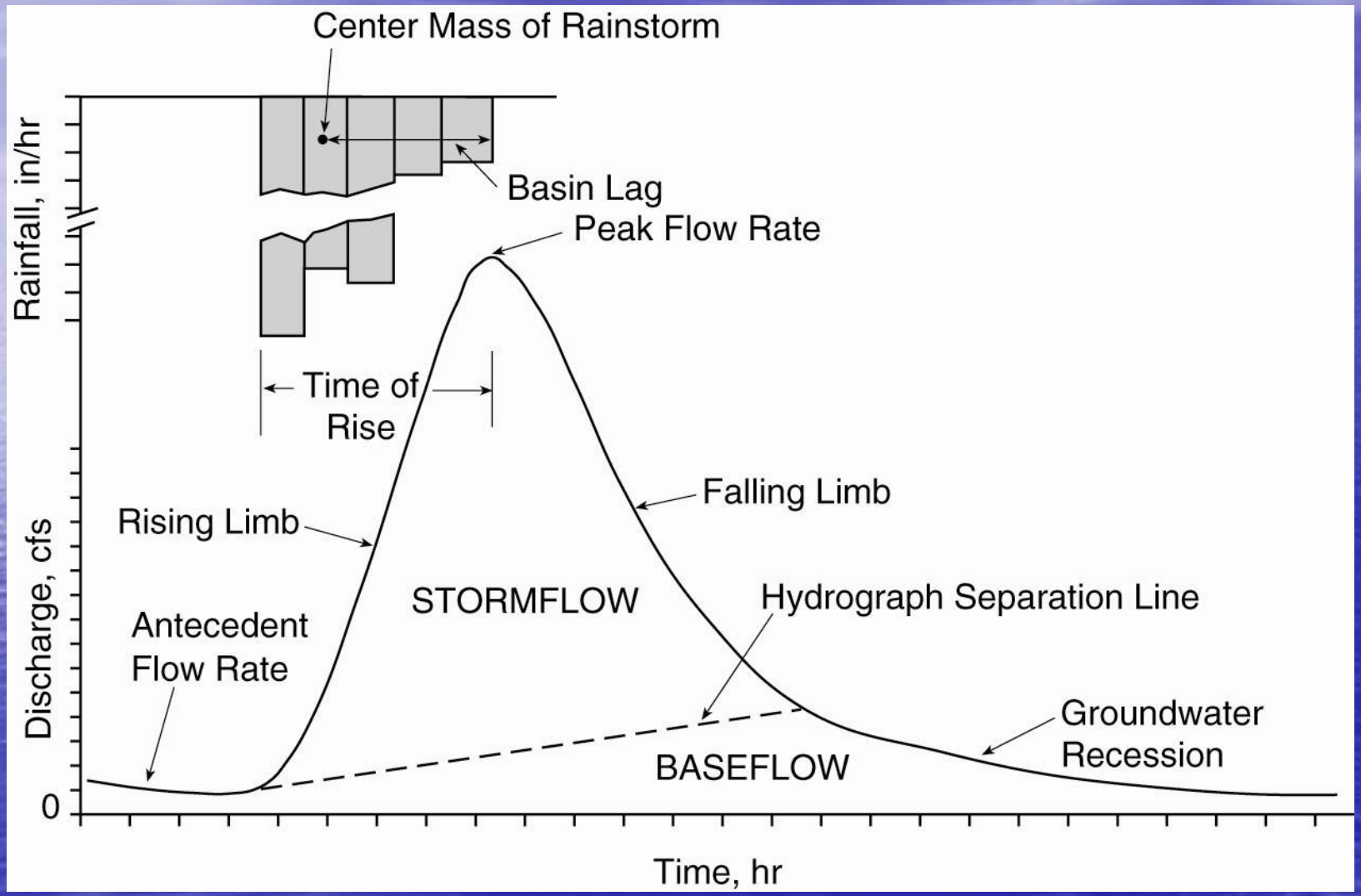
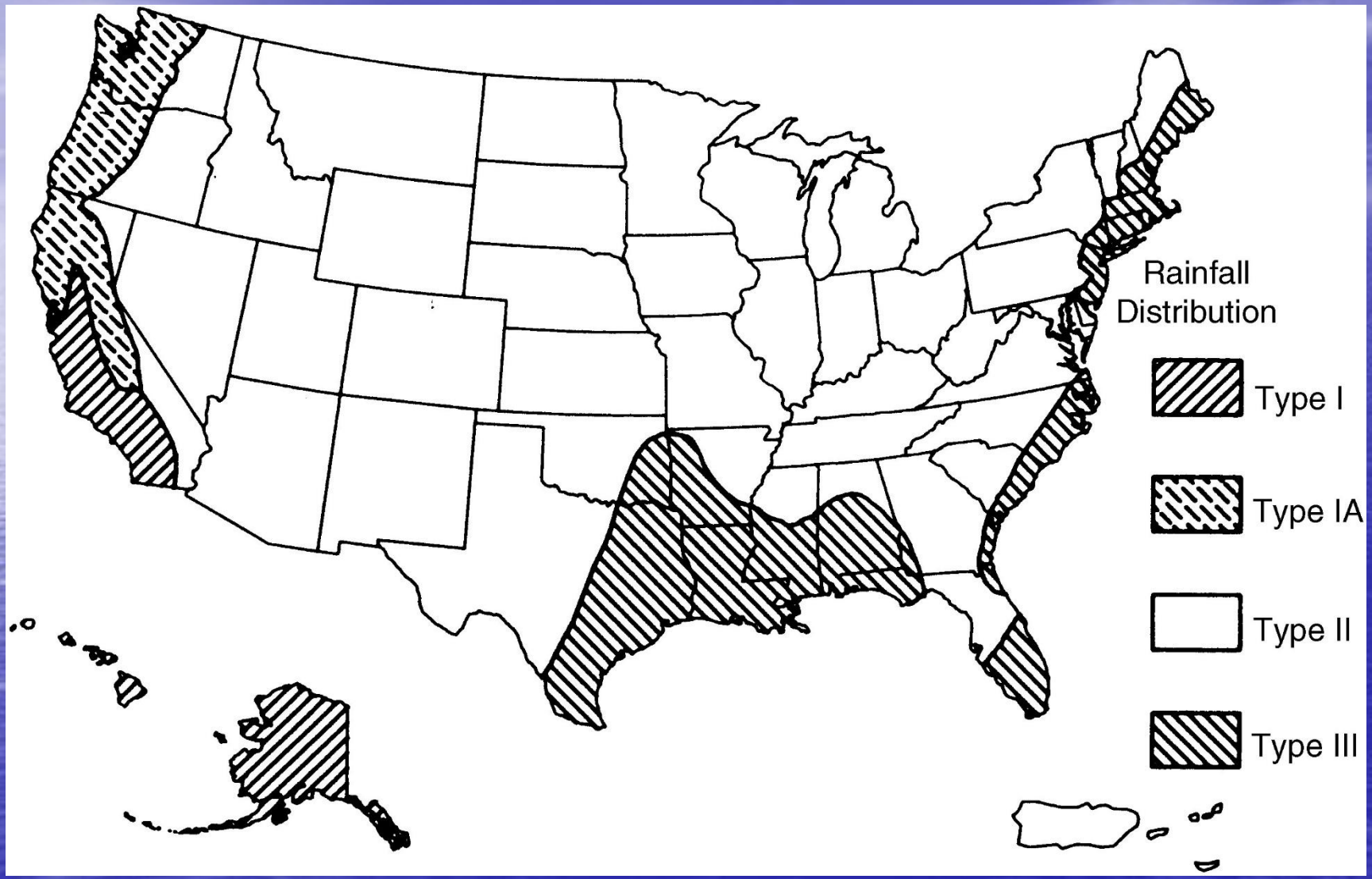
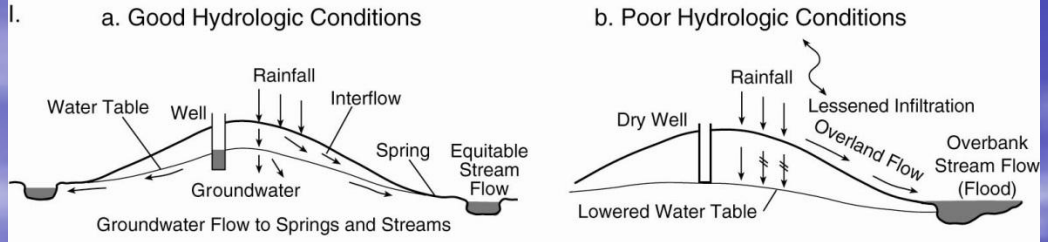
Storm Runoff

