URBAN HYDROGRAPH METHOD

COLORADO URBAN HYDROGRAPH PROCEDURE

1982 Version

For basins that are larger than 160 acres, it is recommended that the design storm runoff be analyzed by deriving synthetic unit hydrographs. However, if desired, the 5-minute unit hydrograph can be used for basins as small as 90 acres. The presentation given in this chapter is termed the Colorado Urban Hydrograph Procedure (CUHP) because coefficients and the form of the equation are based upon data collected in Colorado and on studies conducted or financed by the Urban Drainage and Flood Control District.

Definition

A unit hydrograph is defined as the hydrograph of one inch of direct runoff from the tributary area resulting from a unit storm. The unit hydrograph thus represents the integrated effects of factors such as tributary area, shape, street pattern, channel capacities, and street and land slopes.

The basic premise of the unit hydrograph is that individual hydrographs resulting from the successive increments of rainfall excess that occur throughout a storm period will be proportional in discharge throughout their length. Thus, the hydrograph of total storm discharge is obtained by summing the ordinates of the individual hydrographs.

Basic Assumptions

The derivation and application of the unit hydrograph are based on the following assumptions:

1. The rainfall intensity is constant during the storm that produces the unit hydrograph.
2. The rainfall is uniformly distributed throughout the whole area of the drainage basin.
3. The base or time duration of the design runoff due to an effective rainfall of unit duration is constant.
4. The ordinates of the design runoff with a common base time are directly proportional to the total amount of direct runoff represented by each hydrograph.
5. The effects of all physical characteristics of a given drainage basin, including shape, slope, detention, infiltration, drainage pattern, channel storage, etc., are reflected in the shape of the unit hydrograph for that basin.

Equations

There are four basic equations used in defining the limits of the synthetic unit hydrograph. The first equation defines the lag time of the basin in terms of time to peak, t_p, which, for the CUHP Method, is defined as the time from the center of the unit storm duration to the peak of the unit hydrograph as shown in Figure 28.

$$t_p = C_t [(L\, L_{ca} / \sqrt{S})]^{0.48} \qquad \text{Equation 1}$$

In which t_p = time to peak of the unit hydrograph from midpoint of unit rainfall in hours.

L = Length along stream from study point to upstream limits of the basin in miles.

L_{ca} = length along stream from study point to a point along stream adjacent to the centroid of the basin in miles.

S = weighted average slope of basin along the stream to upstream limits of the basin in feet per foot.

C_t = coefficient reflecting time to peak.

The time from the beginning of unit rainfall to the peak of the unit hydrograph is determined by:

$$T_p = 60t_p + 0.5t_u \qquad \text{Equation 2}$$

In which T = time from beginning of unit rainfall to peak of hydrograph in minutes.

t_u = time of unit rainfall duration in minutes.

The unit peak of the unit hydrograph is defined by:

$$q_p = \frac{640\ C_p}{t_p} \qquad \text{Equation 3}$$

In which q_p = peak rate of runoff in C.F.S. per square mile
C_p = coefficient related to peak rate of runoff

Once q_p is determined, the peak of the unit hydrograph for the basin is computed by:

$$Q_p = q_p A \qquad \text{Equation 4}$$

In which Q_p = peak of the unit hydrograph in C.F.S.
A = area of basin in square miles.

Determination of C_t and C_p Coefficients

The value of C_t in Equation 1 may be determined using Figure 24. Note that the curve in Figure 24 can be represented using parabolic equations having the percent impervious (I_a) as an independent variable.

The value of C_p to be used in Equation 3 may be determined using Figure 25. The curve in Figure 25 is also represented with parabolic equation. To determine C_p, first obtain the value of the Peaking Parameter P from Figure 25. Then calculate C_p using Equation 5:

$$C_p = P\,C_t A^{0.15} \qquad \text{Equation 5}$$

in which,
C_t = coefficient from Figure 24
P = peaking parameter from Figure 25
A = basin area in square miles

Unit Storm Duration

For most urban studies, the unit storm duration, t_u, should be 5 minutes. However, the unit duration may be increased for larger basins. It is convenient to have the unit duration incremented in multiples of 5 minutes (i.e., 10 or 15 minutes), with the maximum unit duration recommended at 15 minutes for the 1982 version of the CUHP.

An acceptable unit storm duration, whenever it is larger than 5 minutes, should not exceed one-third of t_p = 35 minutes, then an appropriate unit storm duration would be 5 minutes or 10 minutes (i.e., less than or equal to $1/3\ t_p$).

Basin Shape Limits

The basin shape can have a profound effect on the final results and, in some instances, can result in underestimates of peak flows. Experience with the 1982 version of the CUHP has shown that whenever basin length is increased faster than basin area, the storm hydrograph peak will tend to decrease. Although hydrologic routing is an integral part of runoff analysis, the data used to develop the 1982 version of the CUHP is insufficient to say that the observed CUHP response with disproportionately increasing basin length is valid. For this reason, it is important to subdivide irregularly shaped or very long basins (i.e., basin length to width ratios of 4 or more) into more regularly shaped sub-basins. A composite basin storm hydrograph can be developed using appropriate routing and by adding of the individual sub-basin storm hydrographs.

All tables, graphs and standard forms allowing for the calculation of the major storm runoff hydrograph are enclosed within the pertaining "Tables and Figures" section of this chapter.

Example - One Homogeneous Basin Hydrograph

Given: A basin that has the following characteristics:
Watershed Area (A) = 0.38 square miles = 243 acres
Watershed Length (L) = 1.28 miles
Distance to Centroid (L_{ca}) = 0.52 miles
Impervious area (Ia) = 44%
Slope along waterway (s) = 0.0102 ft/ft

Required: A storm hydrograph for the 100-year design storm

Solution:

Step 1. Using the given percent of impervious cover (i.e., 44%) find from Figure 24 the value of C_t.

$$C_t = 0.091$$

Step 2. Determine t_p using Equation 1.

$$t_p = C_t (L\ Lca/\sqrt{S})^{0.48}$$
$$= 0.091\ (1.28 \times 0.52/\sqrt{0.0102})^{0.48}$$
$$t_p = 0.225 \text{ hours (13.5 minutes)}$$

Step 3. Determine if a 5-minute unit hydrograph needs to be used or a longer unit hydrograph may be used in this case.

$$t_u\ 1/3t_p \text{ (5-minute minimum)}$$
$$1/3\ (13.5) = 4.5$$
$$\text{Use } t_u = 5 \text{ minutes (0.083 hours)}$$

Step 4. Determine C_p using Figure 25, the value of imperviousness, the given basin area, the C_t found in Step 2 and Equation 4-5 from Figure 25.

$$P = 6.21$$

Then

$$C_p = P\ C_t A^{0.15} \quad \text{Equation 5}$$
$$= 6.21 \times 0.021 \times (0.38)^{0.15}$$
$$= 0.49$$

Step 5. Determine q_p using Equation 3.

$$q_p = 640\ C_p/t_p$$
$$= 640 \times 0.49/0.225$$
$$= 1394\ \text{C.F.S./Sq. mi.}$$

Step 6. Determine Q_p using Equation 4.

$$Q_p = q_pA$$
$$= 1394 \times 0.38$$
$$= 530\ \text{C.F.S.}$$

Step 7. Determine T_p using Equation 2.

$$T_p = 60\ t_p + 0.5t_u$$
$$= (60 \times 0.225) + (0.5 \times 5.0)$$
$$= 16.0\ \text{minutes}$$

Step 8. Determine the width of the unit hydrograph and the portion of that width ahead of Q_p at 50 and 75 percent of Q_p using Figures 26 and 27.

