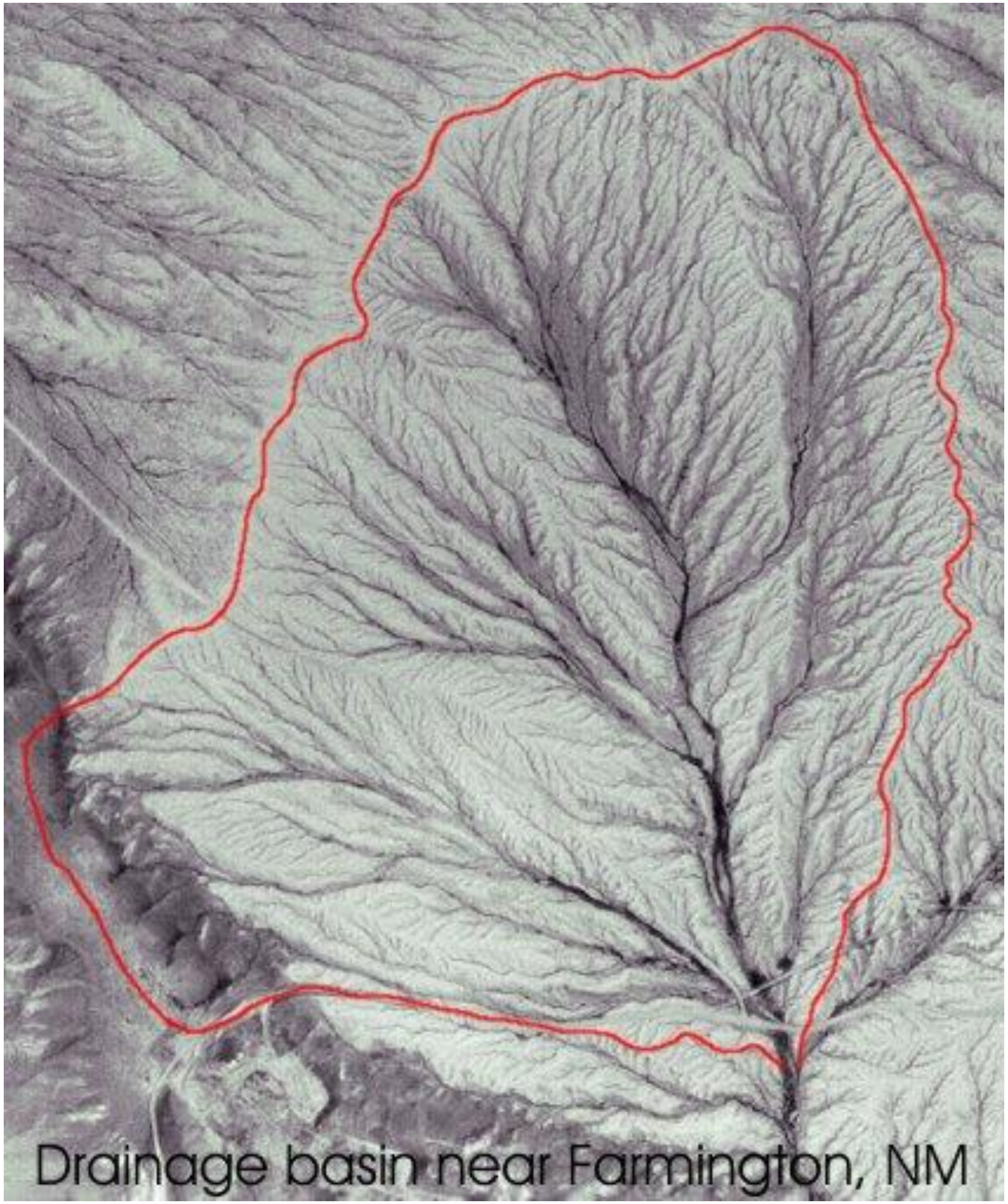
The Drainage Basin

“your friend, and all of its secrets”


Drainage basin near Farmington, NM

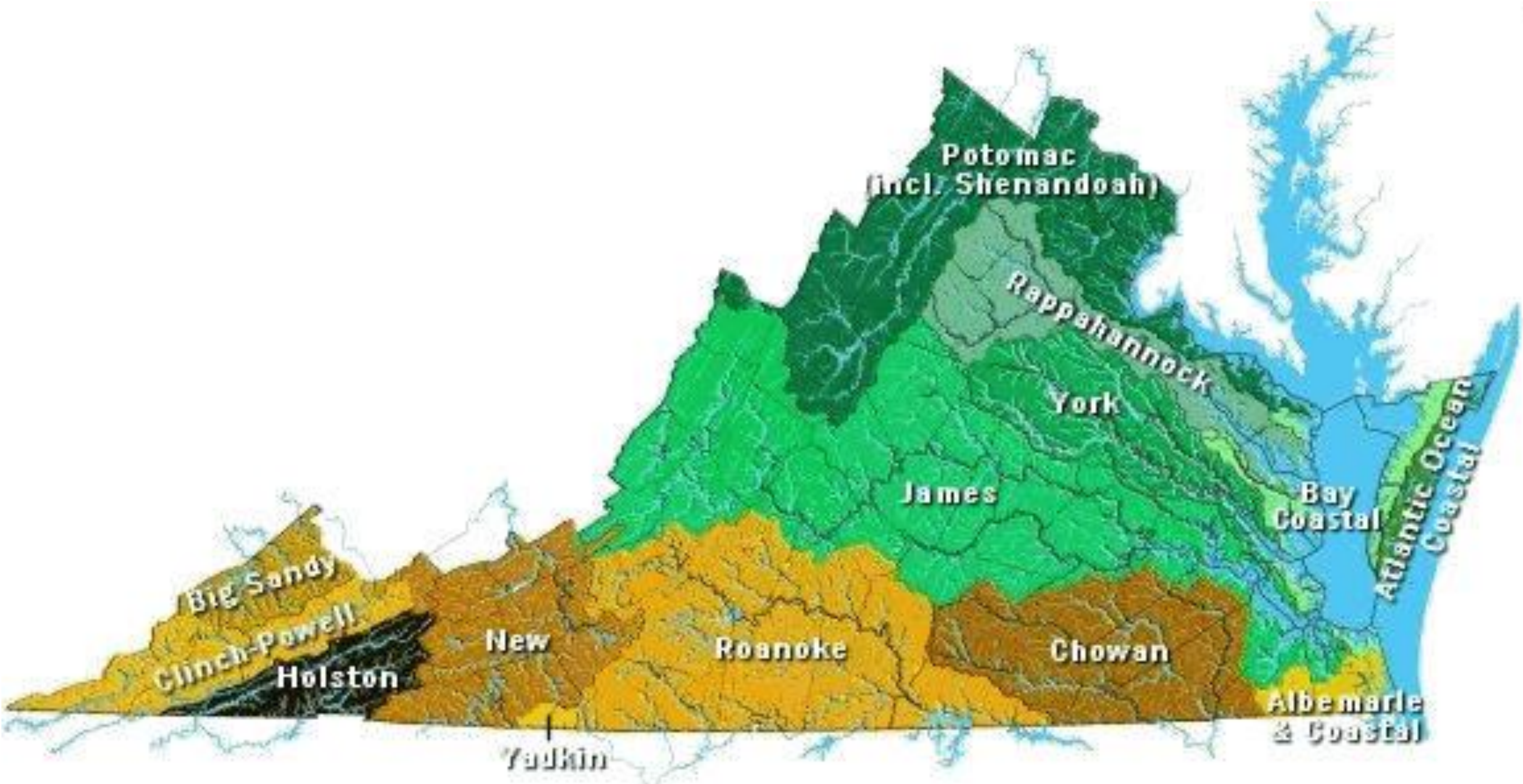

Potomac
(incl. Shenandoah)
Rappahannock
York
James
Bay
Coastal
Atlantic Ocean
Coastal
Big Sandy
Clinch-Powell
Holston
New
Roanoke
Chowan
Albemarle
& Coastal
Yadkin

FIGURE 17.6

Earth: Portrait of a Planet, 2nd Edition

I. Introduction

--two general relationships realized concerning drainage basins

I. Introduction

--two general relationships realized concerning drainage basins

* streams form their valleys in which they flow

I. Introduction

--two general relationships realized concerning drainage basins

* streams form their valleys in which they flow
* every river consists of a major stream that is fed by a number of mutually adjusted branches that diminish in size away from the main stem.

I. Introduction

II. Slope Hydrology and Runoff Generation

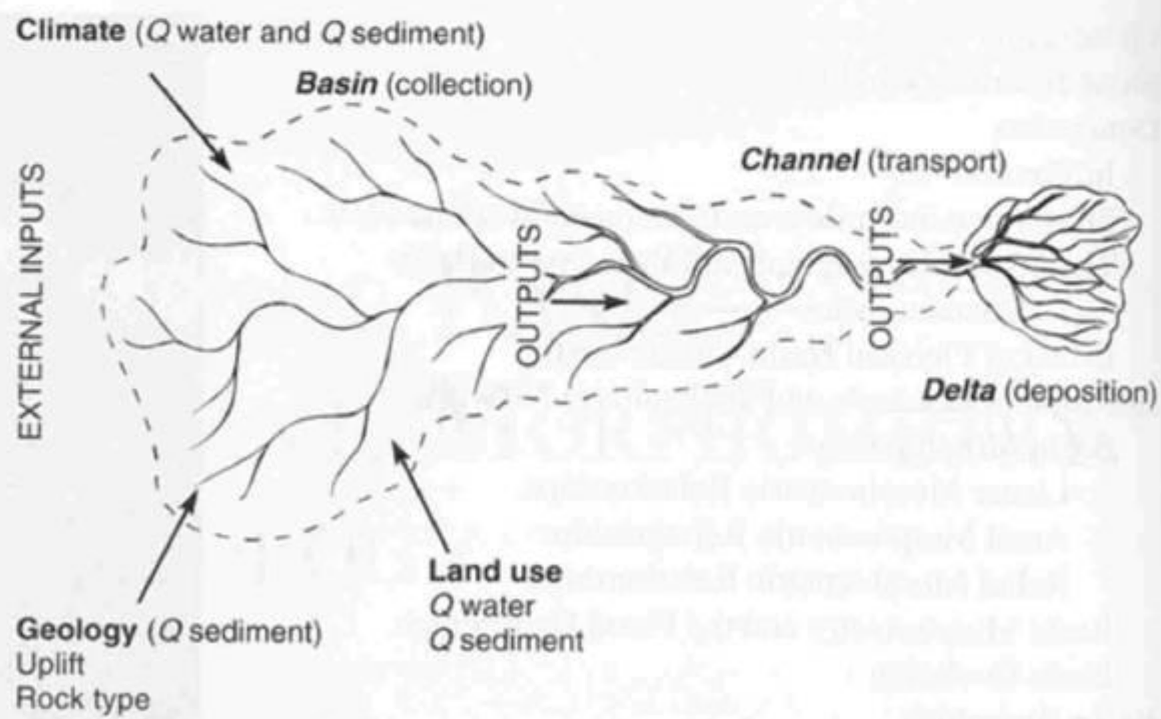
I. Introduction

II. Slope Hydrology and Runoff Generation

A. Basin Hydro. Cycle and Budget

Input = Output + change in storage

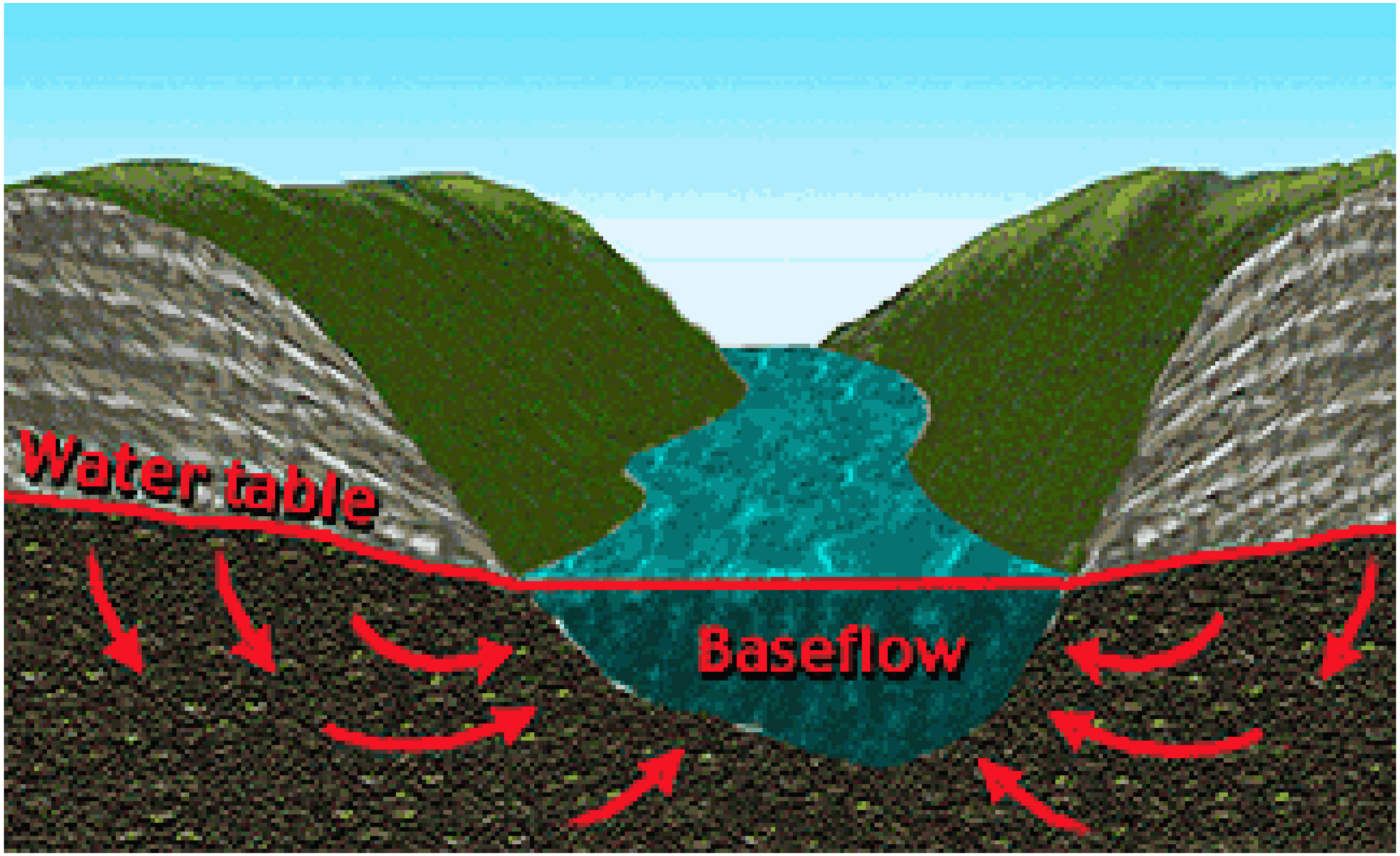
Figure 5.1B
Schematic surface components of the fluvial system. The tributaries provide links between lithology and climate and are adjusted to both. Channel characteristics vary in response to the external variables of sediment and water discharge (*Q*), which are influenced naturally from climate, tectonic, and lithologic factors. Human influence also modifies these variables through land use alterations.