- Factors affecting runoff
- Hydrographs
  - Volume, Peak Rate, Timing

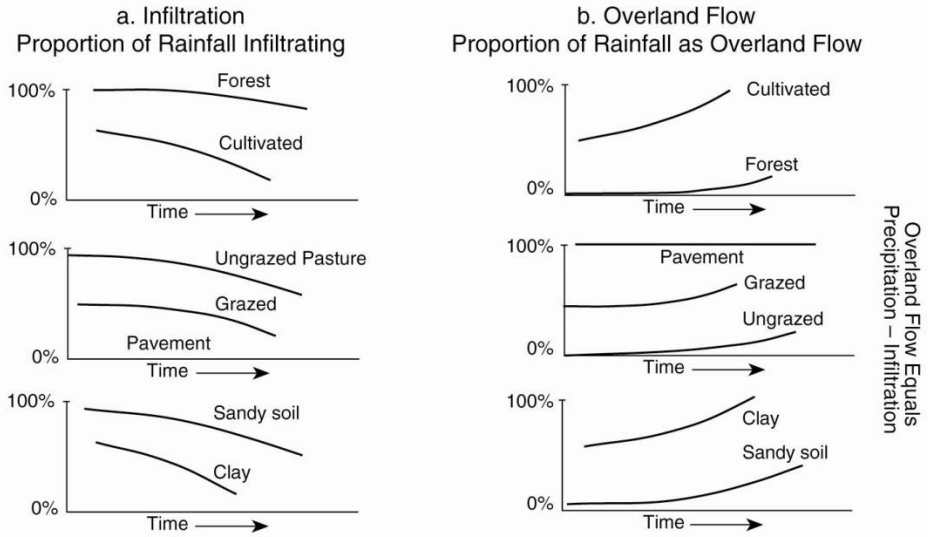

Center Mass of Rainstorm
Rainfall, in/hr
Basin Lag
Peak Flow Rate
Time of Rise
Rising Limb
Falling Limb
STORMFLOW
Hydrograph Separation Line
Antecedent Flow Rate
Groundwater Recession
BASEFLOW
Discharge, cfs
0
Time, hr


Rainfall
Distribution
Type I
Type IA
Type II
Type III

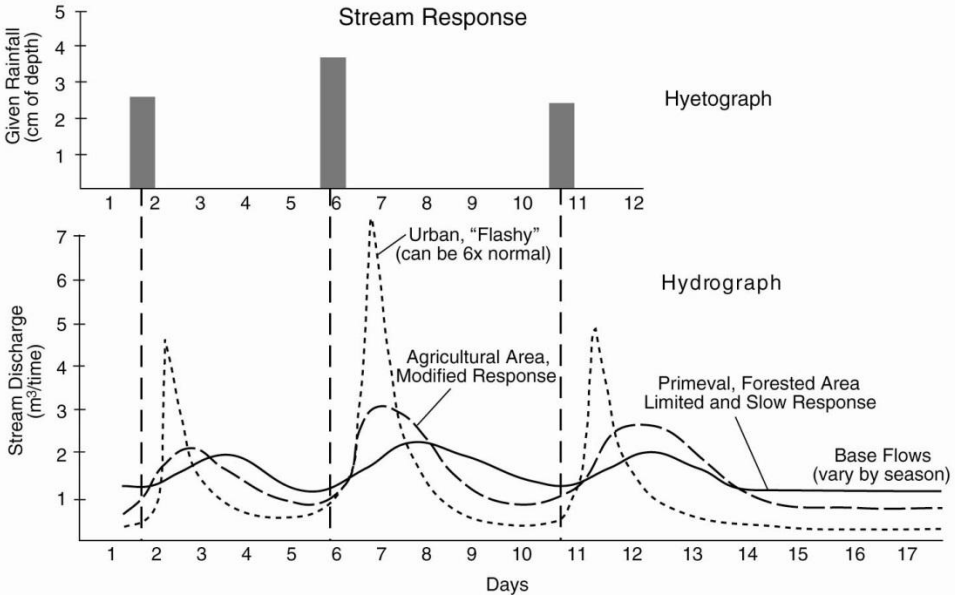
I.

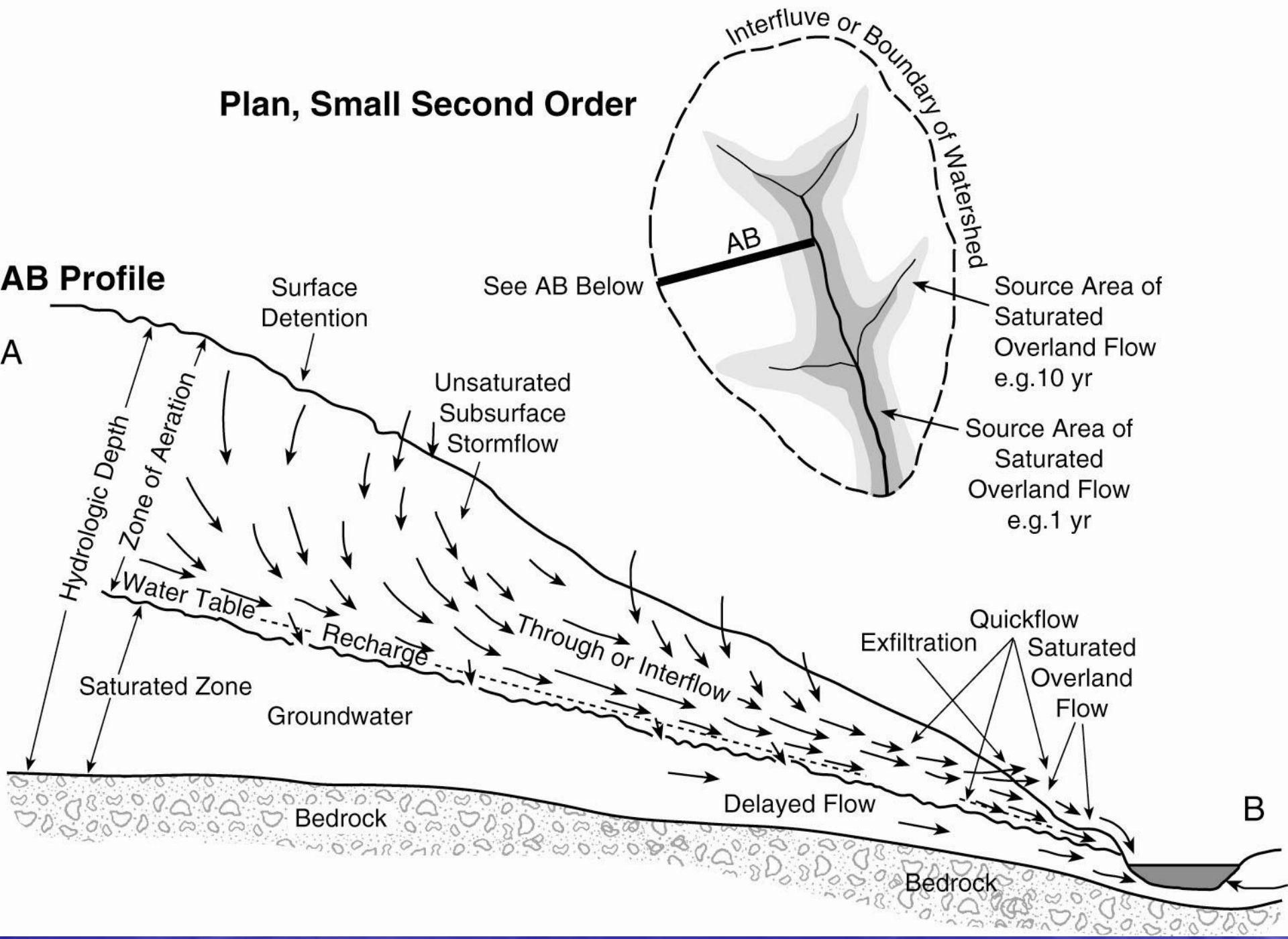

a. Good Hydrologic Conditions
Rainfall
Water Table
Well
Interflow
Spring
Equitable Stream Flow
Groundwater
Groundwater Flow to Springs and Streams
b. Poor Hydrologic Conditions
Rainfall
Lessened Infiltration
Dry Well
Overland Flow
Overbank Stream Flow (Flood)
Lowered Water Table

