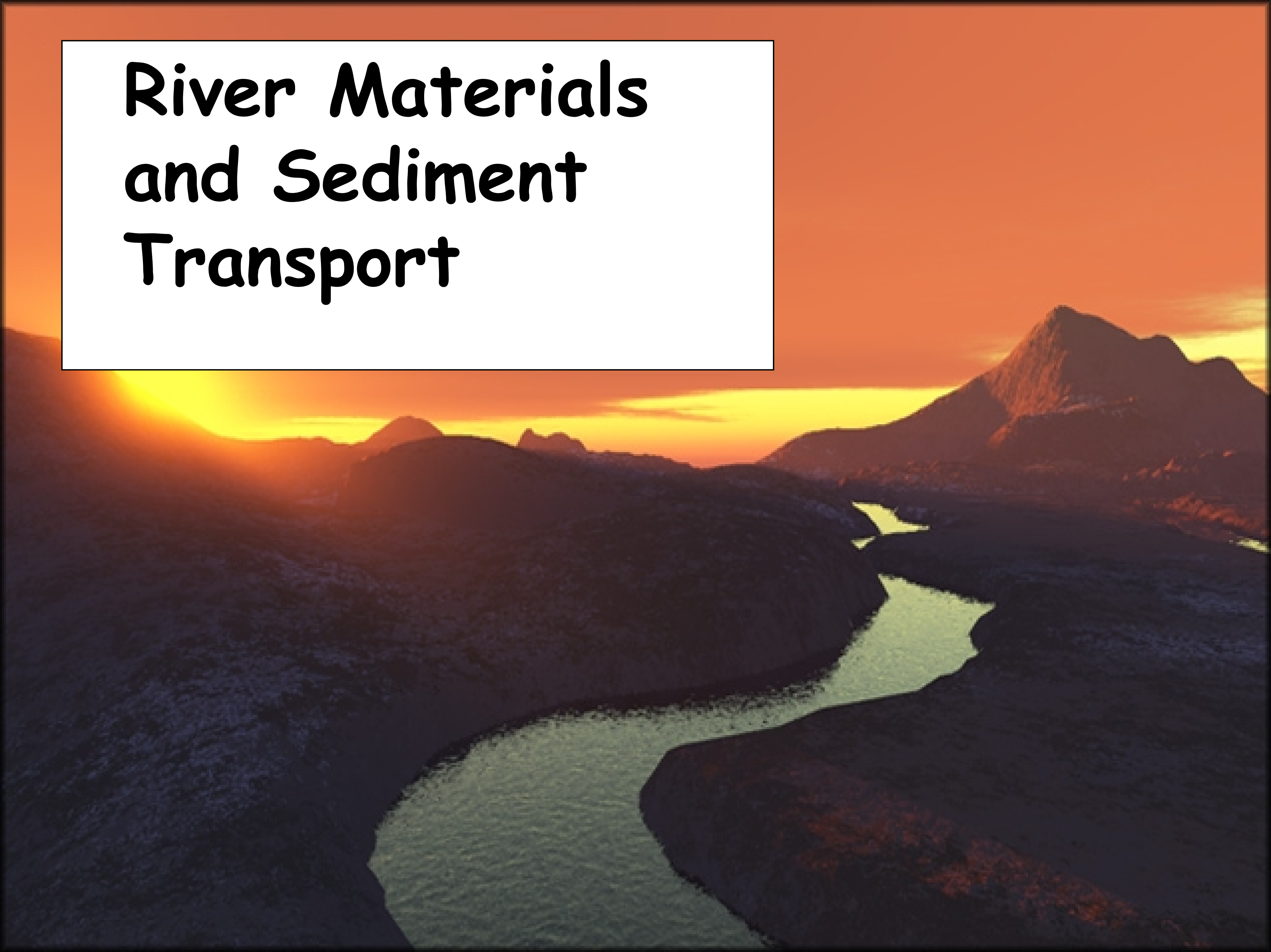
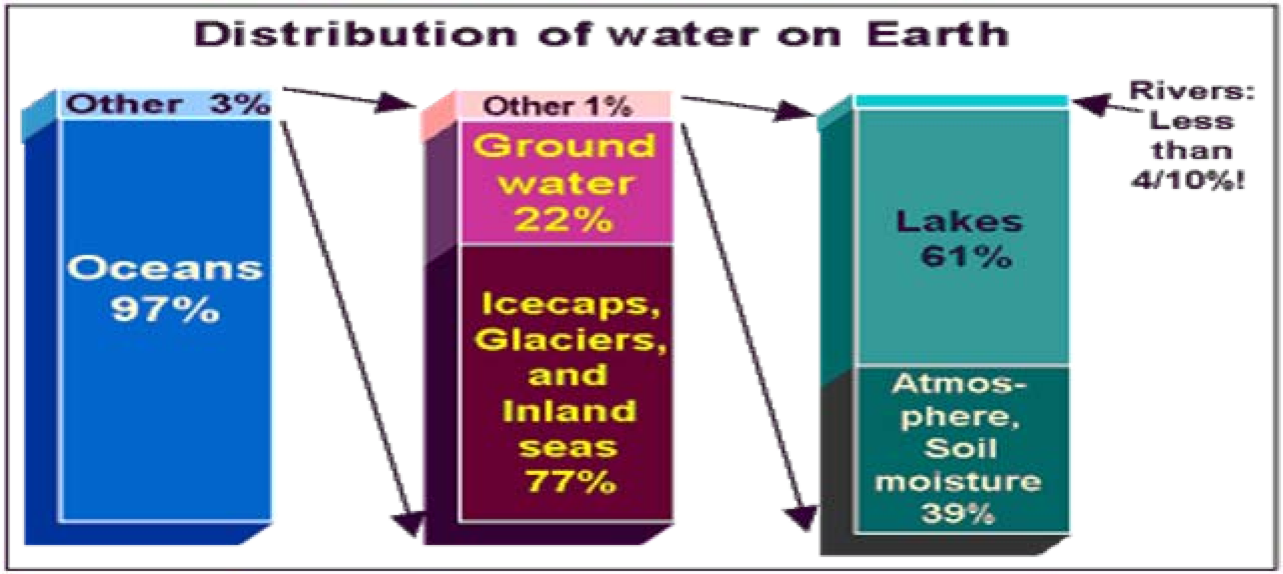
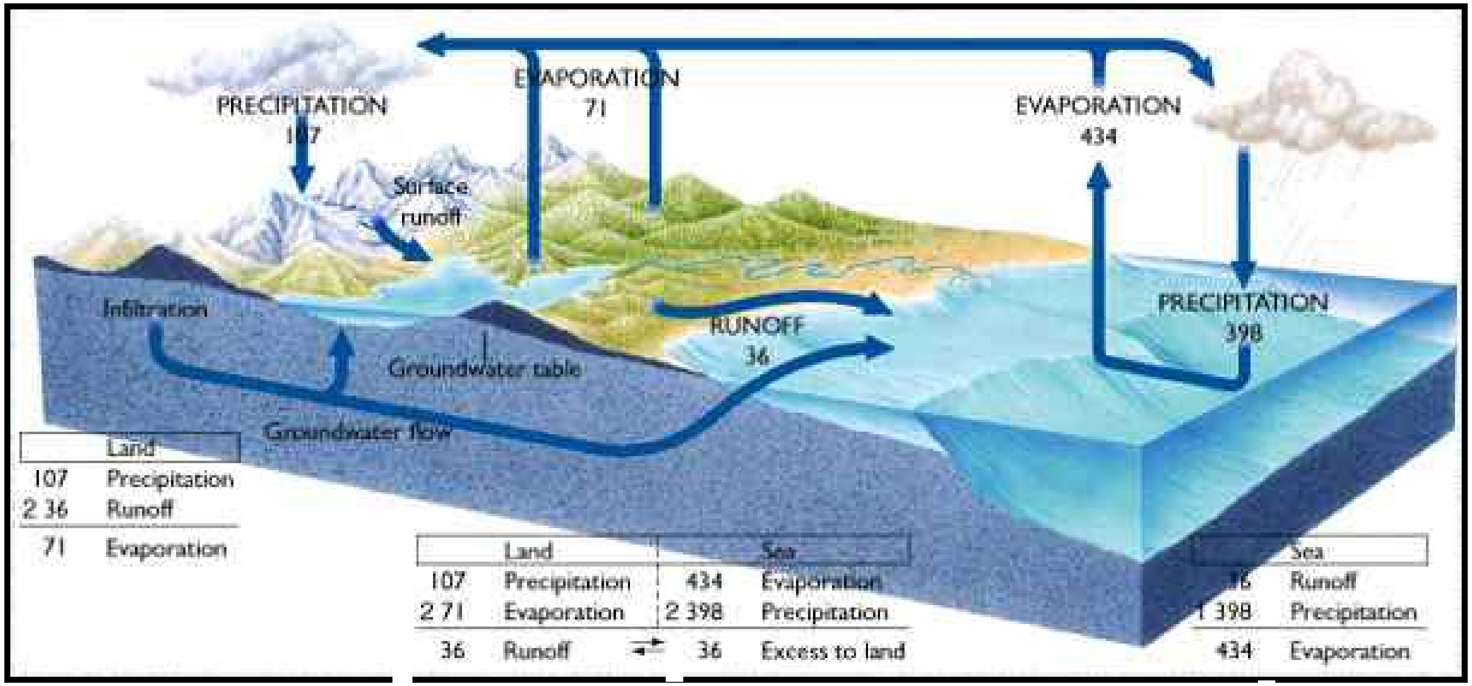
River Materials and Sediment Transport



