Synthetic Unit Hydrograph, Snyder’s Method, SCS Methods, Lecture 8, 04/25/2013

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Adapted from textbook and notes of Philip B. Bedient, David Maidment and Areeya Rittima

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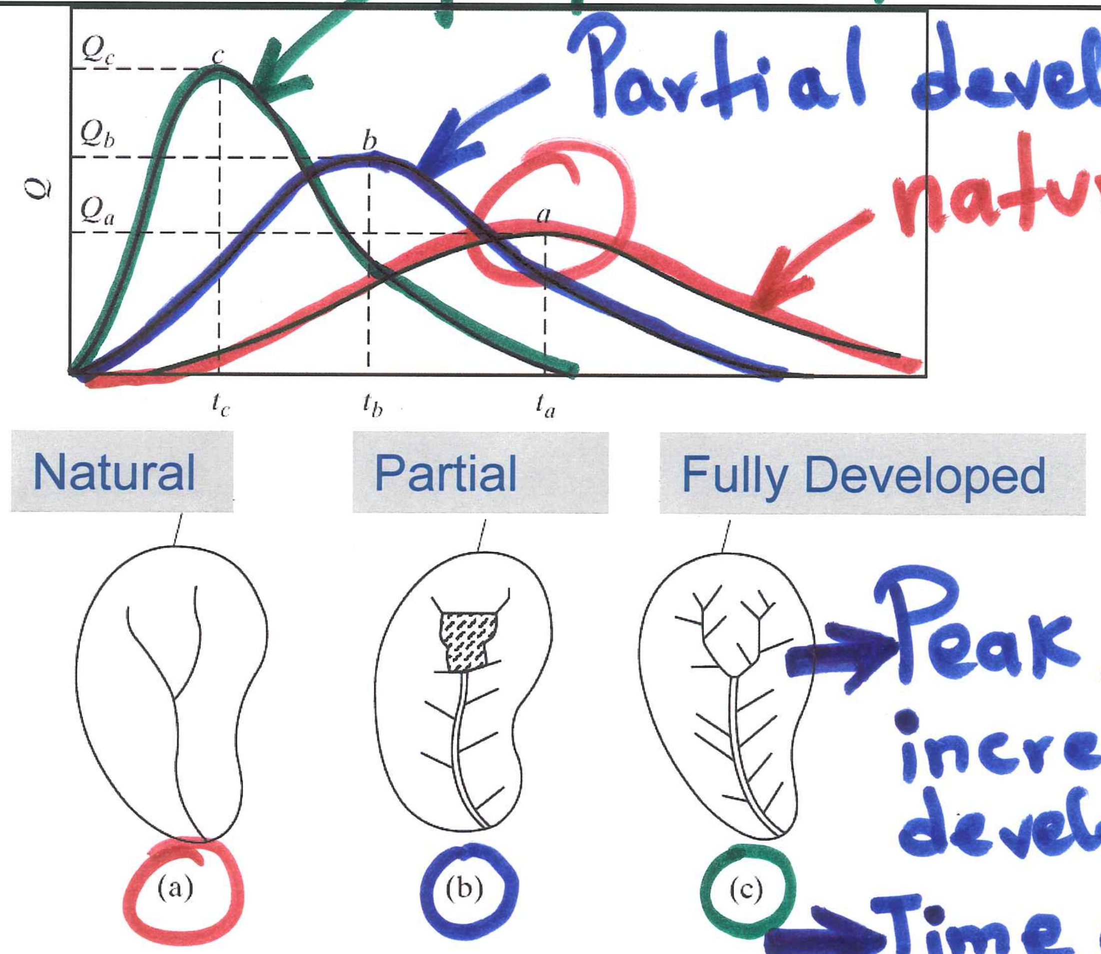
Development Effects on UH

