CHAPTER 3
SCS PEAK DISCHARGE METHOD

The peak discharge method of calculating runoff was developed by the USDA Soil Conservation Service and is contained in SCS Technical Release No. 55 (TR-55) entitled Urban Hydrology for Small Watersheds, Second Ed.; June 1986. This method of runoff calculation yields a total runoff volume as well as a peak discharge. Use of the SCS method is illustrated in Sample Problem 3-1.

Step 1. Measure the drainage area (in acres); the hydraulic length (distance from most remote point to design point, in feet); and the average slope (percent) of the watershed.

Step 2. Calculate a curve number, CN, for the drainage area.

The curve number, CN, is an empirical value, which establishes a relationship between rainfall and runoff based upon characteristics of the drainage area. Table 3-1 contains CN values for different land uses, cover conditions, and hydrologic soil groups. Hydrologic group assignments for soils in Guilford County are given in the Soil Survey of Guilford County, North Carolina. See the soil group descriptions below:

- **Soil Group A** - Represents soil having a low runoff potential due to high infiltration rates. These soils consist primarily of deep, well-drained sands and gravels. Guilford County does not have any of these type of soils mapped.

- **Soil Group B** - Represents soils having a moderately low runoff potential due to moderate infiltration rates. These soils consist primarily of moderately deep to deep, moderately well-drained to well-drained soils with moderately fine to moderately coarse textures.

- **Soil Group C** - Represents soils having a moderately high runoff potential due to slow infiltration rates. These soils consist primarily of soils in which a layer exists near the surface that impedes the downward movement of water, or soils with moderately fine to fine texture.

- **Soil Group D** - Represents soils having a high runoff potential due to very slow infiltration rates. These soils consist primarily of soils with high water tables, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious parent material.

If the watershed is homogeneous (i.e., uniform land use and soils) the CN value can be determined directly from Table 3-1. Curve numbers for nonhomogeneous watersheds may be determined by dividing the watershed into homogeneous subareas and computing a composite average.

TABLE 3-1
Runoff Curve Numbers (CN)

Land Use/Cover	Average % Impervious	Hydrologic Soil Group A	B	C	D
Cultivated land					
without conservation		72	81	88	91
with conservation		62	71	78	81
Pasture land					
poor condition		68	79	86	89
fair condition		49	69	79	84
good condition		39	61	74	80
Meadow					
good condition		30	58	71	78
Wood or forest land					
Thin stand - poor cover, no mulch		45	66	77	83
Good stand - good cover		25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.					
good condition: grass cover on 75% or more of the area		39	61	74	80
fair condition: grass cover on 50 to 75% of the area		49	69	79	84
Commercial and business areas (85% impervious)		89	92	94	95
Industrial districts (72% impervious)		81	88	91	93
Residential:[1] Development completed and vegetation established					
Average lot size	Average % Impervious				
1/8 acre or less	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acre	15	47	66	77	81
Paved parking lots, roofs, driveways, etc.		98	98	98	98
Streets and roads					
paved with curbs and storm sewers		98	98	98	98
gravel		76	85	89	91
dirt		72	82	87	89
Newly graded area		81	89	93	95
Residential: Development underway and no vegetation					
Lot sizes of 1/4 acre		88	93	95	97
Lot sizes of 1/2 acre		85	91	94	96
Lot sizes of 1 acre		82	90	93	95
Lot sizes of 2 acres		81	89	92	94

[1]Curve numbers are computed assuming the runoff from the house and driveway is directed toward the street

source: USDA-SCS

Step 3. Select design storm and determine runoff depth and volume. For erosion and sediment control, and pipe design use the 10-yr, 24-hr storm.

a. Determine rainfall amount, in inches, from Table 3-2 for the selected design storm. (The design storm is based on an SCS Type II, 24-hr rainfall distribution.)

TABLE 3-2
RAINFALL DATA TABLE

DESIGN STORM (YEARS)	24-HOUR PRECIPITATION (INCHES)
2	3.5
5	4.5
10	5.2
25	6.0
50	6.8
100	7.5

b. Determine runoff depth (in inches) from the curve number and rainfall depth using Table 3-3.