Distribution of water on earth



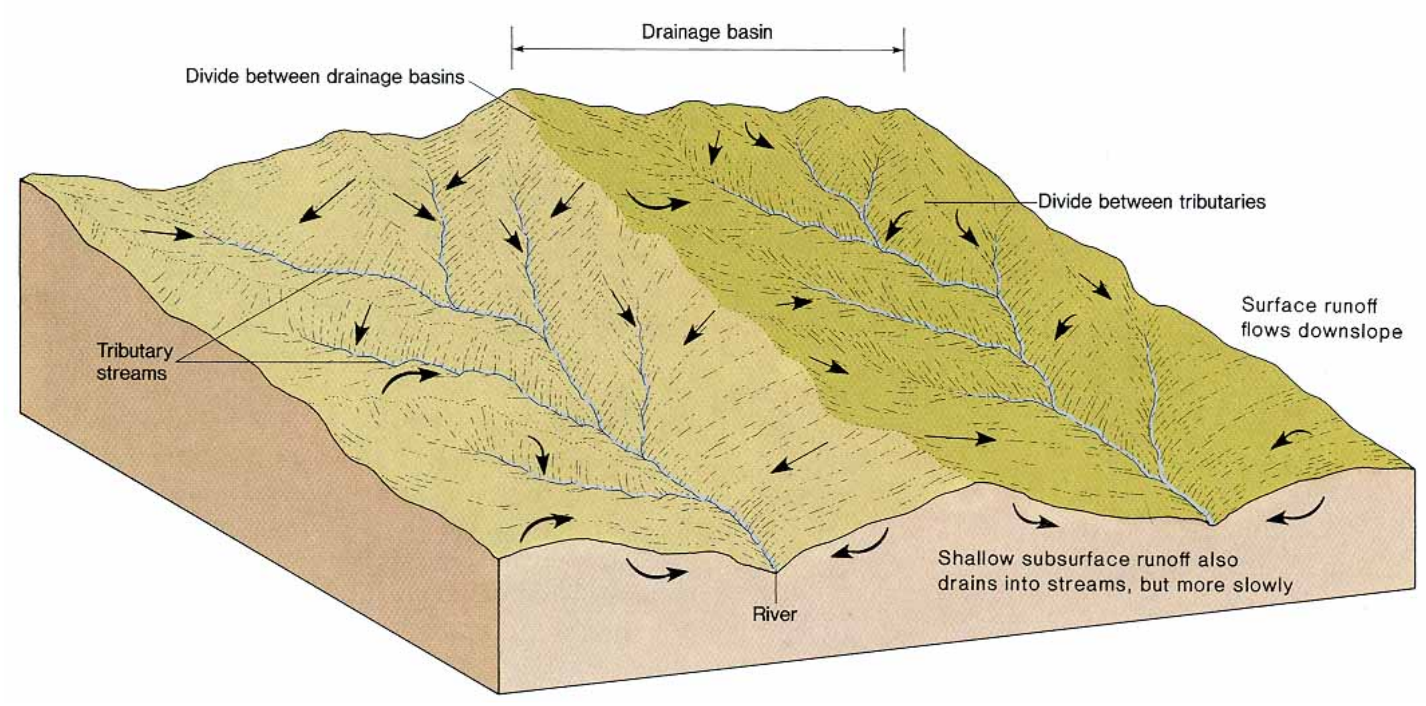
HYDROLOGIC CYCLE



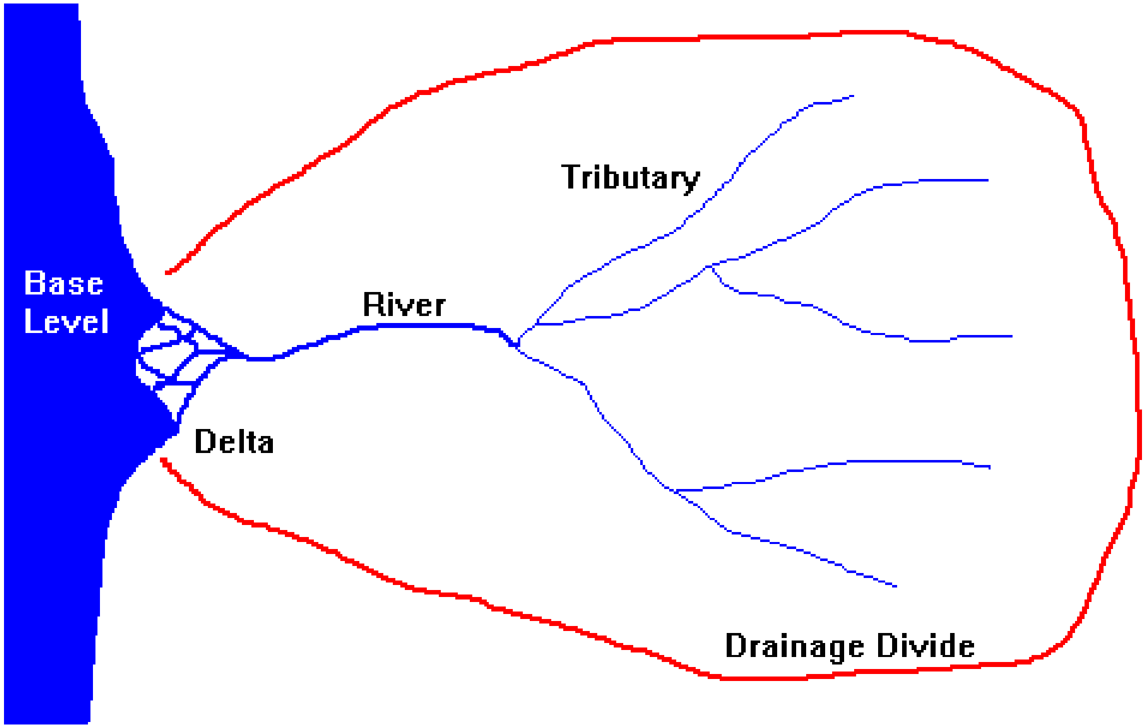
- Infiltration = Groundwater System
- Runoff = Surface Water System
- Runoff = Precipitation - Infiltration - Evaporation

Stream Systems

- Each stream drains a specific portion of the landmass, this is called the watershed or drainage basin