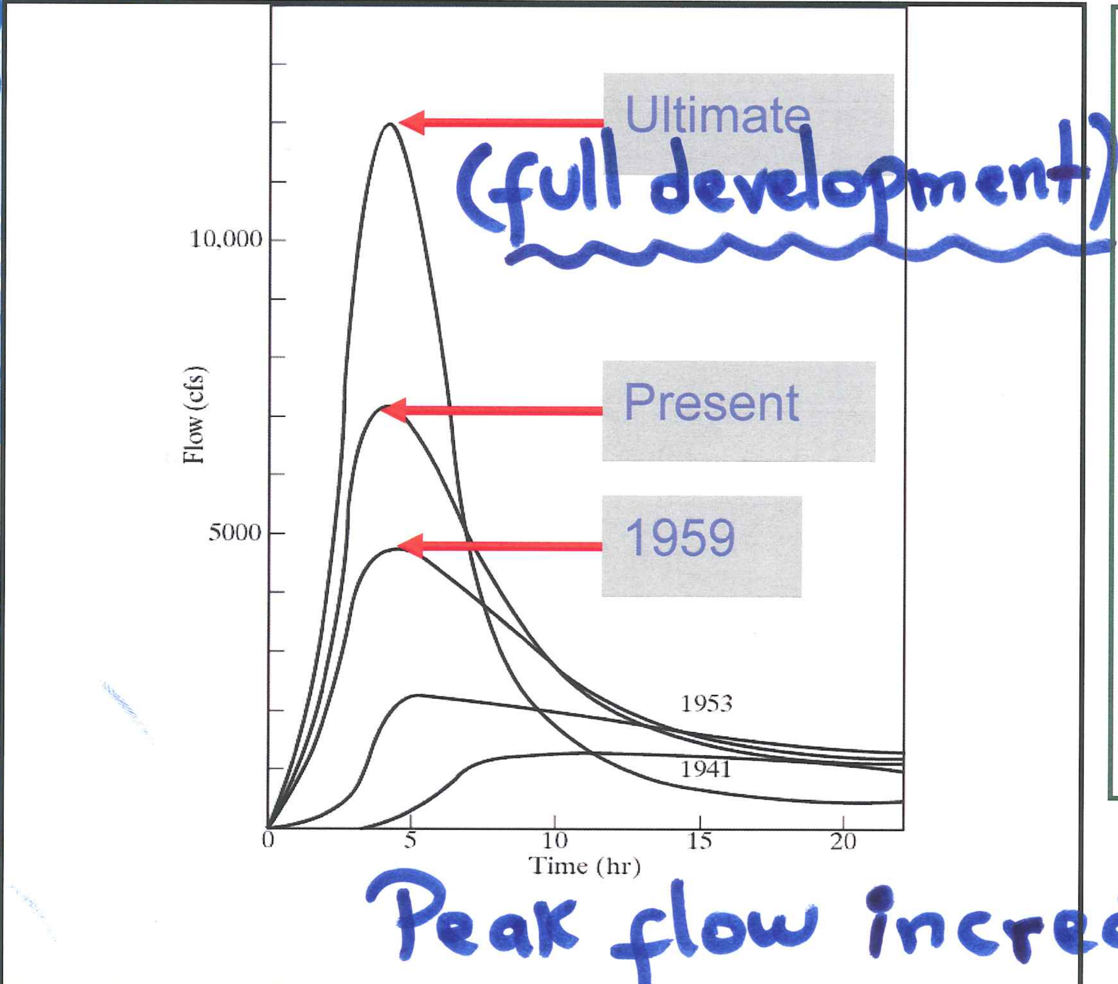


→ Peak flow will increase with development

→ Time of Rise will decrease

Modifying factors on unit hydrographs. (a) Natural watershed development, represented by curve *a* in the top part of the figure. (b) Partial development, represented by curve *b*. (c) Fully developed watershed, represented by curve *c*.

Brays Bayou (Texas) UH



Brays Bayou unit hydrograph changes as a function of land use changes.

Peak flow increases

Time of rise decreases

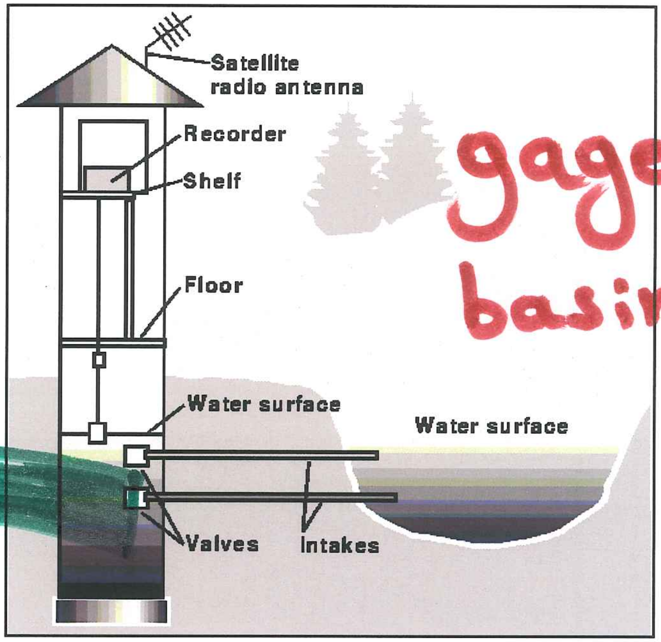
- Faster response with Development
- Higher peak flow with Development
- Need to provide downstream capacity (to avoid flooding)

Synthetic UH Methods

- Developed for basins that were ungaged
- Based on data from similar gaged basins
- Most methods are very similar in nature
- Variety of approaches but most based on Tp and Qp
- England and U.S. led the efforts to standardize UH