TABLE 3-3
Runoff Depth

Rainfall (inches)	**Curve Number (CN)[1]**							
	60	**65**	**70**	**75**	**80**	**85**	**90**	**95**
1.0	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56
1.2	0.00	0.00	0.03	0.07	0.15	0.28	0.46	0.74
1.4	0.00	0.02	0.06	0.13	0.24	0.39	0.61	0.92
1.6	0.01	0.05	0.11	0.20	0.34	0.52	0.76	1.11
1.8	0.03	0.09	0.17	0.29	0.44	0.65	0.93	1.30
2.0	0.06	0.14	0.24	0.38	0.56	0.80	1.09	1.48
2.5	0.17	0.30	0.46	0.65	0.89	1.18	1.53	1.97
3.0	0.33	0.51	0.72	0.96	1.25	1.59	1.98	2.44
4.0	0.76	1.03	1.33	1.67	2.04	2.46	2.92	3.42
5.0	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.41
6.0	1.92	2.35	2.80	3.28	3.78	4.31	4.85	5.40
7.0	2.60	3.10	3.62	4.15	4.69	5.26	5.82	6.40
8.0	3.33	3.90	4.47	5.04	5.62	6.22	6.81	7.39
9.0	4.10	4.72	5.34	5.95	6.57	7.19	7.79	8.39
10.0	4.90	5.57	6.23	6.88	7.52	8.16	8.78	9.39
11.0	5.72	6.44	7.13	7.82	8.48	9.14	9.77	10.39
12.0	6.56	7.32	8.05	8.76	9.45	10.12	10.76	11.39

[1] To obtain runoff depths for CN's and other rainfall amounts not shown in this table, use an arithmetic interpolation.

The volume of runoff for the point of interest can be calculated by multiplying the area of the drainage basin by the runoff depth.

Step 4. Determine the peak rate of runoff for the design storm by adjusting for watershed shape as follows:

a. Determine an "equivalent drainage area" from the hydraulic length of the watershed using Figure 3-1. Hydraulic length is the length of the flow path from the most remote point in the watershed to the point of discharge.