W50% = 0.349 hours (21.0 minutes)
W75% = 0.186 hours (11.2 minutes)
W50% ahead of Q_p = 0.45 x 11.2
= 5.0 minutes
w75% ahead of Q_p = 0.45 x 11.2
= 5.0 minutes

*Note: Less than 0.6 T_p = 9.6 minutes; therefore use 7.4 minutes and 5.0 minutes at W50% and W75%, respectively. If the 7.4 minutes were greater than 0.6 T_p, the alternate procedure would have been used.

Step 9. Sketch the unit hydrograph (Figure 27) using T_p, Q_p, W50%, W75% and the portions of W50% and W75% ahead of Q_p determined above.
Needed Unit Hydrograph volume:
(243 acres) x (1 inch/12 inch/foot) = 20.2 ac. ft.
Planimeter the unit hydrograph to obtain its volume. Adjust recession leg of the hydrograph until 20.2 ac. ft. (±5%) is obtained.

Step 10. Obtain the design effective precipitation by using the form table shown in Figure 18. To determine the effective rainfall, we will use the following procedure:

Col. 1 For the design location, select a rainfall time interval, equivalent to the one used for the unit hydrograph (usually 5 minutes.

Col. 2 Enter the rainfall increments for the appropriate basin size and selected storm frequency from the table shown in Figure 19.

Pervious Area, Columns 3 through 6

Col. 3 Select and enter the increments of infiltration for each time period. Use the table shown in Figure 20 to that purpose.

Col. 4 the total pervious depression storage is determined from Figure 21. It appears as the total at the bottom of Column 4. For each time period, the depression storage in Col. 4 is found by subtracting infiltration, Col. 3, from precipitation, Col. 2. If the result is negative, there is no excess for this period, and Col. 4 and Col. 5 are zero. If the result is positive, the amount is entered in Col. 4 as the depression storage for the time period. When the cumulative amount in Col. 4 equals the total shown at the bottom of the column, the depression storage is fully used and all remaining values are zero. Not that the last value of depression storage will usually be less than Col. 2 minus Col. 3 and will be determined by finding the difference between the maximum amount and the cumulative amount of infiltration through the previous time periods.

Col. 5 Effective precipitation for the pervious area is Col. 2 minus Columns 3 and 4. Use positive only.

Col. 6 Col. 5 times the (decimal) percent of the pervious area gives the area-weighted depth of water that will run off in each time increment for the pervious area.

Impervious Area, Columns 7 - 10

Col. 7 Enter the total assumed impervious depression storage, determined from Figure 21, at the bottom of Col. 7. The impervious depression storage in Co. 7 is then either the amount of precipitation in Col. 2 or the amount available as determined by deducting the total accumulated amount from the total assumed value shown at the bottom of Col. 7. When the total assumed amount is fully used, all remaining values are zero.

Col. 8 After all of the impervious storage has been filled, an impervious loss will still occur. To account for this, Col. 8 is computed by taking 5 percent of Col. 2 less Col. 7.

Col. 9 Effective precipitation for the impervious area is Col. 2 less Columns 7 and 8.

Col. 10 Col. 9 times the (decimal) percent of impervious area gives the area-weighted depth of water that will run off in each time increment for the pervious area.

Col. 11 Add Col. 10 and Col. 6 to obtain the average effective rainfall. This is the "design effective rainfall" that will be applied to the unit hydrograph to obtain the design storm runoff hydrograph.

Step 11. Use the table shown in Figure 31 and enter Col. 11 values in columns 3 through 24.

Step 12. Multiply the precipitation value at the top of Column 3 by each of the unit hydrograph ordinates and put in Column 3 for the corresponding time. Next, multiply the precipitation value in Column 4 by each of the unit hydrograph ordinates and place in Column 4 lagged by one time increment from the corresponding unit hydrograph time. Proceed to multiply each of the precipitation values times the unit hydrograph ordinates, each time lagging the new hydrograph by one more time unit.

Step 13. Column 25 is the design storm hydrograph obtained by summing horizontally the individual hydrographs in Columns 3 through 24.

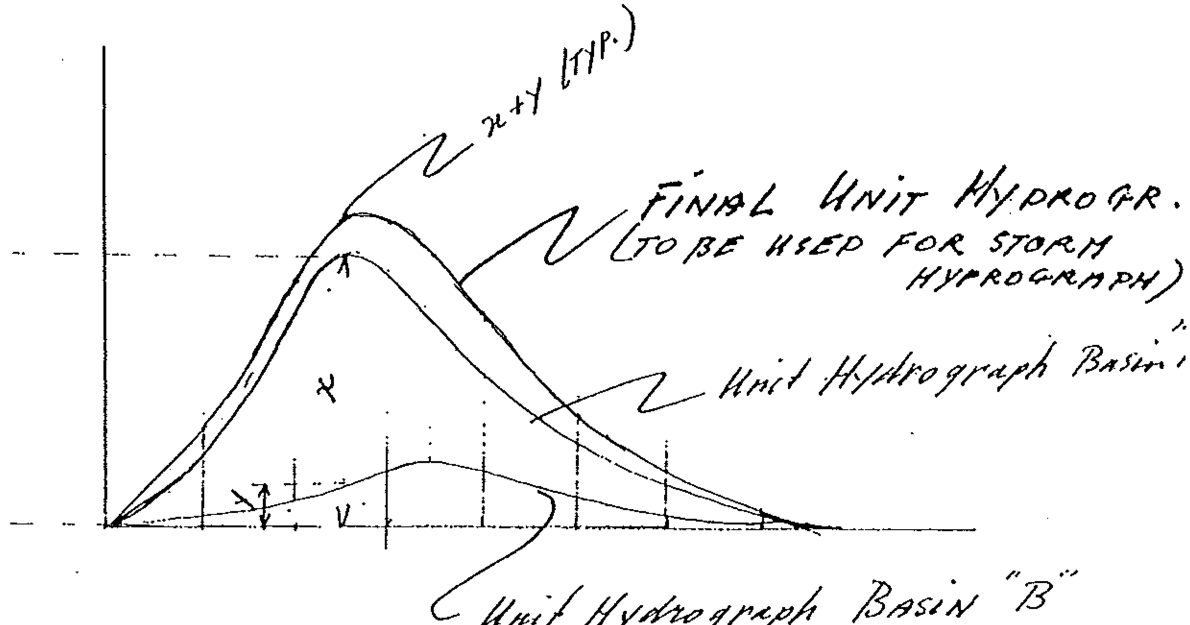
When 2 (or more) major basins converge at the design point:

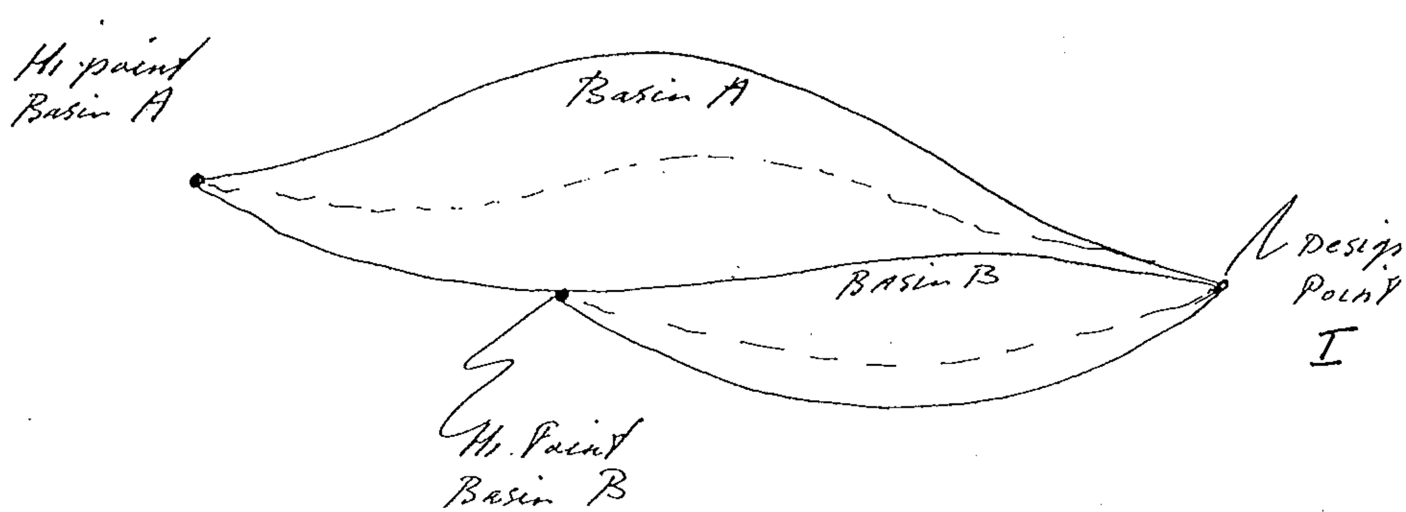
1. Determine the Unit Hydrograph for each basin

2. Combine both (or more) Unit Hydrographs into single Unit Hydrograph

   Determine the storm Hydrograph from this final Unit Hydrograph.

Example:





TABLES & FIGURES

(URBAN HYDROGRAPH)

EXAMPLE

EXAMPLE NOT IN ADAMS COUNTY

DETERMINATION OF EFFECTIVE RAINFALL

LOCATION : SECTION 18 **, TOWNSHIP** T1S **, RANGE** R66W

DESIGN STORM : 10-Year Recurrance

		Pervious Area 60%				Impervious Area 40%				
Time (min.) 1	Incremental Precipitation (in.) 2	Maximum Infiltration (in.) 3	Depression storage (in.) 4	Effective Precipitation (in.) 5	60% Effective Precipitation (in.) 6	Depression Storage (in.) 7	Loss (in.) 8	Effective Precipitation (in.) 9	40% Effective Precipitation (in.) 10	Total Effective Precipitation (in.) 11
5	0.03	0.20	0	0	0	0.03	0	0	0	0
10	0.06	0.13	0	0	0	0.06	0	0	0	0
15	0.13	0.10	0.03	0	0	0.01	0.01	0.11	0.04	0.04
20	0.24	0.07	0.17	0	0	0	0.01	0.23	0.09	0.09
25	0.40	0.06	0.10	0.26	0.16	0	0.02	0.38	0.15	0.31
30	0.19	0.05	0	0.14	0.08	0	0.01	0.18	0.07	0.15
35	0.09	0.05	0	0.04	0.02	0	0	0.09	0.04	0.06
40	0.07	0.04	0	0.03	0.02	0	0	0.07	0.03	0.05
45	0.06	0.04	0	0.02	0.01	0	0	0.06	0.02	0.03
50	0.05	0.04	0	0.01	0.01	0	0	0.05	0.02	0.03
55	0.05	0.04	0	0.01	0.01	0	0	0.05	0.02	0.03
60	0.05	0.04	0	0.01	0.01	0	0	0.05	0.02	0.03
65	0.05	0.04	0	0.01	0.01	0	0	0.05	0.02	0.03
70	0.05	0.04	0	0.01	0.01	0	0	0.05	0.02	0.03
75	0.05	0.04	0	0.01	0.01	0	0	0.05	0.02	0.03
80	0.04	0.04	0	0	0	0	0	0.04	0.02	0.02
85	0.03	0.04	0	0	0	0	0	0.03	0.01	0.01
90	0.03	0.04	0	0	0	0	0	0.03	0.01	0.01
95	0.03	0.04	0	0	0	0	0	0.03	0.01	0.01
100	0.03	0.04	0	0	0	0	0	0.03	0.01	0.01
105	0.03	0.04	0	0	0	0	0	0.03	0.01	0.01
110	0.03	0.04	0	0	0	0	0	0.03	0.01	0.01
115	0.03	0.04	0	0	0	0	0	0.03	0.01	0.01
120	0.02	0.04	0	0	0	0	0	0.02	0.01	0.01
Total	1.84	—	0.30	0.55	0.35	0.10	0.05	1.69	0.66	1.01

DETERMINATION OF EFFECTIVE RAINFALL

LOCATION : SECTION ___, TOWNSHIP ___, RANGE ___

DESIGN STORM : ________

Time (min.) 1	Incremental Precipitation (in.) 2	Pervious Area: Maximum Infiltration (in.) 3	Pervious Area: Depression storage (in.) 4	Pervious Area: Effective Precipitation (in.) 5	Pervious Area: ___ Effective Precipitation (in.) 6	Impervious Area: Depression Storage (in.) 7	Impervious Area: Loss (in.) 8	Impervious Area: Effective Precipitation (in.) 9	Impervious Area: ___ Effective Precipitation (in.) 10	Total Effective Precipitation (in.) 11

DESIGN STORMS FOR ADAMS COUNTY

INCREMENTAL RAINFALL DEPTH/RETURN PERIOD

TIME	BASINS LESS THAN 5 SQ. MILES					BASINS BETWEEN 5 AND 10 SQ. MILES					BASINS BETWEEN 10 AND 20 SQ MILES				
(Min)	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)
5	0.02	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03
10	0.04	0.05	0.06	0.08	0.08	0.04	0.05	0.06	0.08	0.08	0.04	0.05	0.06	0.08	0.08
15	0.08	0.12	0.14	0.12	0.12	0.08	0.12	0.14	0.12	0.12	0.08	0.12	0.14	0.12	0.12
20	0.16	0.22	0.25	0.19	0.22	0.15	0.21	0.25	0.19	0.22	0.14	0.20	0.25	0.19	0.22
25	0.25	0.36	0.42	0.35	0.38	0.24	0.35	0.40	0.34	0.36	0.23	0.32	0.38	0.32	0.34
30	0.14	0.18	0.20	0.59	0.68	0.13	0.17	0.19	0.57	0.65	0.13	0.16	0.18	0.53	0.61
35	0.06	0.08	0.09	0.28	0.38	0.06	0.08	0.09	0.27	0.36	0.06	0.08	0.09	0.25	0.34
40	0.05	0.06	0.07	0.19	0.22	0.05	0.06	0.07	0.19	0.22	0.05	0.06	0.07	0.19	0.22
45	0.03	0.05	0.06	0.12	0.17	0.03	0.05	0.06	0.12	0.17	0.03	0.05	0.06	0.12	0.17
50	0.03	0.05	0.05	0.12	0.14	0.03	0.05	0.05	0.12	0.14	0.03	0.05	0.05	0.12	0.14
55	0.03	0.04	0.05	0.08	0.11	0.03	0.04	0.05	0.08	0.11	0.03	0.04	0.05	0.08	0.11
60	0.03	0.04	0.05	0.08	0.11	0.03	0.04	0.05	0.08	0.11	0.03	0.04	0.05	0.08	0.11
65	0.03	0.04	0.05	0.08	0.11	0.03	0.04	0.05	0.08	0.11	0.03	0.04	0.05	0.08	0.11
70	0.02	0.04	0.05	0.06	0.05	0.02	0.04	0.05	0.06	0.05	0.02	0.04	0.05	0.06	0.05
75	0.02	0.03	0.05	0.06	0.05	0.02	0.03	0.05	0.06	0.05	0.02	0.03	0.05	0.06	0.05
80	0.02	0.03	0.04	0.04	0.03	0.02	0.03	0.04	0.04	0.03	0.02	0.03	0.04	0.04	0.03
85	0.02	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.04	0.03
90	0.02	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03
95	0.02	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03
100	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03
105	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03
110	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03
115	0.01	0.02	0.03	0.03	0.03	0.01	0.02	0.03	0.03	0.03	0.01	0.02	0.03	0.03	0.03
120	0.01	0.02	0.02	0.03	0.03	0.01	0.02	0.02	0.03	0.03	0.01	0.02	0.02	0.03	0.03
125											0.01	0.02	0.02	0.02	0.02
130											0.01	0.01	0.02	0.02	0.02
135											0.01	0.02	0.01	0.02	0.02
140											0.01	0.02	0.01	0.02	0.02
145											0.01	0.01	0.01	0.02	0.02
150											0.01	0.01	0.01	0.01	0.02
155											0.01	0.01	0.01	0.01	0.01
160											0.01	0.01	0.01	0.01	0.01
165											0.01	0.01	0.01	0.01	0.01
170											0.01	0.01	0.01	0.01	0.01
175											0.01	0.01	0.01	0.01	0.01
180											0.01	0.01	0.01	0.00	0.00
TOTAL:	1.15	1.61	1.89	2.72	3.12	1.12	1.58	1.86	2.68	3.05	1.22	1.68	1.97	2.76	3.14