II.


a. Infiltration
Proportion of Rainfall Infiltrating
100%
0%
Time
Forest
Cultivated
Ungrazed Pasture
Grazed
Pavement
Sandy soil
Clay
b. Overland Flow
Proportion of Rainfall as Overland Flow
Cultivated
Forest
Pavement
Grazed
Ungrazed
Clay
Sandy soil
Overland Flow Equals Precipitation – Infiltration

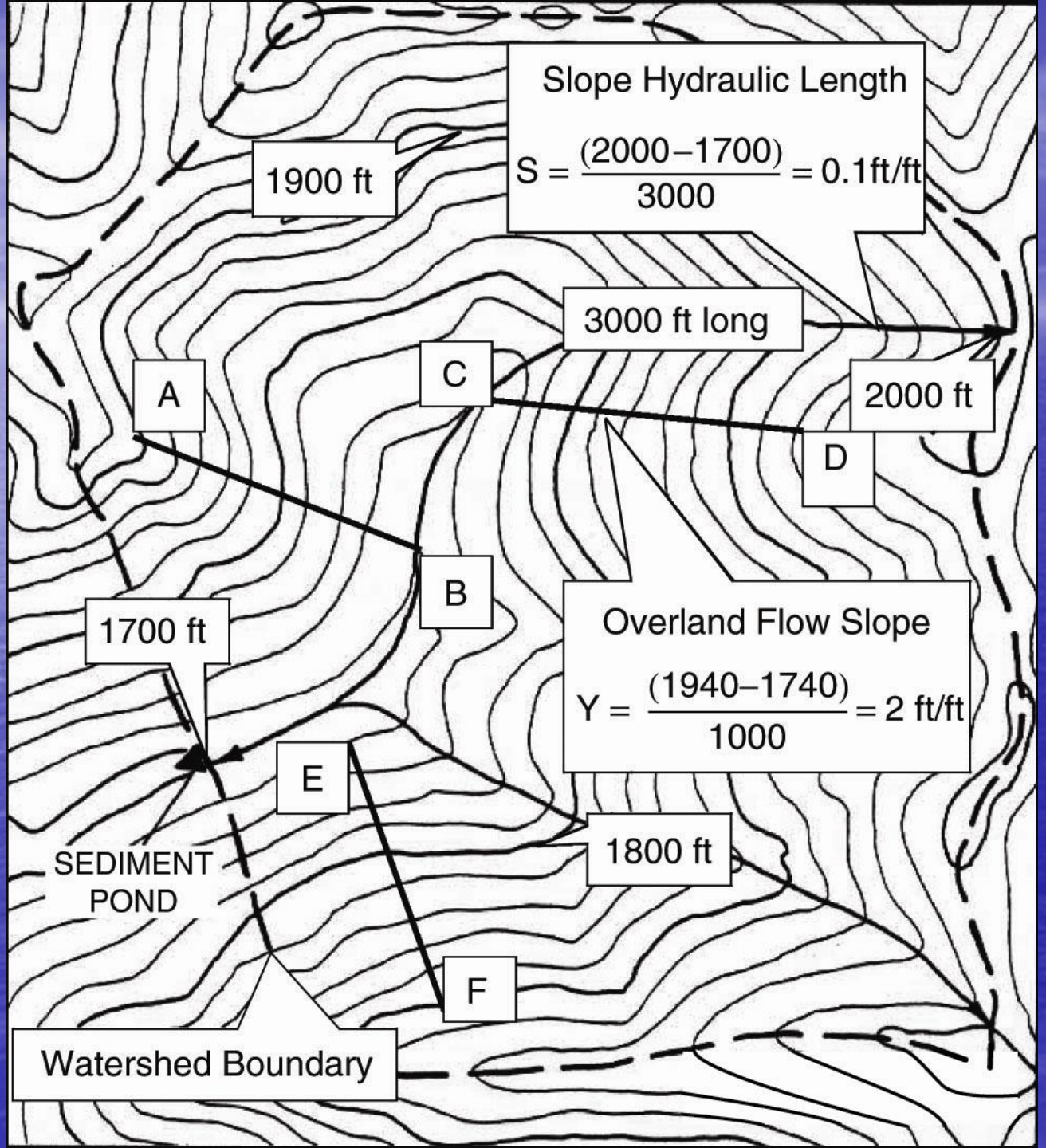
III.

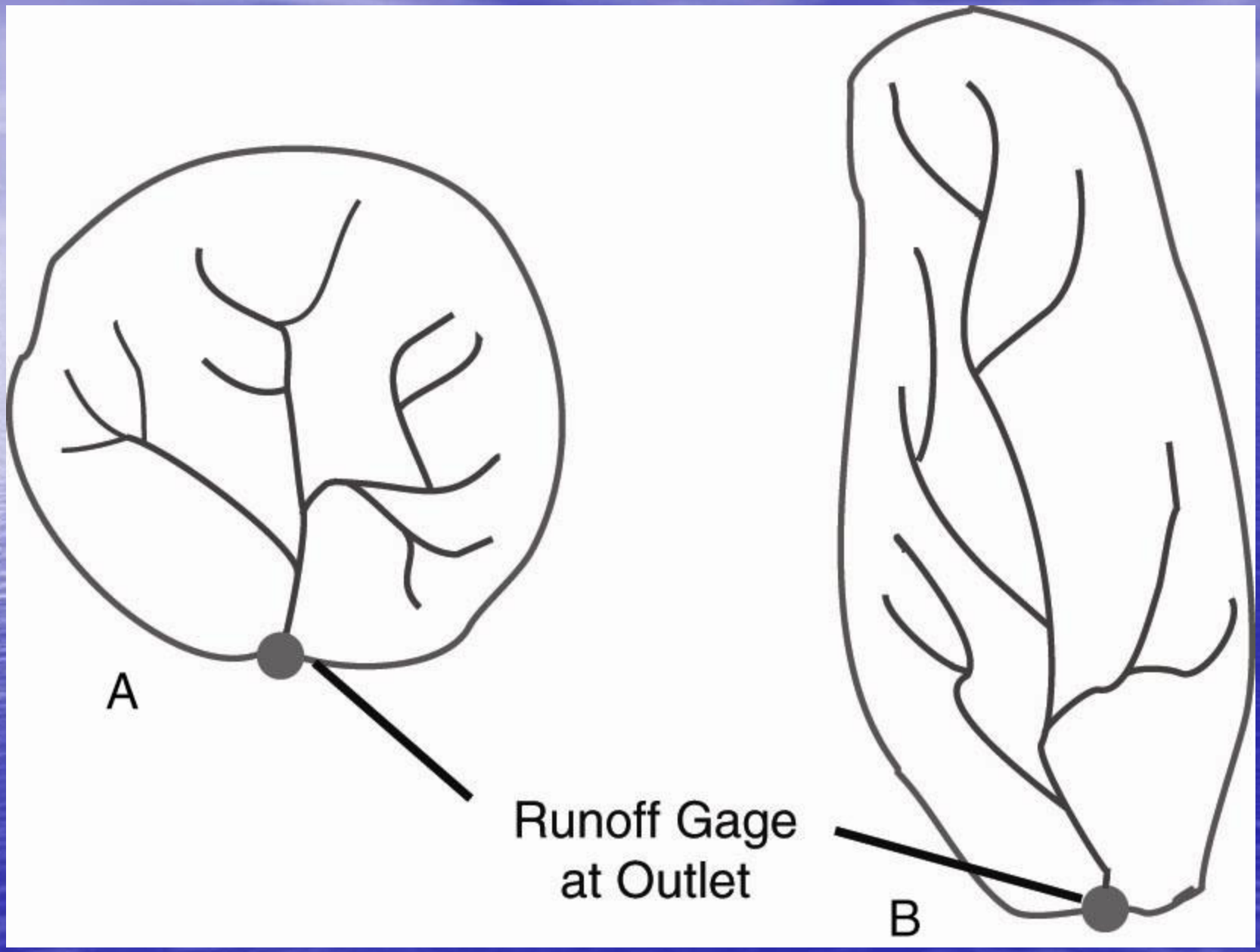

Stream Response
Given Rainfall (cm of depth)
Hyetograph
Urban, "Flashy" (can be 6x normal)
Hydrograph
Stream Discharge (m³/time)
Agricultural Area, Modified Response
Primeval, Forested Area Limited and Slow Response
Base Flows (vary by season)
Days

