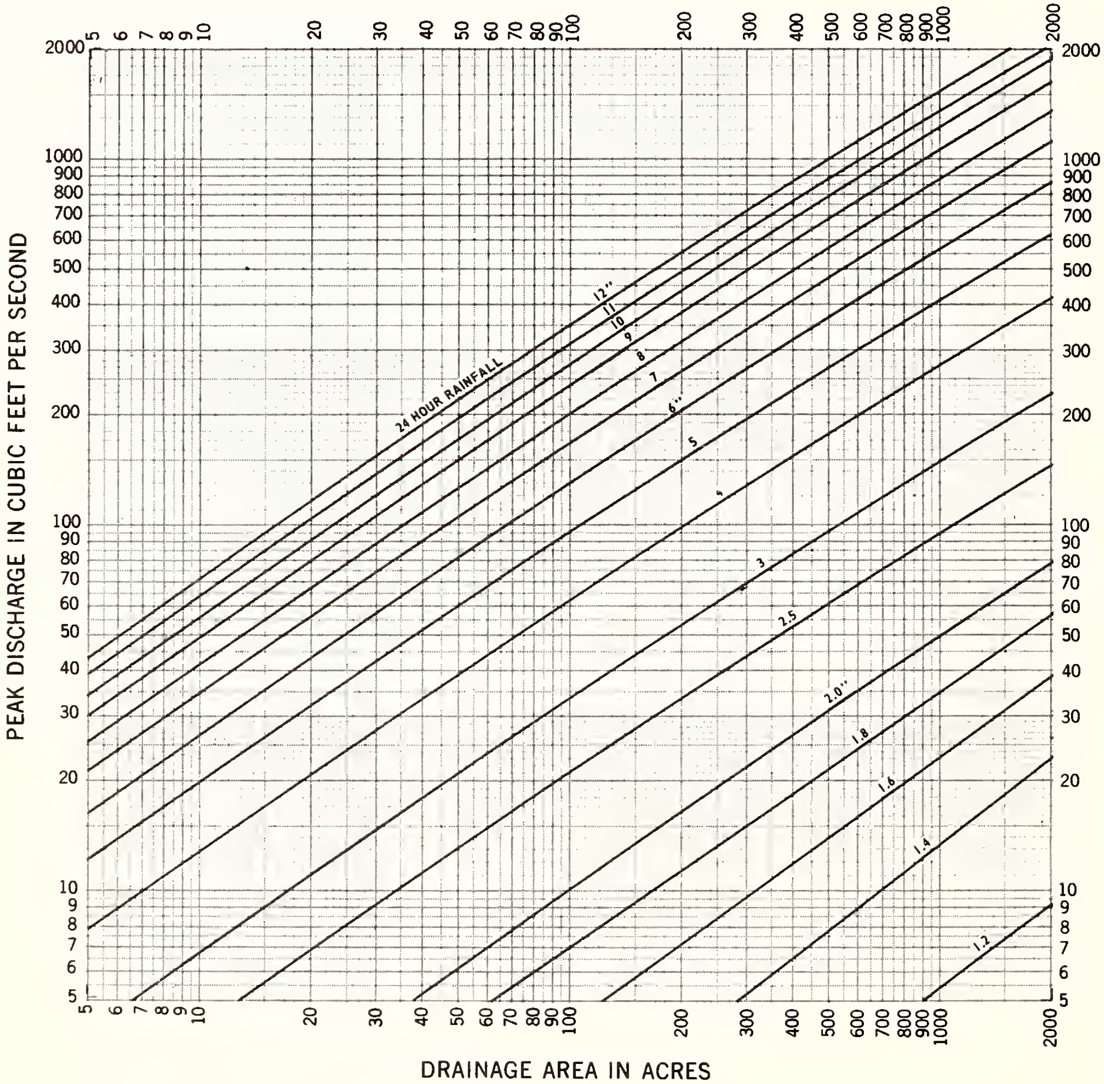
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - FLAT
CURVE NUMBER - 75

24 HOUR RAINFALL FROM US WB TP-40



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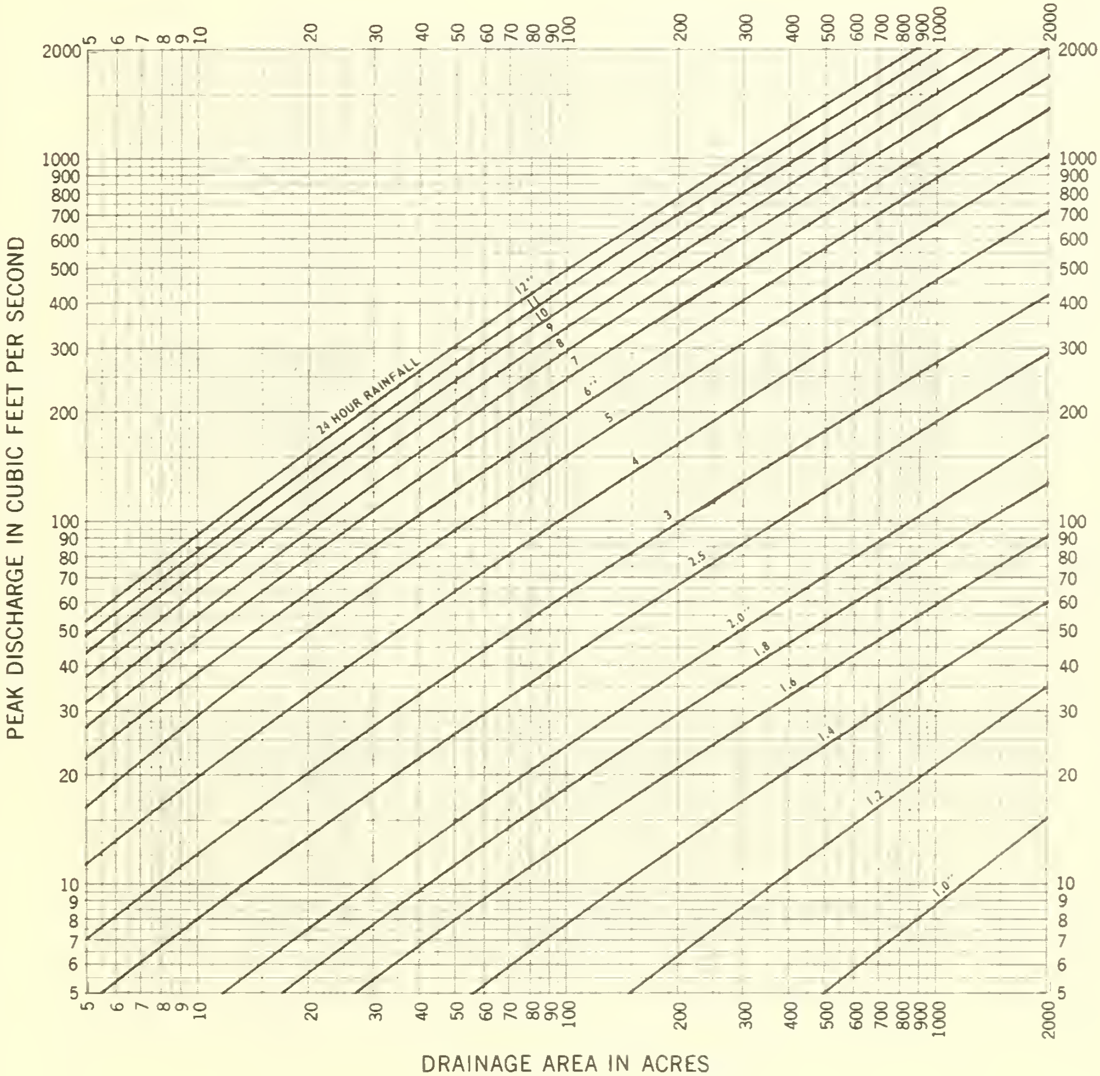
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES – FLAT
CURVE NUMBER – 80