DATE:
REV:

REFERENCE: WRC Engineering, Inc. TM-1, February 1989

FIGURE 20

INCREMENTAL INFILTRATION DEPTHS IN INCHES*

Time Minutes**	SCS Hydrologic Soil Group A	B	C&D
5	.384	.298	.201
10	.329	.195	.134
15	.284	.134	.096
20	.248	.099	.073
25	.218	.079	.060
30	.194	.067	.052
35	.175	.060	.048
40	.159	.056	.045
45	.146	.053	.044
50	.136	.052	.043
55	.127	.051	.042
60	.121	.051	.042
65	.115	.050	.042
70	.111	.050	.042
75	.107	.050	.042
80	.104	.050	.042
85	.102	.050	.042
90	.100	.050	.042
95	.098	.050	.042
100	.097	.050	.042
105	.096	.050	.042
110	.095	.050	.042
115	.095	.050	.042
120	.094	.050	.042

* Based on central value of each time increment in Horton's Equation.

** Time at end of the time increment

FIGURE 21

TYPICAL DEPRESSION RETENTION FOR VARIOUS LAND COVERS

(all values in inches)

(For use with CUHP Method)

Land Cover	Depression & Detention	Recommended
Impervious:		
Large Paved Areas	0.05 - 0.15	0.1
Roofs - Flat	0.1 - 0.3	0.1
Roofs - Sloped	0.05 - 0.1	0.05
Pervious		
Lawn Grass	0.2 - 0.5	0.35
Wooded Area and Open Fields	0.2 - 0.6	0.4

FIGURE 22

HYDRO DATA SHEET

DATE: ____________________

BY: ____________________

Basin: ____

Basin No.: ____________________________________

Location: (point of interest) ____

____

Basin Parameters:

A (sq. mi.) = ______________ Lca. (mi.) = ______________

L (mi.) = ______________ Slope (%) = ______________

Flow Time

0-10 yrs. = ______________

10-100 yrs. = ______________

Degree/Type of development:

(A) Existing ☐ ____

____

(B) Projected ☐ ____

____

(C) Other ☐ ____

____

Hydrological Characteristics:

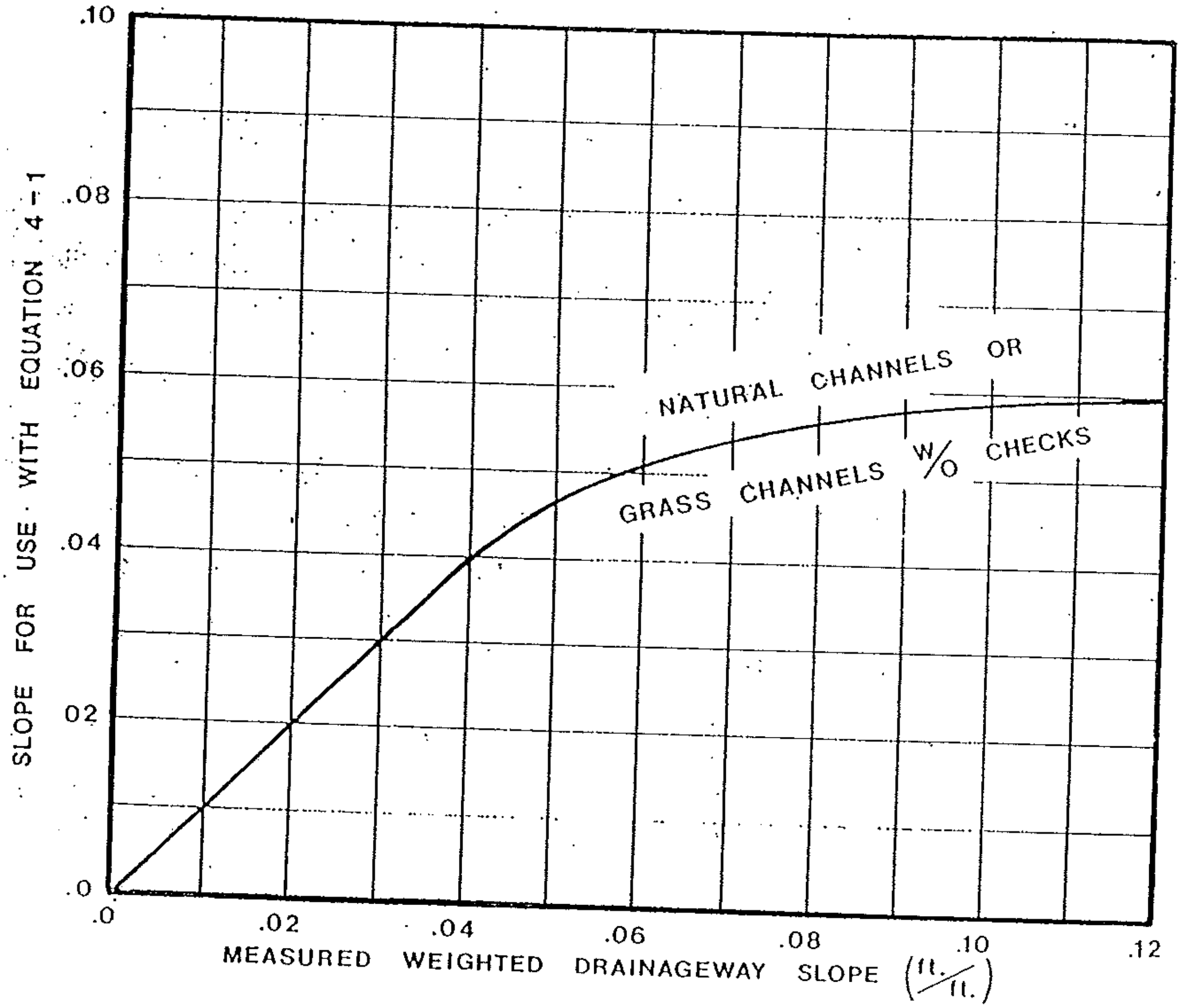
Pervious (%) = ____________ CT = ____________