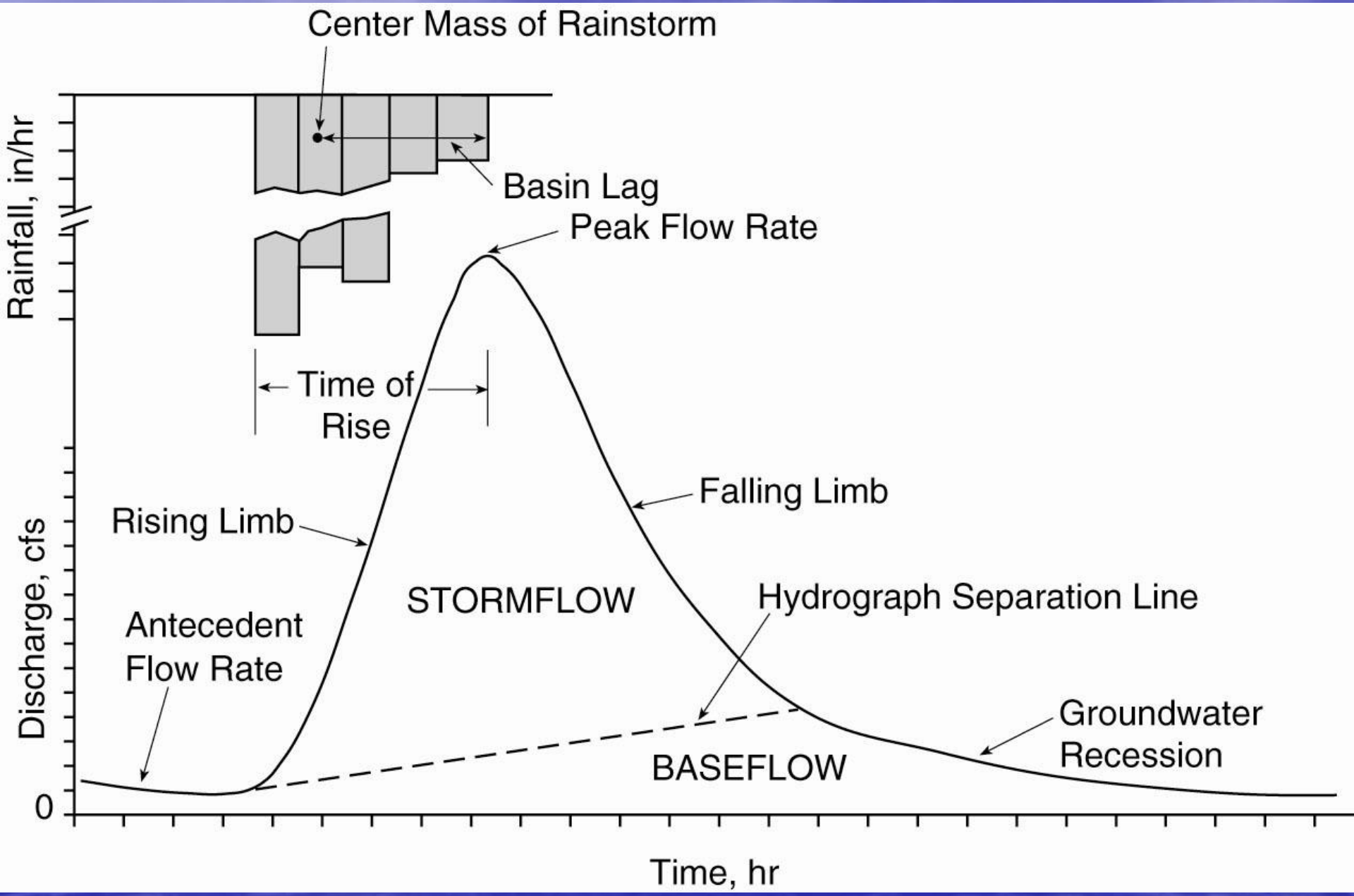

Plan, Small Second Order
Interfluve or Boundary of Watershed
AB
See AB Below
Source Area of Saturated Overland Flow e.g.10 yr
Source Area of Saturated Overland Flow e.g.1 yr
AB Profile
A
Surface Detention
Unsaturated Subsurface Stormflow
Hydrologic Depth
Zone of Aeration
Water Table
Recharge
Through or Interflow
Exfiltration
Quickflow
Saturated Overland Flow
Saturated Zone
Groundwater
Delayed Flow
Bedrock
Bedrock
B