24 HOUR RAINFALL FROM US WB TP-40



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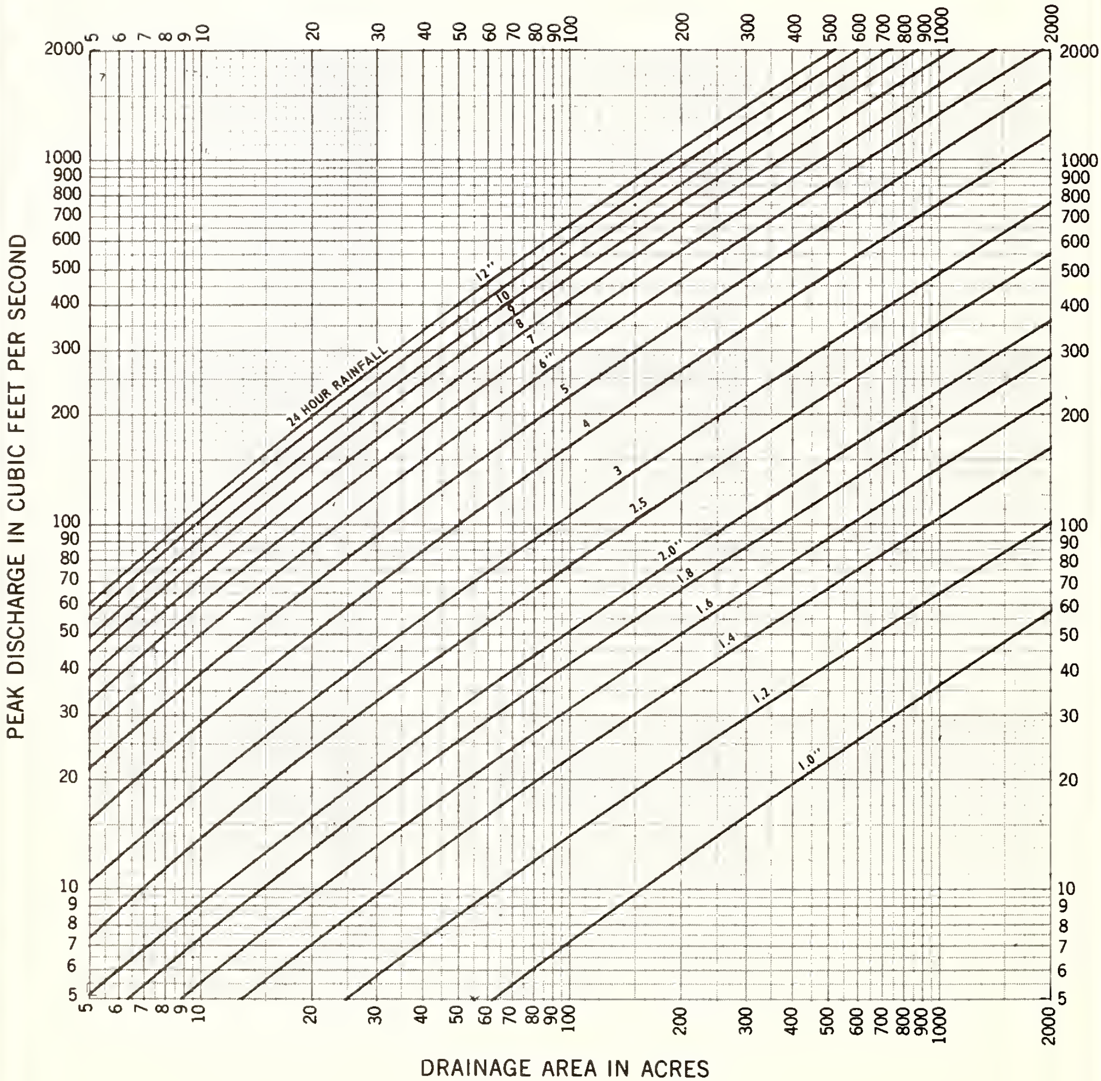
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - FLAT
CURVE NUMBER - 85

24 HOUR RAINFALL FROM US WB TP-40



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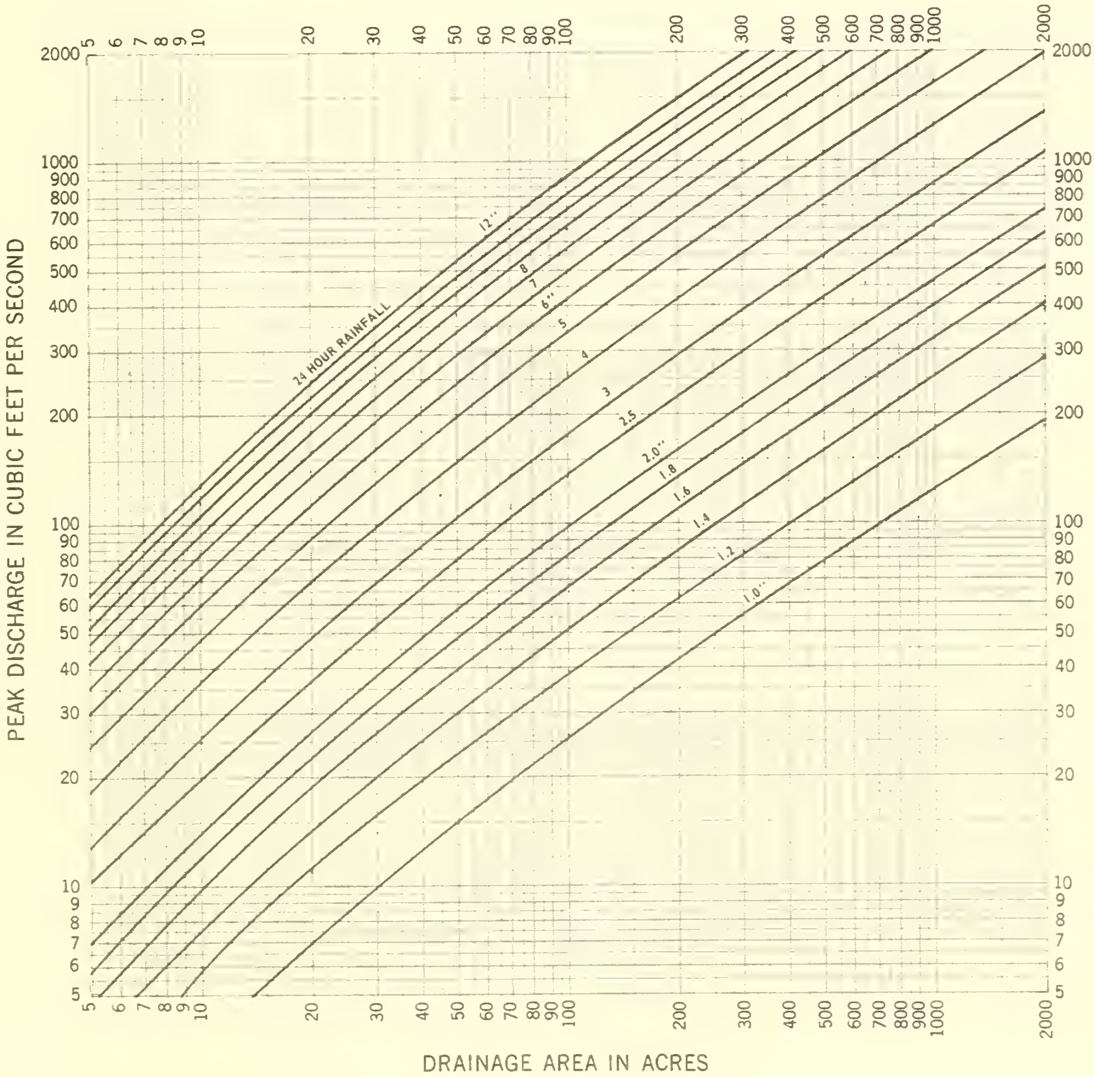
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - FLAT
CURVE NUMBER - 90