Impervious (%) = ____________ CP = ____________

Infiltration (in/hr) = ____________ Loss (%) = ____________

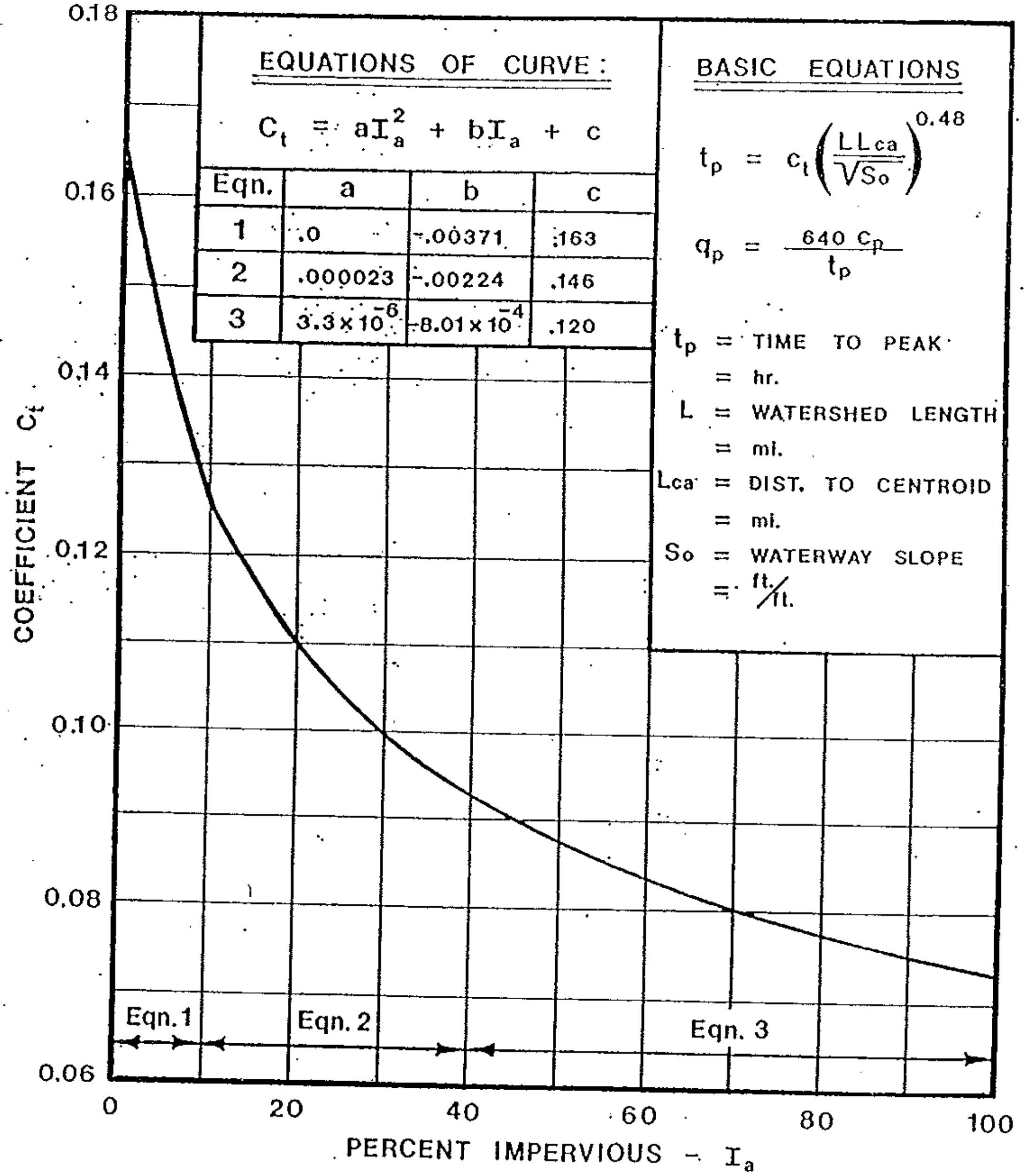
Perv. Retention (in) = ____________ Imperv. Retention (in) = ____________

FIGURE 23



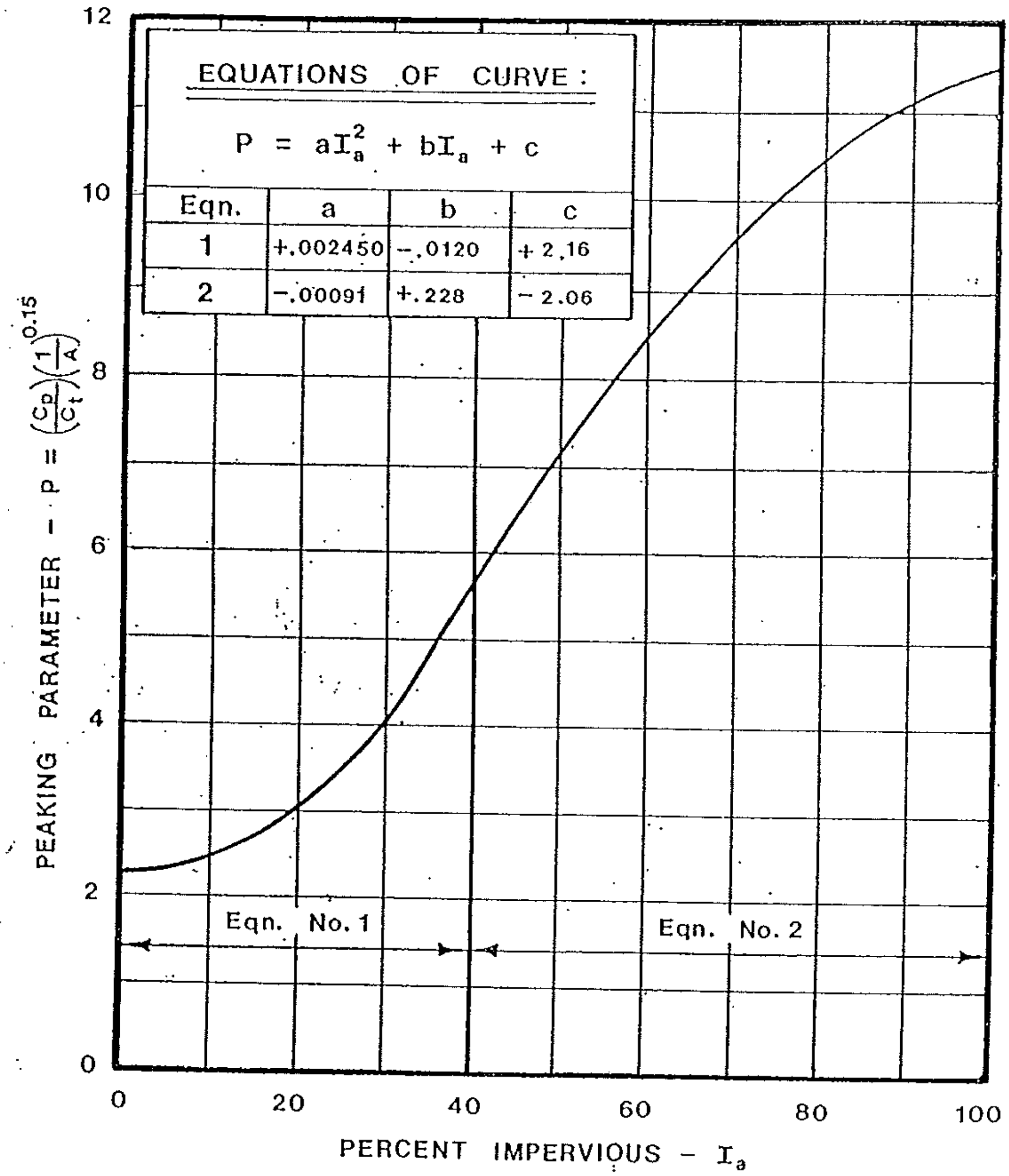
SLOPE CORRECTION FOR NATURAL DRAINAGEWAYS