- Drainage basins are separated by drainage divides
- Drainage divides may be distinct (mountain ridges) or much more subtle



Stream Systems



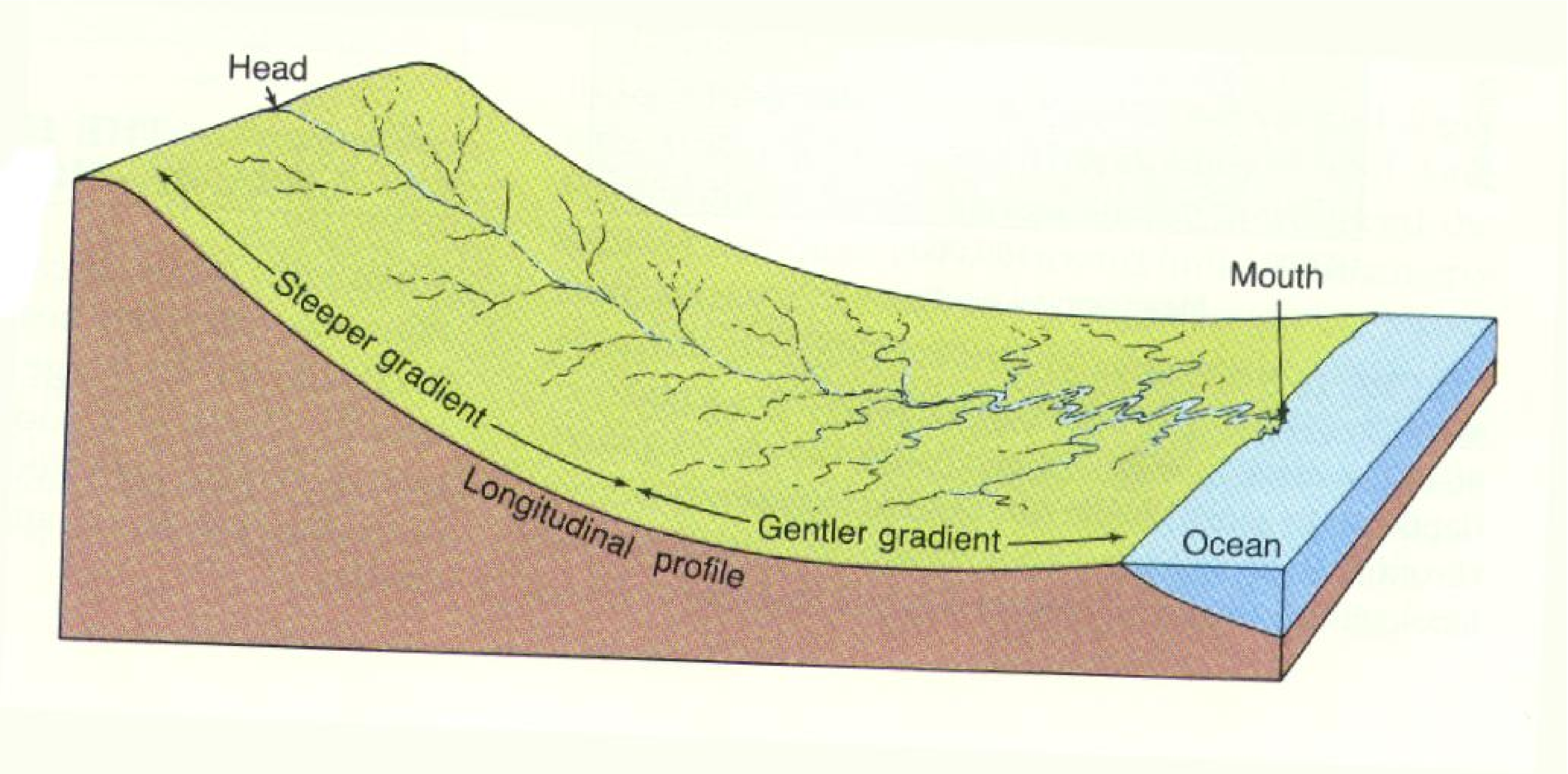
Anatomy of a Drainage Basin

Tributaries

Tributaries are any smaller streams that feed larger streams within a drainage basin.