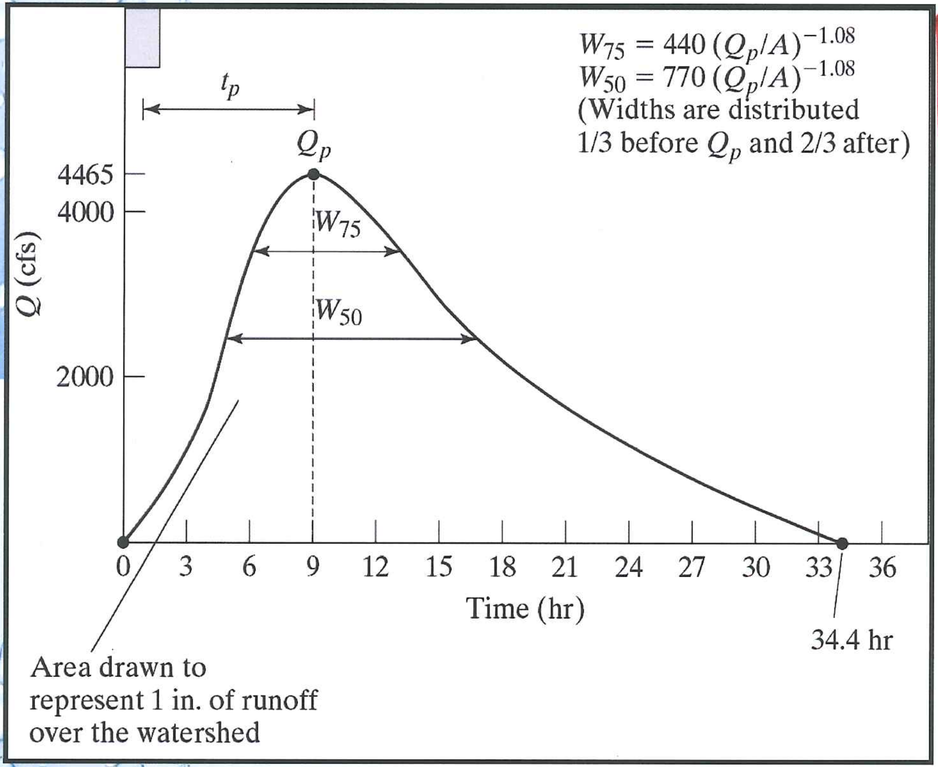
Tp : lagtime
Qp : Peak flow

https://webspace.utexas.edu/cm2877/giswr06.html



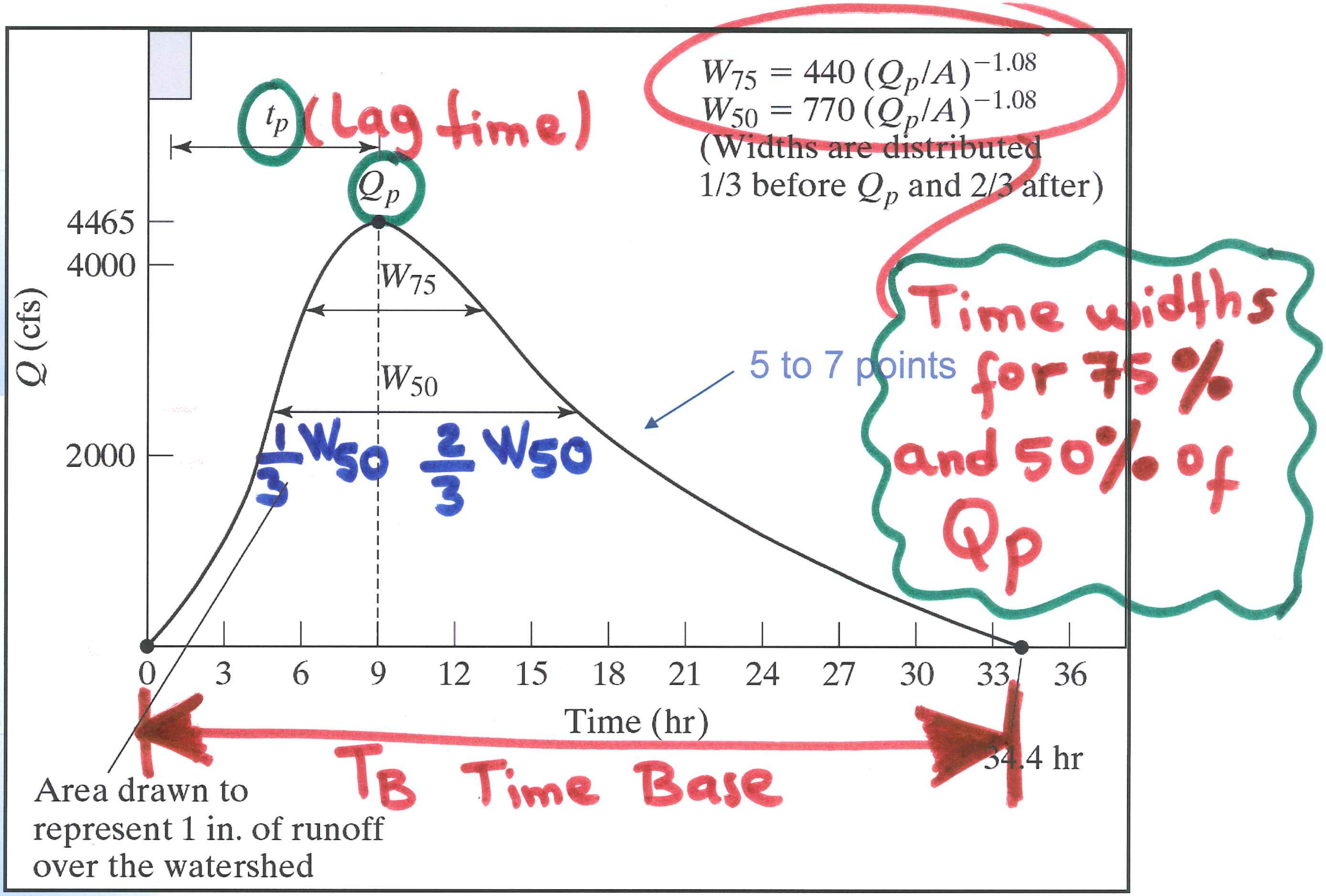
http://water.usgs.gov/wid/FS_209-95/mason-weiger.html

Synthetic UH Methods



- **Snyder's Method (1938)**
- Clark Method (1945)
- Nash (1958)
- **SCS (1964, 1975)**
- Espey-Winslow (1968)
- Kinematic Wave (1970s)

Snyder's Method



$W_{75} = 440\,(Q_p/A)^{-1.08}$
$W_{50} = 770\,(Q_p/A)^{-1.08}$
(Widths are distributed
1/3 before Q_p and 2/3 after)

5 to 7 points

Time widths for 75% and 50% of Qp

Area drawn to
represent 1 in. of runoff
over the watershed

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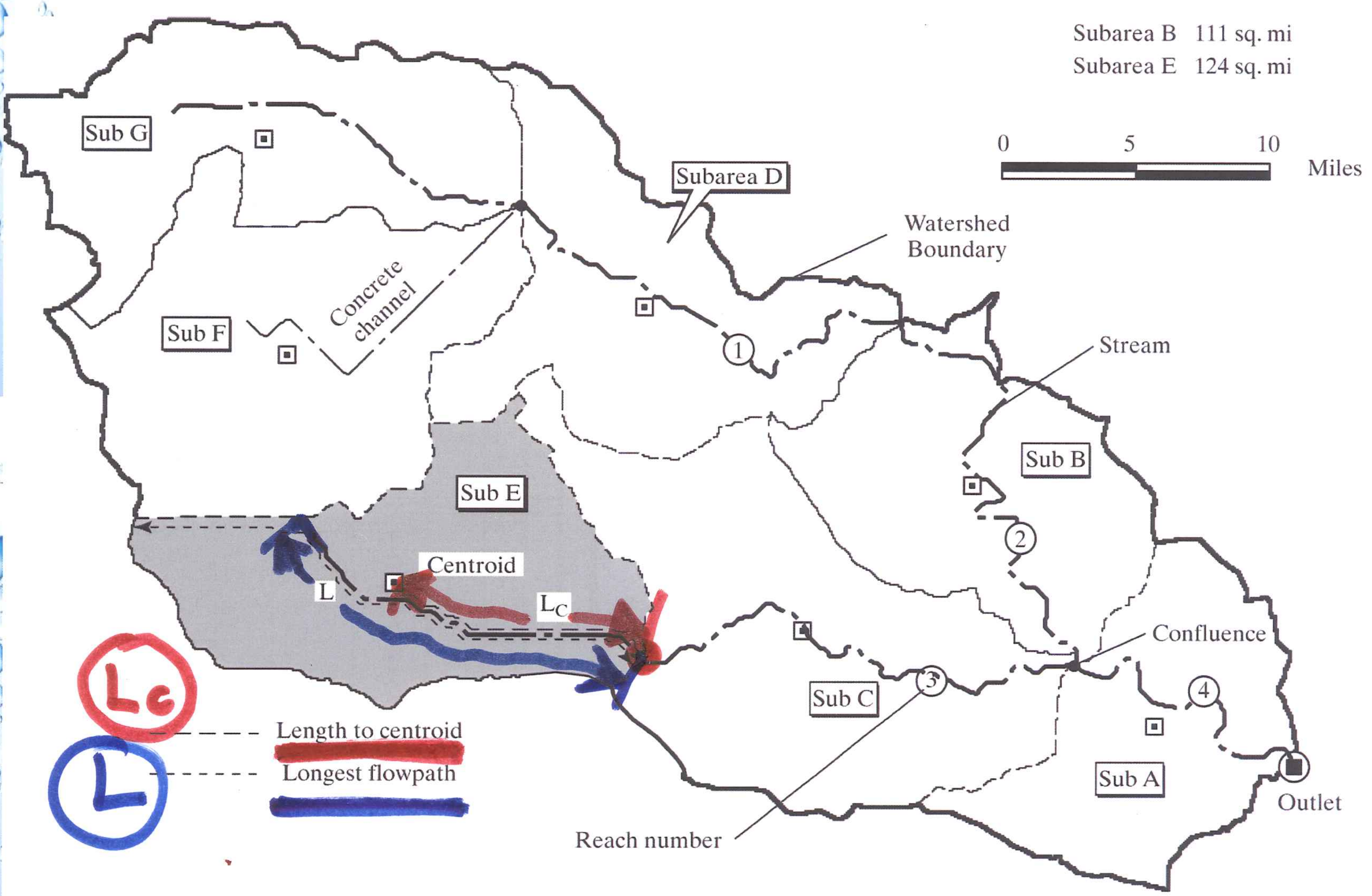
Typical subwatershed delineation in a watershed.