FIGURE 24



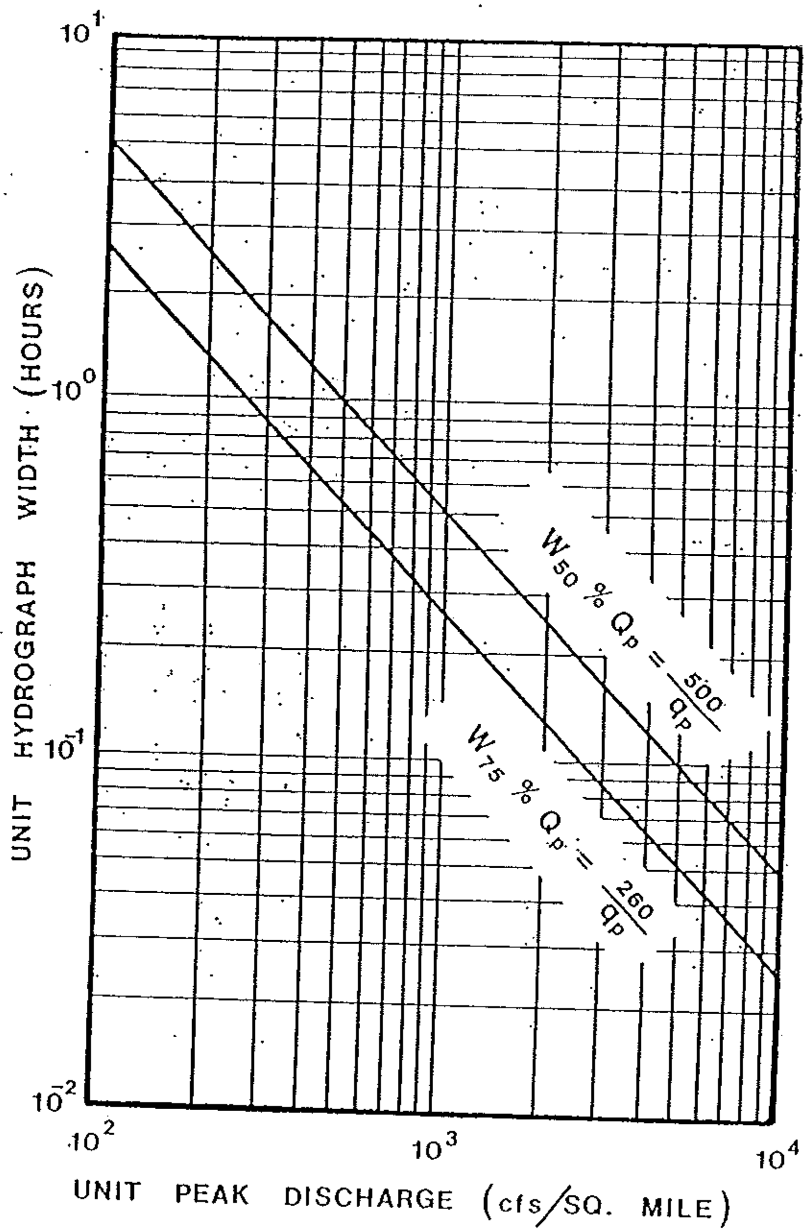
RELATIONSHIP BETWEEN C_t & IMPERVIOUSNESS