I. Introduction
II. Slope Hydrology and Runoff Generation
A. Basin Hydro. Cycle and Budget

Overland flow
Interflow
Baseflow

Input = Output + change in storage



I. Introduction

II. Slope Hydrology and Runoff Generation

A. Basin Hydro. Cycle and Budget

B. The Storm Hydrograph

B. The Storm Hydrograph

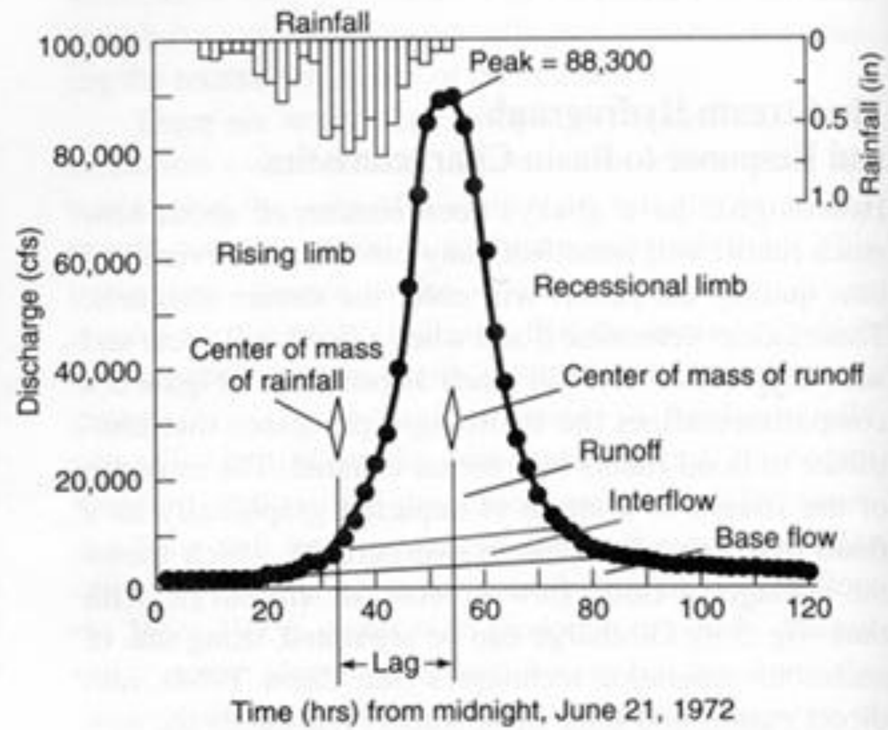
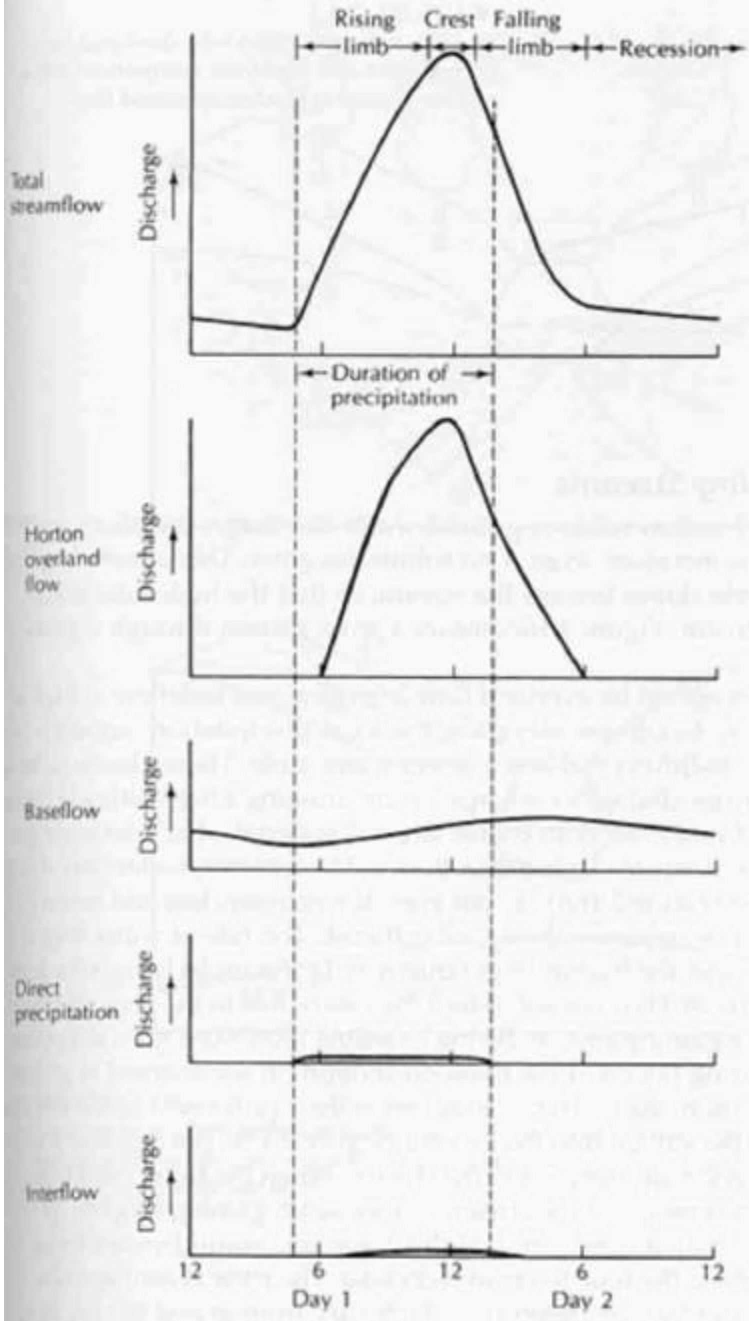


Figure 5.8
Flood hydrograph of the Hurricane Agnes flood of June 1972 on the Conestoga River at Lancaster, Pa. Although the curve is rather symmetrical, most hydrographs show significant skewness with a broader recessional limb reflecting interflow and groundwater inputs after a storm.

Unit hydrograph: 'where the runoff volume is adjusted to the same unit value (e.g., one inch of rainfall spread evenly over a basin in one day"



◄ FIGURE 2.14 Hypothetical storm hydrograph for a period of evenly distributed precipitation, separated into Horton overland flow, baseflow, direct precipitation, and interflow.

Overland flow

Baseflow

Direct ppt

Interflow

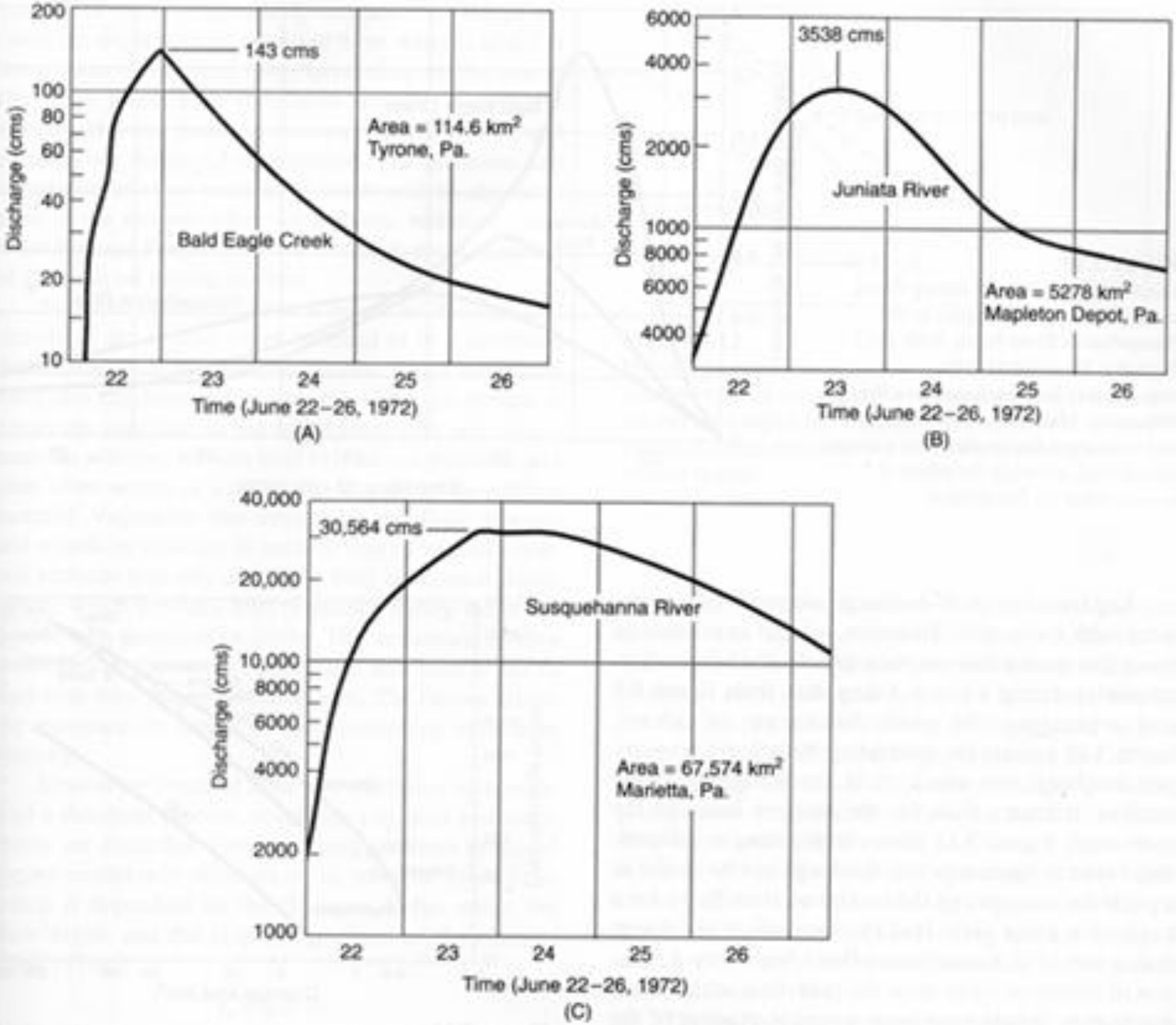
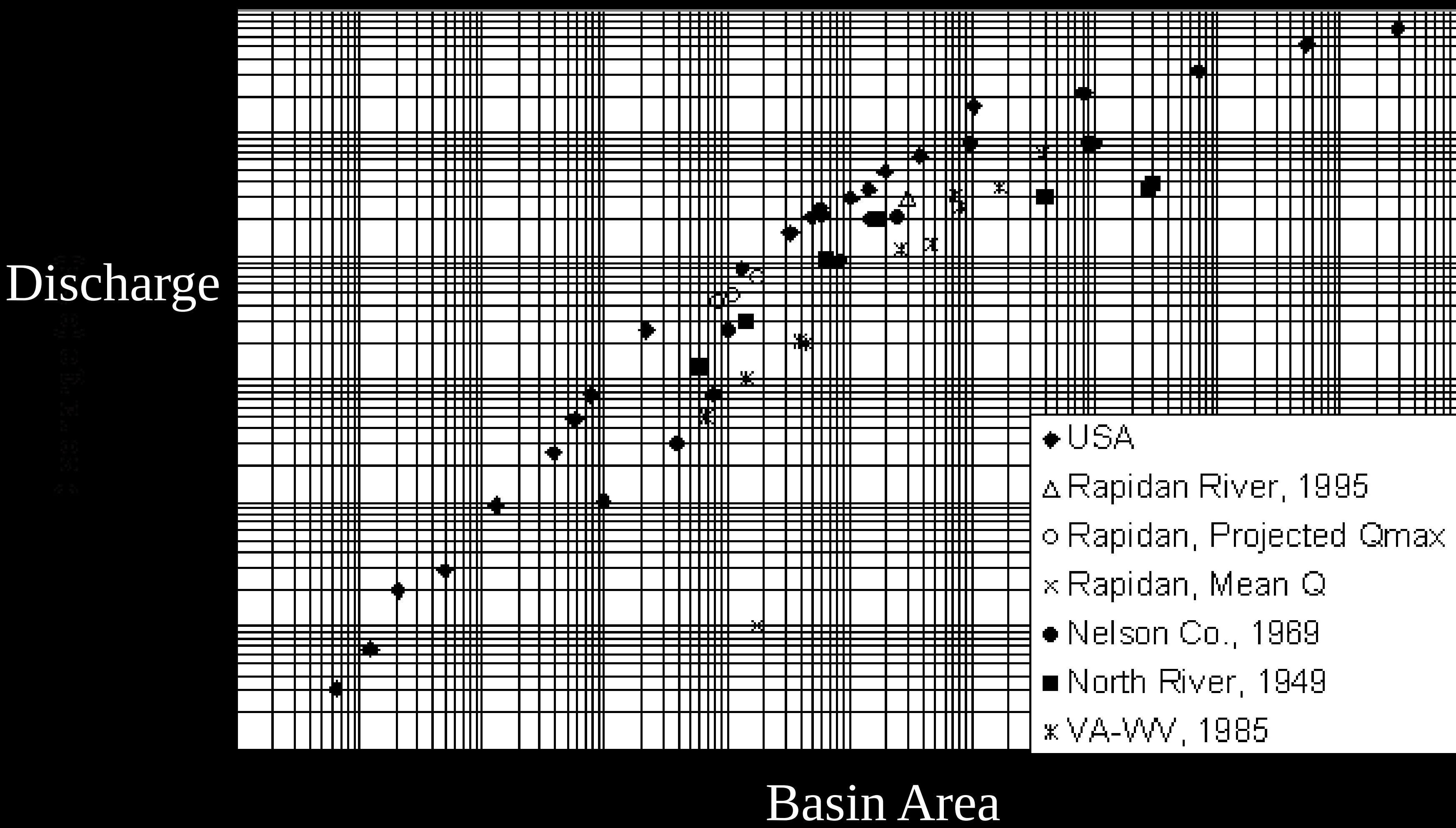


Figure 5.9

Progress of flood crests caused by Hurricane Agnes in the Susquehanna River basin, June 1972. Basins of increasing size: (A) Bald Eagle Creek; (B) Juniata River; (C) Susquehanna River.