Base Level

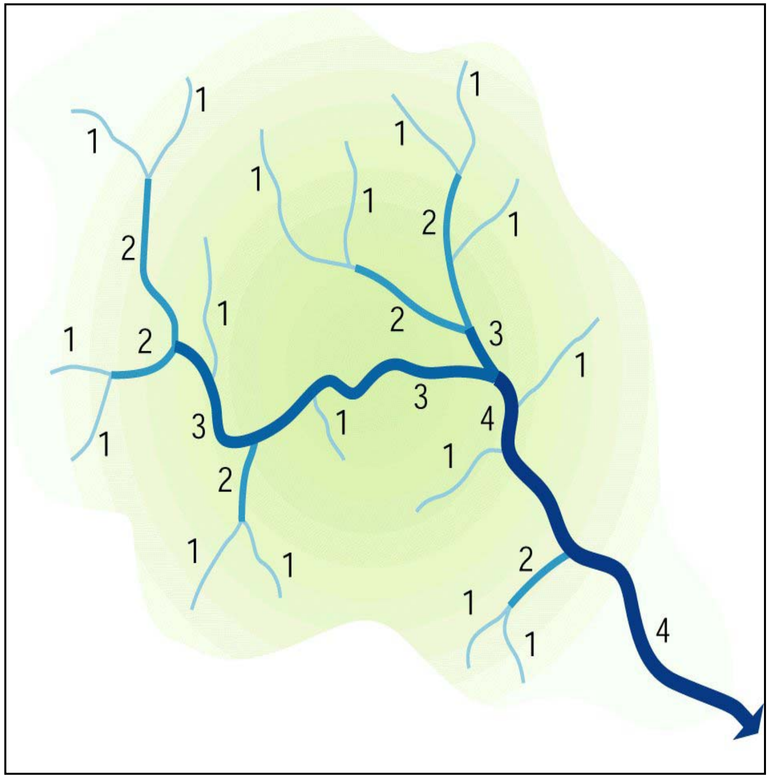
The level below which a river or stream cannot incise.



Stream order

- A method of classifying or ordering the hierarchy of natural channels.

- Stream order correlates well with drainage area, but is also regionally controlled by topography & geology.



Rivers vs. Streams

Stream and **river** can be used interchangeably; a stream is a small river

- A stream(or river) is a body of water that:
  - Flows downslope along a clearly defined natural passageway.
  - Transports particles and dissolved substances.
- The passageway is called the stream's **channel**.
- The quantity of water passing by a point on the stream bank in a given interval of time is the stream's **discharge**.

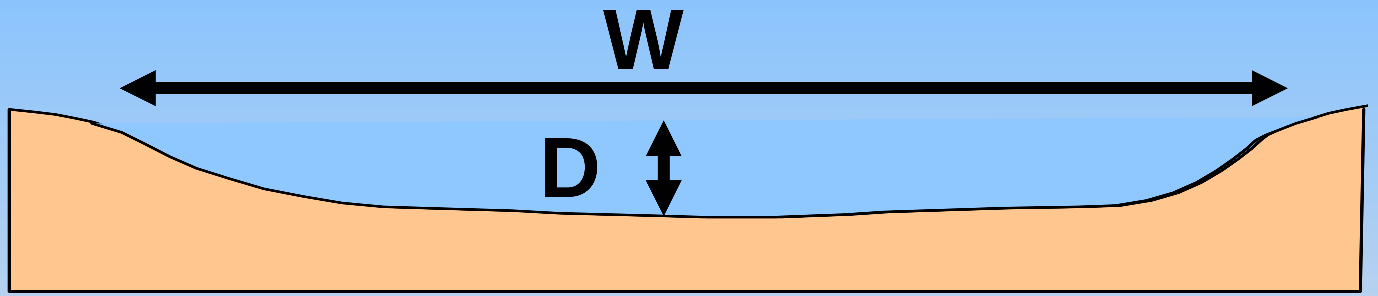
- A stream’s discharge may vary because of changes in precipitation or the melting of winter snow cover.
- In response to varying discharge and load, the channel continuously adjusts its shape (and location).

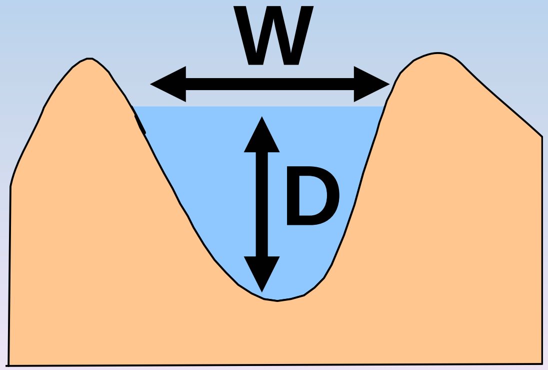
Factors Controlling Stream Behavior

- **Gradient** (expressed in meters per kilometer).
- **Stream-cross-sectional area** (width x average depth, expressed in square meters [A]).
- **Average velocity of waterflow** (expressed in meters per second [V]).
- **Discharge** (expressed in cubic meters per second [Q]).
- **Load** (expressed in kilograms per cubic meter).
  - Dissolved matter generally does not affect stream behavior.

Cross section profile

(width, W & depth, D)



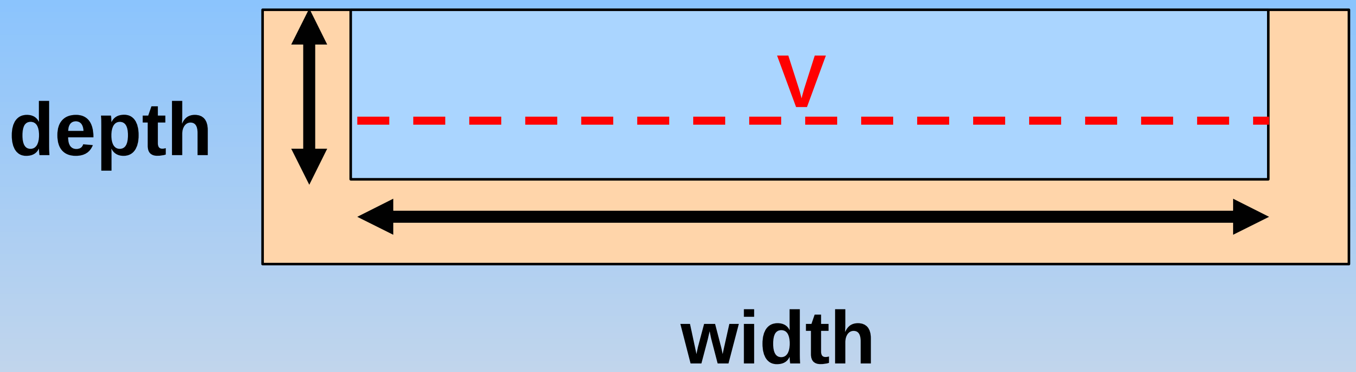


Flat terrain W >> D

Steep terrain W =D

Discharge, “Q”