Example 2-4 SNYDER'S METHOD

Use Snyder's method to develop a UH for the area of 100 mi^2 described below. Sketch the approximate shape. What duration rainfall does this correspond to?

$$C_t = 1.8, \quad L = 18 \text{ mi},$$
$$C_p = 0.6, \quad L_c = 10 \text{ mi}$$

The UH is sketched in Figure E2–4. Note that width equations for W50 and W75 are given there to help shape the UH.

By Equation (2–8),

Lag time

$$\boxed{t_p = C_t(LL_c)^{0.3},}$$

$$t_p = 1.8(18 \cdot 10)^{0.3} \text{ hr},$$

$$\boxed{t_p = 8.6 \text{ hr.}} \checkmark$$

Use units
as indicated
in the empirical
equations

By Equation (2–9),

$$\boxed{Q_p = 640(C_p)(A)/t_p,}$$

$$= 640(0.6)(100)/8.6,$$

$$\boxed{Q_p = 4465 \text{ cfs.}}$$

Peak flow

Example 2-4 (continued) SNYDER'S METHOD

Since this is a small watershed, (A < ~ 200–500 mi²)

$$T_b \approx 4t_p = 4(8.6) \text{ hr},$$

$$\boxed{T_b = 34.4 \text{ hr.}}$$ ✓

Tb ~ 3-5 tp

$$\boxed{T_b \sim 4\,t_p}$$

And the duration of rainfall (D)