Discharge
USA
Rapidan River, 1995
Rapidan, Projected Qmax
Rapidan, Mean Q
Nelson Co., 1969
North River, 1949
VA-WV, 1985
Basin Area

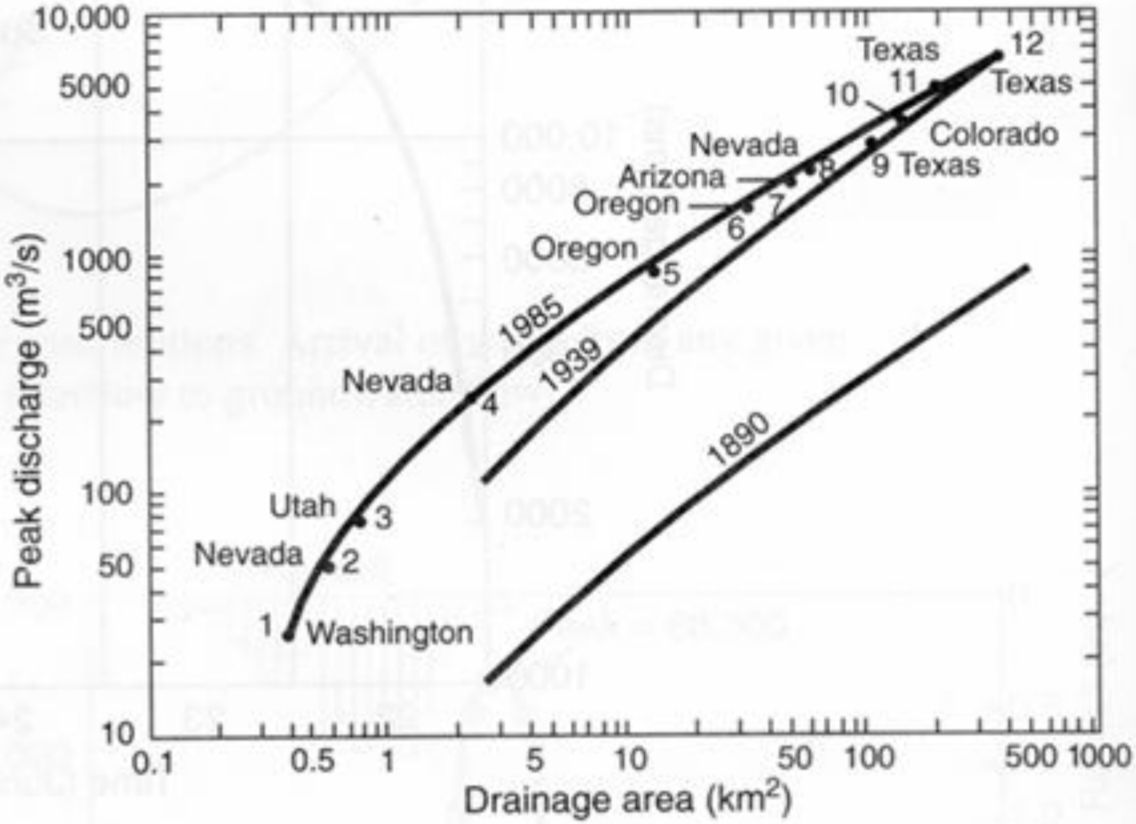


Figure 5.11

Peak discharge per unit from the largest flash floods in U.S. history. Note how the relationship indicates an increase in discharge coincident with development and land use alterations over the past 100 years.

(From Costa 1987)

III. Initiation of Channels and the Drainage Network

A. The concept

III. Initiation of Channels and the Drainage Network

A. The concept

Shear stress…….

III. Initiation of Channels and the Drainage Network

A. The concept

Shear stress……. $\tau = \rho gds$

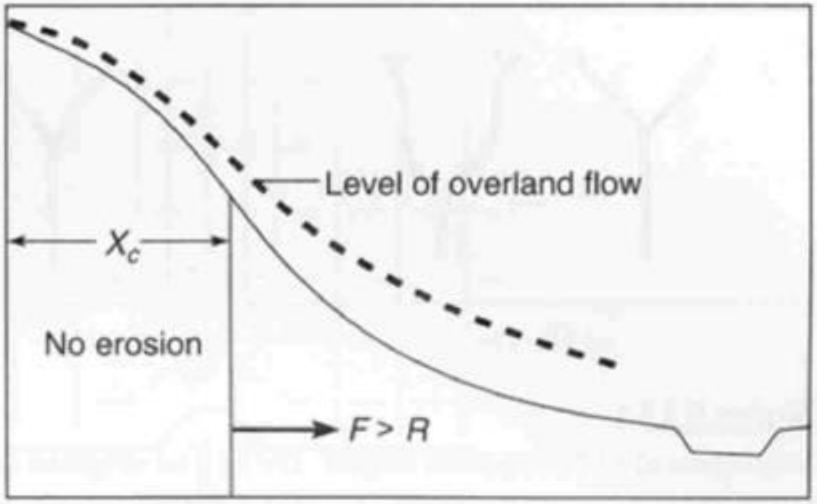


Figure 5.12
Hypothetical slope showing overland flow. No erosion occurs until the force of overland flow (*F*) exceeds the resistance of the surface material (*R*). Upslope from that point no erosion occurs. X_c is the distance from the divide to point where erosion begins.
(After Horton 1945)

Effects of Vegetation….

III. Initiation of Channels and the Drainage Network

A. The concept

*Rills develop, and they begin to "**bifurcate**"*

"repeated divisions of single channel segments"

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"repeated divisions of single channel segments"

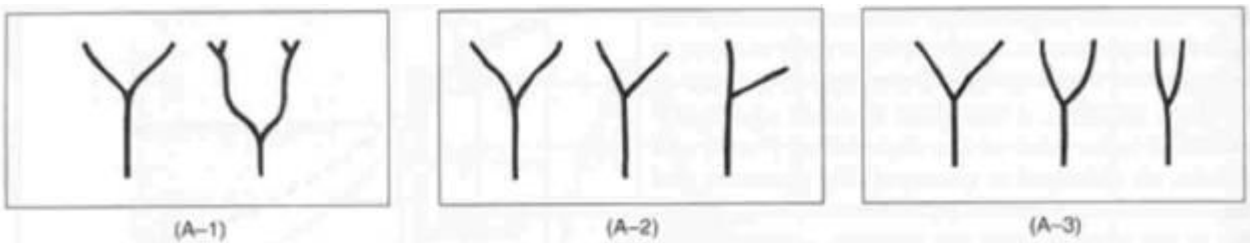

Figure 5.13A
Development of bifurcation angles. (A-1) The original angle is preserved. (A-2) One branch becomes dominant. (A-3) Angle decreases and branches merge into one channel; occurs on steep slopes.
(After Schumm 1956)

*Rills develop, and they begin to “**bifurcate**”*

“repeated divisions of single channel segments”

Figure 5.13B

View of small rilles developing a drainage network on a Texas hillslope. Note the cross-grading and micropiracy that is occuring on the slope to the right.

(Photo by R. Craig Kochel)

III. Initiation of Channels and the Drainage Network

B. Basin Morphometry

refers to the geometry of the basin

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refers to the geometry of the basin

Drainage Composition

refers to the distinct fabric of the drainage basin

1. Drainage Composition
   refers to the distinct fabric of the drainage basin

Strahler (1952)

Shreve (1967)

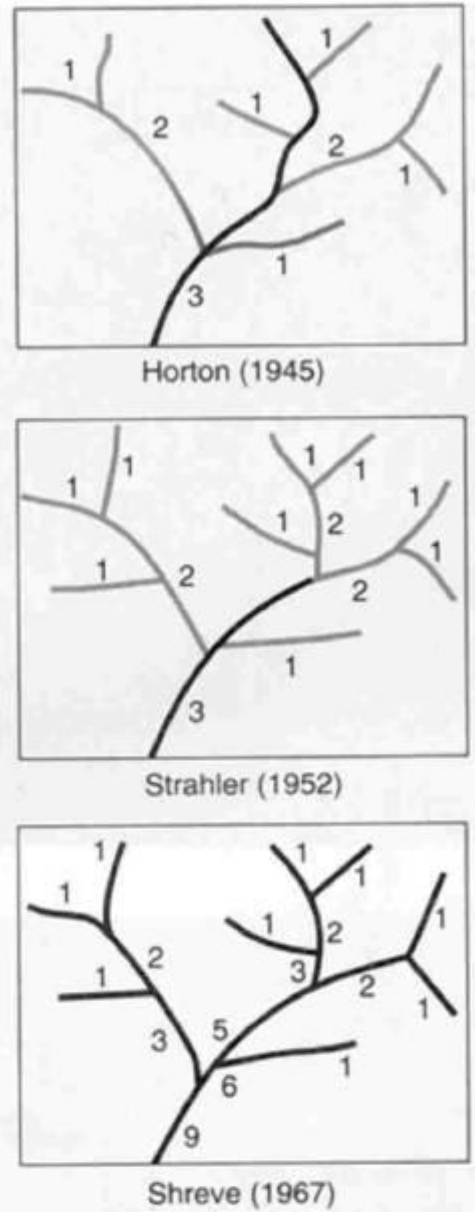


Figure 5.17
Methods of ordering streams within a drainage basin.

2. Linear Morphometric Relationships

Certain linear parameters of a basin are proportionally related to stream order.

a. Bifurcation ratio (Rb)

$$\frac{\text{streams of one order}}{\text{streams of the next highest order}}$$

Ex: 1 6th order stream

3 5th order

9 4th order

27 3rd order

81 2nd order

$$\frac{27}{9} = 3$$

Ratio value is nearly constant between adjacent orders AND….where geology is homogeneous, Rb = 3.0 – 5.0

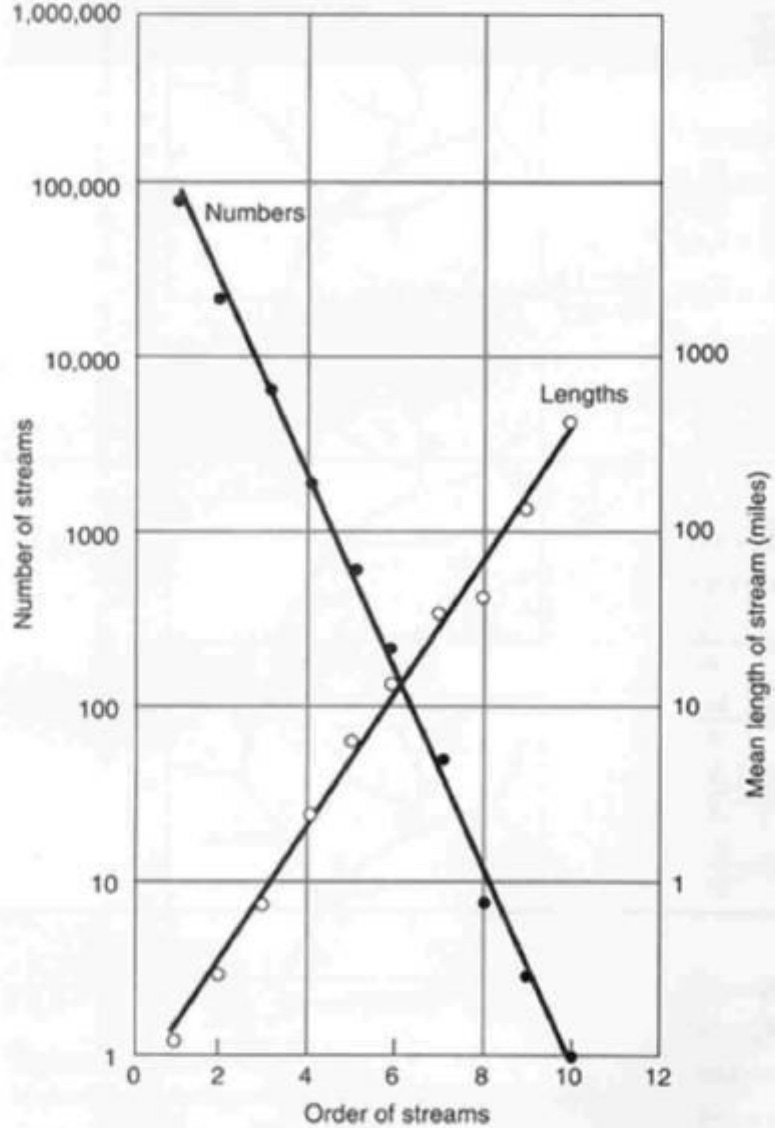


Figure 5.18
Relation of stream order to the number and mean lengths of streams in the Susquehanna River basin.
(After Brush 1961)

2. Linear Morphometric Relationships

Certain linear parameters of a basin are proportionally related to stream order.

b. Length ratio $$\frac{\text{ave length of streams of one order}}{\text{ave length streams of the next highest order}}$$

Can be used to determine the average length of streams in an unmeasured order.

3. Aerial Morphometric Relationships

a. Drainage density (Dd)

$$Dd = \frac{\text{total length of streams in basin}}{\text{basin area}}$$

Reflects the interaction between geology and climate

In general….