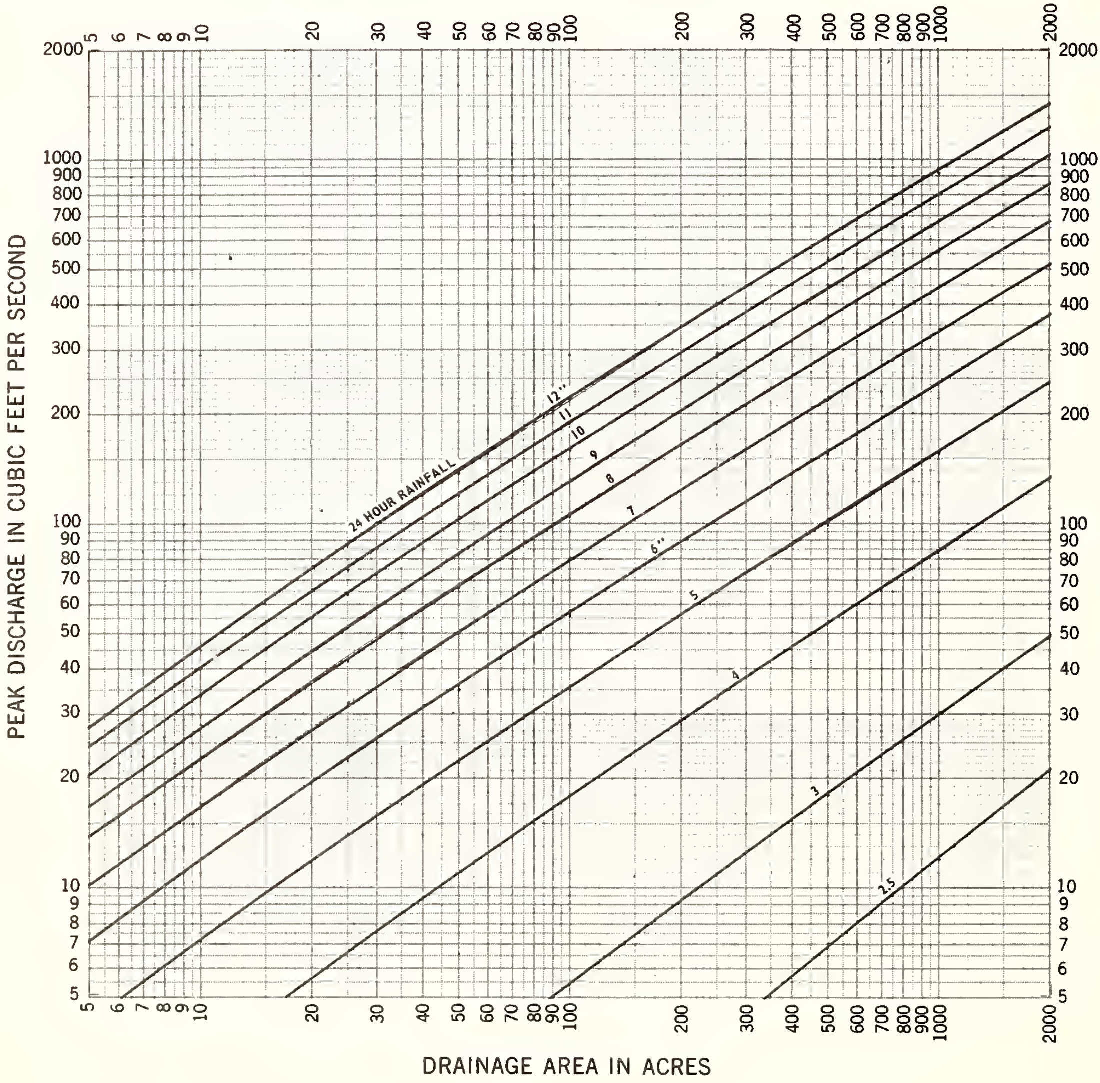
24 HOUR RAINFALL FROM US WB TP-40



PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - MODERATE
CURVE NUMBER - 60

24 HOUR RAINFALL FROM US WB TP-40



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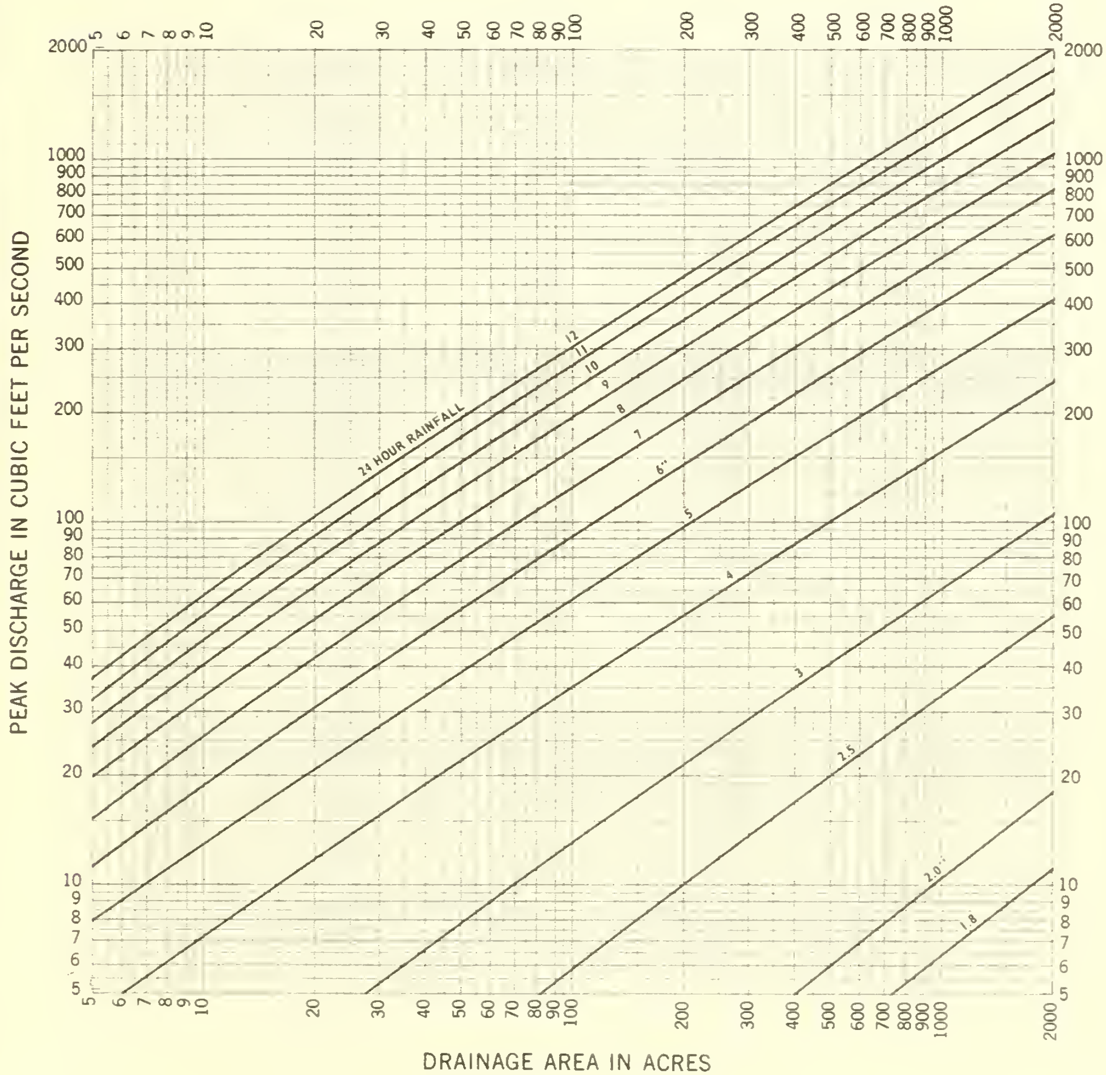
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - MODERATE

CURVE NUMBER - 65

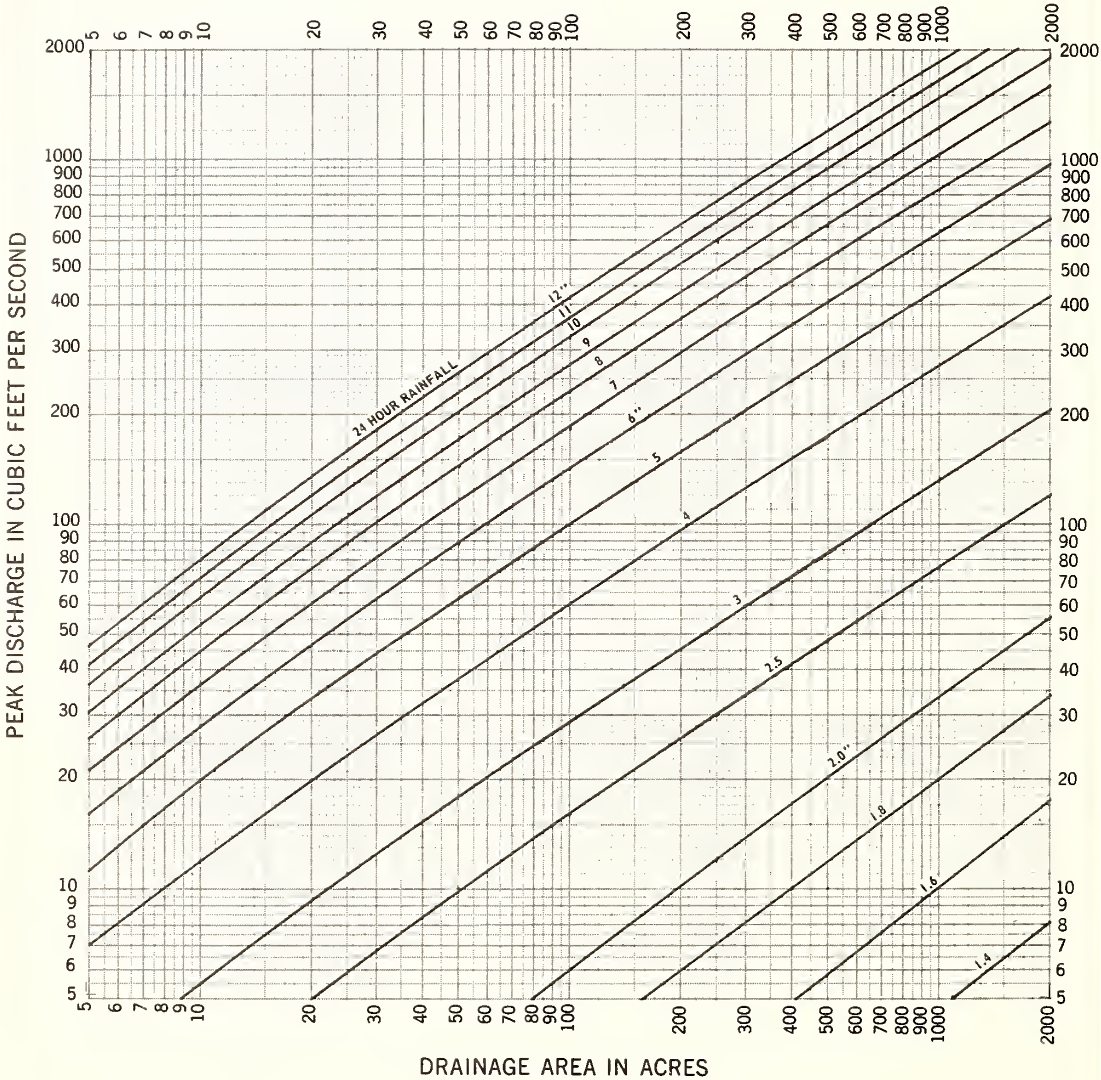
24 HOUR RAINFALL FROM US WB TP-40



PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - MODERATE
CURVE NUMBER - 70