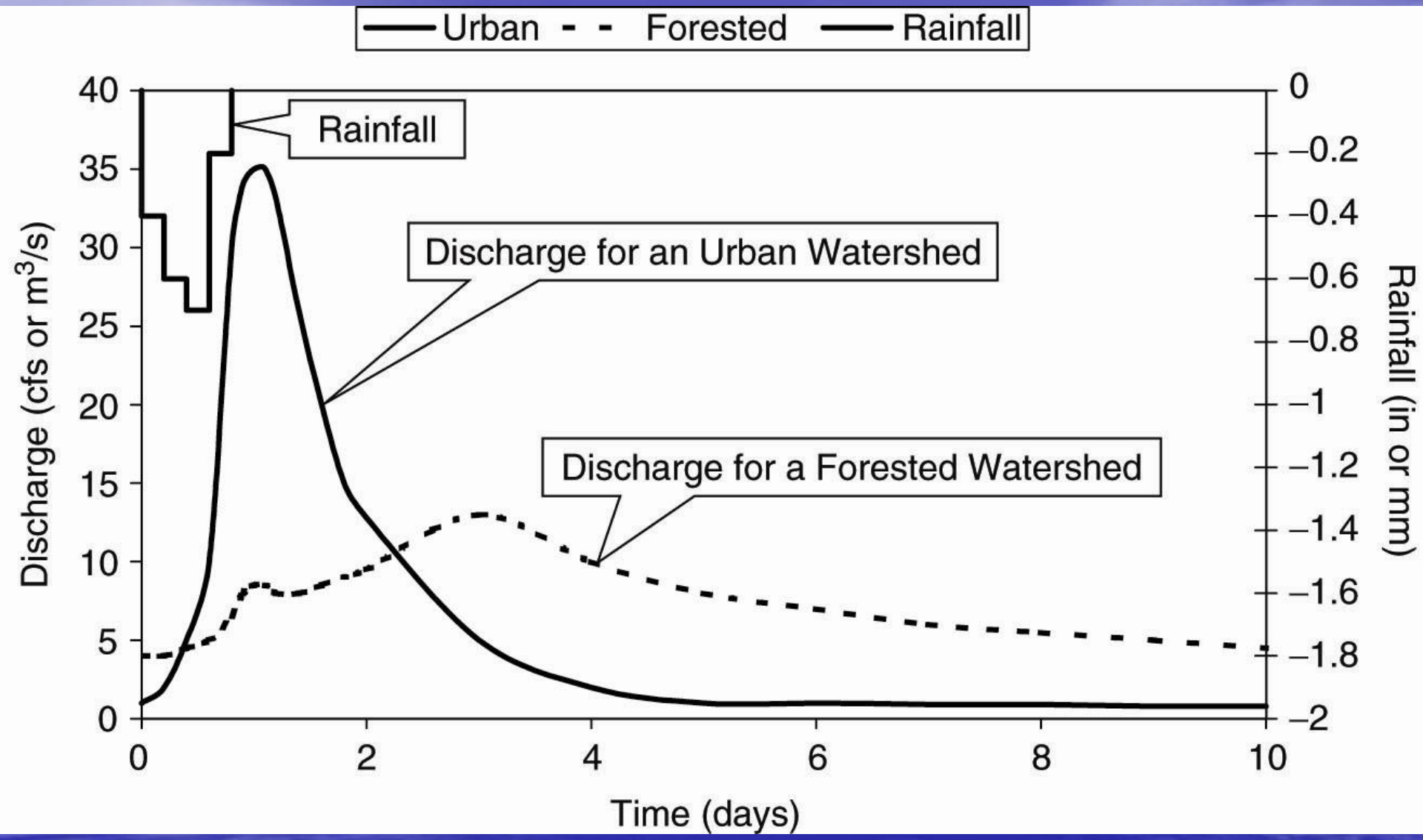
Factors Affecting Runoff

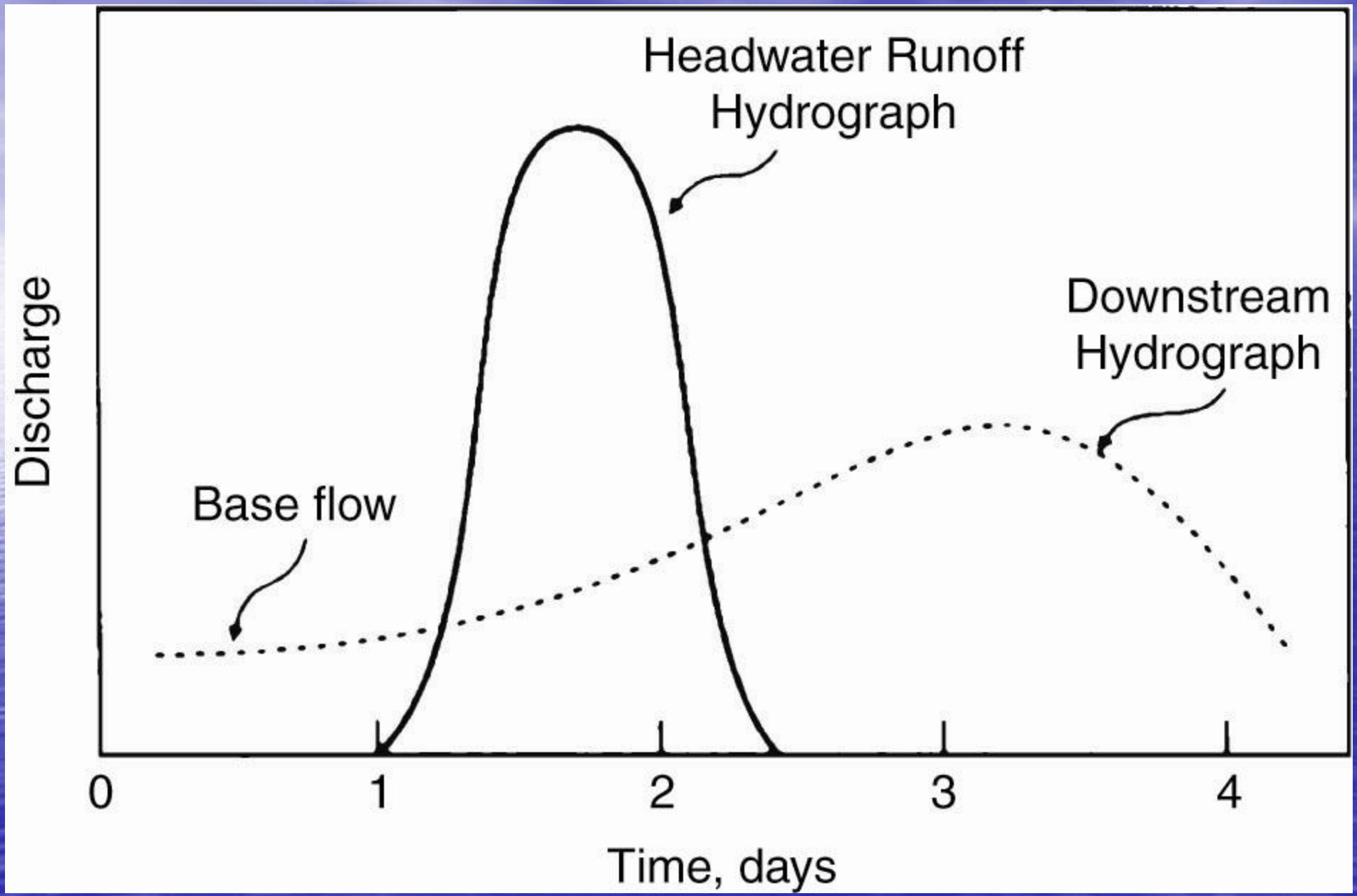
- Precipitation-
  - Type, duration, amount, intensity
  - Design storm event
- Watershed
  - Size, topography, shape, orientation, geology, interflow, soil, land use.


Slope Hydraulic Length
$S = \frac{(2000-1700)}{3000} = 0.1 ft/ft$
1900 ft
3000 ft long
2000 ft
A
B
C
D
1700 ft
Overland Flow Slope
$Y = \frac{(1940-1740)}{1000} = 2 ft/ft$
E
1800 ft
SEDIMENT
POND
F
Watershed Boundary


A
Runoff Gage
at Outlet
B


Center Mass of Rainstorm
Basin Lag
Peak Flow Rate
Rainfall, in/hr
Time of
Rise
Falling Limb
Rising Limb
STORMFLOW
Hydrograph Separation Line
Antecedent
Flow Rate
Groundwater
Recession
BASEFLOW
Discharge, cfs
0
Time, hr


Urban
Forested
Rainfall
Rainfall
Discharge for an Urban Watershed
Discharge for a Forested Watershed
Discharge (cfs or m3/s)
Rainfall (in or mm)
Time (days)
40
35
30
25
20
15
10
5
0
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4
−1.6
−1.8
−2
0
2
4
6
8
10


Headwater Runoff
Hydrograph
Downstream
Hydrograph
Base flow
Discharge
0
1
2
3
4
Time, days

Predicting Volume of Runoff

- NRCS Curve Number method (5.5)
- We will use 2 equations and 2 Tables

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

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

Runoff

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

S **-term related to soil type and moisture condition**

CN **-the curve number. Varies dependent on soil group and moisture condition. See Tables 5.1 and 5.2.**

Soil Group

CLASSIFICATION	TYPE OF SOIL
A (low runoff potential)	Soils with high infiltration capacities, even when thoroughly wetted. Chiefly sands and gravels, deep and well drained.
B	Soils with moderate infiltration rates when thoroughly wetted. Moderately deep to deep, moderately well to well drained, with moderately fine to moderately coarse textures.
C	Soils with slow infiltration rates when thoroughly wetted. Usually have a layer that impedes vertical drainage, or have a moderately fine to fine texture.
D (high runoff potential)	Soils with very slow infiltration rates when thoroughly wetted. Chiefly clays with a high swelling potential; soils with a high permanent water table; soils with a clay layer at or near the surface; shallow soils over nearly impervious materials.

TABLE 5.1

Curve Numbers for Antecedent Soil Moisture Condition II

	Hydrologic Soil Group			
Land Use Description	**A**	**B**	**C**	**D**
Commercial, row houses and townhouses	80	85	90	95
Fallow, poor condition	77	86	91	94
Cultivated with conventional tillage	72	81	88	91
Cultivated with conservation tillage	62	71	78	81
Lawns, poor condition	58	74	82	86
Lawns, good condition	39	61	74	80
Pasture or range, poor condition	68	79	86	89
Pasture or range, good condition	39	61	74	80
Meadow	30	58	71	78
Pavement and roofs	100	100	100	100
Woods or forest thin stand, poor cover	45	66	77	83
Woods or forest, good cover	25	55	70	77
Farmsteads	59	74	82	86
Residential quarter-acre lot, poor condition	73	83	88	91
Residential quarter-acre lot, good condition	61	75	83	87
Residential half-acre lot, poor condition	67	80	86	89
Residential half-acre lot, good condition	53	70	80	85
Residential 2-acre lot, poor condition	63	77	84	87
Residential 2-acre lot, good condition	47	66	77	81
Roads	74	84	90	92

Source: From NRCS, 1984.

TABLE 5.2

Adjustments to Runoff Curve Number (CN) for Dry or Wet Antecedent Soil Moisture Conditions

	Factors to Convert Curve Number for AMC II to AMC I or AMC III	
Curve Number (AMC II)	**AMC I (dry)**	**AMC III (wet)**
10	0.40	2.22
20	0.45	1.85
30	0.50	1.67
40	0.55	1.50
50	0.62	1.40
60	0.67	1.30
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1.00	1.00

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

- Q -excess rainfall (runoff), inches
- P -rainfall depth, inches
- After calculating Q, multiply by watershed area to get volume

Let's try an example:

George's house is just downstream of a 4-acre watershed that presently has mature forest on top of a Crosby soil. He is worried that the new townhouse development will increase the amount of water flowing in the creek by his house.
Using a 2 inch storm determine the increase in water volume that will flow by George's house due to the development.