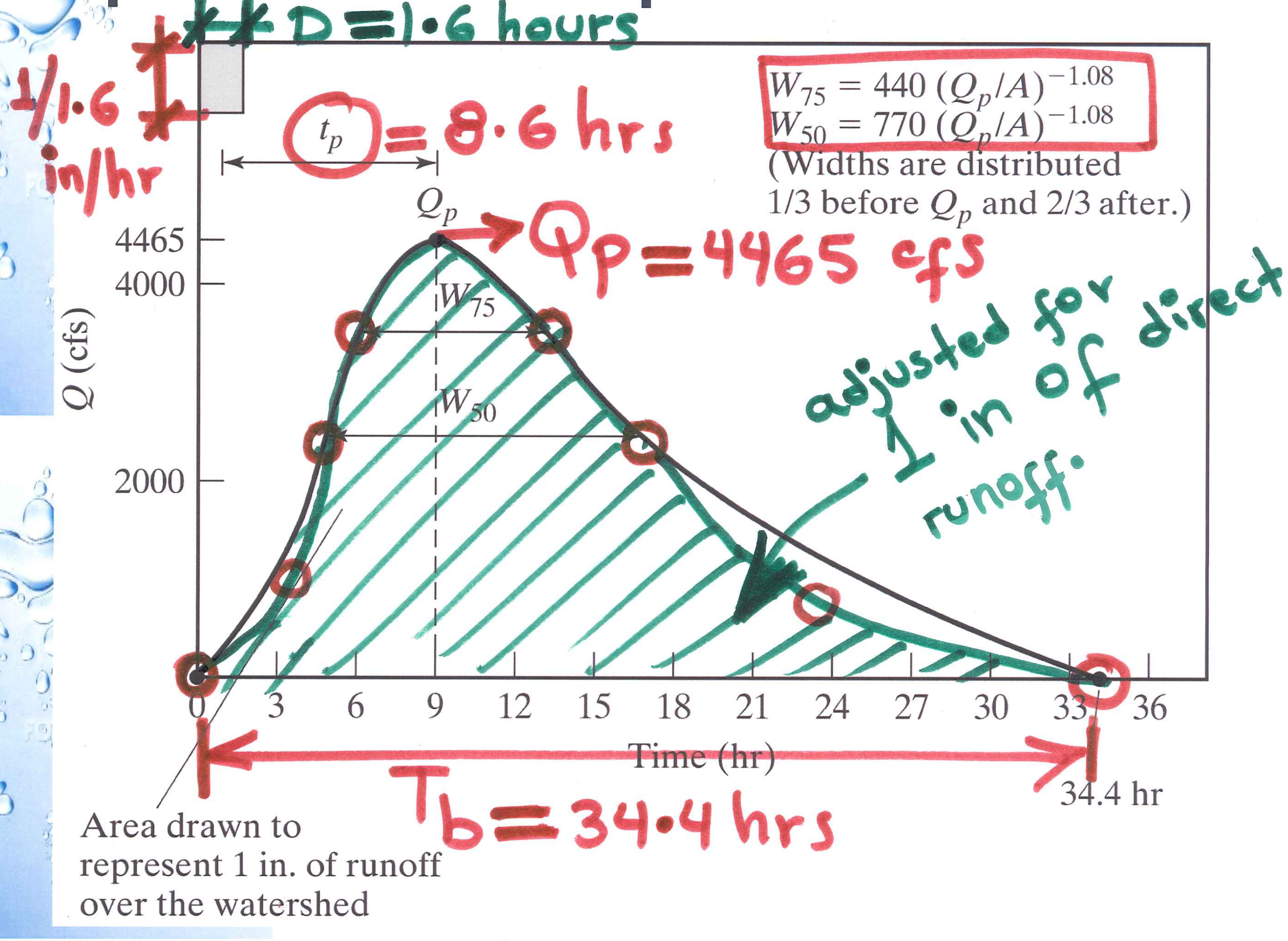
$$D = t_p/5.5 \text{ hr},$$

$$= 8.6/5.5 \text{ hr},$$

$$\boxed{D = 1.6 \text{ hr.}}$$ ✓

Finally, the hydrograph should be smoothed to represent 1.0 in. of direct runoff.

Typical Snyder unit hydrograph with special relationships indicated



$W_{75} = 440\ (Q_p/A)^{-1.08}$
$W_{50} = 770\ (Q_p/A)^{-1.08}$
(Widths are distributed 1/3 before Q_p and 2/3 after.)

Area drawn to represent 1 in. of runoff over the watershed

** D = 1.6 hours

1/1.6 in/hr

t_p = 8.6 hrs

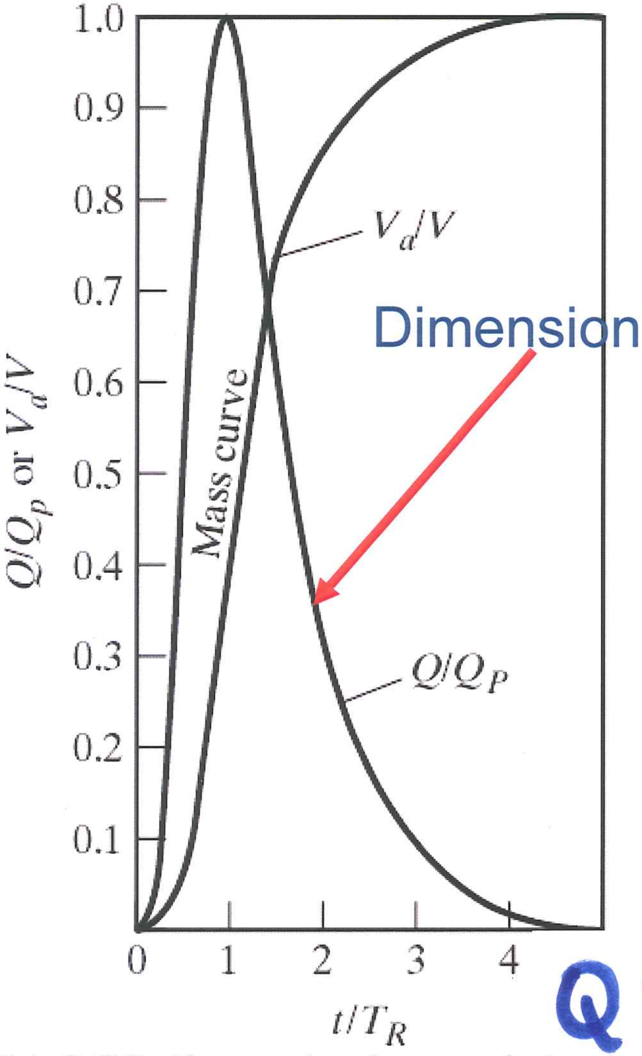
Q_p = 4465 cfs

adjusted for 1 in of direct runoff.

T_b = 34.4 hrs

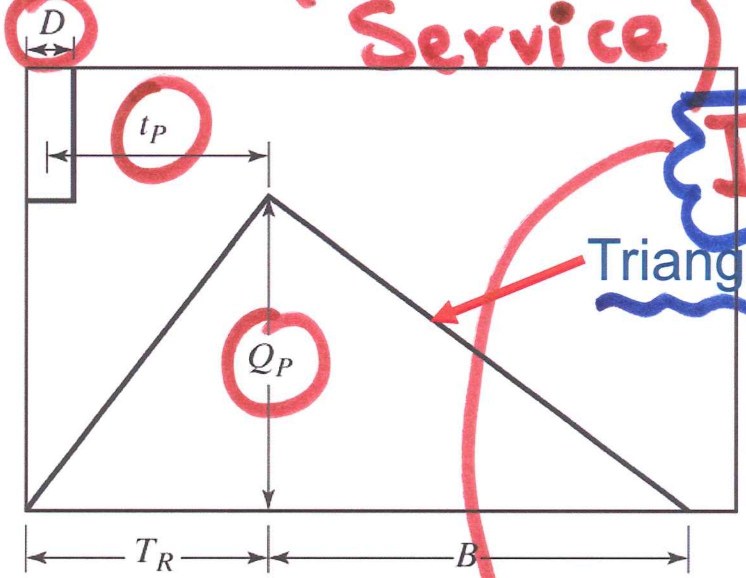
SCS Method (triangular unit hydrograph)

SCS (Soil Conservation Service)



Dimensionless UH

(b) SCS dimensionless unit hydrograph. (SCS, 1964)



Triangular UH

(a) SCS triangular unit hydrograph.