24 HOUR RAINFALL FROM US WB TP-40



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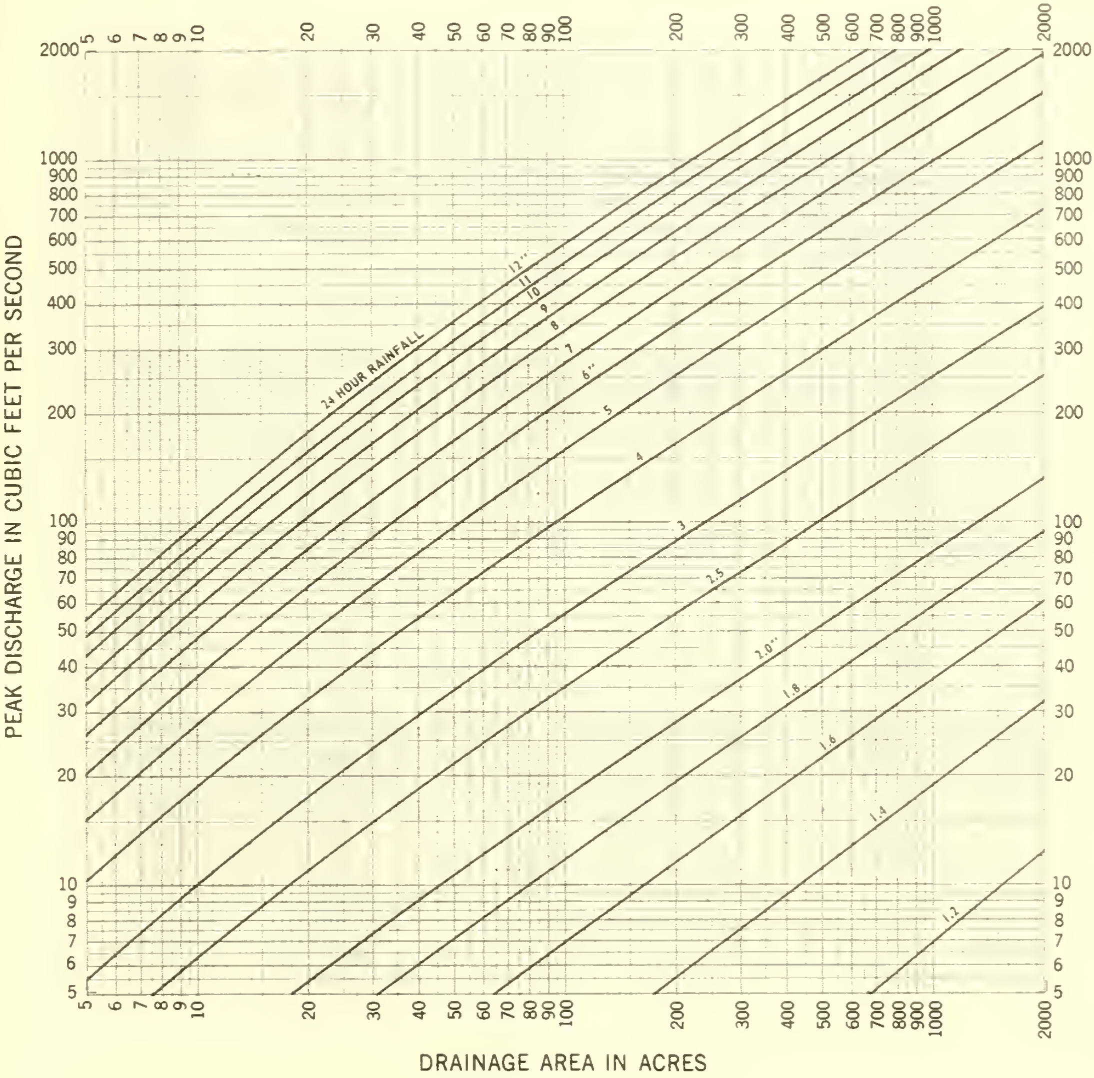
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - MODERATE
CURVE NUMBER - 75

24 HOUR RAINFALL FROM US WB TP-40



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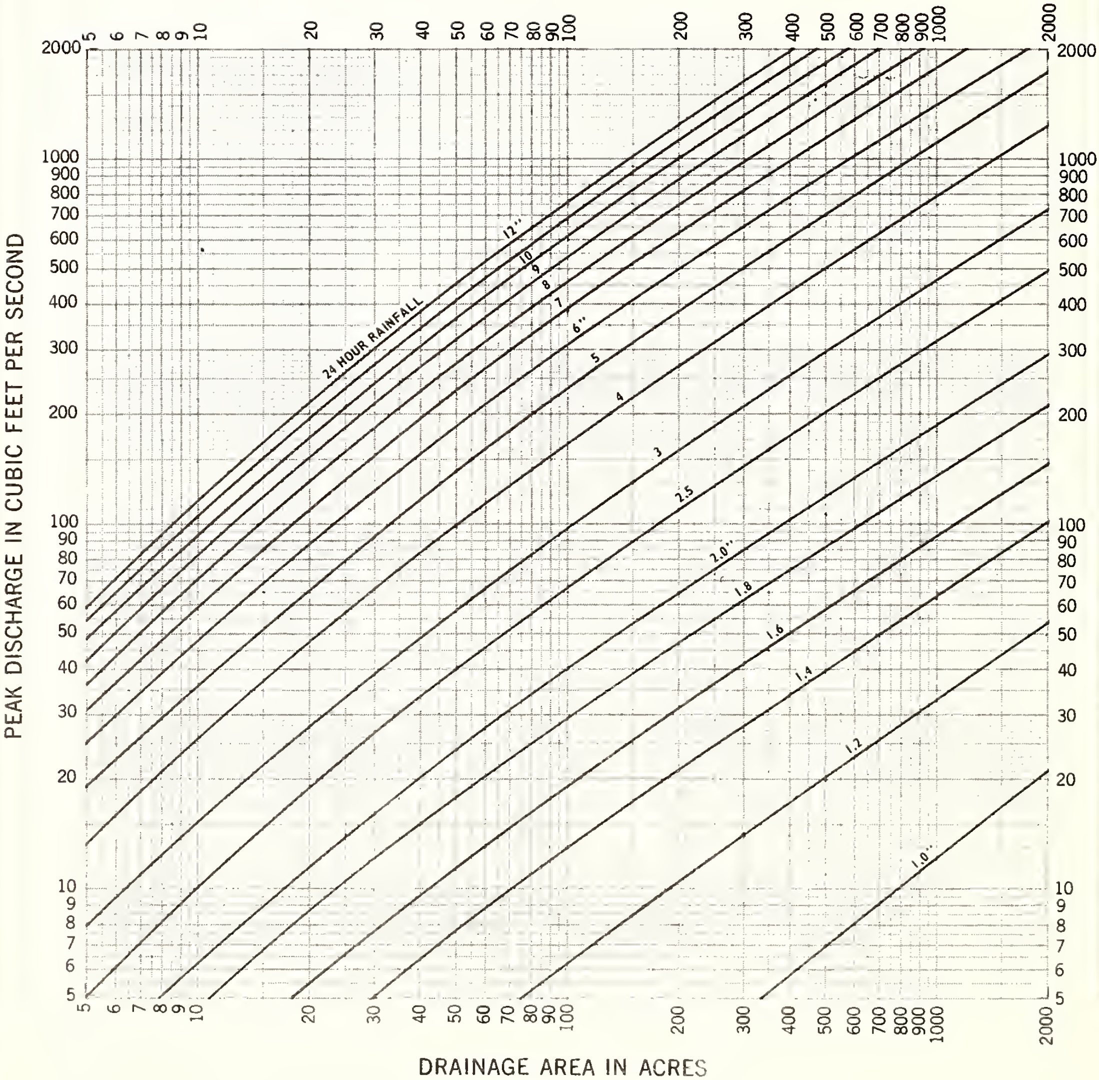
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - MODERATE
CURVE NUMBER - 80