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

Step 1--Calculate S numbers

-Crosby soil is Type C (appedix D)

-CN (AMC II) mature forest is 70

-CN (AMC II) townhouses is 90

-Convert to AMC III-worst case scenario

-CN 70*1.21=84.7

-CN 90*1.07=96.3

-S (forest) = 1.81

-S (townhouses) = 0.38

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

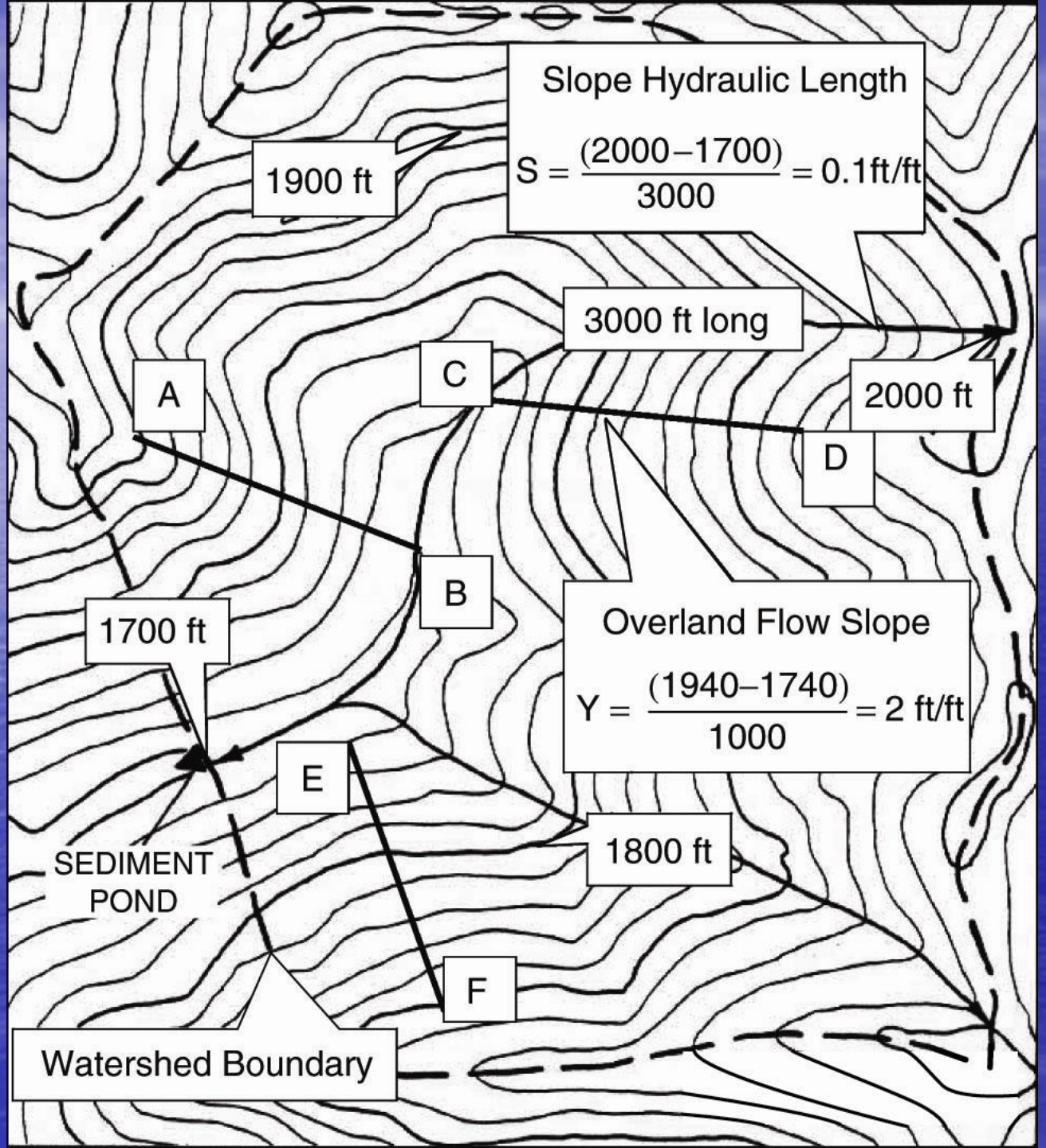
- Step 2-Calculate Q (excess runoff)
- P = 2 inches rainfall
- Q(forest) = 0.91 inches
- Q(townhouses) = 1.61 inches

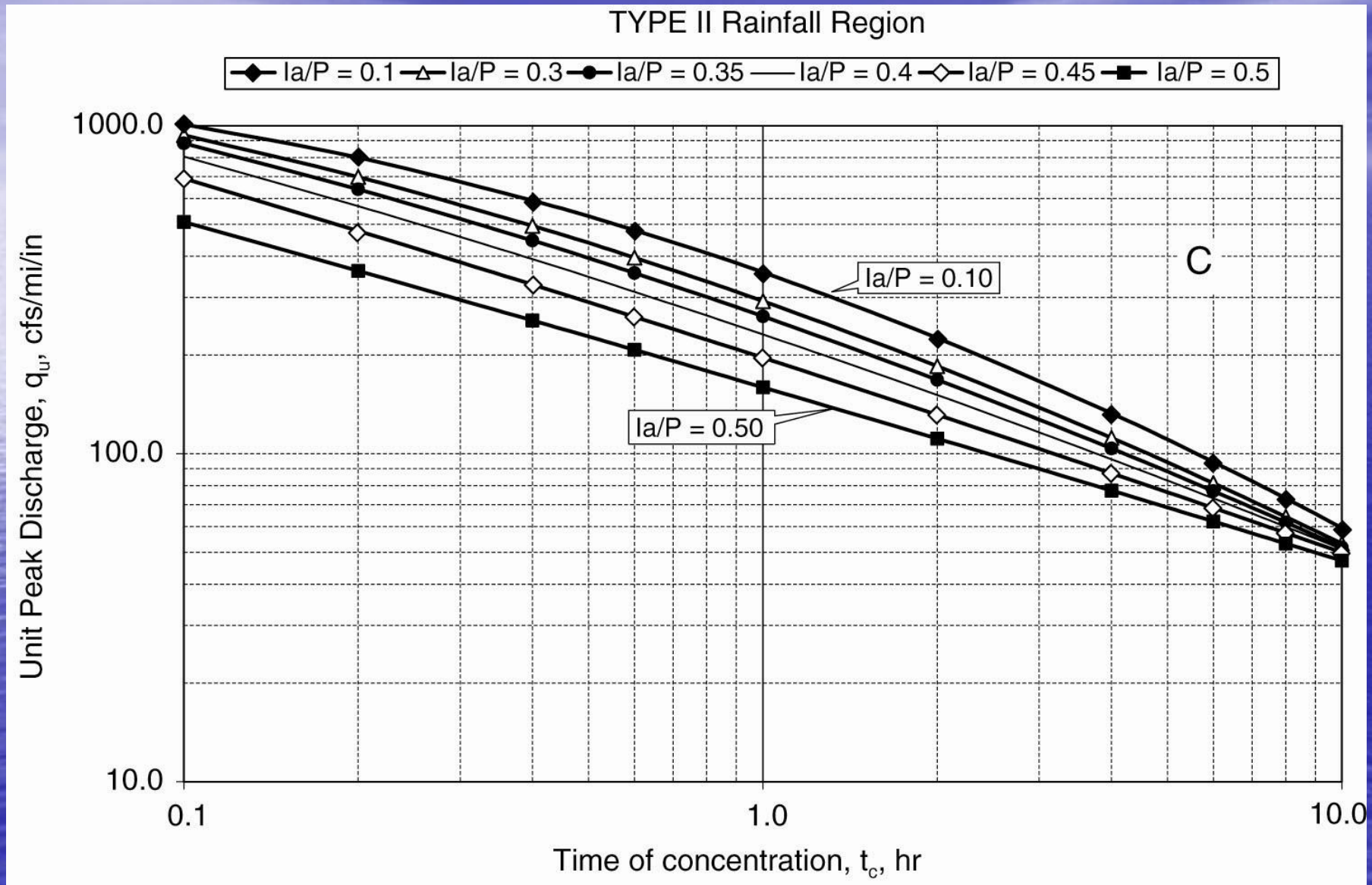
- Step 3-Calculate volume
- Area= 4 acre
- Excess rainfalls= 0.91in (forest) = 0.08ft
- Excess rainfalls= 1.61in (townh) = 0.13ft
- Volume (forest)= 4*0.08=0.32 acre ft
- Volume (townh)= 4*0.13=0.52 acre ft
- Volume (forest)= 14,000ft^3
- Volume (townh)= 22,600ft^3
- Volume of runoff will increase 61%