$I_a \approx 0.2S$

CN: Curve Number

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

I_a: Initial abstraction

S: Potential abstraction

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

Q: direct runoff

P: total storm rainfall

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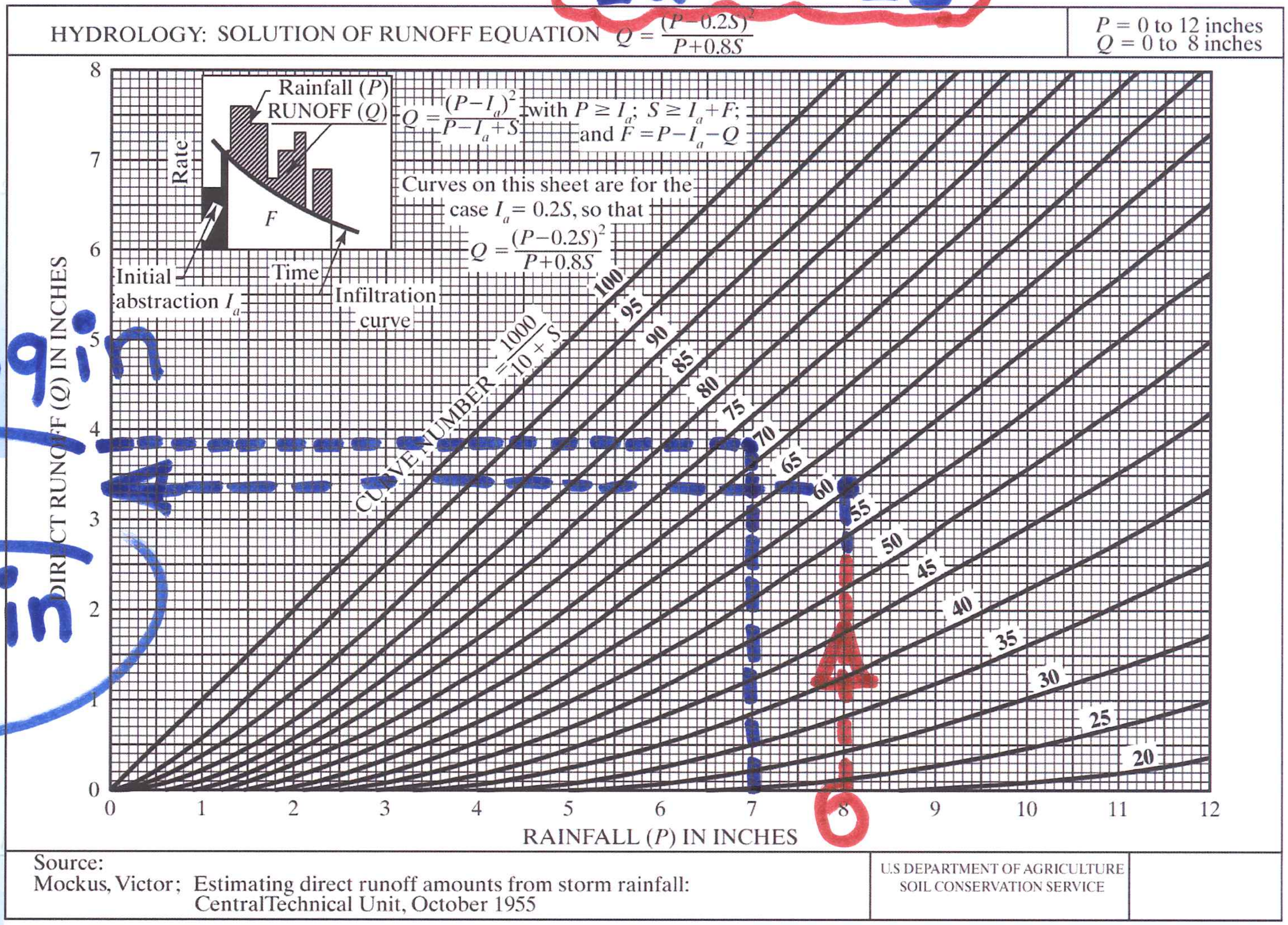
SCS RAINFALL RUNOFF CURVES

$I_a = 0.2S$



Source:
Mockus, Victor; Estimating direct runoff amounts from storm rainfall: CentralTechnical Unit, October 1955

$Q = 3.9$ in

$Q = 3.3$ in

Runoff Curve Numbers (Antecedent Moisture Condition II; $I_a = 0.2S$)

Table 2.1 (textbook)

Land Use Description		Hydrologic Soil Group			
		A	B	C	D
Cultivated land[1]					
Without conservation treatment		72	81	88	91
With conservation treatment		62	71	78	81
Pasture or range land					
Poor condition		68	79	86	89
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 cover[2]		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%–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[3]					
Average lot size	Average % impervious[4]				
1/8 ac or less	65	77	85	90	92
1/4 ac	38	61	75	83	87
1/3 ac	30	57	72	81	86
1/2 ac	25	54	70	80	85
1 ac	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.[5]		98	98	98	98
Streets and roads					
Paved with curbs and storm sewers[5]		98	98	98	98
Gravel		76	85	89	91
Dirt		72	82	87	89

CN

0 ← → 100

highly permeable soils

asphalt

Antecedent Moisture Condition (AMC)

- Antecedent Moisture condition is the preceding relative moisture of the pervious (permeable) surfaces prior to the rainfall event.

- Antecedent Moisture is considered to be **Low** ***when there has been little preceding rainfall*** and **High** ***when there has been considerable preceding rainfall*** prior to the modeled rainfall event.

- For modeling purposes, we consider watersheds to be AMC II, which is essentially an average moisture condition

AMC (Antecedent Moisture Condition).

Hydrologic Soil Groups

Group Asoils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have a high rate of water transmission (greater than 0.30 in/hr).

Group Bsoils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).