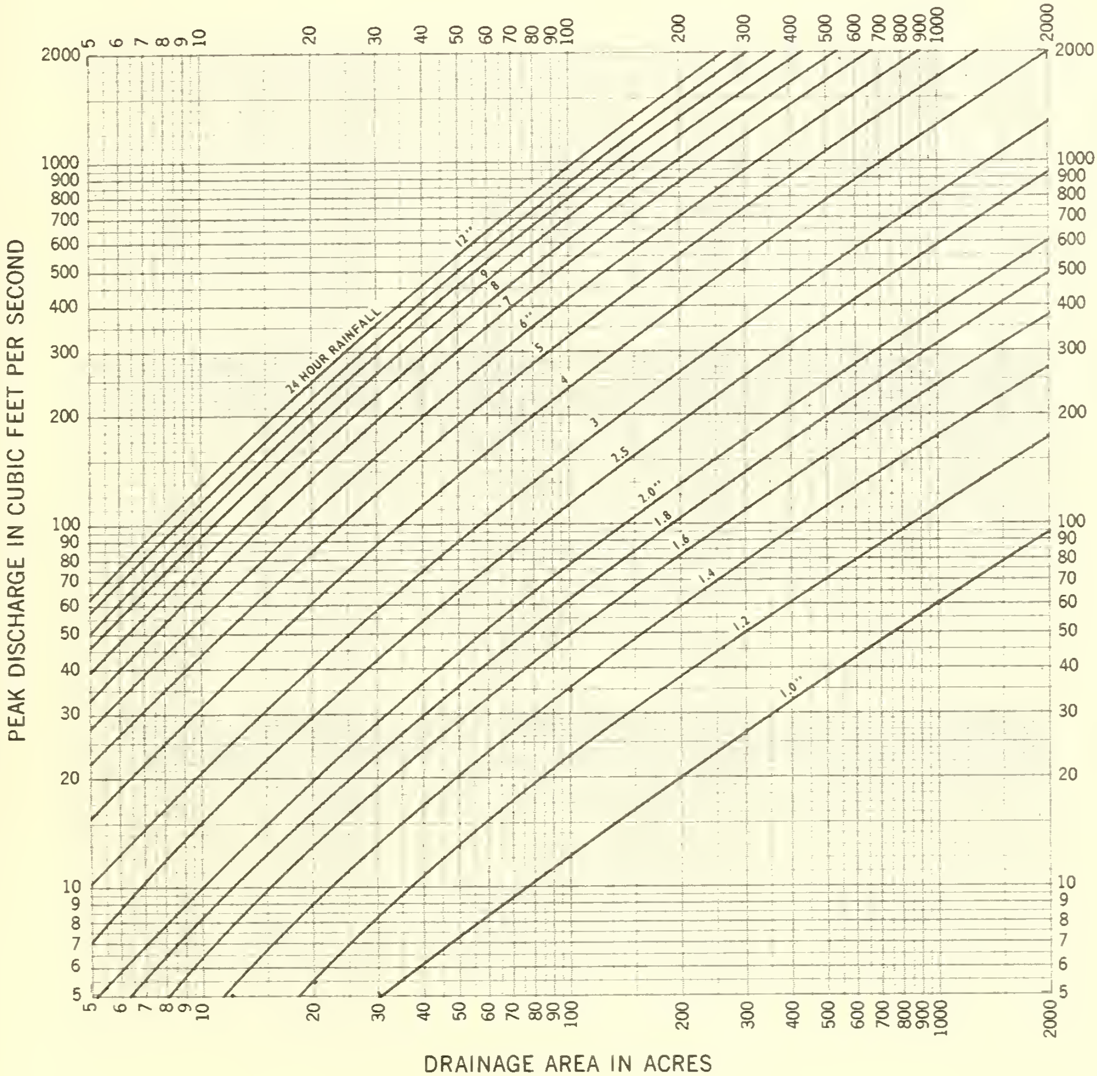
24 HOUR RAINFALL FROM US WB TP-40



PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - MODERATE
CURVE NUMBER - 85

24 HOUR RAINFALL FROM US WB TP-40



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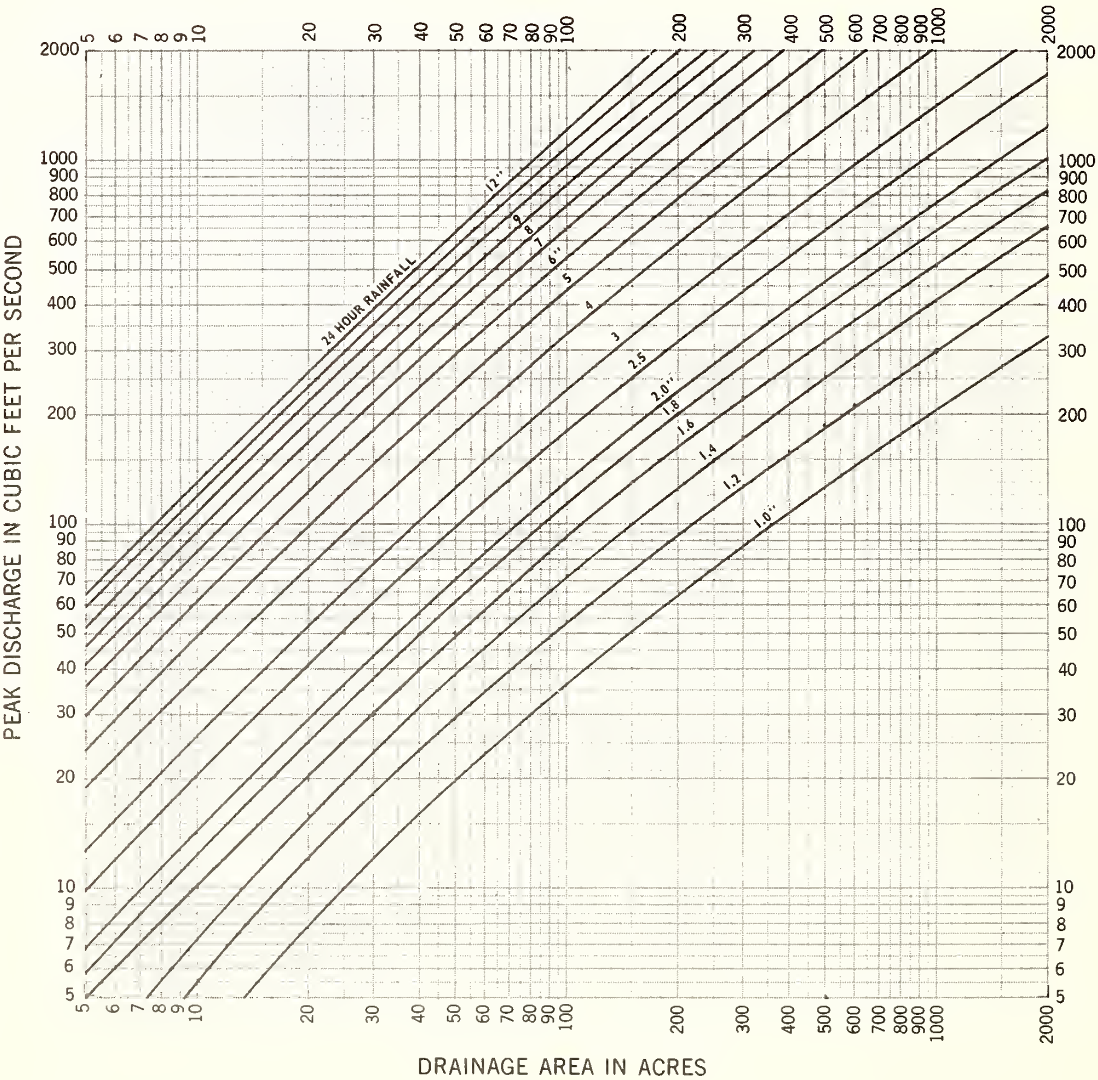
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES – MODERATE
CURVE NUMBER – 90