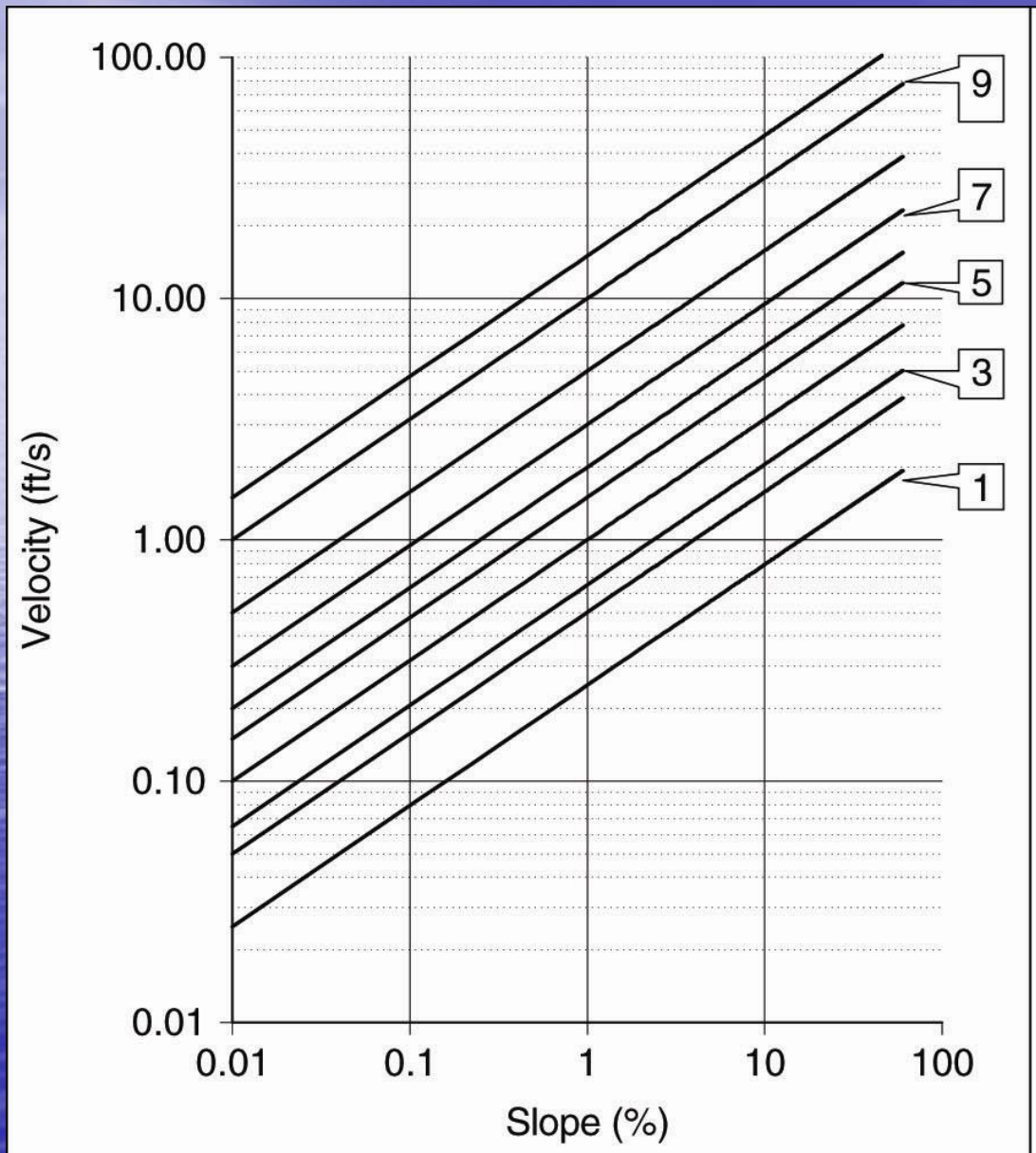
Graphical Peak Discharge Method

$$q = q_u A Q F$$

- q_u is determine from Figure 5.17
- Q is based on the NRCS Curve Number Method a 24 hour event and AMC II
- F consider surface storage from wetlands, lakes, and reservoirs


Slope Hydraulic Length
$S = \frac{(2000-1700)}{3000} = 0.1 ft/ft$
1900 ft
3000 ft long
2000 ft
A
B
C
D
1700 ft
Overland Flow Slope
$Y = \frac{(1940-1740)}{1000} = 2 ft/ft$
E
1800 ft
SEDIMENT
POND
F
Watershed Boundary


TYPE II Rainfall Region
Ia/P = 0.1
Ia/P = 0.3
Ia/P = 0.35
Ia/P = 0.4
Ia/P = 0.45
Ia/P = 0.5
1000.0
100.0
10.0
0.1
1.0
10.0
Unit Peak Discharge, q_u, cfs/mi/in
Time of concentration, t_c, hr
Ia/P = 0.10
Ia/P = 0.50
C



(1) Forest with dense litter

(2) Conservation tillage or woodland

(3) Short grass pasture

(4) Short row, fallow, and alluvial fans

(5) Grassed waterway

(6) Paved area and upland gullies

(7) Small stream with cobble bed

(8) Streams with sand and gravel beds

(9) Deep (4+ ft) fast flowing rivers with low roughness

(10) Concrete lined channels, storm drains, large fast flowing rivers

	Hydrologic Soil Group			
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Pasture or range, poor condition	68	79	86	89
Pasture or range, good condition	39	61	74	80
Meadow	30	58	71	78
Pavement and roofs	100	100	100	100
Woods or forest thin stand, poor cover	45	66	77	83
Woods or forest, good cover	25	55	70	77
Farmsteads	59	74	82	86
Residential 1/4 acre lot, poor condition	73	83	88	91
Residential 1/4 acre lot, good condition	61	75	83	87
Residential 1/2 acre lot, poor condition	67	80	86	89
Residential 1/2 acre lot, good condition	53	70	80	85
Residential 2 acre lot, poor condition	63	77	84	87
Residential 2 acre lot, good condition	47	66	77	81
Roads	74	84	90	92

Curve Number AMC II	Factors to Convert Curve Number for AMC II to AMC I or AMC III	
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60	0.67	1.30
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1.00	1 00

Swamp & Pond Areas (%)	*F*
0.0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

Example Calculation

Calculation the 10 year RI peak discharge from a two square mile watershed in Franklin County with the following properties:

- Hydraulic length of 10,800 ft
- Slope along the hydraulic length of 1%
- The hydraulic length is mainly a small cobble-bed stream
- Residential half-acre lots with good hydrologic conditions
- Soil Group C
- 0.2% of the watershed is wetlands and ponds

Calculate the Runoff Depth

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

Duration	2 years	5 years	10 years	25 years	50 years	100 years
5 min	0.35	0.45	0.51	0.59	0.61	0.71
10	0.55	0.72	0.83	0.98	1.08	1.18
15	0.65	0.88	1.05	1.22	1.38	1.50
30	0.90	1.20	1.40	1.70	1.87	2.07
1 hr	1.10	1.50	1.75	2.10	2.32	2.60
2	1.26	1.72	2.00	2.40	2.65	3.00
4	1.42	1.93	2.26	2.68	2.96	3.30
8	1.61	2.16	2.52	2.96	3.30	3.64
12	1.80	2.36	2.74	3.20	3.53	3.88
24	2.14	2.76	3.18	3.75	4.08	4.50

Obtain P from Table 2.12 in Chapter 2

TABLE 5.1

Curve Numbers for Antecedent Soil Moisture Condition II

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Meadow	30	58	71	78
Pavement and roofs	100	100	100	100
Woods or forest thin stand, poor cover	45	66	77	83
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Residential quarter-acre lot, good condition	61	75	83	87
Residential half-acre lot, poor condition	67	80	86	89
Residential half-acre lot, good condition	53	70	**80**	85
Residential 2-acre lot, poor condition	63	77	84	87
Residential 2-acre lot, good condition	47	66	77	81
Roads	74	84	90	92

Source: From NRCS, 1984.