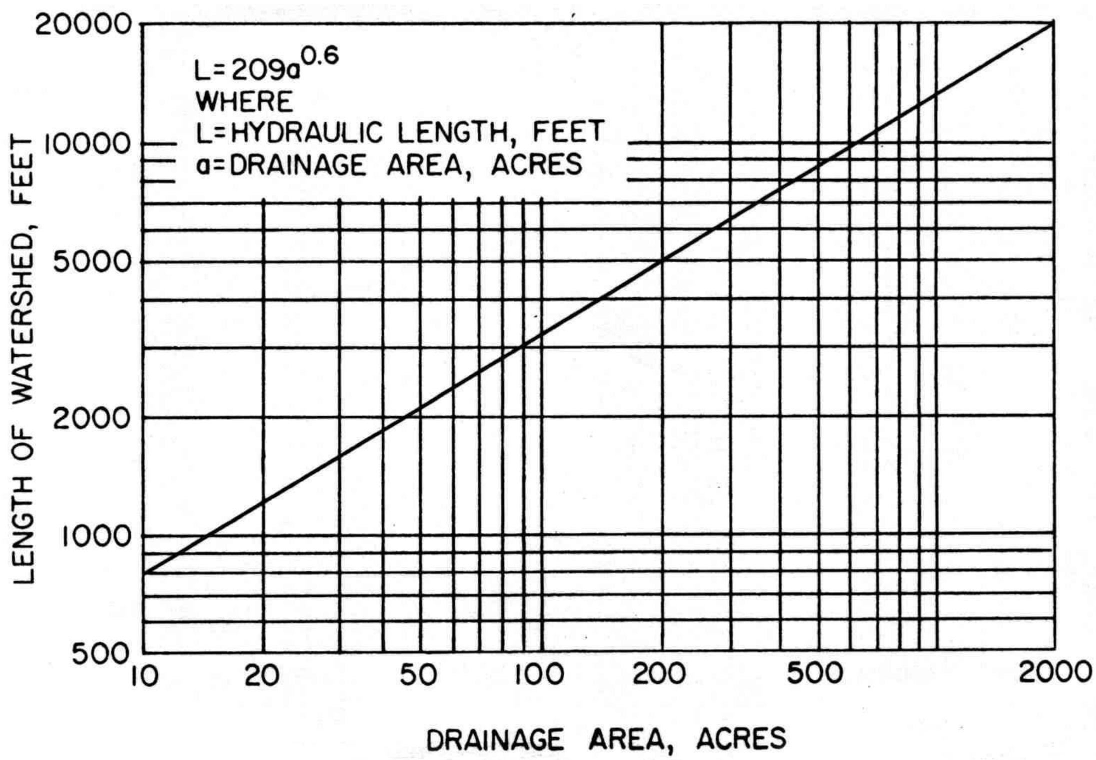


FIGURE 3-1 Hydraulic length and drainage area relationship.

Calculate the peak discharge, Q_1, of the equivalent watershed by multiplying equivalent drainage area by runoff depth from Table 3-3 in Step 3b.

b. Determine the discharge (cfs/inch of runoff) for the equivalent drainage area from Figure 3-2 through 3-4:

Figure 3-2 - for average watershed slopes 0-3%
Figure 3-3 - for average watershed slopes 3-7%
Figure 3-4 - for average watershed slopes 8-50%

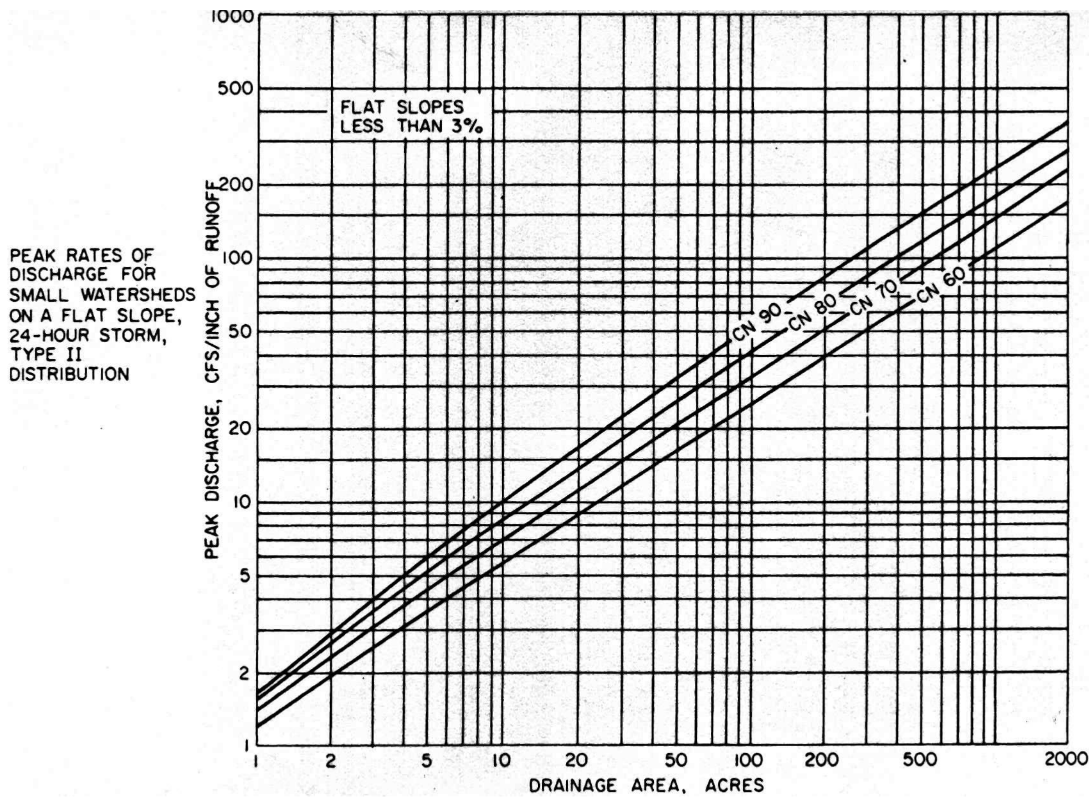


FIGURE 3-2 Discharge vs. equivalent drainage area for average watershed slopes 0 – 3%.