Channel dimensions times the average velocity



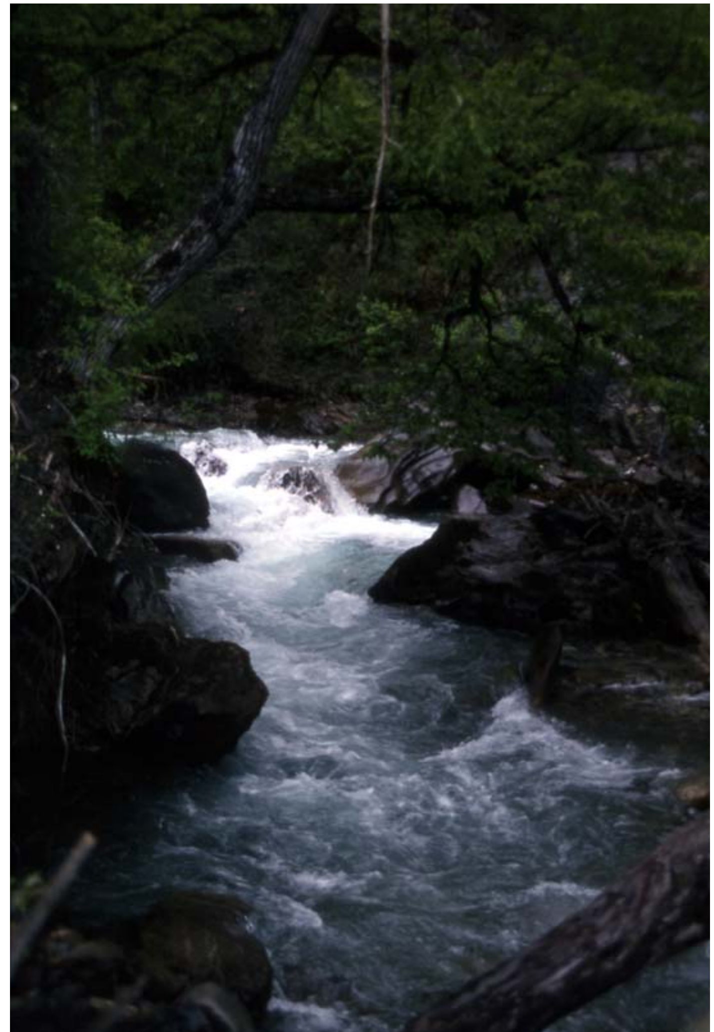
Simple channel:

Q = W x D x V

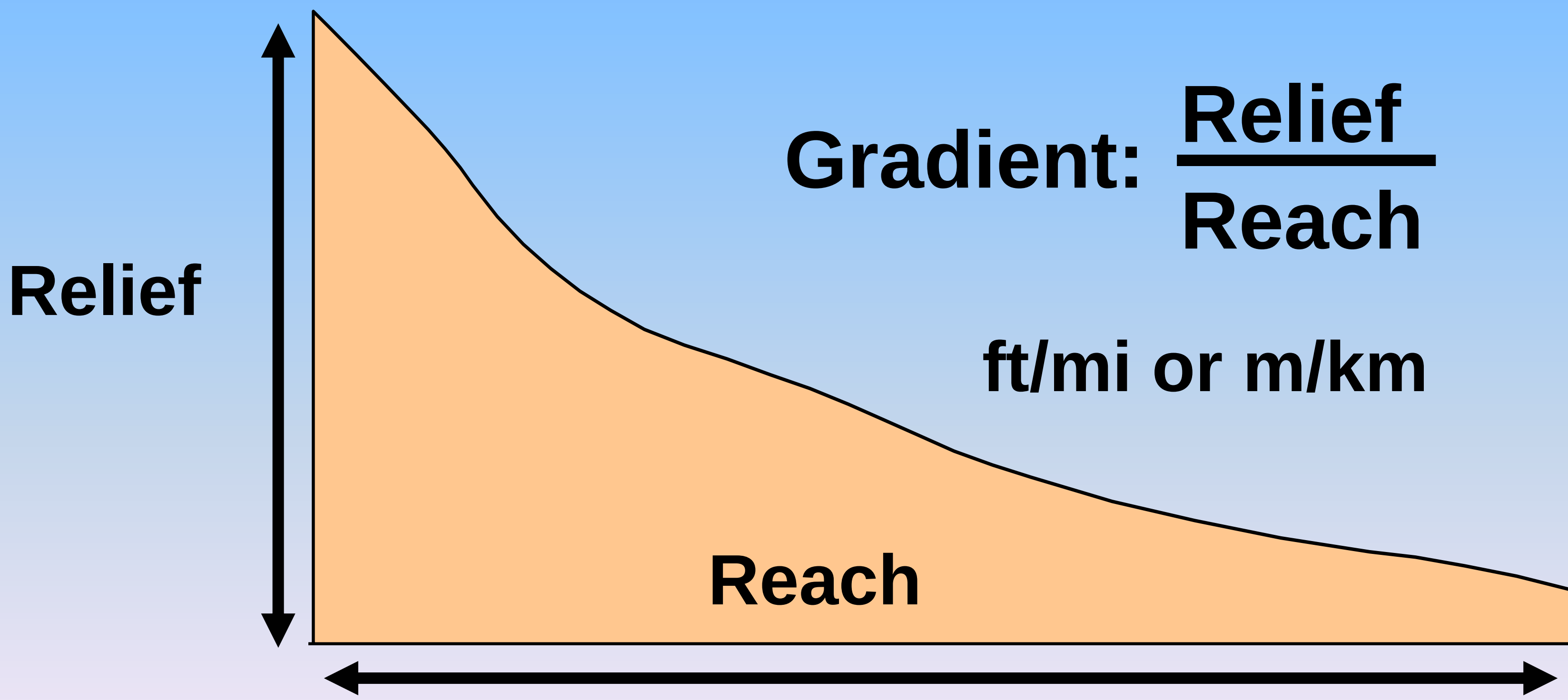
Discharge increases downstream but how do W, D, and V adjust to the increasing discharge?