4. Relief Morphometric Relationships

a. Relief Highest elevation – lowest elevation

Reflects the vertical dimensions of drainage basin

Includes factors of gradient and elevation

IV. Basin Morphology and Flood Hydrograph

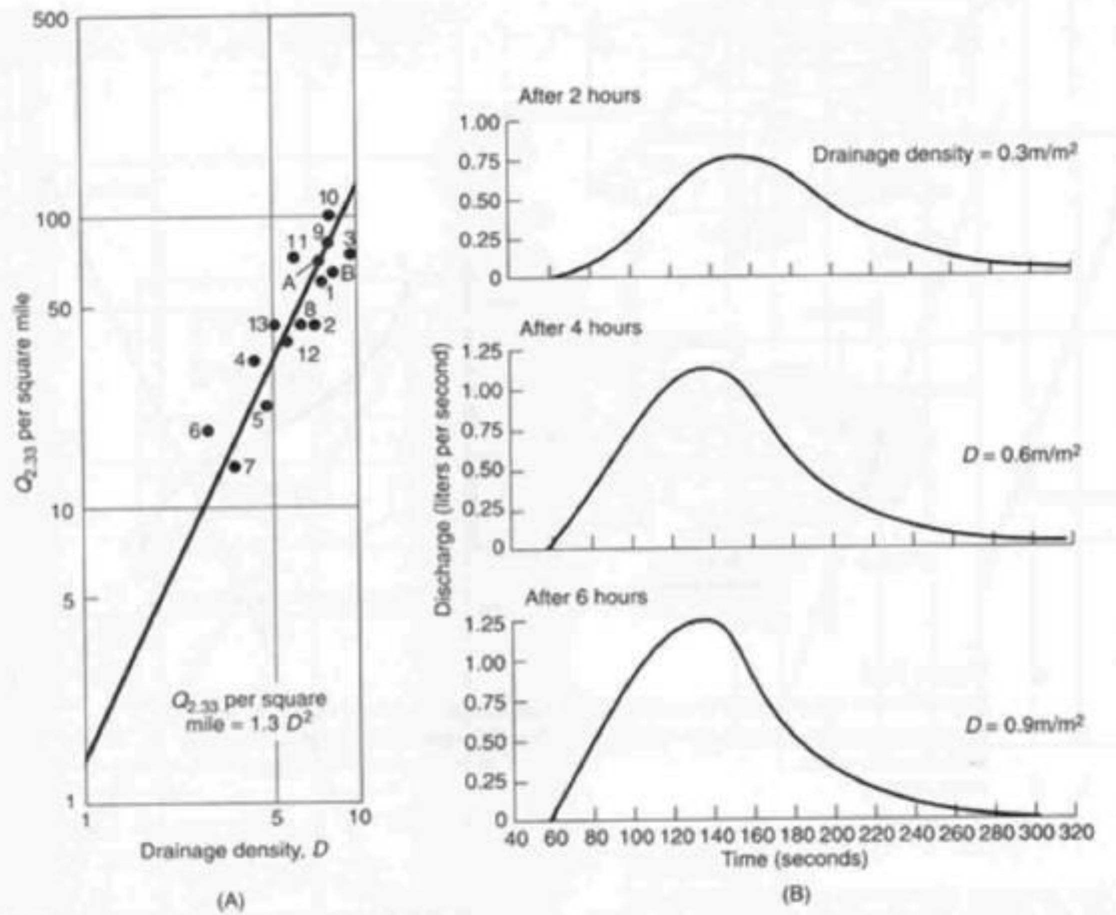
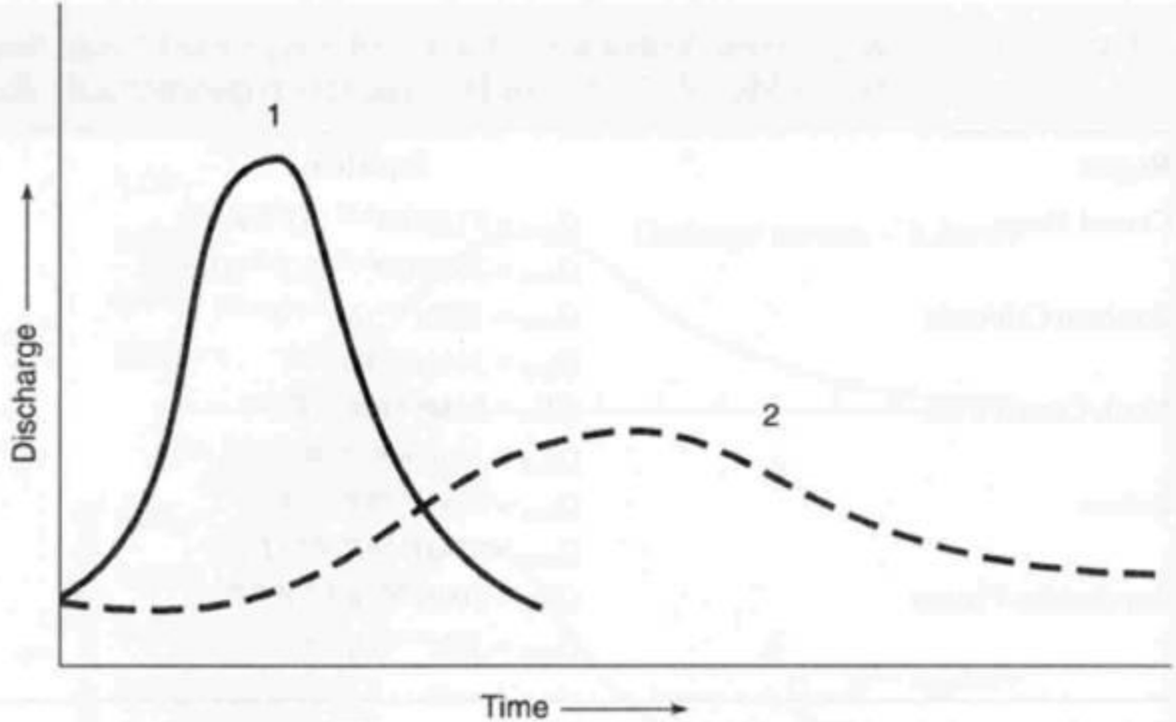


Figure 5.21

(A) Discharge (mean annual flood, $Q_{2.33}$) controlled by drainage density in 13 basins. (B) Effect of increasing drainage density on flood hydrograph in an experimental drainage system.

(A): (Carlston 1963), (B): (Zimpfer 1982)

IV. Basin Morphology and Flood Hydrograph



Characteristic	Flashy (hydrograph 1)	Sluggish (hydrograph 2)
Basin area	Small	Large
Drainage density	High	Low
Basin magnitude	High	Low
Relief	High	Low
Ruggedness number	High	Low
Basin shape	Equidimensional	Elongate
Soils	Thin	Thick
Vegetation	Sparse	Dense
Storm track	Down the basin	Up the basin

Figure 5.22
Idealized flood hydrograph and generalized responses to drainage basin characteristics. The effect of an individual characteristic is shown assuming the other characteristics are held constant.

V. Basin Evolution and Denudation

V. Basin Evolution and Denudation

A. Factors affecting sediment yield

* climate

V. Basin Evolution and Denudation

A. Factors affecting sediment yield

* climate

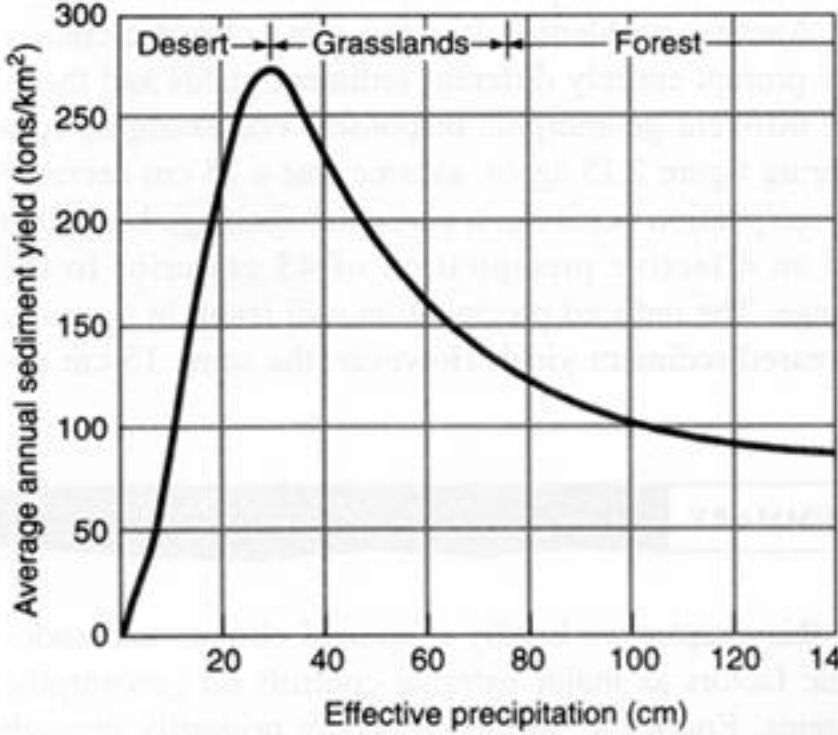


Figure 2.15

Average annual sediment yield as it varies with effective precipitation and vegetation.

(Langbein and S. A. Schumm, *Transactions of the American Geophysical Union*, vol. 39, p. 1077, 1958, copyright by the American Geophysical Union.)

V. Basin Evolution and Denudation

A. Factors affecting sediment yield

* basin size

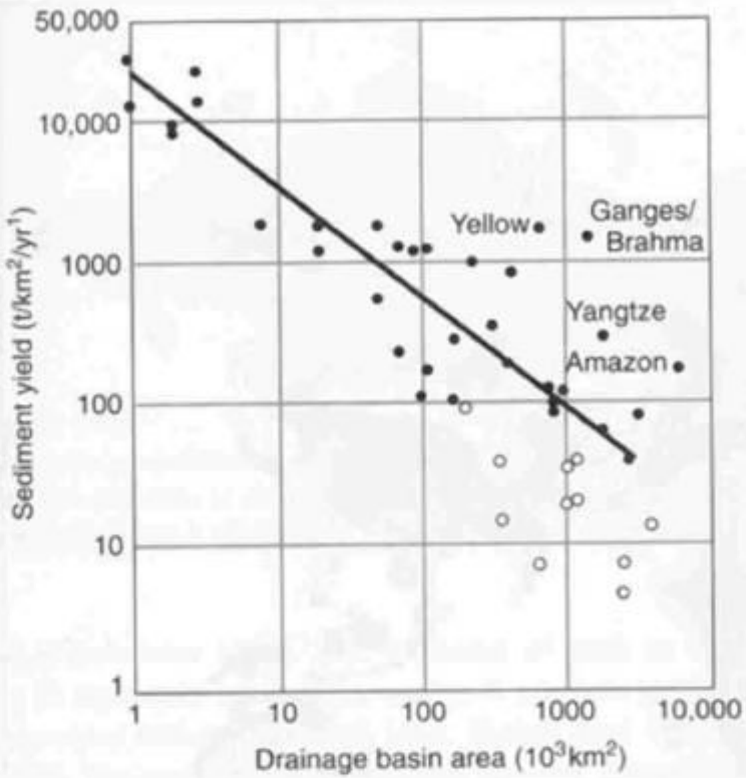


Figure 5.45

Comparison of sediment yields and drainage basin areas for all major sediment-discharging rivers (greater than 10×10^6 t yr^{-1}). Open circles represent low-yield rivers draining Africa and the Eurasian Arctic. Smaller basins have larger yields, although the largest rivers (Amazon, Yangtze, Ganges/Brahmaputra, and Yellow) all have greater loads than their basin areas would predict.

(Milliman and Meade 1983)

V. Basin Evolution and Denudation

A. Factors affecting sediment yield

* elevation and relief

V. Basin Evolution and Denudation
A. Factors affecting sediment yield
* rock type

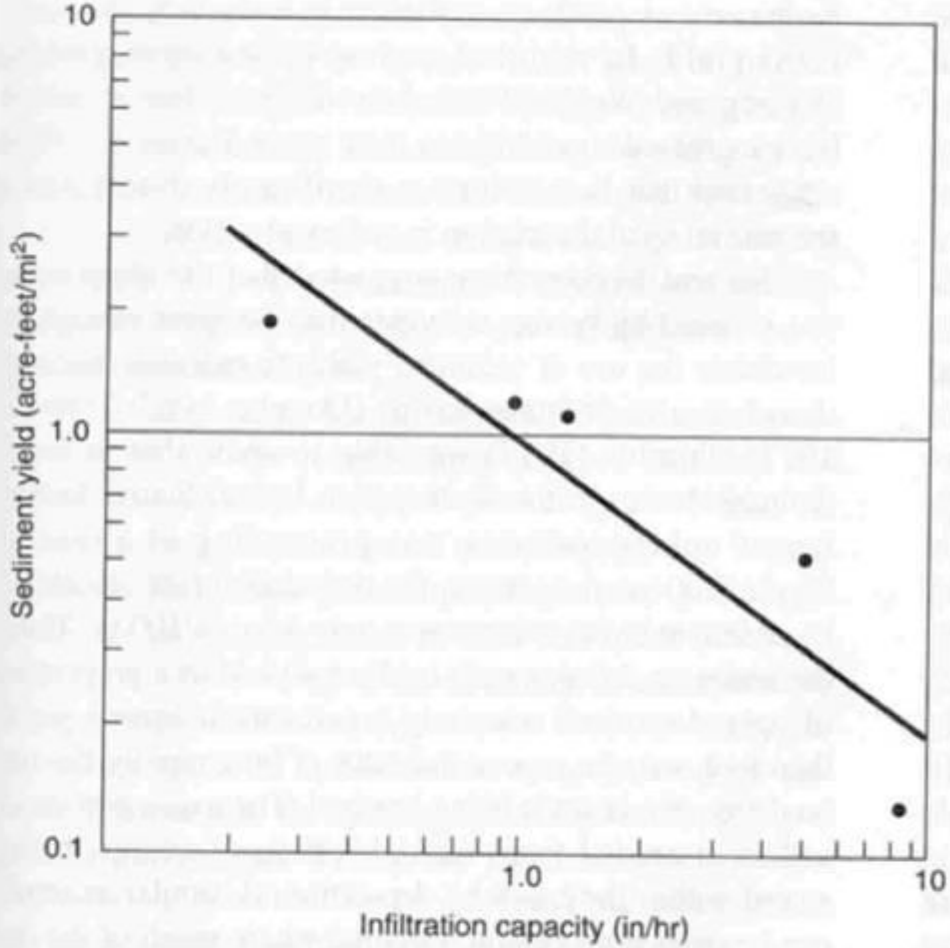


Figure 5.49
Relation between infiltration capacity and sediment yield, indicating lithologic influence.
(Hadley and Schumm 1961)