FIGURE 25



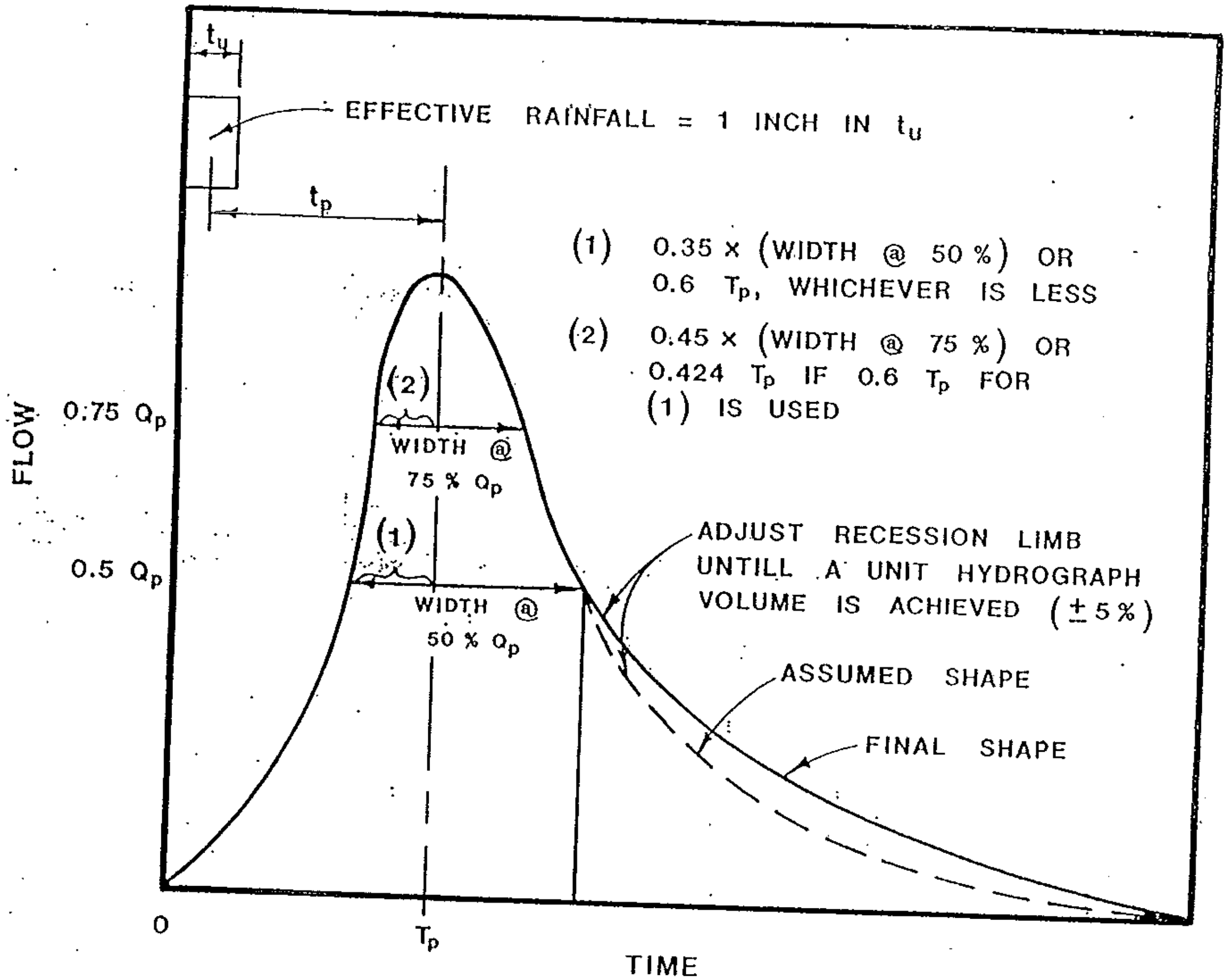
RELATIONSHIP BETWEEN PEAKING PARAMETER AND IMPERVIOUSNESS

FIGURE 26



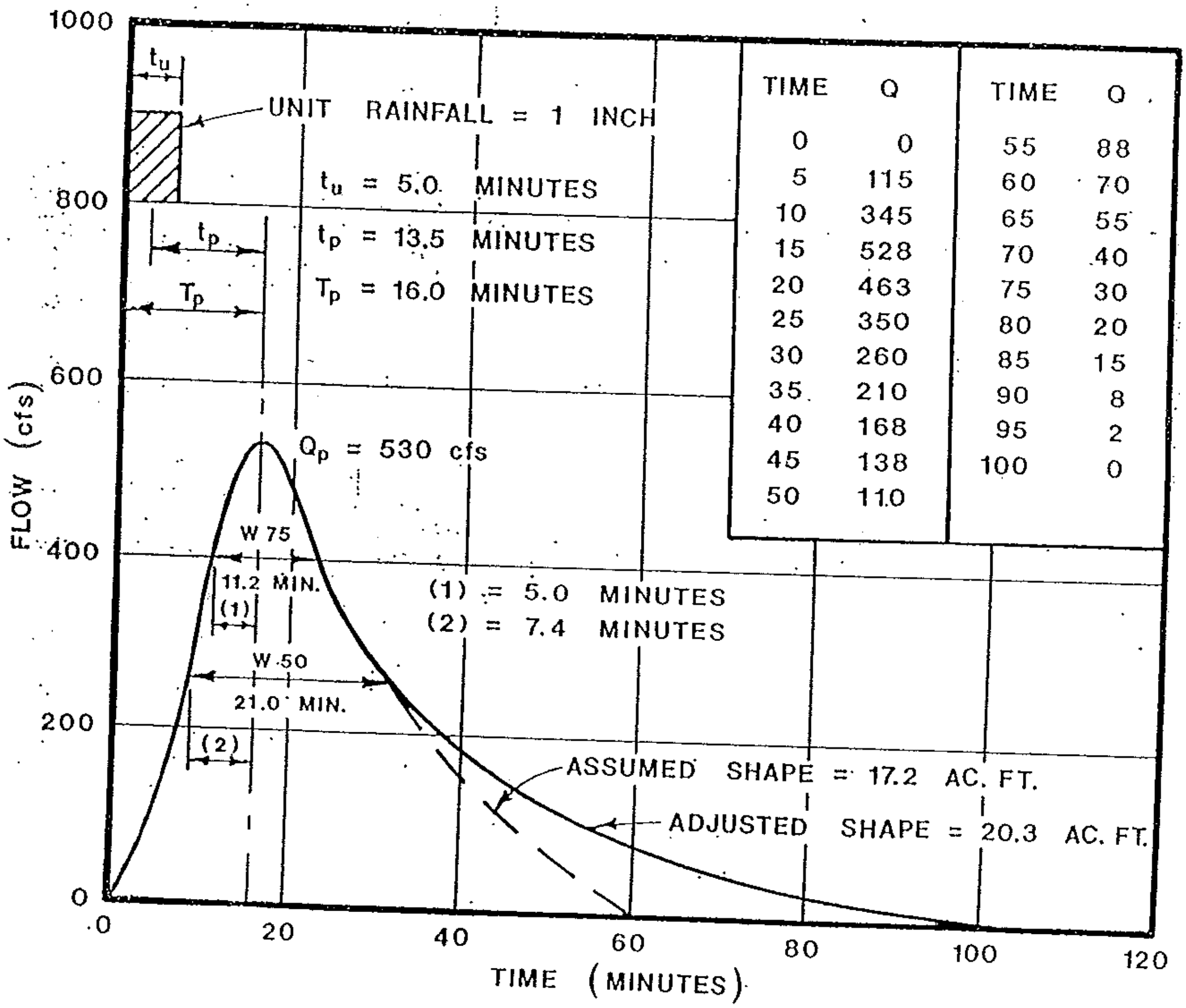
UNIT HYDROGRAPH WIDTHS

FIGURE 27



UNIT HYDROGRAPH

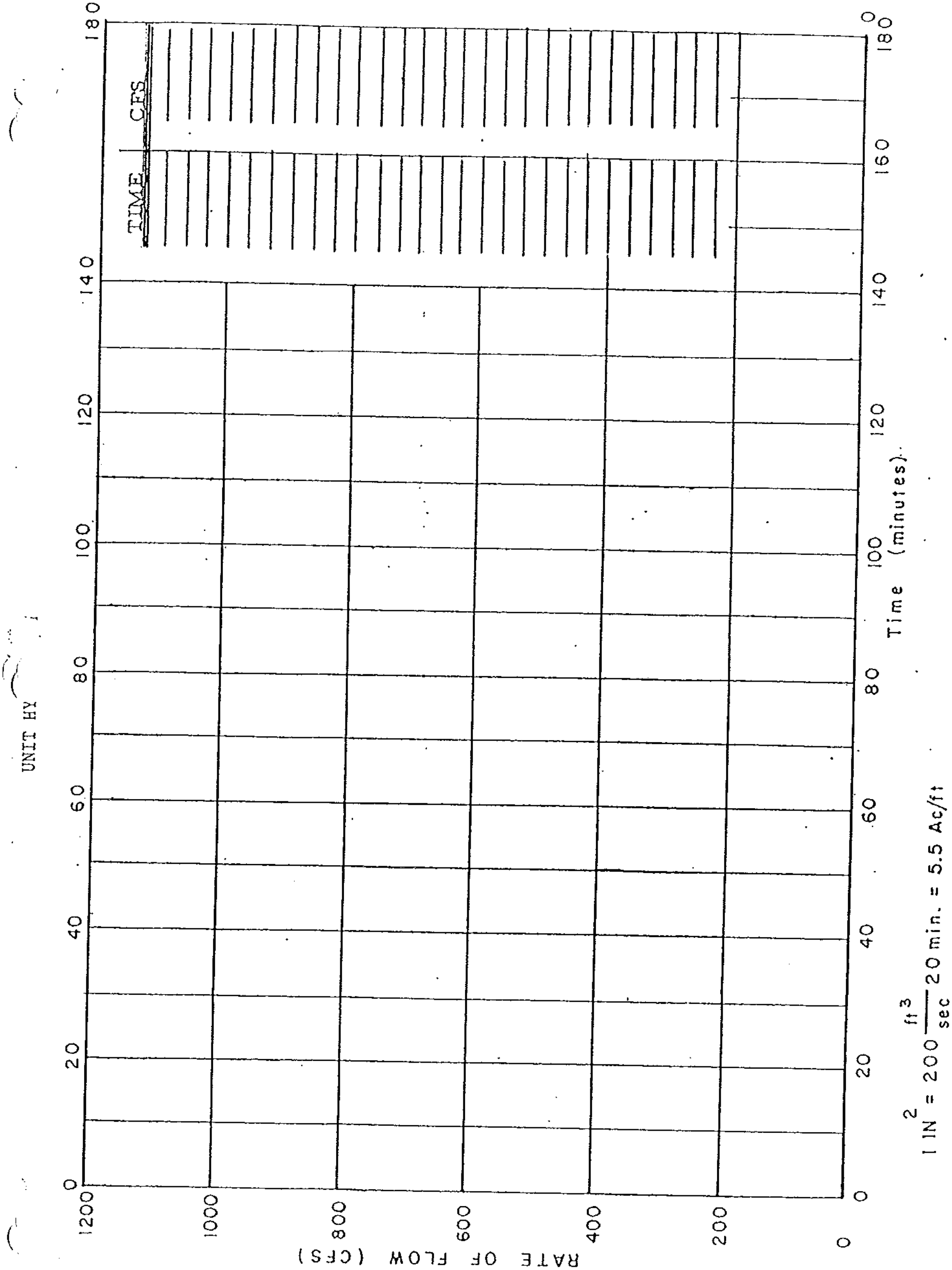
FIGURE 28



TIME	Q	TIME	Q
0	0	55	88
5	115	60	70
10	345	65	55
15	528	70	40
20	463	75	30
25	350	80	20
30	260	85	15
35	210	90	8
40	168	95	2
45	138	100	0
50	110		

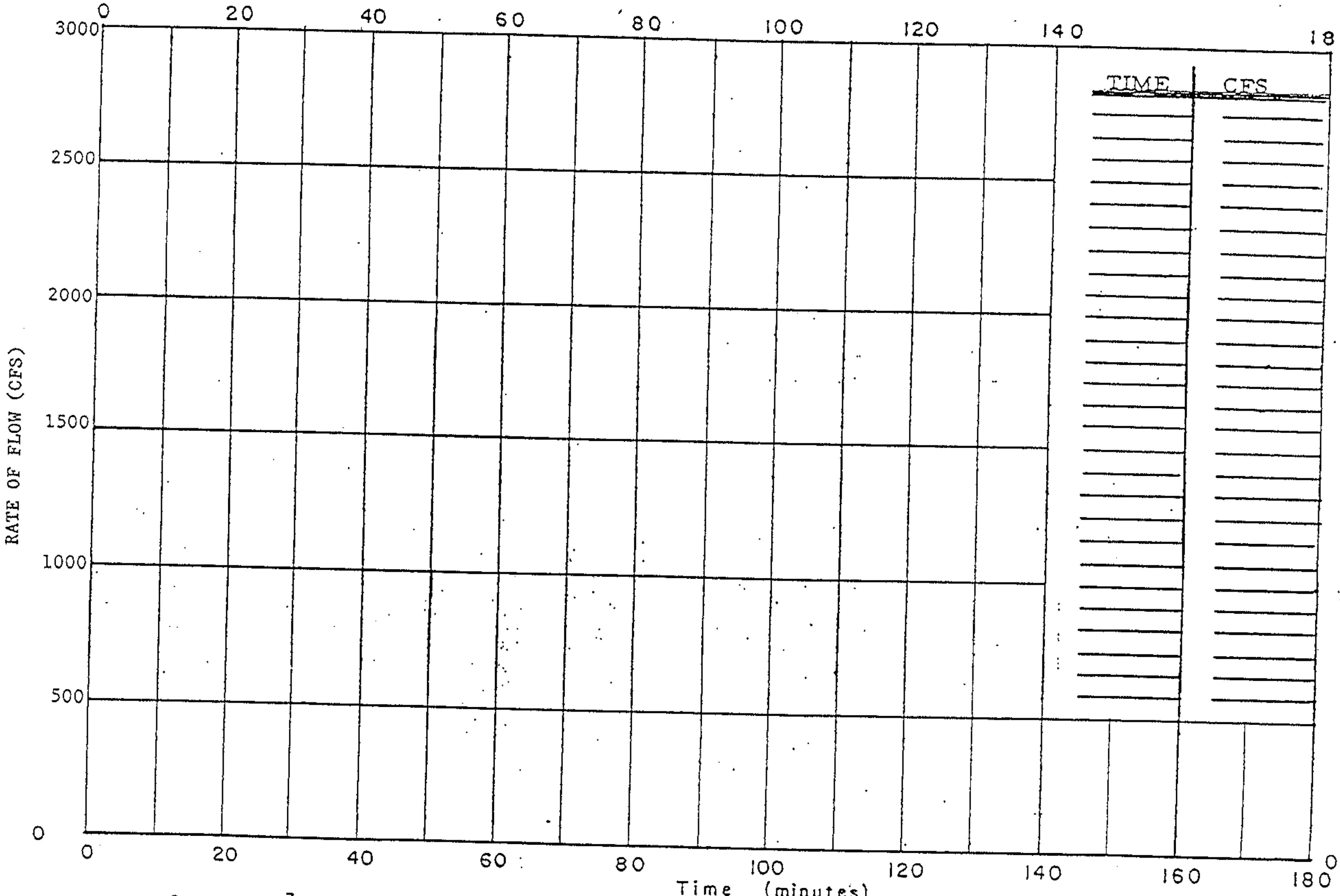
EXAMPLE OF UNIT HYDROGRAPH SHAPING

FIGURE 29



UNIT HY
TIME
CFS
Time (minutes)
0
20
40
60
80
100
120
140
160
180
RATE OF FLOW (CFS)
0
200
400
600
800
1000
1200
1 IN^2 = 200 ft^3/sec 20 min. = 5.5 Ac/ft

UNIT HYDI



$1 \ IN^2 = 500 \frac{ft^3}{sec} \ 20 \ min. = 13.77 \ Ac./ft.$

FROM UNIT HYDROGRAPH

EXAMPLE (NOT IN ADAMS COUNTY)

FROM EFFECTIVE RAINFALL

Time (min) (1)	Unit Hydrograph (cfs) (2)	Excess Precipitation in inches 0.02 (3)	0.05 (4)	0.69 (5)	0.24 (6)	0.16 (7)	0.06 (8)	0.03 (9)	0.03 (10)	0.02 (11)	0.02 (12)	0.02 (13)	(14)	(15)	(16)	Storm Hydrograph (cfs) (17)