Q = W D V

~~W = width~~
D = depth
V = velocity



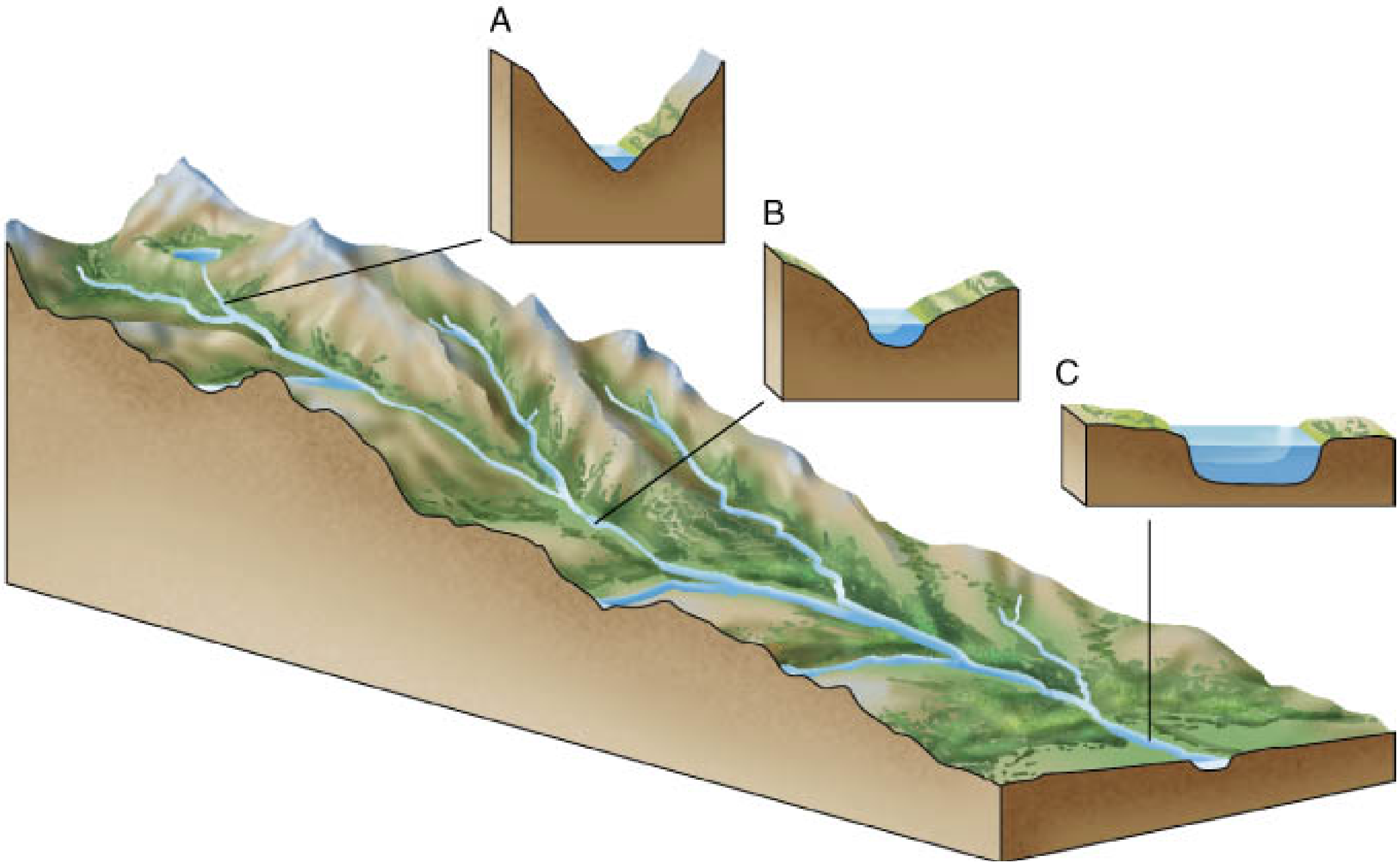
Long profile



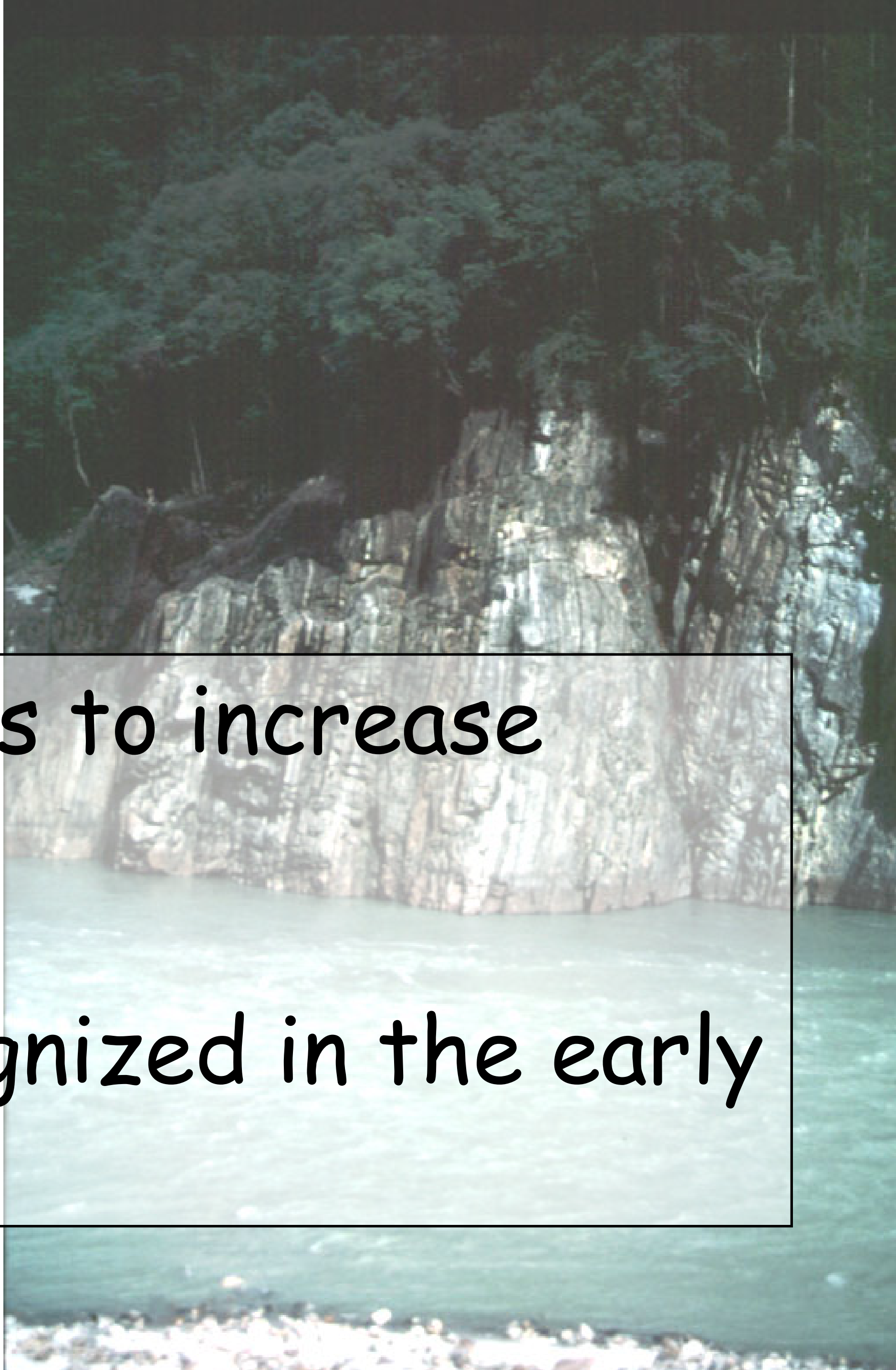
Traveling down a typical stream from its head to its mouth:

- Discharge increases.
- Gradient decreases.
- Stream cross-sectional area increases.
- Width to depth ratio increases.