V. Basin Evolution and Denudation
A. Factors affecting sediment yield
* Human Factor

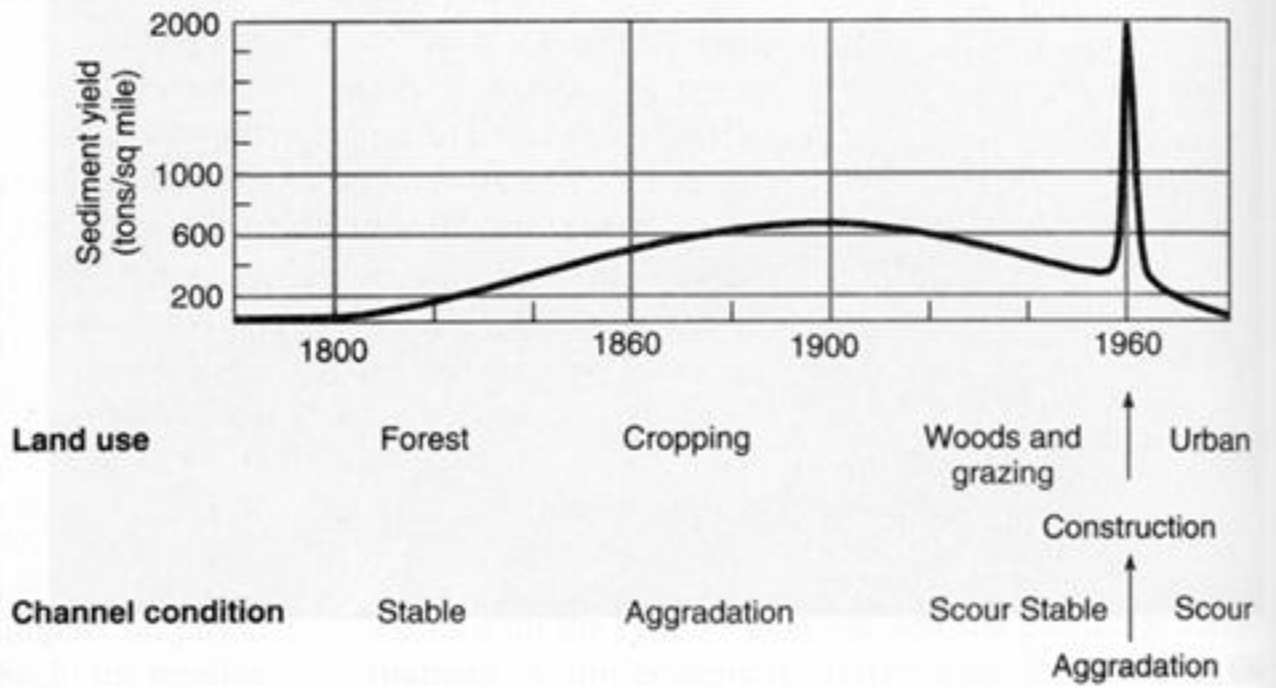
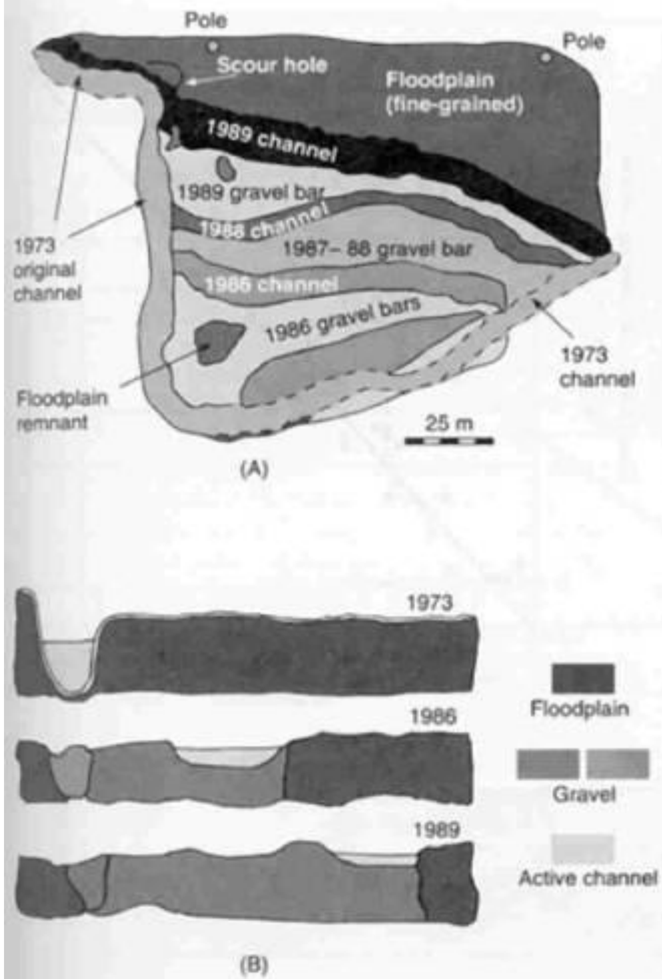


Figure 5.51
Changes in sediment yield and channel behavior in one area under various types of land use.
(Wolman 1967)

V. Basin Evolution and Denudation

A. Factors affecting sediment yield

* Human Factor



(C)

Figure 5.46

Channel changes and disequilibrium response triggered by land use changes upstream, Sexton Creek, southern Illinois. (A) Plan view map of channel adjustments between 1973 and 1989. Note the narrow, sinuous, fine-grained channel mapped in 1973. Major adjustments began suddenly with a flood in 1986, replacing the sinuous channel with a straight, wide, gravel-bed channel concurrent with the erosion of fine-grained floodplain alluvium. (B) Change in channel and floodplain cross-section taken normal to the axis of the 1989 channel in (A). (C) Sexton Creek channel in 1988 after a significant flood. Mud from the former valley fill sediment is visible along the cut bank on the left. The channel at this location increased width by over 500 percent since 1986, replacing a sinuous, fine-grained channel with a coarse-grained, cobbly straight reach.

(C) (Photo by R. Craig Kochel)

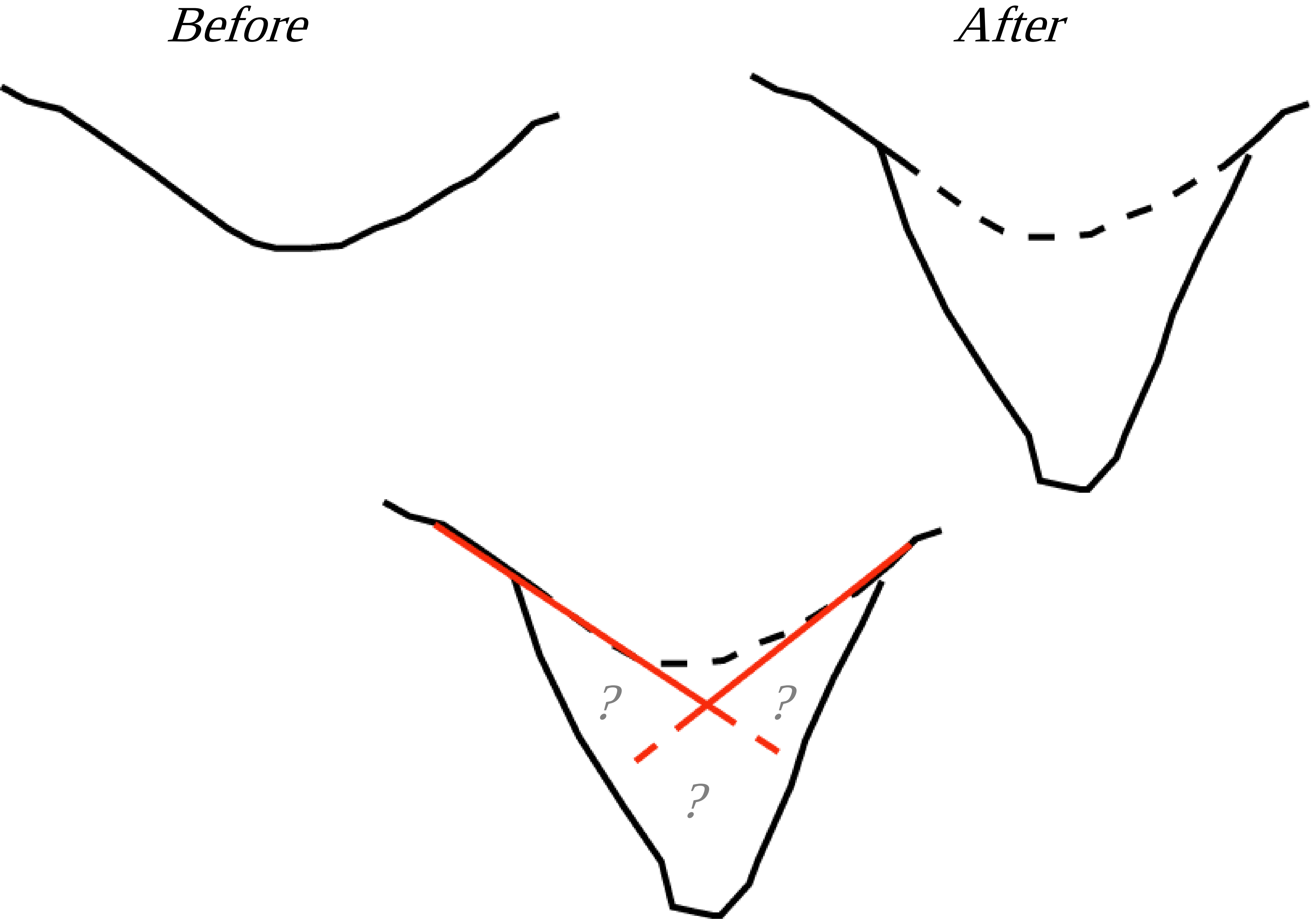
V. Basin Evolution and Denudation

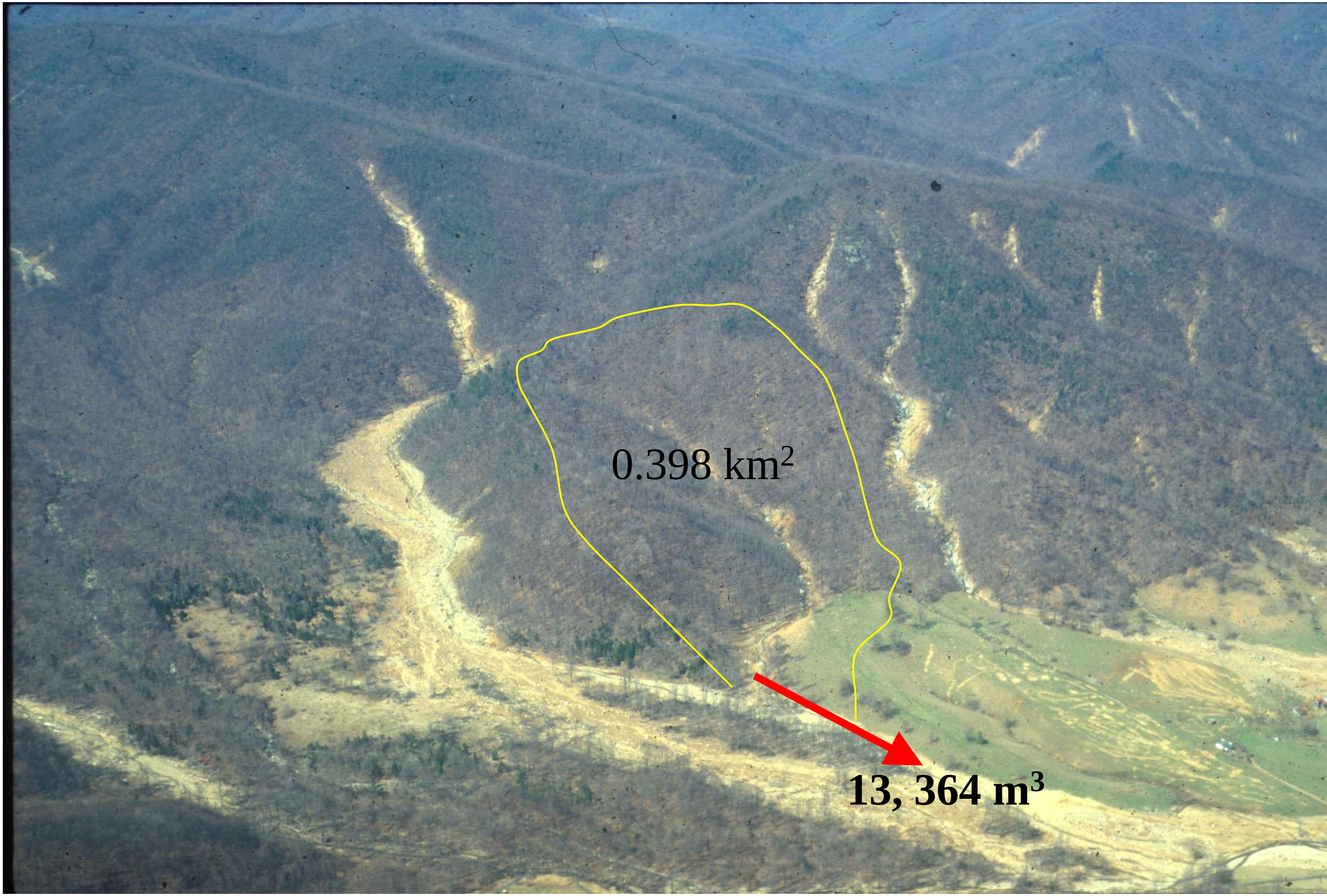
A. Factors affecting sediment yield

B. How do basins erode (denute?)

Sediment Transport and Denudation


0.398 km²


Before
After
?
?
?