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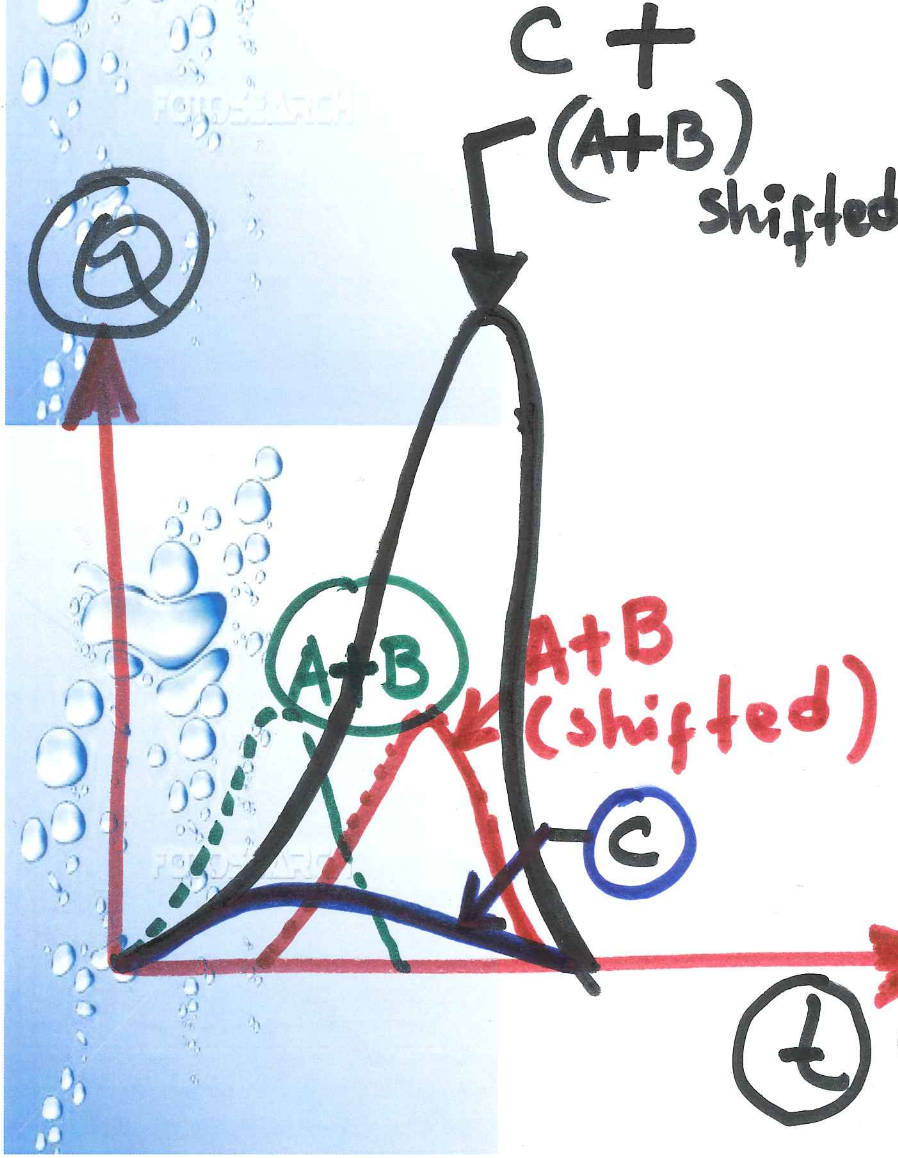
b

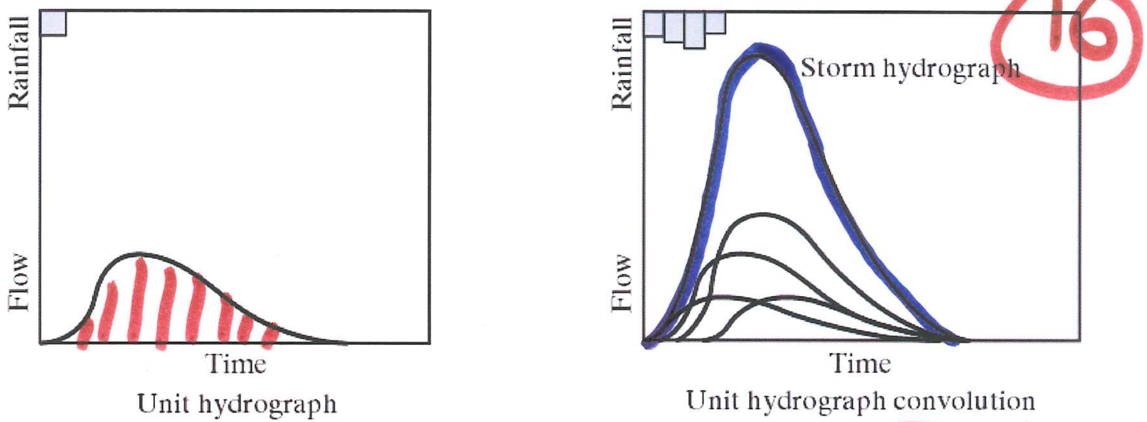
Hydrologic Soil Groups (Cont.)

Group Csoils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).

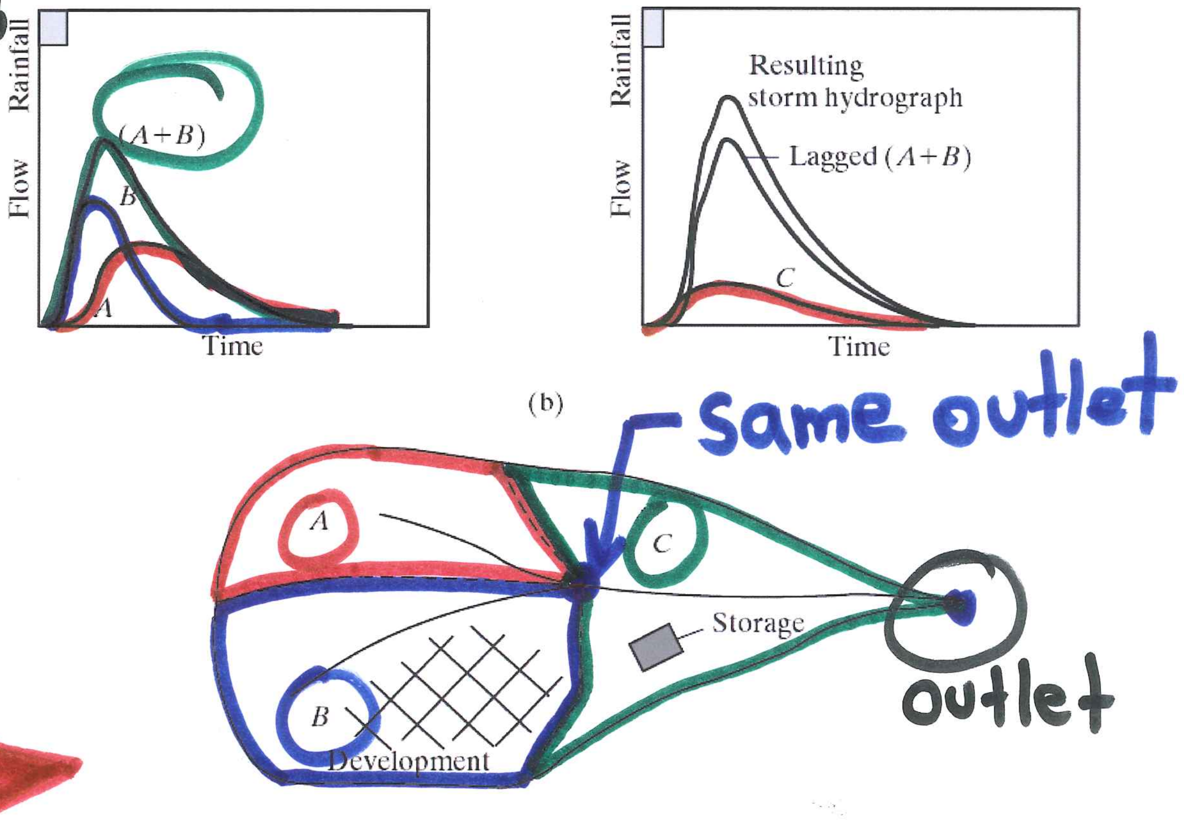
Group Dsoils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr).