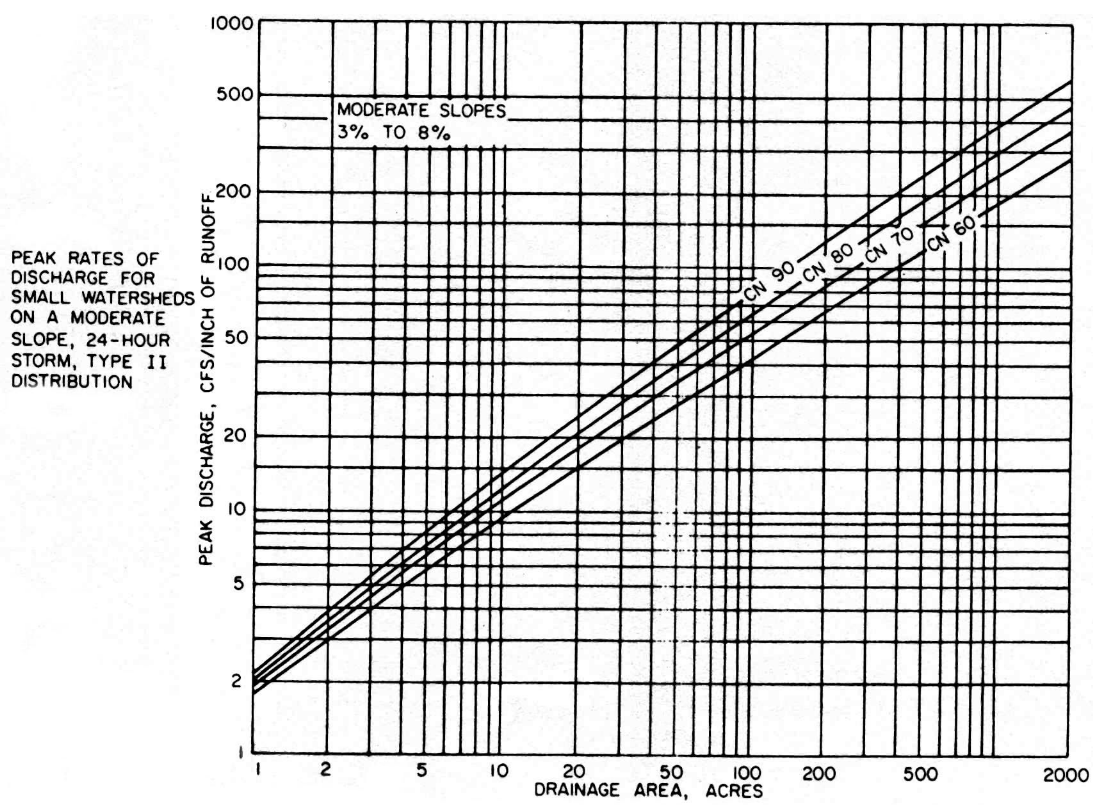


FIGURE 3-3 Discharge vs. equivalent drainage area for average watershed slopes 3 – 8%.