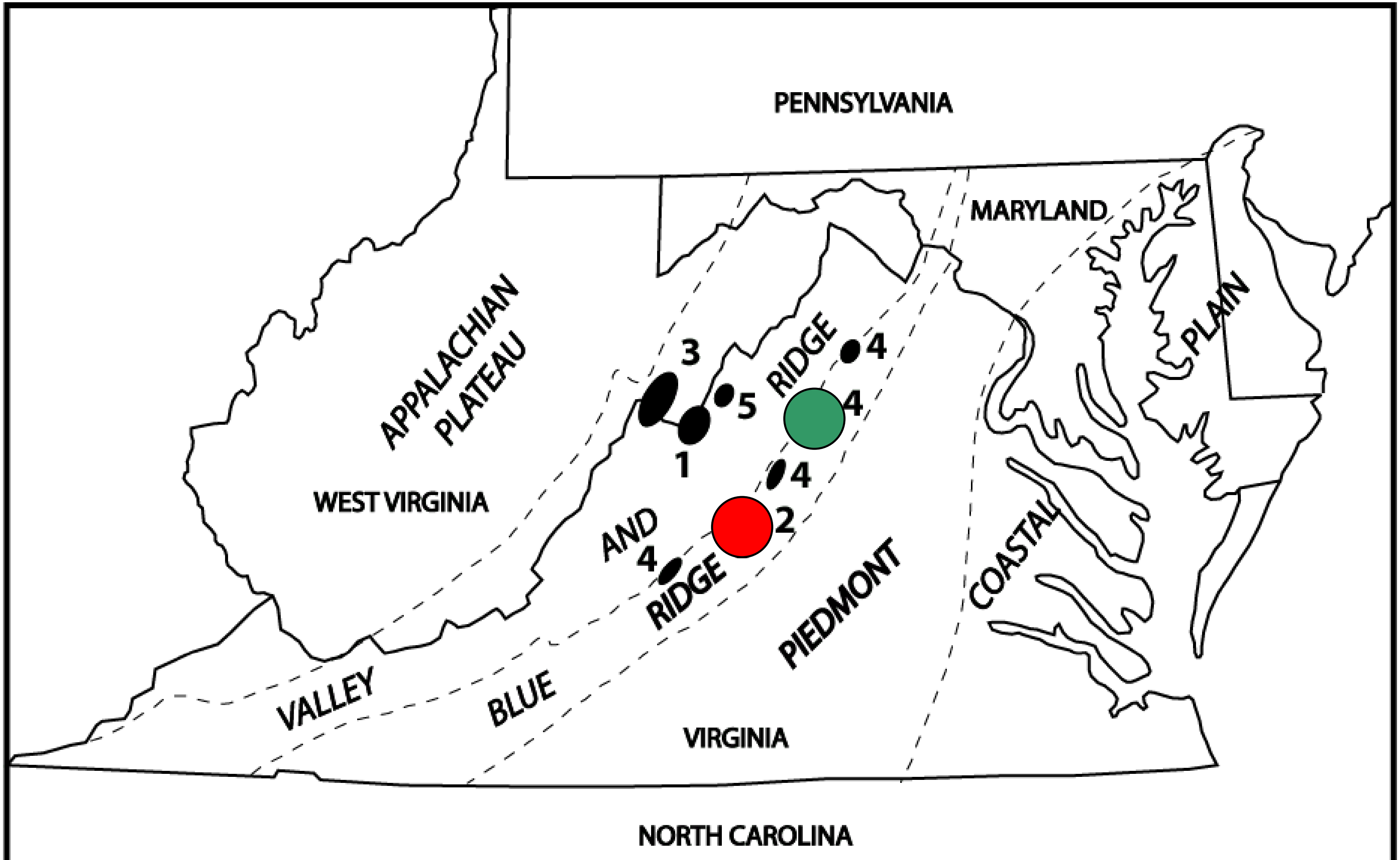

0.398 km2
13, 364 m3

$$\frac{\text{Volume}}{\text{Area}} = \frac{13,364 \text{ m}^3}{0.398 \text{ km}^2 \text{ or } 398,000 \text{ m}^2} = 0.034 \text{ m}$$

= 3.4 cm

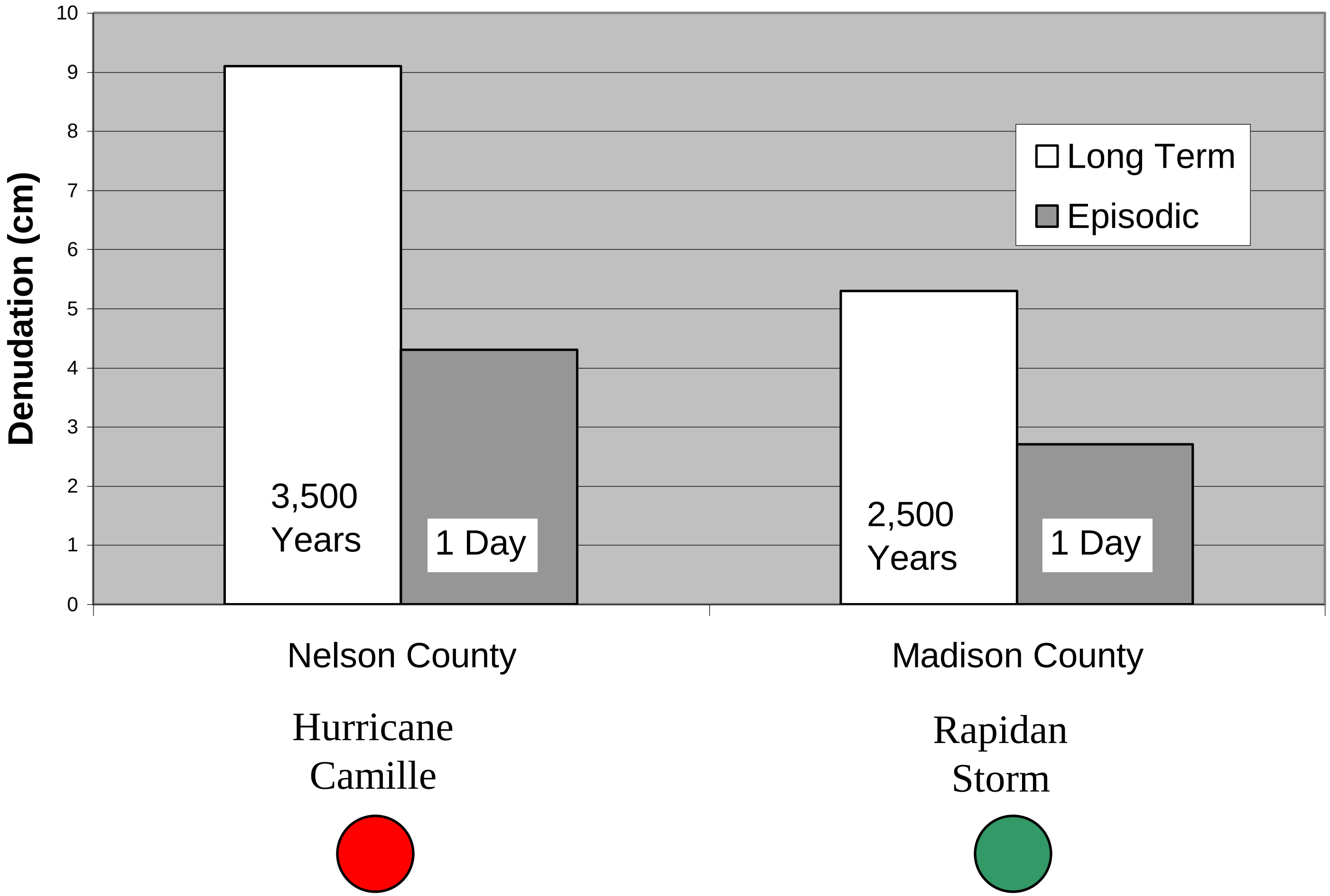
Summary of Basin Denudation of Blue Ridge Systems

Event	Basin	Basin Area (km^2)	Volume of Sediment Eroded (m^3)	Mean Basin Denuda-tion (cm)
Hurricane Camille	Willis Cove	4.08	173,488	4.25
Hurricane Camille	Ginseng Hollow	1.75	88,727	5.07
Hurricane Camille	Polly Wright Cove	2.47	87,707	3.55
Rapidan Flood	Jenkins Hollow	0.398	13,364	3.36
Rapidan Flood	Teal Hollow	0.123	2,492	2.03



PENNSYLVANIA
MARYLAND
APPALACHIAN
PLATEAU
RIDGE
3
4
4
5
1
4
WEST VIRGINIA
2
AND
4
RIDGE
PIEDMONT
COASTAL
PLAIN
VALLEY
BLUE
VIRGINIA
NORTH CAROLINA

Long Term and Episodic Denudation



B. How do basins erode (denute?)

VI. Basin Hydrology
A. Subsurface Water

Hydrogeology (GEOL 460)
M W 10:10-11, Friday Lab

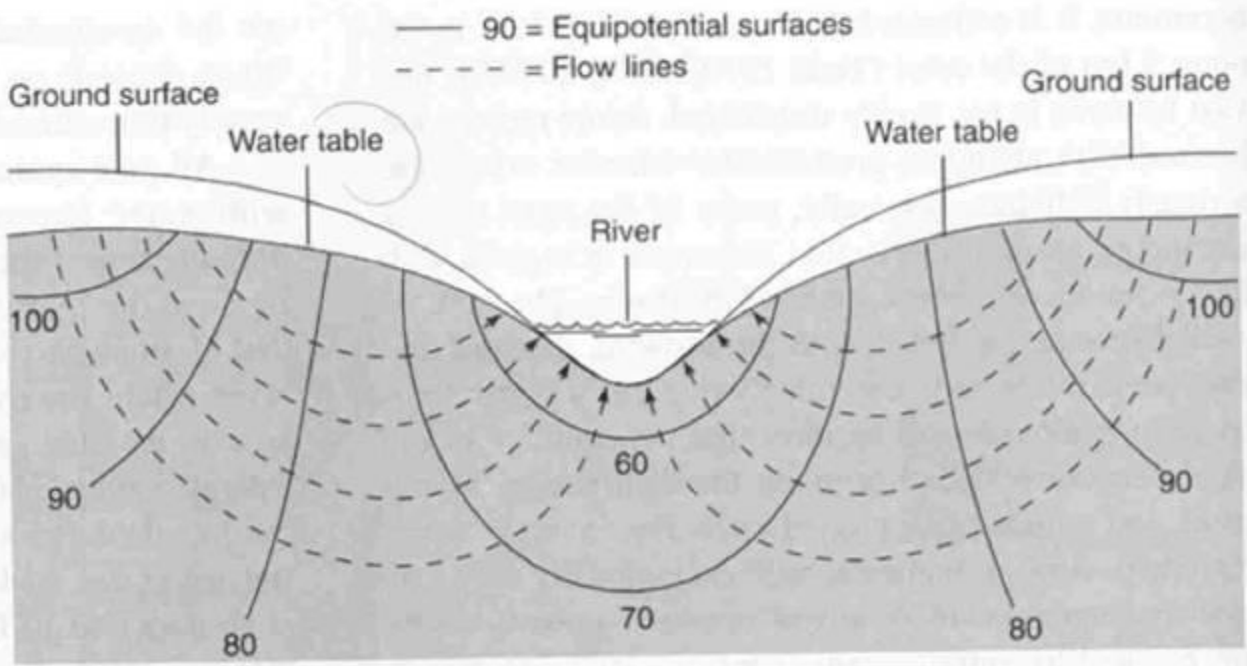


Figure 5.27
Movement of groundwater according to distribution of potential in the underground system. Water moves from high to low potential and perpendicular to the equipotential surfaces.

VI. Basin Hydrology
A. Subsurface Water

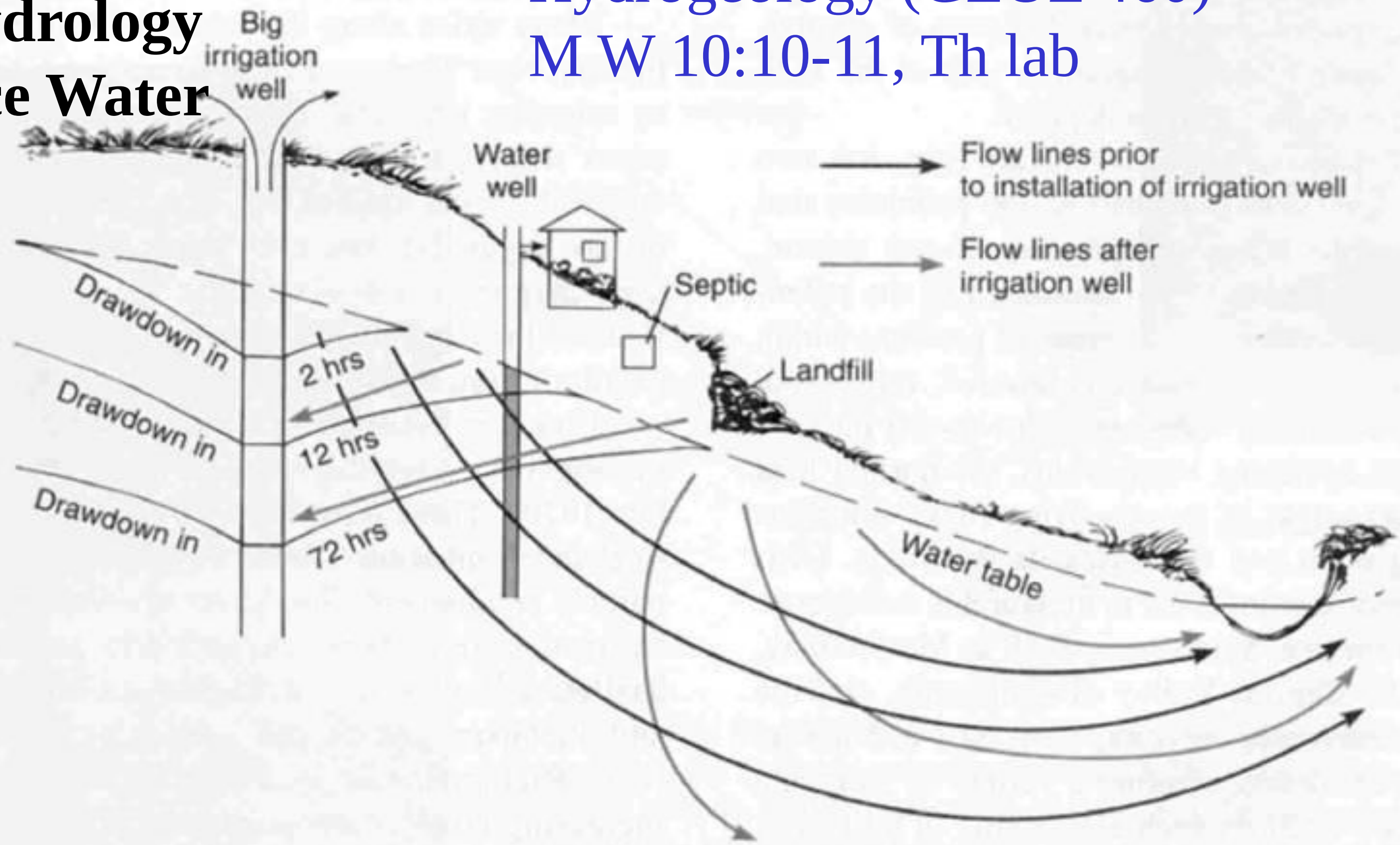


Figure 5.30
Development of cone of depression drawing down the water table due to the pumping of a major irrigation well. The cone of depression can alter groundwater flow patterns significantly as indicated here where the leachate from a landfill, which normally would move to the right, would now flow toward the water supply well for the home. This example assumes a simple homogenous system.