Unit Hydrograph Applications





(a) Development of design storm hydrograph.



(b) Development of watershed hydrograph.

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Example 2-5 SCS CURVE-NUMBER METHOD

A watershed is 40% wooded (good condition) and 60% residential (1/4-ac lots). The watershed has 50% soil group B and 50% soil group C. Determine the runoff volume if the rainfall is 7 in. Assume antecedent moisture condition number II (Table 2–1).

SOLUTION

Land Use	Soil Group	Fraction of Area	CN
Wooded (40%)	B 50%	0.4(0.5) = 0.2	55
	C 50%	0.4(0.5) = 0.2	70
Residential (60%)	B 50%	0.6(0.5) = 0.3	75
	C 50%	0.6(0.5) = 0.3	83

1.0 (100%)

The weighted CN is

$$CN = 0.2(55) + 0.2(70) + 0.3(75) + 0.3(83) \text{ or}$$

$$CN = 11 + 14 + 22.5 + 24.9 = \boxed{72.4} \leftarrow \text{weighted CN.}$$

or, using CN = 72, runoff volume is 3.9 in for the given rainfall (Fig. 2–8).

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

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

$$\boxed{S = 3.81 \text{ in}}$$

$$\boxed{Q = 3.87 \text{ in}}$$

Example 2-6 SCS TRIANGULAR UNIT HYDROGRAPH

Use the SCS method to develop a UH for the area of 10 mi^2 described below. Use rainfall duration of $D = 2.0$ hr. Sketch the approximate shape of the triangular UH.

$$L = 5 \text{ miles}$$

$$L_c = 2 \text{ miles}$$

The watershed consists of meadows in good condition with soil group D. The average slope in the watershed is 100 ft/mi. Sketch the resulting SCS triangular hydrograph.

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Example 2-6 (continued) SCS TRIANGULAR UNIT HYDROGRAPH

L (ft)
S (in)
y (%)
CN = 78

Equation (2–18) gives the following relationship for t_p:

Lag time →

$$\boxed{t_p = \frac{L^{0.8}(S + 1)^{0.7}}{1900\sqrt{y}}}$$

From Table 2–1, the SCS curve number is found to be 78. Therefore,

Potential abstraction →

$$S = 1000/\text{CN} - 10$$

$$= 1000/78 - 10,$$

$$\boxed{S = 2.82 \text{ in.}}$$

Converting $L = 5$ mi, or

$$L = (5 \text{ mi})(5280 \text{ ft/mi}) = 26{,}400 \text{ ft}$$

⑳

Example 2-6 (continued) SCS TRIANGULAR UNIT HYDROGRAPH

The slope is 100 ft/mi, so convert to percent for the equation

$$y = (100\ \text{ft/mi})(1\ \text{mi}/5280\ \text{ft})\underset{\uparrow\ \text{for percent conversion}}{(100)}$$
$$= 1.9\%$$

and

$$t_p = \left[\frac{(26{,}400)^{0.8}(2.82 + 1)^{0.7}}{1900\sqrt{1.9}}\right]$$
$$= \underline{3.36\ \text{hr.}}\ \checkmark$$

From Equation (2–17) and with rainfall duration $D = 2.0$ hr,

$$\boxed{T_R = D/2 + t_p}$$
$$= (2/2) + 3.36\ \text{hr},$$
$$\boxed{T_R = 4.36\ \text{hr}}\text{, the rise time of the hydrograph,}\ \checkmark$$

Example 2-6 (continued) SCS TRIANGULAR UNIT HYDROGRAPH

and Equation (2–16) gives for A = 10 mi^2

$$\boxed{Q_p = \frac{484\,A}{T_R}}$$

$$= \frac{484(10)}{4.36}\ \text{cfs},$$

$$\boxed{[Q_p = 1{,}110\ \text{cfs.}]}\ ✓$$

To complete the graph, it is also necessary to know the time of fall B. The volume is known to be 1 in. of direct runoff over the watershed, so

1 inch of rain

$$\text{Vol} = (10\ \text{mi}^2)\left(\frac{5280\ \text{ft}}{\text{mi}}\right)^2\left(\frac{\text{ac}}{43{,}560\ \text{ft}^2}\right)(1\ \text{in.}) = 6400\ \text{ac-in.}$$

$B \sim 1.67\ T_R$ (but don't use this)

Example 2-6 (continued) SCS TRIANGULAR UNIT HYDROGRAPH

From Equation (2–12),

$$\boxed{\text{Vol} = \frac{Q_p T_R}{2} + \frac{Q_p B}{2}} = 6400 \text{ ac-in} = 6400 \text{ cfs-hr},$$

$$6400 \text{ cfs-hr} = \frac{(1110 \text{ cfs} \times 4.36 \text{ hr})}{2} + \frac{(1110 \text{ cfs})(B \text{ hr})}{2},$$

so

$$\boxed{B = 7.17 \text{ hr.}}$$

The triangular unit hydrograph is shown in Figure E2–6; note the time base of 11.5 hr. The next example demonstrates the use of the dimensionless SCS UH; for this example. Table E2–6 lists the resulting shaped SCS hydrograph.

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Triangular unit hydrograph for Example E2–6.