Calculate the Curve Number from Table 5.1

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

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

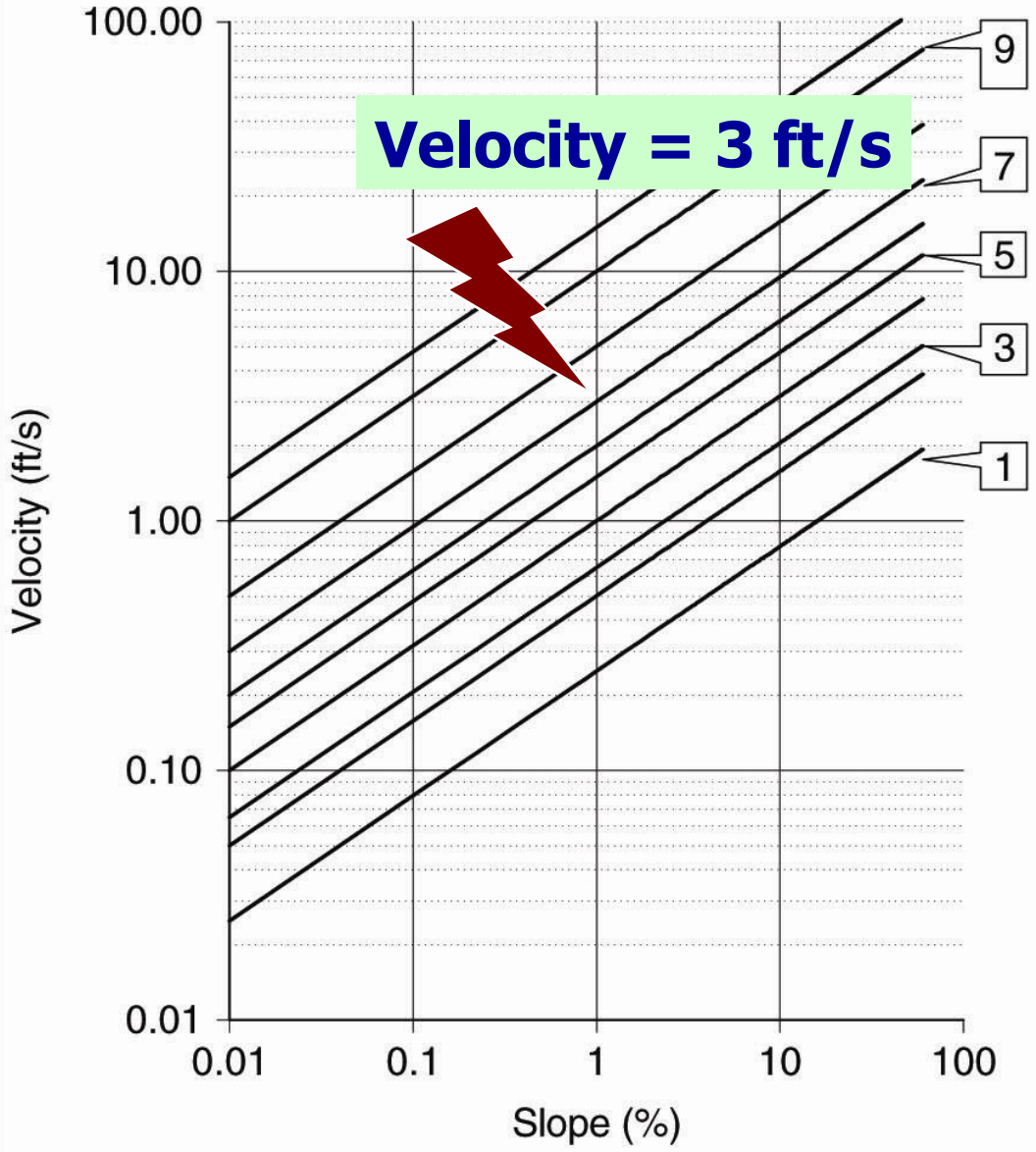
- ✓ **CN = 80**
- ✓ **S = 2.5 inches**
- ✓ **P = 3.18 inches**
- ✓ **Q = 1.39 inches**

Calculate the F Factor

Swamp & Pond Areas (%)	*F*
0.0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

Swamp & Pond areas are 0.2%

F = 0.97



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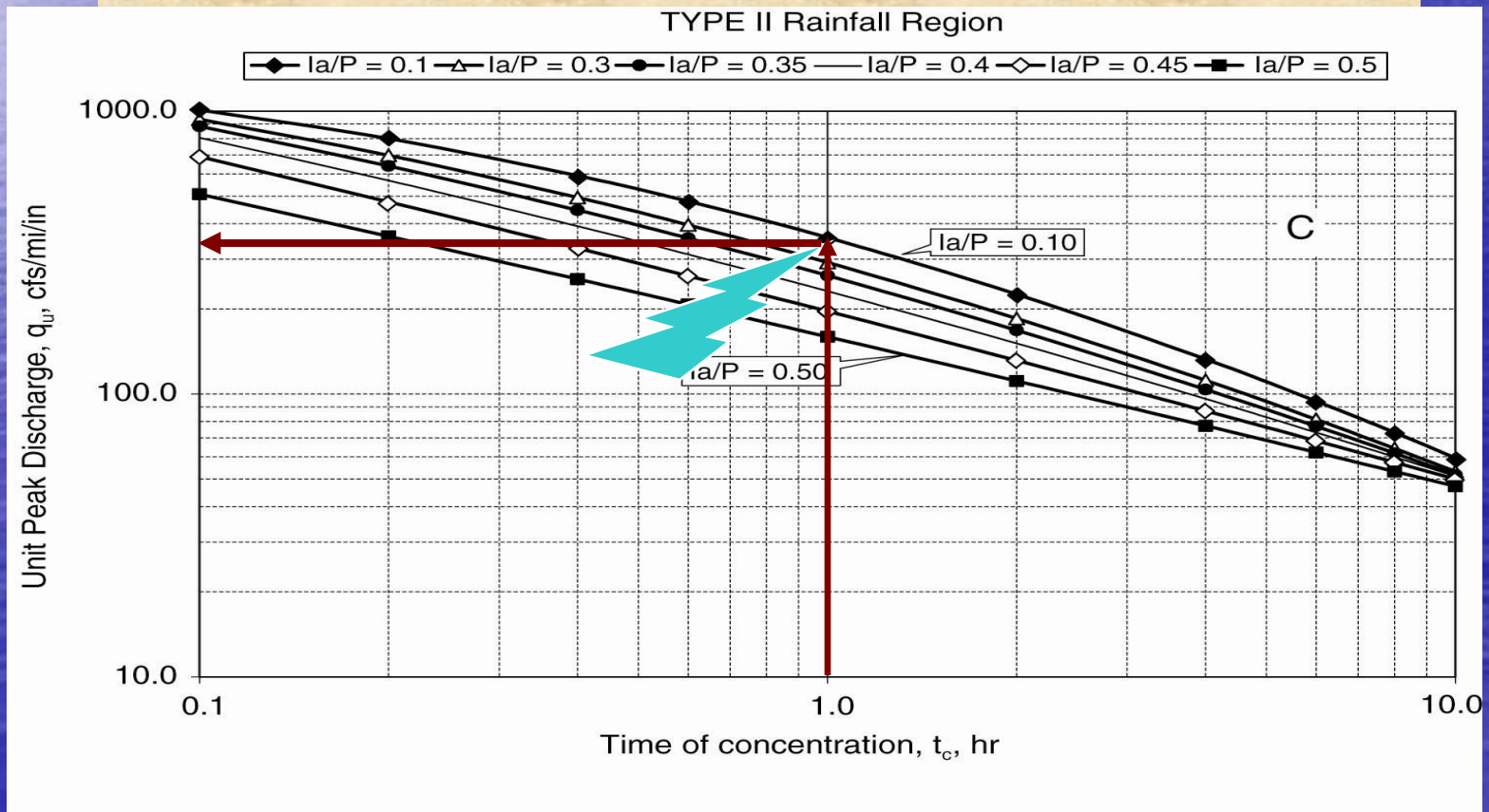
(8) Streams with sand and gravel beds

(9) Deep (4+ ft) fast flowing rivers with low roughness

(10) Concrete lined channels, storm drains, large fast flowing rivers

Calculate q_u

- Time of Concentration calculated as 10,800ft divided by 1 ft/s divided by 3600 seconds in each hour = **3 hours**
- **I_a/P = 0.5/3.18 = 0.16**



Answer

$$q = q_u A Q F$$

- q_u is about 350
- A is 2 square miles
- Q is about 1.39 inches
- F is 0.97
- q = (350)(2)(1.39)(0.97) = 944 cfs