VI. Basin Hydrology

B. Surface Water

1. Terms

Discharge

$Q = V * A$

VI. Basin Hydrology

B. Surface Water

1. Terms

Discharge

Q = V * A

Velocity is highly variable; depends where measured.

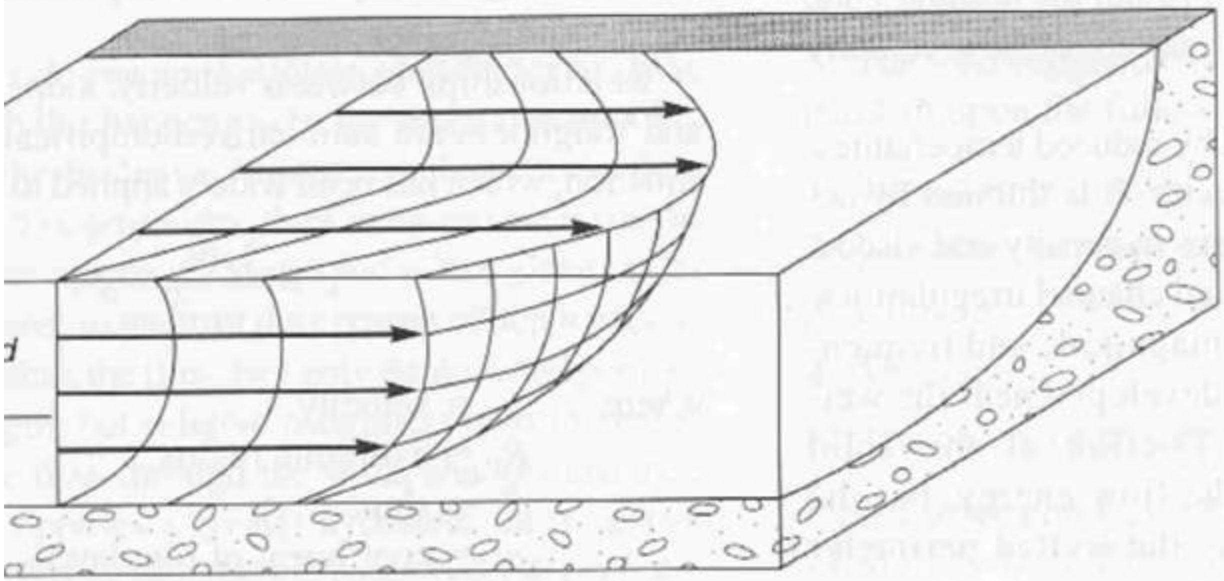
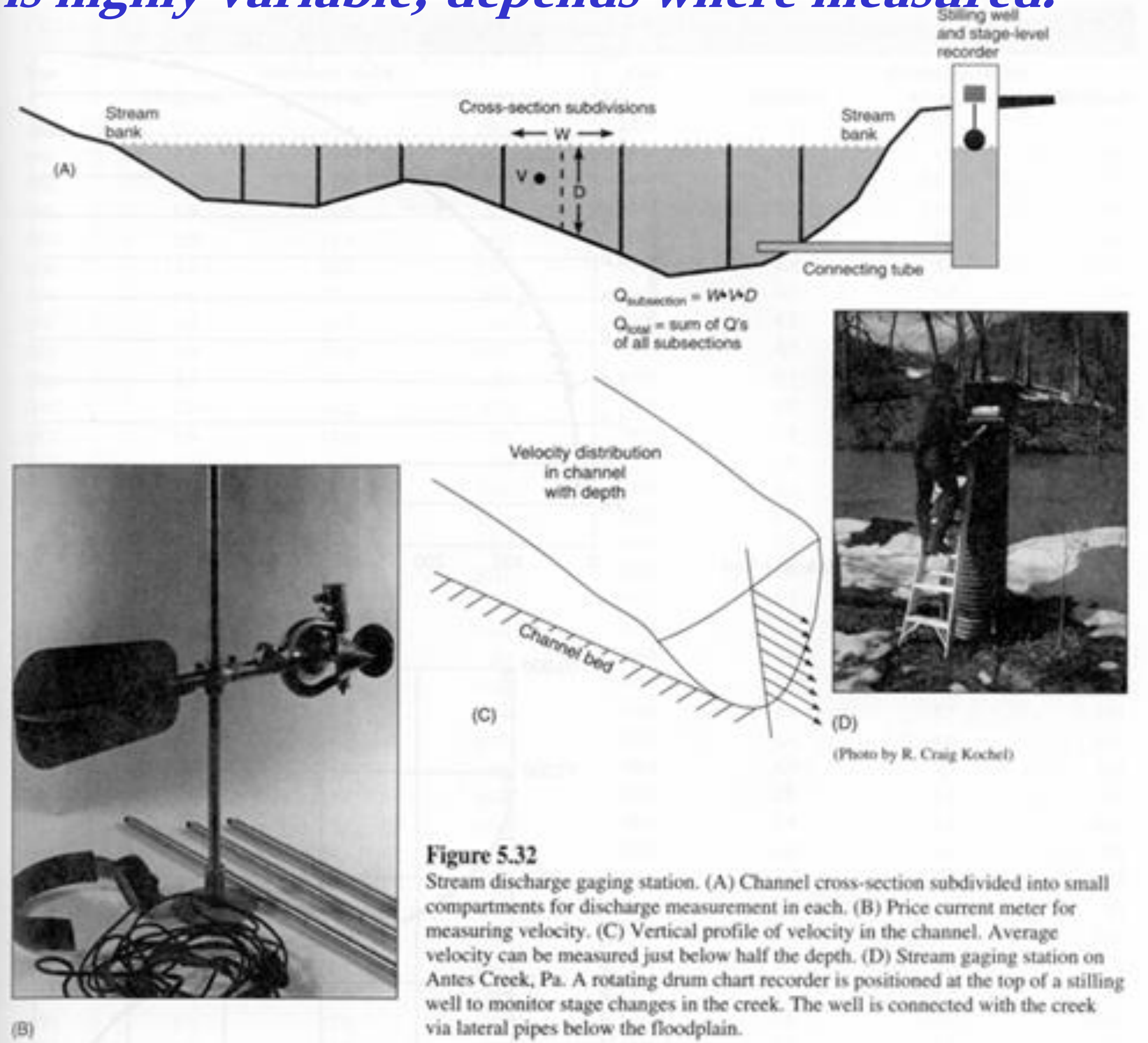


FIGURE 5–15
Three-dimensiona
gradient curve for
in a stream chann

Velocity is highly variable; depends where measured.



(Photo by R. Craig Kochel)

Figure 5.32
Stream discharge gaging station. (A) Channel cross-section subdivided into small compartments for discharge measurement in each. (B) Price current meter for measuring velocity. (C) Vertical profile of velocity in the channel. Average velocity can be measured just below half the depth. (D) Stream gaging station on Antes Creek, Pa. A rotating drum chart recorder is positioned at the top of a stilling well to monitor stage changes in the creek. The well is connected with the creek via lateral pipes below the floodplain.

VI. Basin Hydrology
B. Surface Water
2. Reporting discharge

Daily vs annual discharge

mean vs median discharge

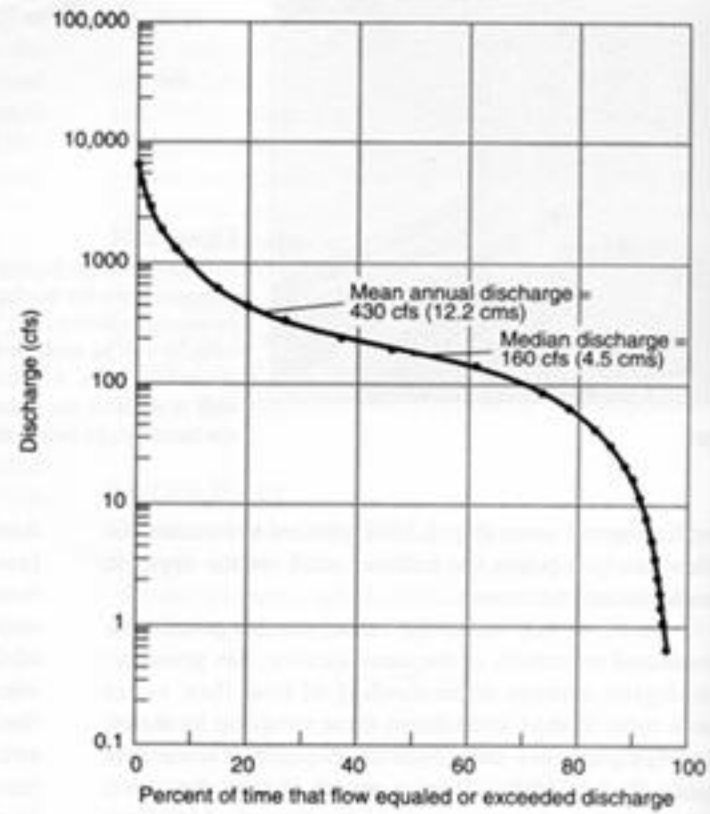
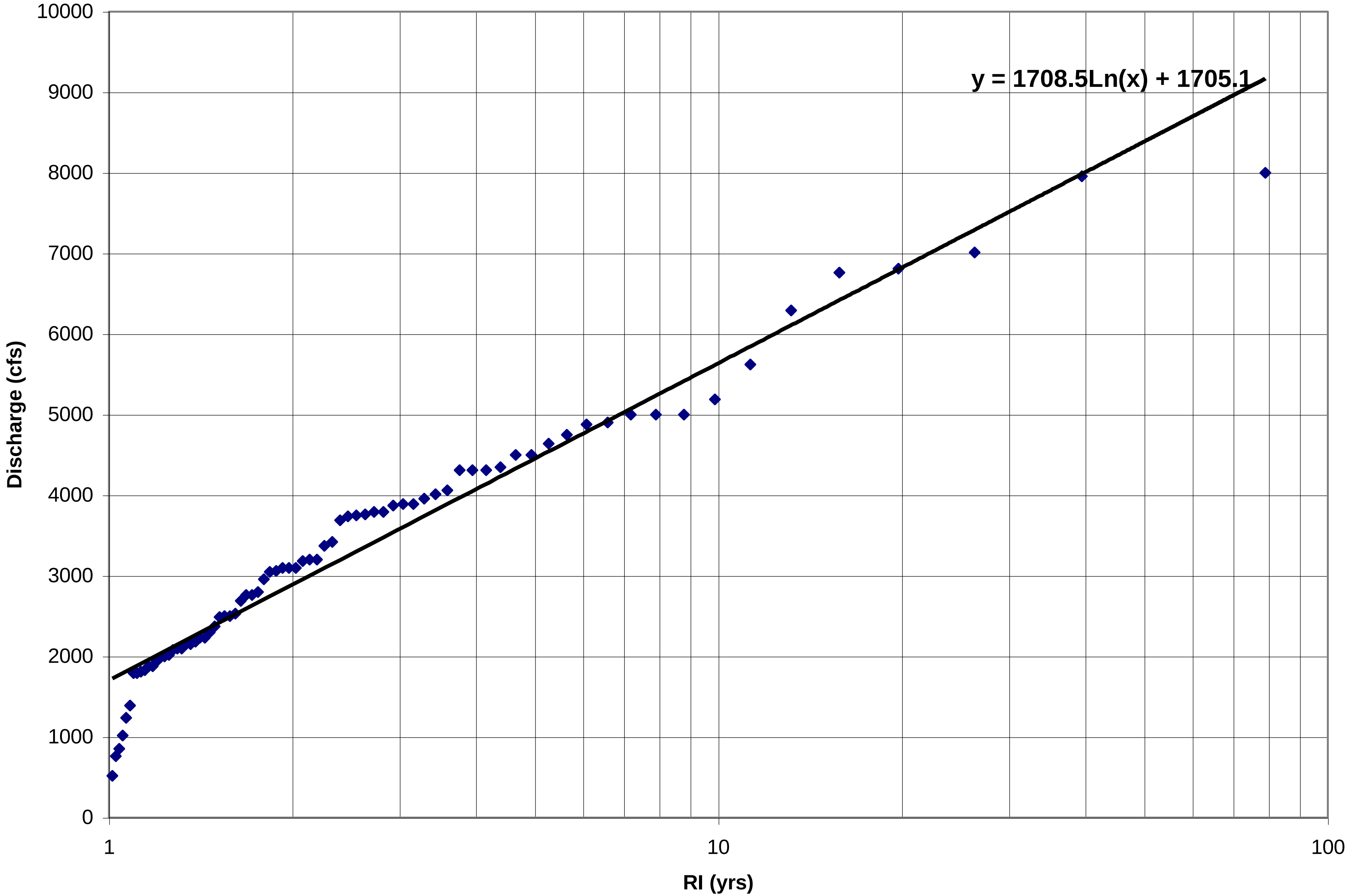
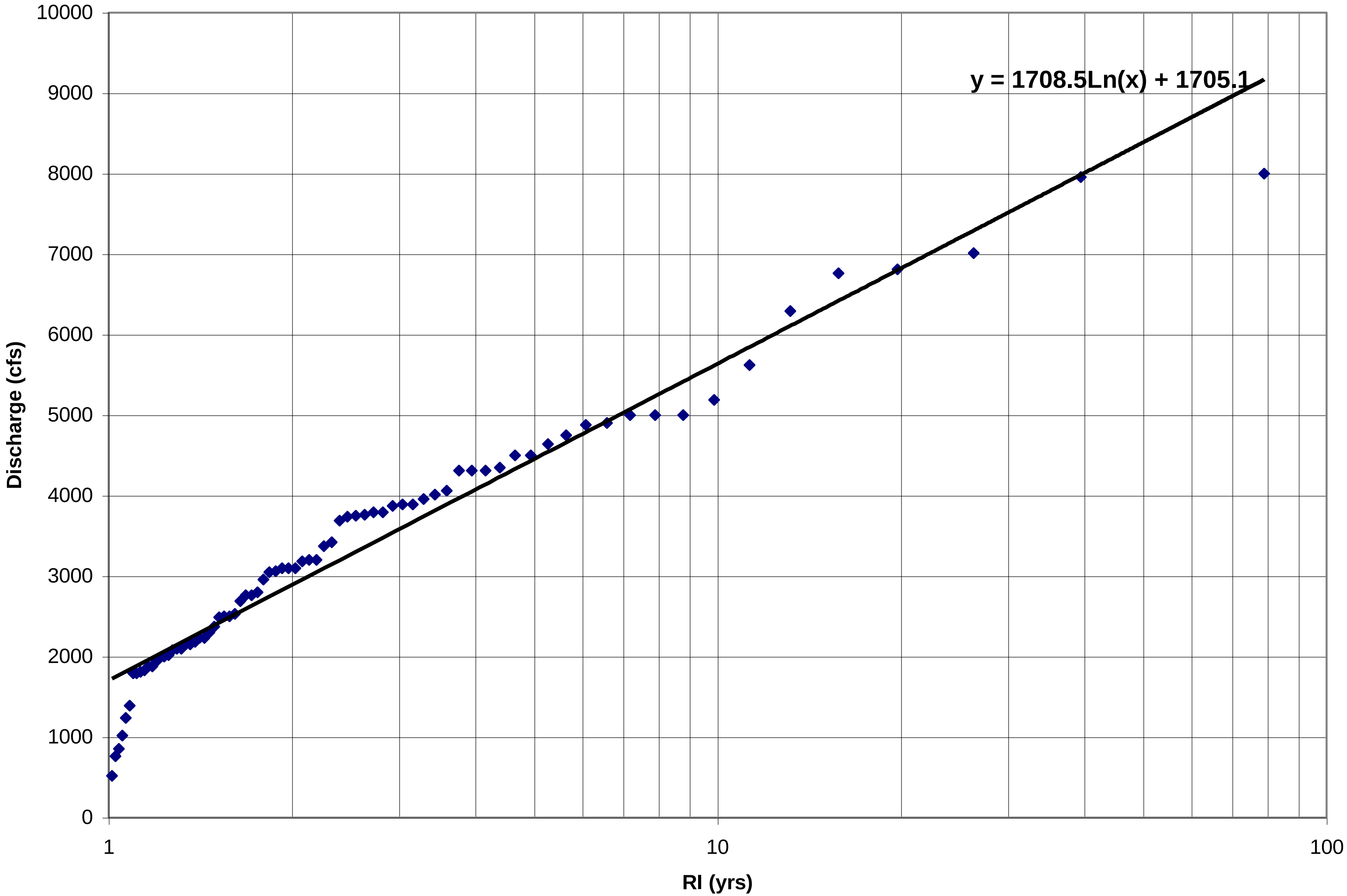