So Where Does The Stream Move Fastest?

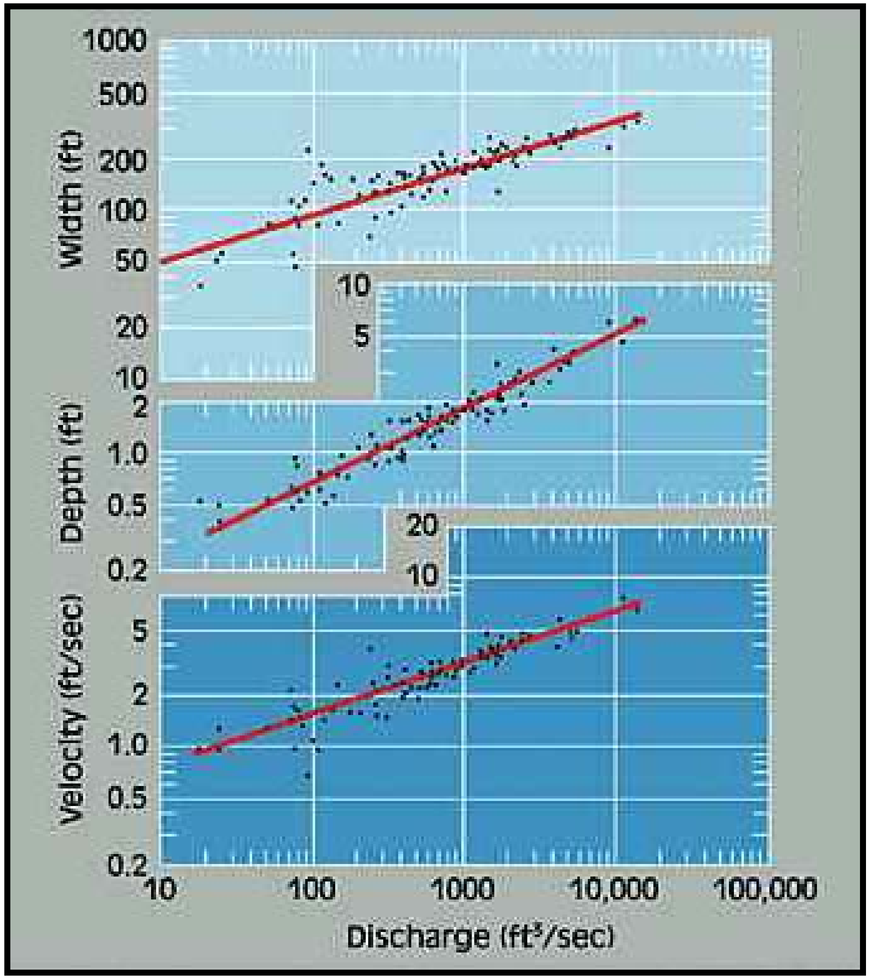


Which flows faster (in general), small headwater rivers or large valley rivers?



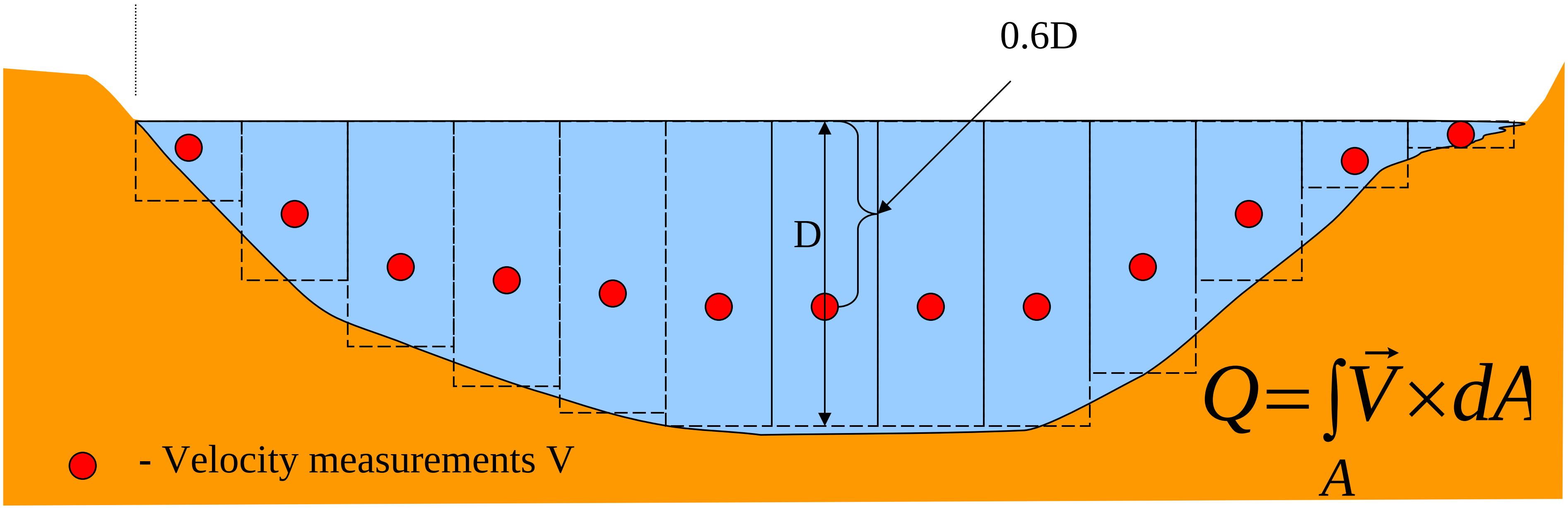
River velocity tends to increase downstream!