0	0	0														0
10	160	3	0													3
20	460	9	8	0												17
30	750	15	23	110	0											148
40	570	11	38	317	38	0										404
50	390	8	29	518	110	26	0									691
60	265	5	20	393	180	74	10	0								682
70	185	4	13	269	137	120	28	5	0							576
80	135	3	9	183	94	91	45	14	6	0						444
90	100	2	7	128	64	62	34	23	14	3	0					337
100	75	2	5	93	44	42	23	17	23	9	3	0				261
110	50	1	4	69	32	30	16	12	17	15	9	3				208
120	40	1	3	52	24	22	11	18	12	11	15	9				168
130	30	1	2	35	18	16	8	6	8	8	11	15				128
140	20	0	2	28	12	12	6	4	6	5	8	11				94
150	10		1	21	10	8	5	3	4	4	5	8				69
160	0		1	24	7	6	3	2	3	3	4	5				48
170			0	7	5	5	2	2	2	2	3	4				32
180				0	2	3	2	1	2	2	2	3				17
190					0	2	1	1	1	1	2	2				10
200						0	1	1	1	1	1	2				7
210							0	0	1	1	1	1				4
220									0	0	1	1				2
											0	1				1
												0				0

ΣQ''

EXAMPLE

DETERMINATION of STORM HYDROGRAPH

me ln)	Unit Hydrograph (cfs)	Excess Precipitation in inches																					Storm Hydrograph (cfs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)