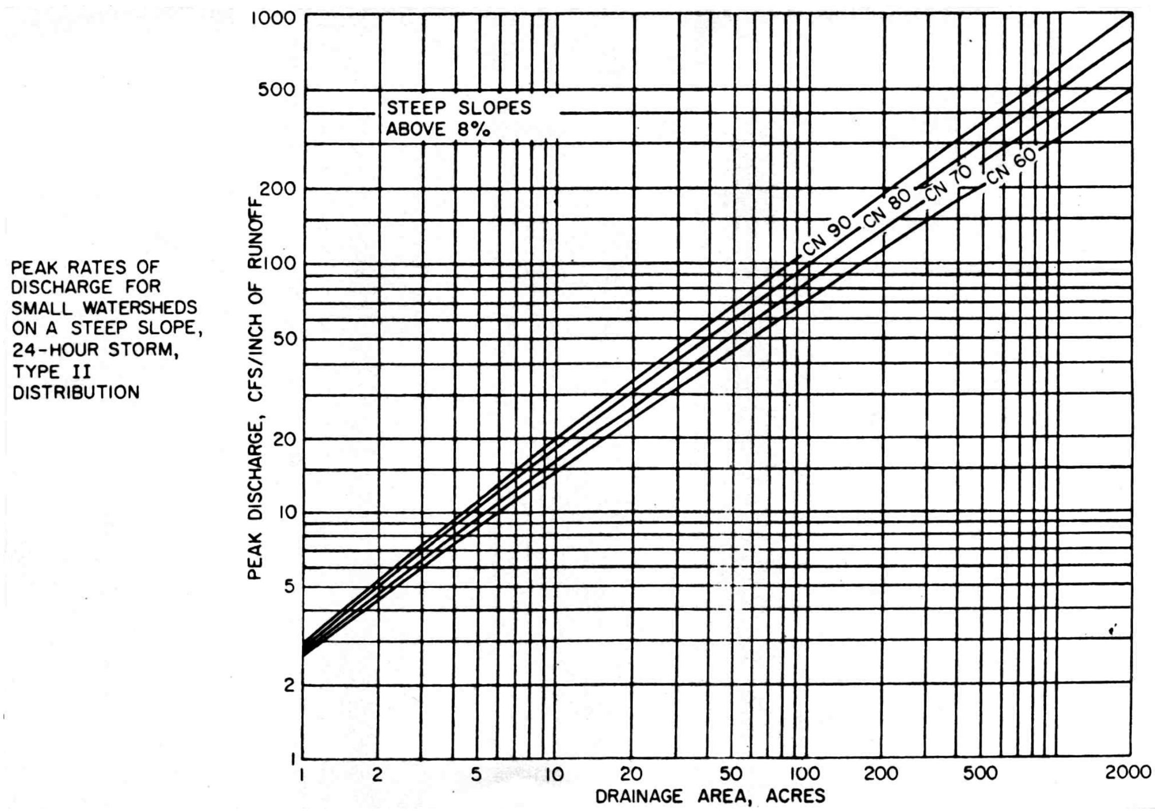


FIGURE 3-4 Discharge vs. equivalent drainage area for watershed slopes 8 – 50%.

c. Compute peak discharge, Q_2, by multiplying the "equivalent watershed" peak discharge, Q_1, by the ratio of the actual drainage area to the equivalent drainage area:

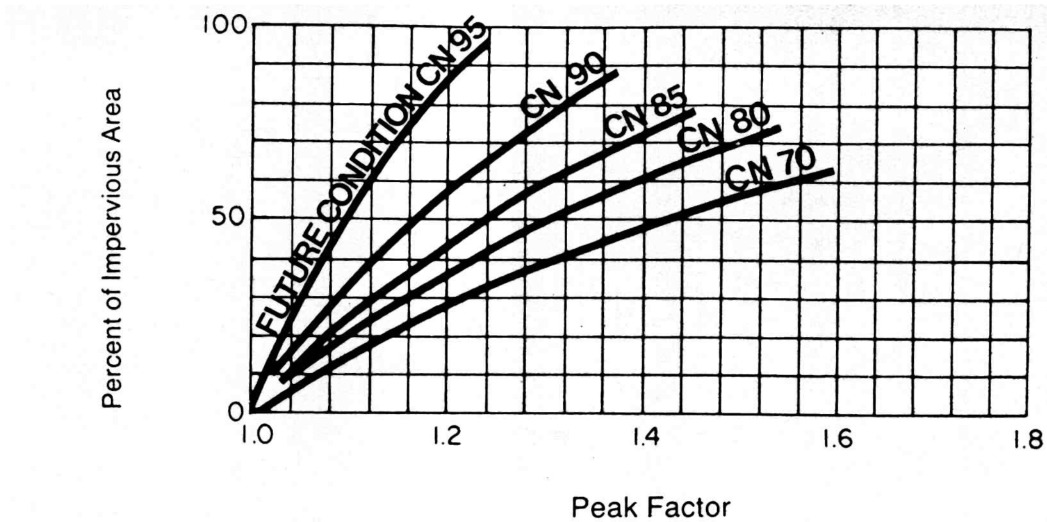
$$Q_2 = Q_1 \times \frac{\text{(actual drainage area)}}{\text{(equiv. drainage area)}}$$