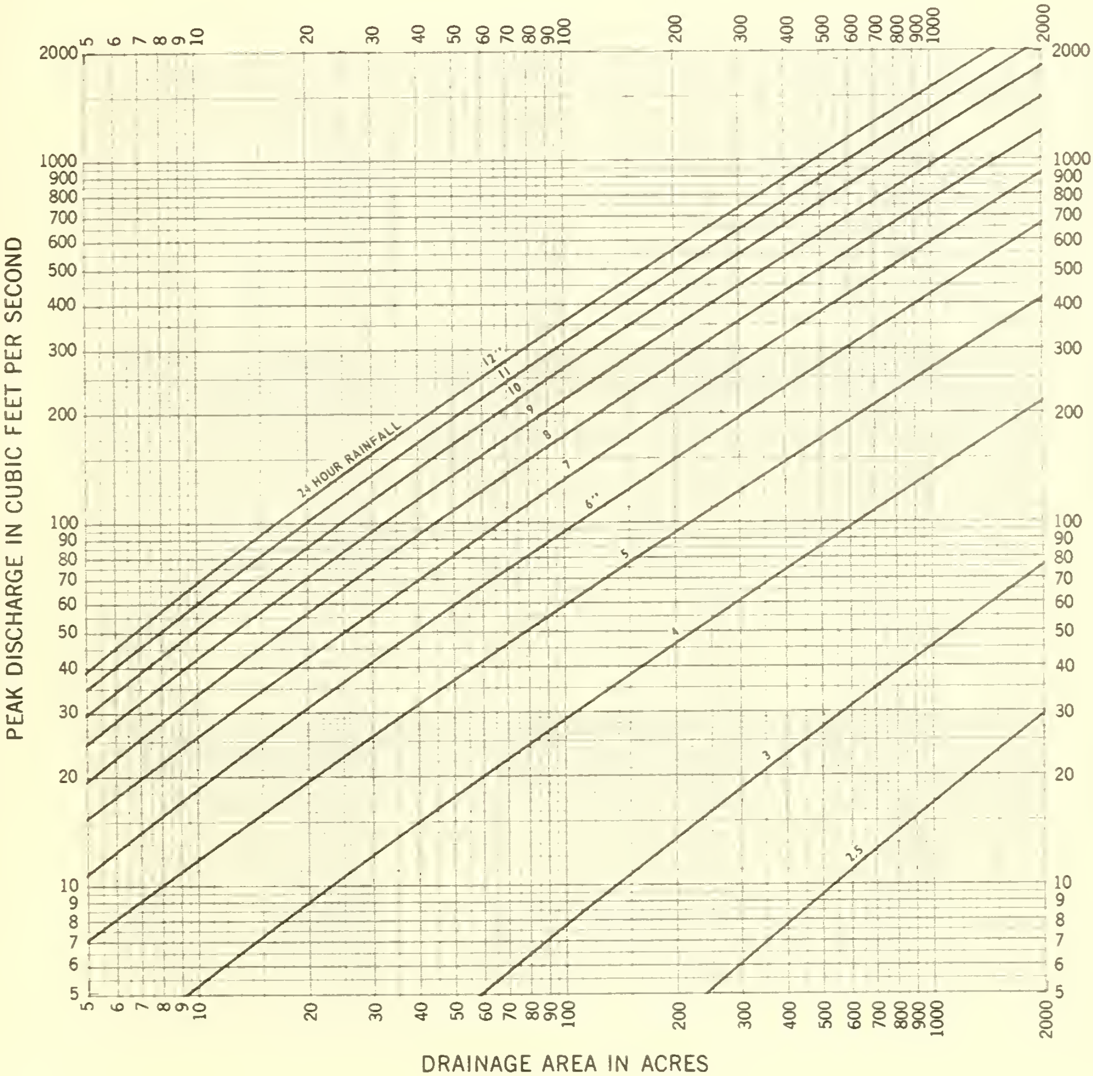
24 HOUR RAINFALL FROM US WB TP-40



PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES – STEEP
CURVE NUMBER – 60

24 HOUR RAINFALL FROM US WB TP-40



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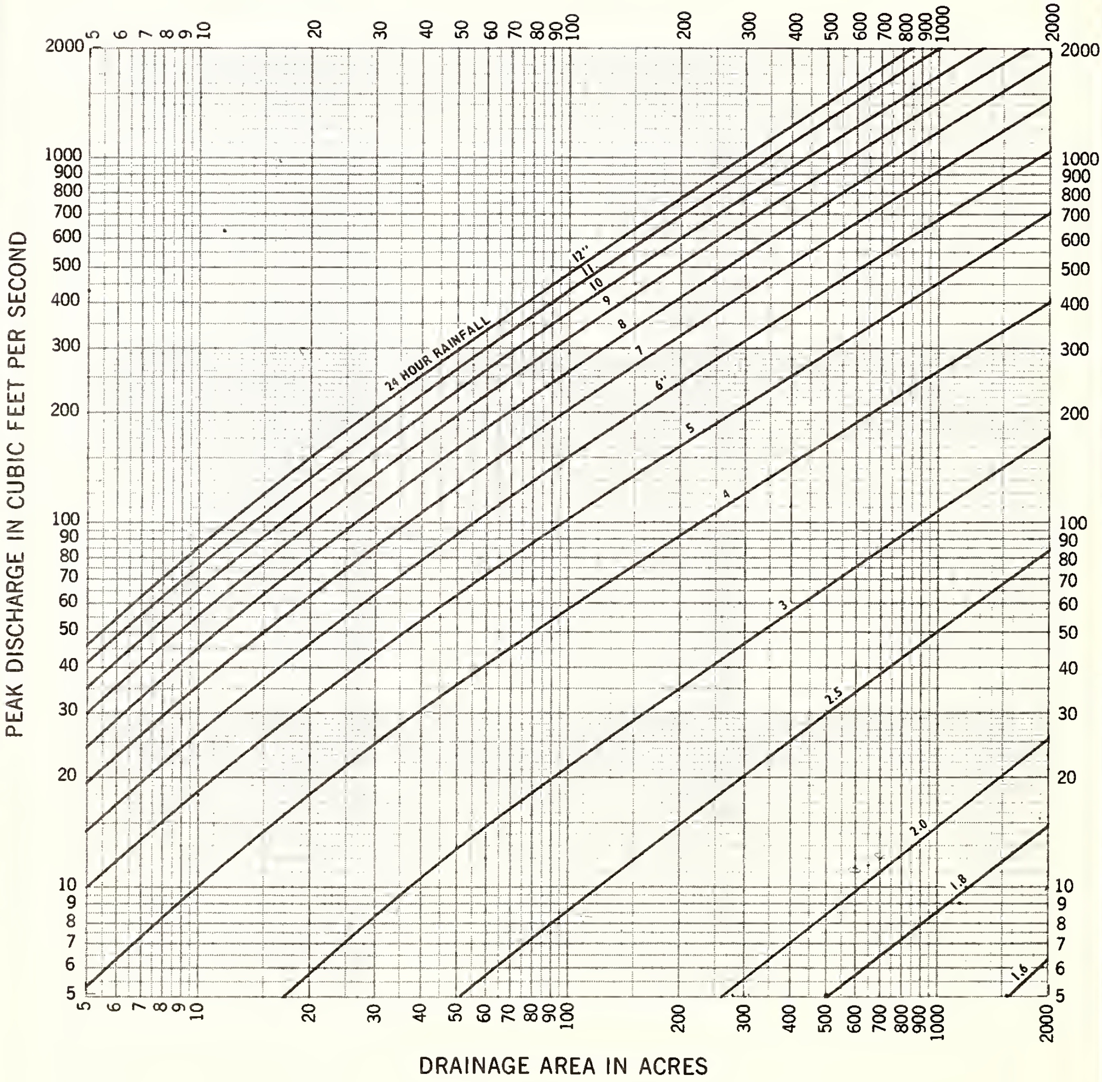
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES - STEEP
CURVE NUMBER - 65