Figure 5.34
Flow duration curve for the Powder River near Arvada, Wyo., 1917–1950.
(Leopold and Maddock 1953)

3. Flood Frequency



What does this mean???



What does this mean???

the curve estimates the magnitude of a flood that can be expected within a specified period of time

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The probability that a flow of a given magnitude will occur during Any year is P = 1/RI.

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The probability that a flow of a given magnitude will occur during a year is P = 1/RI.

EX: a 50 year flood has a 1/50, or a 2 percent chance of occurring in any given year

For multiple years:

$$q = 1 - (1 - 1/T)^n$$

where q = probability of flood with RI of T with a specified number of years n

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$q = 1 - (1 - 1/RI)^n$

where q = probability of flood with RI with a specified number of years n

EX: a 50 year flood has an 86% chance of occurring over 100 years

CAUTION!!! ANALYSIS GOOD FOR 1.5x length of data set

VI. Basin Hydrology
B. Surface Water
3. Flood Frequency

Flood recurrence interval (R.I.)

VI. Basin Hydrology
B. Surface Water
3. Flood Frequency

Flood recurrence interval (R.I.)

use Weibull Method - calculates the R.I. by taking the average time between 2 floods of equal or greater magnitude.

$$RI = (n + 1) / m$$

where n is number of years on record,
m is magnitude of given flood

VI. Basin Hydrology

B. Surface Water

3. Flood Frequency

What does this mean???

the curve estimates the magnitude of a flood that can be expected within a specified period of time

The probability that a flow of a given magnitude will occur during a year is P = 1/R.

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VI. Basin Hydrology
B. Surface Water
3. Flood Frequency

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EX: a 50 year flood has an 86% chance of occurring over 100 years

VI. Basin Hydrology
C. Paleoflood Hydrology

Slackwater deposits……

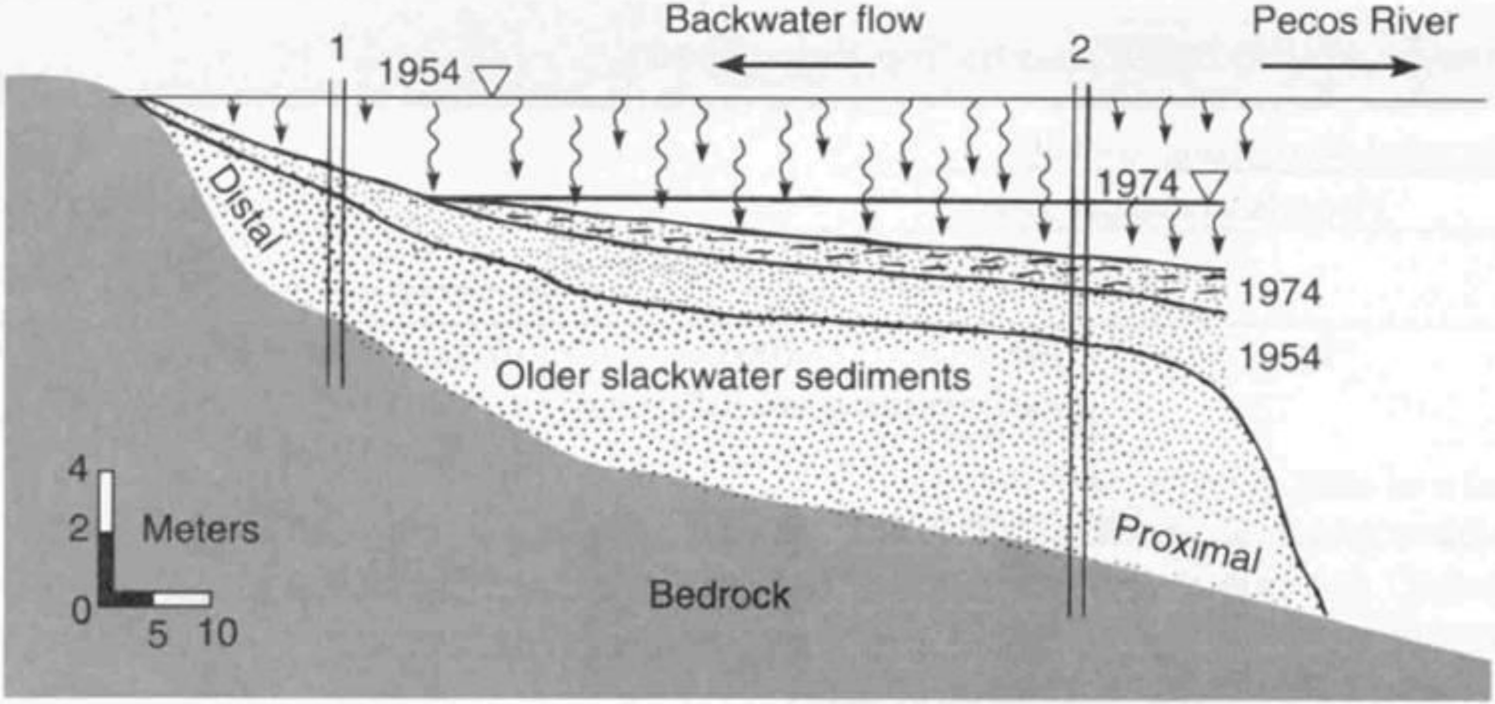

Figure 5.37
Schematic of on- and off-lap sequences and peak flood stage in a tributary valley for the 1954 and 1974 floods on the Pecos River, Texas. Sections in the proximal region (area 2) contain both floods, while distal regions (area 1) farther up the tributary record only the larger 1954 flood. Paleostage reconstructions are based on the elevation of the most distal sediments of each flood unit.

Kochel et al. 1982

VI. Basin Hydrology
C. Paleoflood Hydrology

Which one is right????

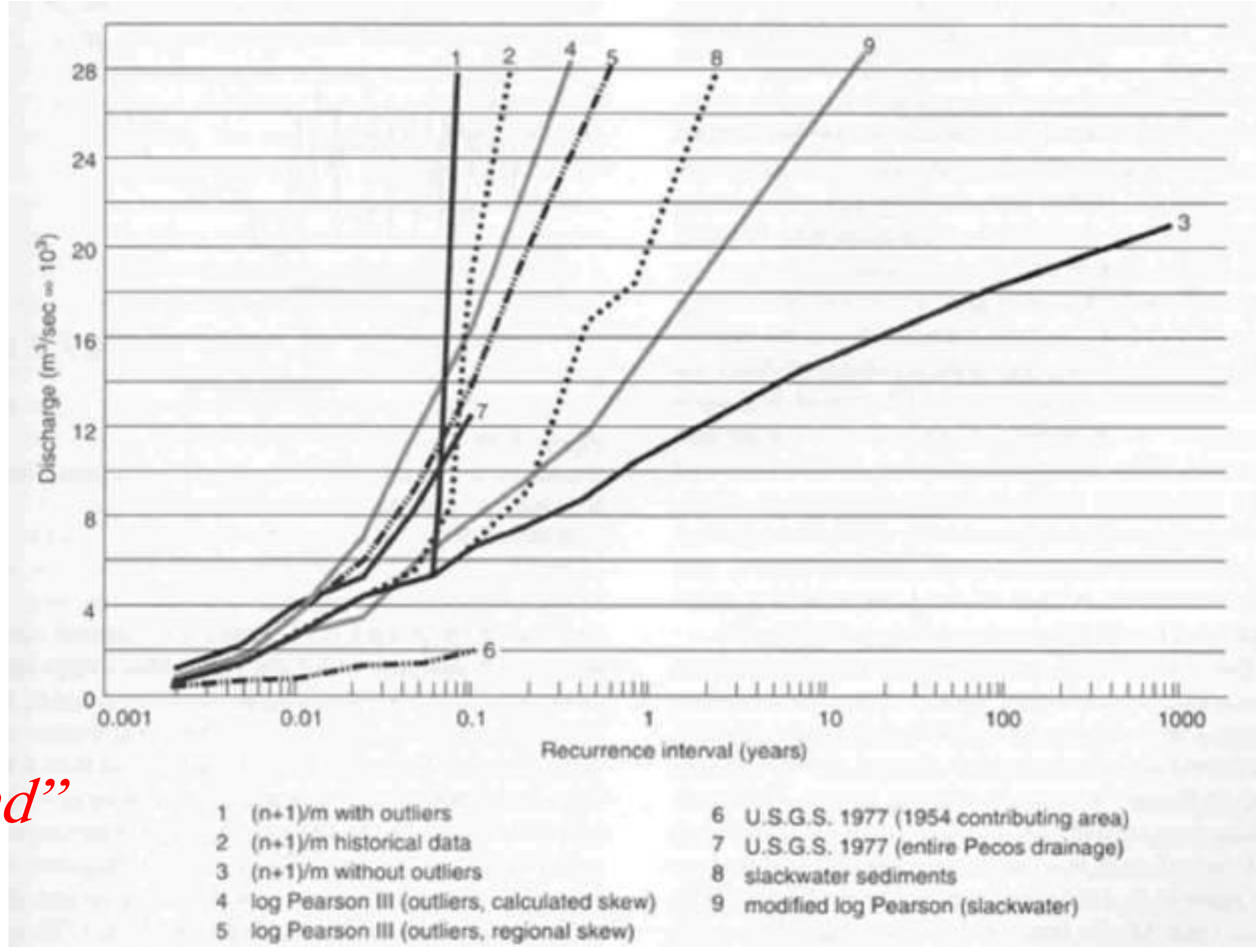

Figure 5.38
Range of potential flood frequency curves calculated using a variety of common standard techniques applied to the Pecos River flow data. Estimates of flood frequency for the 1954 flood outlier range from less than 100 years to more than 20 million years. Slackwater paleoflood deposits were used to provide a more realistic estimate based on physical flood evidence of around 2000 years.

Kochel and Baker 1982

"carbon is your friend"