Step 5. Adjust peak discharge to account for impervious area and channel improvements (modified hydraulic length shown in Figure 3-5).

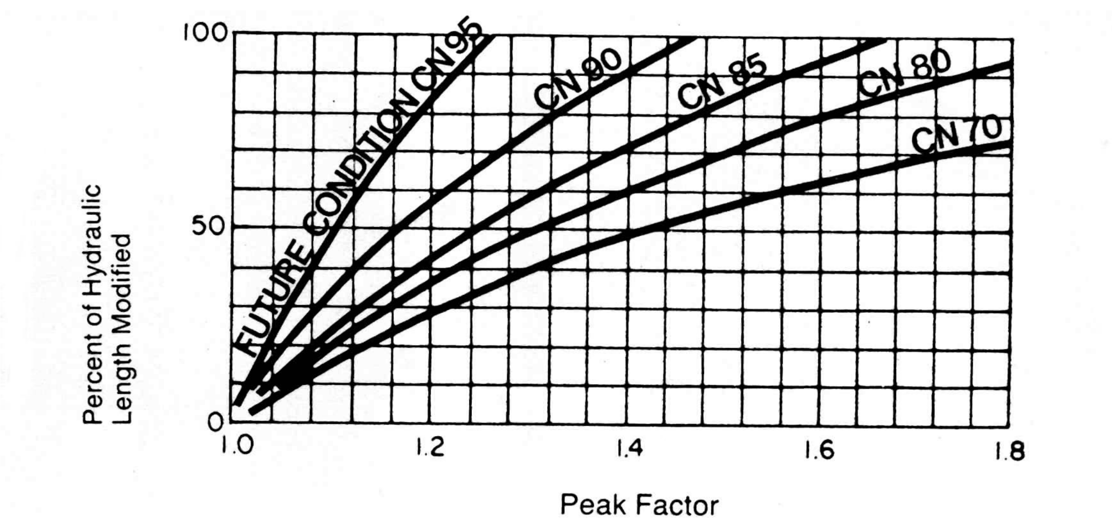
a. Use the top graph in Figure 3-5 to determine the peak factor for impervious area in the watershed (Factor $_{IMP}$).

b. Use the bottom graph in Figure 3-5 to determine the peak factor based upon the percentage of hydraulic length that has been modified (i.e., deepened, widened, lined, etc.) to increase channel capacity (Factor $_{HLM}$).

c. Adjust peak discharge, Q_2, from step 4 by multiplying by the two peak factors.
Q_3 mod. = Q_2 x (Factor $_{IMP}$) x (Factor $_{HLM}$)



Peak Discharge Adjustment Factor for Impervious Area



Peak Discharge Adjustment Factor for Hydraulic Length Modification

FIGURE 3-5 Peak discharge adjustment factors (source: USDA-SCS)

Step 6. Adjust the peak discharge based on the average watershed slope (Table 3-4).