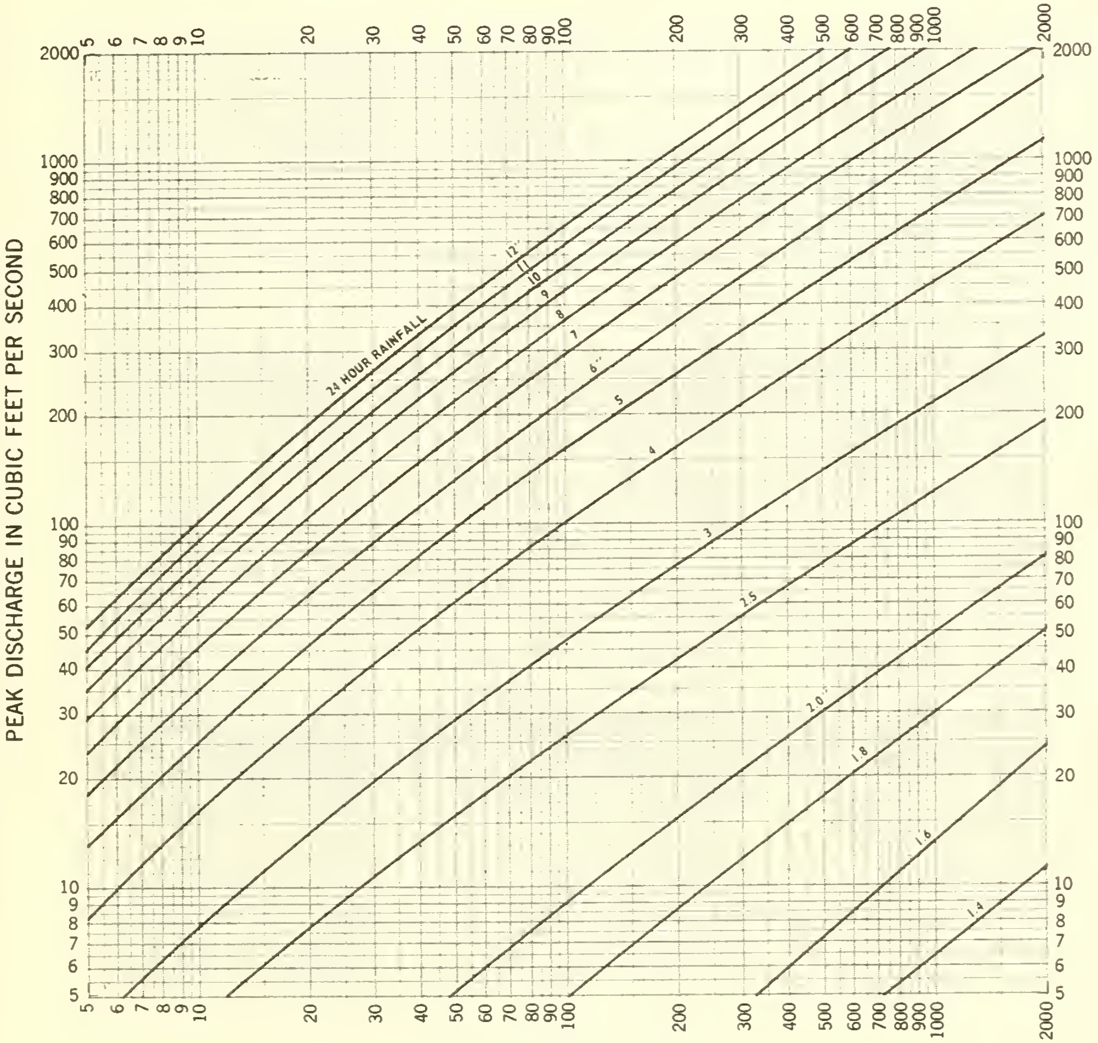
24 HOUR RAINFALL FROM US WB TP-40



PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES – STEEP
CURVE NUMBER – 70

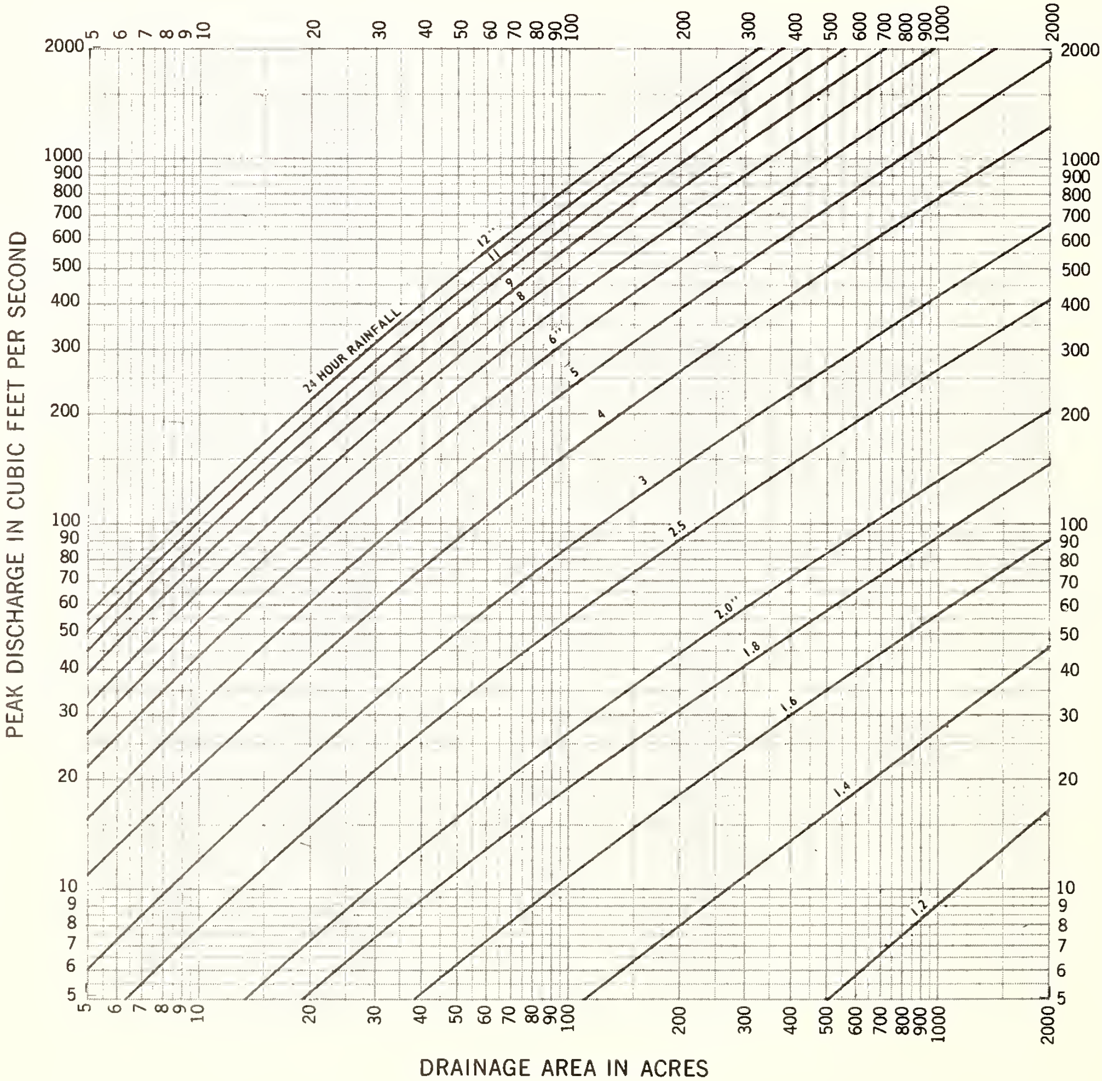
24 HOUR RAINFALL FROM US WB TP-40



PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES – STEEP
CURVE NUMBER – 75

24 HOUR RAINFALL FROM US WB TP-40



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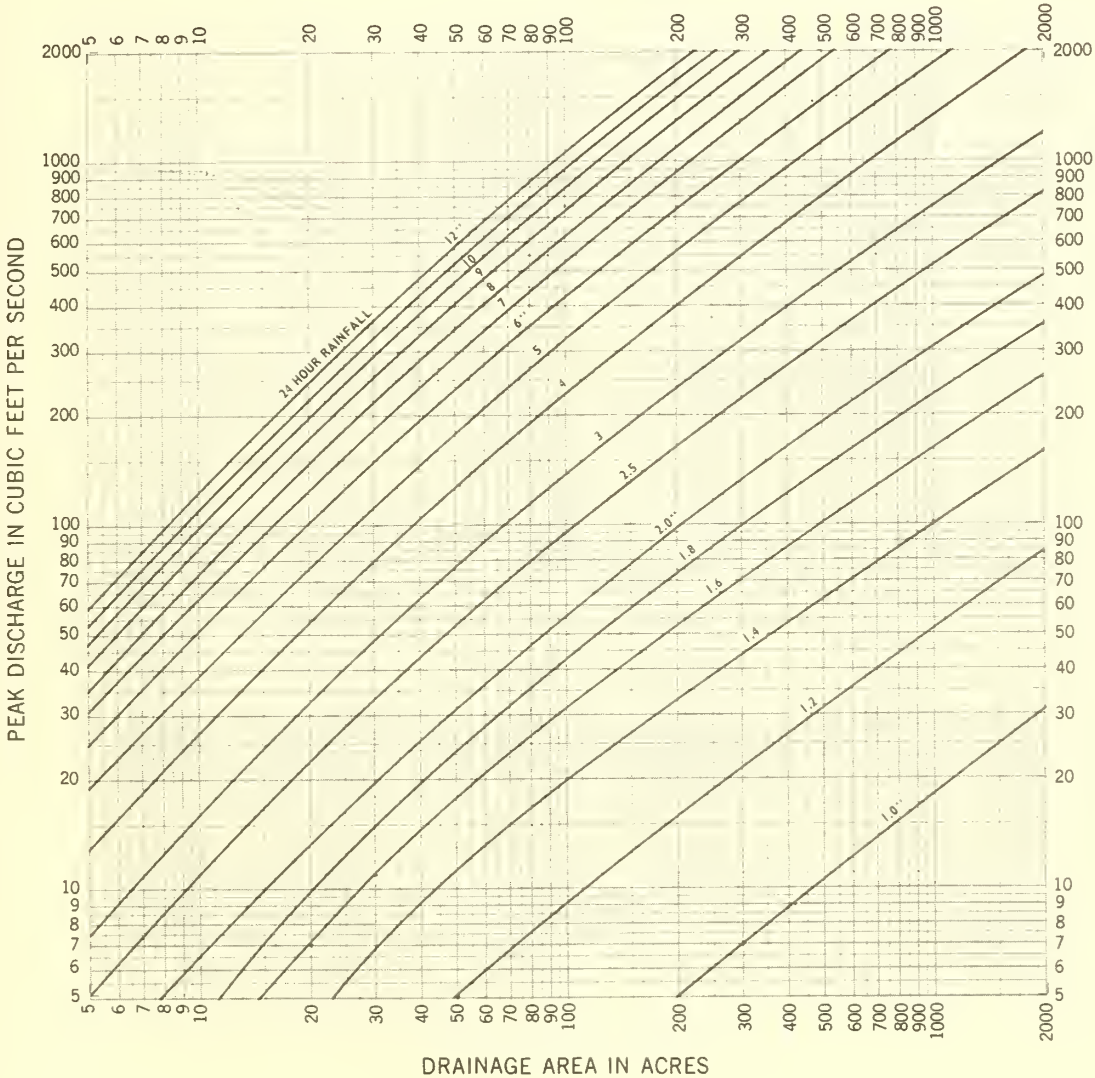
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES – STEEP
CURVE NUMBER – 80