Enter Table 3-4 with the average percentage of slope and acreage of the watershed, and read the appropriate slope adjustment factor (interpolate where necessary). Adjust the peak discharge by multiplying by the slope adjustment factor.

$$Q_4 = Q_3 \text{ x Slope factor}$$

TABLE 3-4
Slope Adjustment Factors

	Slope (percent)	**10 acres**	**20 acres**	**50 acres**	**100 acres**	**200 acres**
Flat	0.1	0.49	0.47	0.44	0.43	0.42
	0.2	0.61	0.59	0.56	0.55	0.54
	0.3	0.69	0.67	0.65	0.64	0.63
	0.4	0.76	0.74	0.72	0.71	0.70
	0.5	0.82	0.80	0.78	0.77	0.77
	0.7	0.90	0.89	0.88	0.87	0.87
	1.0	1.00	1.00	1.00	1.00	1.00
	1.5	1.13	1.14	1.14	1.15	1.16
Moderate	3	0.93	0.92	0.91	0.90	0.90
	4	1.00	1.00	1.00	1.00	1.00
	5	1.04	1.05	1.07	1.08	1.08
	6	1.07	1.10	1.12	1.14	1.15
	7	1.09	1.13	1.18	1.21	1.22
Steep	8	0.92	0.88	0.84	0.81	0.80
	9	0.94	0.90	0.86	0.84	0.83
	10	0.96	0.92	0.88	0.87	0.86
	11	0.96	0.94	0.91	0.90	0.69
	12	0.97	0.95	0.93	0.92	0.91
	13	0.97	0.97	0.95	0.94	0.94
	14	0.98	0.98	0.97	0.96	0.96
	15	0.99	0.99	0.99	0.98	0.98
	16	1.00	1.00	1.00	1.00	1.00
	20	1.03	1.04	1.05	1.06	1.07
	25	1.06	1.08	1.12	1.14	1.15
	30	1.09	1.11	1.14	1.17	1.20
	40	1.12	1.16	1.20	1.24	1.29
	50	1.17	1.21	1.25	1.29	1.34

source: USDA-SCS

Step 7. Adjust the peak discharge for ponding and swampy areas in the watershed (Table 3-5).

Peak flow determined from the previous steps is based on uniform surface flow in ditches, drains, and streams. Where significant ponding areas occur in the watershed, make a reduction in the peak runoff value. Table 3-5 provides adjustment factors based on the ratio of the ponding and swampy areas to the total watershed area for a range of storm frequencies.

To use Table 3-5, first calculate the ratio of drainage area to ponded area, determine generally where the ponded areas occur in the watershed (at the design point, spread throughout the watershed, or located only in upper reaches), then select the adjustment factor for the appropriate design storm.

Adjust the peak discharge by multiplying Q_4 by the adjustment factor for surface ponding:

$$Q_{peak} = Q_4 \text{ x factor for surface ponding}$$

TABLE 3-5
Adjustment Factors for Ponding and Swampy Areas

Adjustment factors where ponding and swampy areas occur at the design point.

Ratio of drainage area to ponding and swampy area	Percentage of ponding and swampy area	Storm frequency (years) 2	5	10	25	50	100
500	0.2	0.92	0.94	0.95	0.96	0.97	0.98
200	0.5	0.86	0.87	0.88	0.90	0.92	0.93
100	1.0	0.80	0.81	0.83	0.85	0.87	0.89
50	2.0	0.74	0.75	0.76	0.79	0.82	0.86
40	2.5	0.69	0.70	0.72	0.75	0.78	0.82
30	3.3	0.64	0.65	0.67	0.71	0.75	0.78
20	5.0	0.59	0.61	0.63	0.67	0.71	0.75
15	6.7	0.57	0.58	0.60	0.64	0.67	0.71
10	10.0	0.53	0.54	0.56	0.60	0.63	0.68
5	20.0	0.48	0.49	0.51	0.55	0.59	0.64

Adjustment factors where ponding and swampy areas are spread throughout the watershed or occur in central parts of the watershed.

Ratio of drainage area to ponding and swampy area	Percentage of ponding and swampy area	Storm frequency (years) 2	5	10	25	50	100
500	0.2	0.94	0.95	0.96	0.97	0.98	0.99
200	0.5	0.88	0.89	0.90	0.91	0.92	0.94
100	1.0	0.83	0.84	0.86	0.87	0.88	0.90
50	2.0	0.78	0.79	0.81	0.83	0.85	0.87
40	2.5	0.73	0.74	0.76	0.78	0.81	0.84
30	3.3	0.69	0.70	0.71	0.74	0.77	0.81
20	5.0	0.65	0.66	0.68	0.72	0.75	0.78
15	6.7	0.62	0.63	0.65	0.69	0.72	0.75
10	10.0	0.58	0.59	0.61	0.65	0.68	0.71
5	20.0	0.53	0.54.	0.56	0.60	0.63	0.68
4	25.0	0.50	0.51	0.53	0.57	0.61	0.66

Adjustment factors where ponding and swampy areas are located only in upper reaches of the watershed.

Ratio of drainage area to ponding and swampy area	Percentage of ponding and swampy area	Storm frequency (years) 2	5	10	25	50	100
500	0.2	0.96	0.97	0.98	0.98	0.99	0.99
200	0.5	0.93	0.94	0.94	0.95	0.96	0.97
100	1.0	0.90	0.91	0.92	0.93	0.94	0.95
50	2.0	0.87	0.88	0.88	0.90	0.91	0.93
40	2.5	0.85	0.85	0.86	0.88	0.89	0.91
30	3.3	0.82	0.83	0.84	0.86	0.88	0.89
20	5.0	0.80	0.81	0.82	0.84	0.86	0.88
15	6.7	0.78	0.79	0.80	0.82	0.84	0.86
10	10.0	0.77	0.77	0.78	0.80	0.82	0.84
5	20.0	0.74	0.75	0.76	0.78	0.80	0.82

SAMPLE PROBLEM 3-1
DETERMINATION OF PEAK RUNOFF RATE USING SCS METHOD

Given:
Location: Greensboro, N.C.
Land use by soil group:

Commercial area: soil group B	8 acres
Newly graded area: soil group C	20 acres
Wooded land: (good stand-good ground cover) soil group B	12 acres
Total Area	40 acres

Avg. watershed slope: 5%
Ratio of drainage area to ponded area: (2 acres wooded, ponded area near center of watershed) 20:1
Hydraulic length: 2,000 ft
Hydraulic length modified: 200 ft
% impervious area: (8 acres commercial, 85% impervious) 17%

Find:
Peak rate of runoff for the 10-yr frequency, 24-hr storm - $Q_{p\ 10,\ 24}$

Solution:

(1) Drainage area = 40 acres (given)
hydraulic length = 2,000ft
average slope = 5%

(2) Calculate average curve number (CN) using Table 3-1

	% drainage area x CN
Commercial area	20% x 92 = 1840
Newly graded area	50% x 93 = 4650
Wooded land	30% x 55 = 1650
	100% 8140

$CN = \frac{8140}{100} = 81.4$ Use 82

(3) Determine runoff depth
a. Rainfall amount for 10-yr, 24-hr storm; Greensboro, NC = 5.2 inches (Table 3-2)
b. Runoff depth = 3.27 inches (Table 3-3 by double interpolation)

(4) Determine peak rate of runoff for the design storm by adjusting for watershed shape
a. Equivalent drainage area = 46 acres (Figure 3-1; hydraulic length = 2,000 ft)
b. Q_1 = 40 cfs/inch x 3.27 inches = 131 cfs (Figure 3-3, 3% to 8% slope; CN = 82)
c. Q_2 = 131cfs x (40ac./46ac.) = 114 cfs

(5) Adjust peak discharge rate Q_2 for percent impervious area and percent hydraulic length modified
a. Impervious factor = 1.08 (Figure 3-5; 17% impervious)
b. Hydraulic length modification factor = 1.05 (Figure 3-5 , 200 ft ÷ 2000 ft = 10%)
c. Q_3 = 114cfs x 1.08 x 1.05 = 129 cfs

(6) Adjust peak discharge for avg. watershed slope
a. Adjustment factor for watershed slope = 1.07 (Table 3-4; 5% avg. slope)
b. Q_4 = 123cfs x 1.06 = 130 cfs

(7) Adjust peak discharge for surface ponding
a. Adjustment factor for surface ponding = 0.68 (Table 3-5; ratio 20:1; center of watershed; 10-yr)
b. $Q_{p\ 10,24}$ = 130cfs x 0.68 = 88 cfs at design point