24 HOUR RAINFALL FROM US WB TP-40



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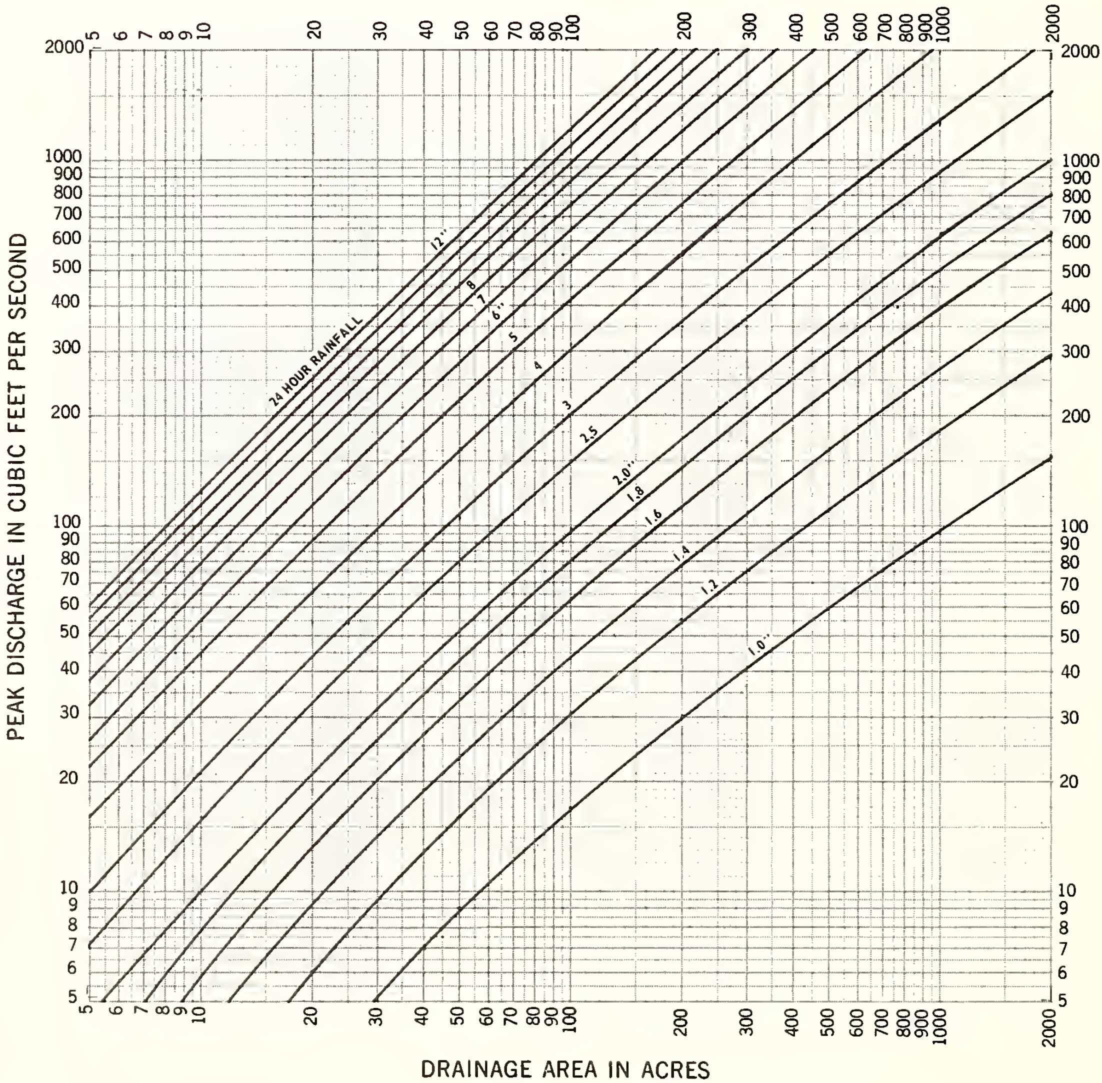
SHEET 19 OF 21

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES – STEEP
CURVE NUMBER – 85

24 HOUR RAINFALL FROM US WB TP-40



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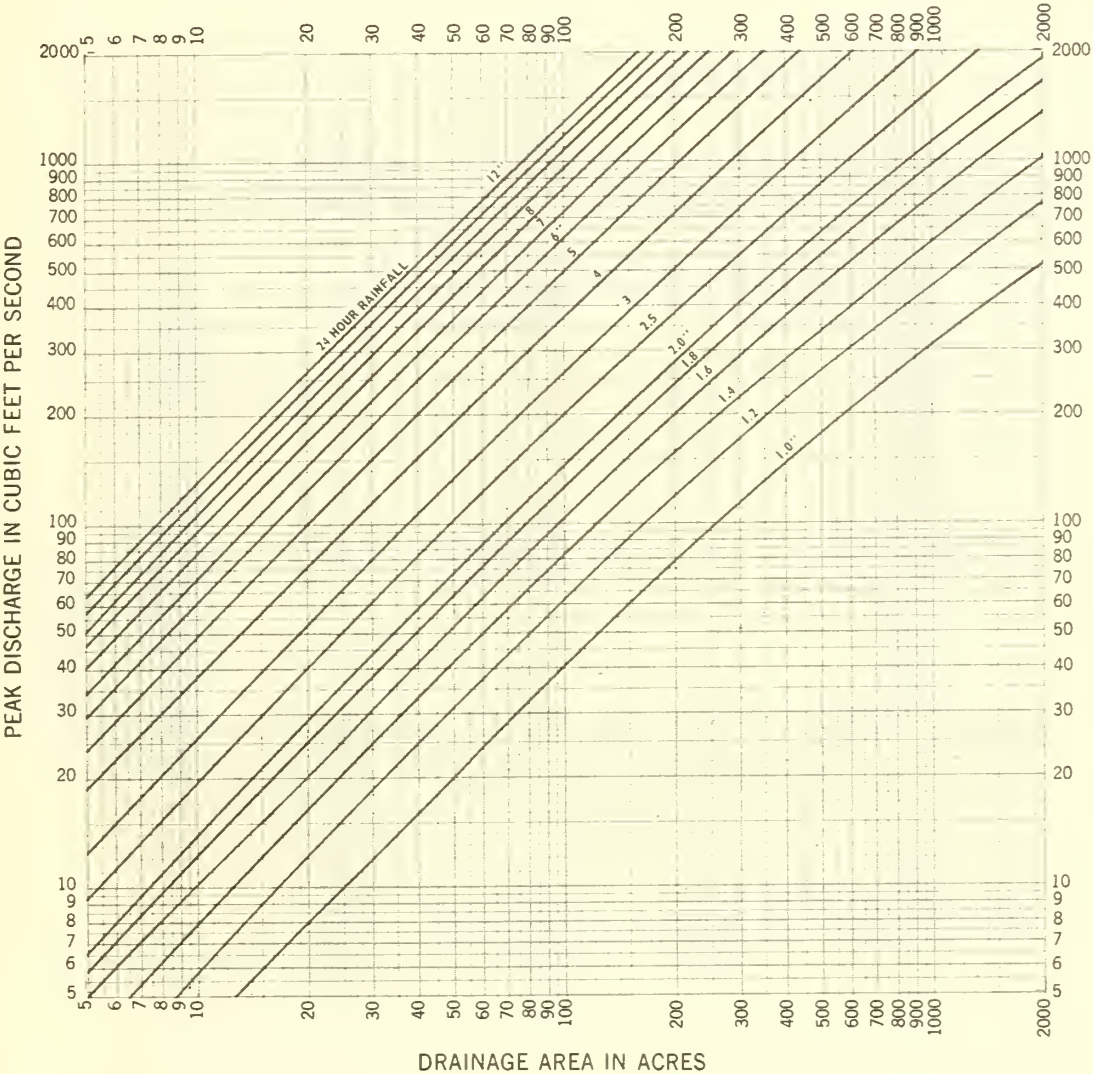
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

SLOPES – STEEP
CURVE NUMBER – 90

24 HOUR RAINFALL FROM US WB TP-40



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