This was only recognized in the early 1950s…



- Headwater streams move slowest
- Mouth of stream moves fastest
- Deeper stream move faster than shallow streams -- less resistance from the stream bed

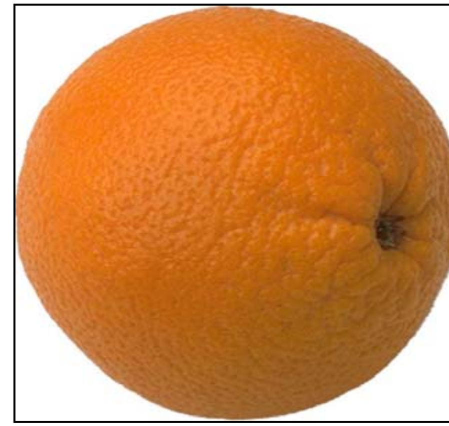
Discharge Measurement



Velocity determination: Float Method

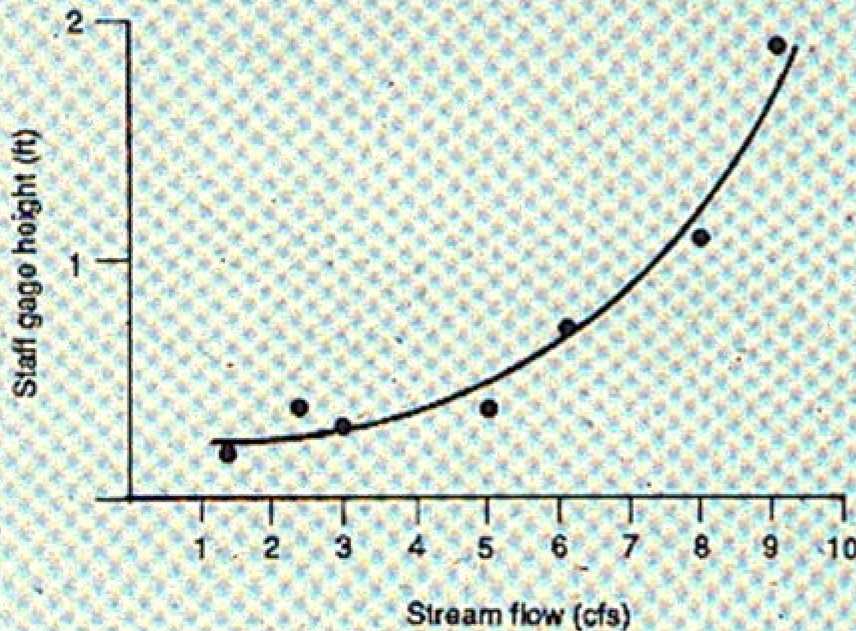
- Inexpensive and simple
- Measures surface velocity

- Basic idea: measure the time that it takes an object to float a specified distance downstream



Rating Curve

Forming a Stage-Discharge Curve



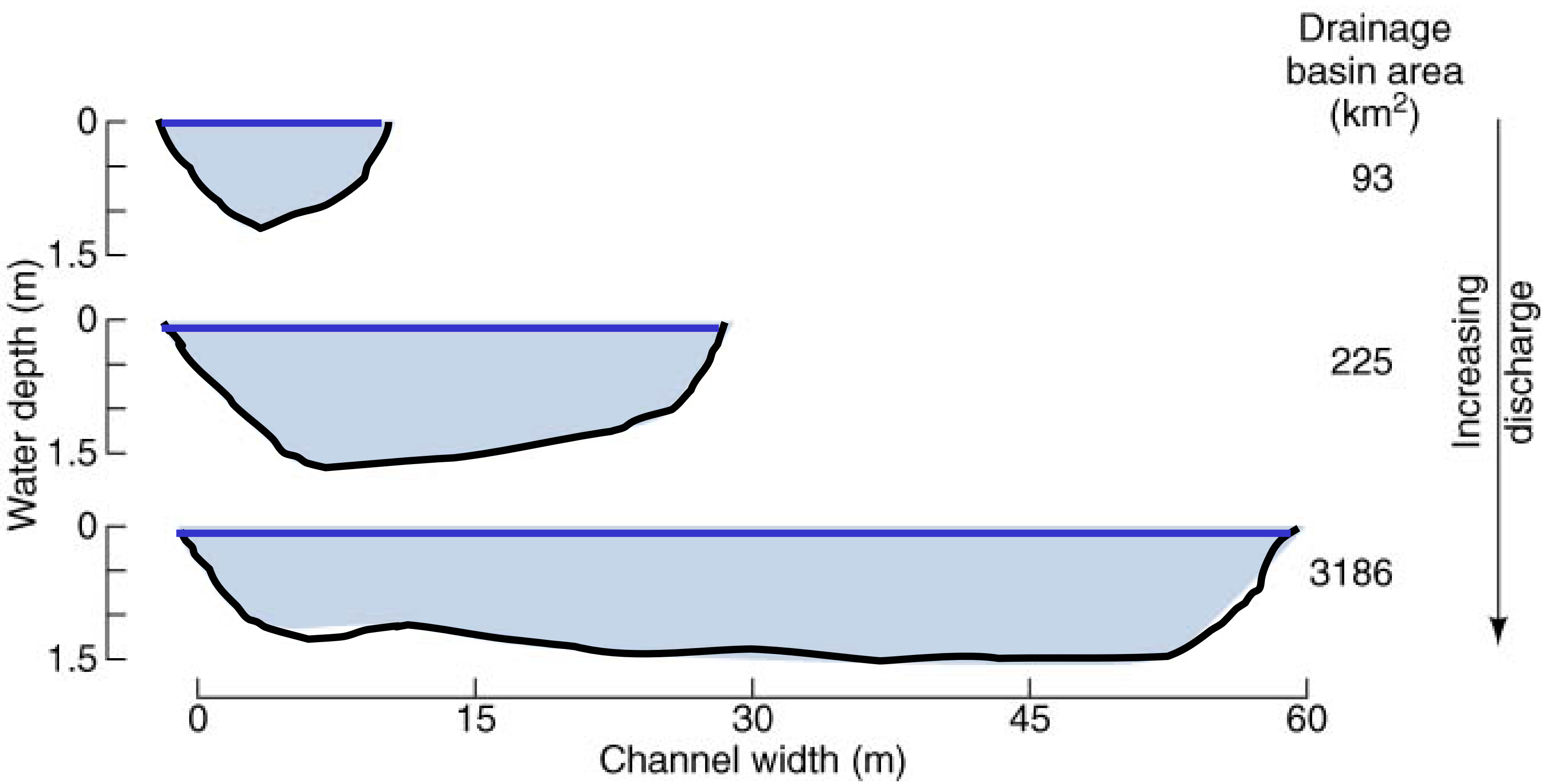
Staff Gage (ft)	Stream Flow (cfs)
.20	1.3
.40	2.3
.30	3.0
.40	5.0
.70	6.1
1.10	8.0
1.40	8.3
1.90	9.0

Can use rating curve to transform stage data to discharge data

Field data generally indicate that channel width varies approximately as the square root of discharge.

Cross-Sectional Shape

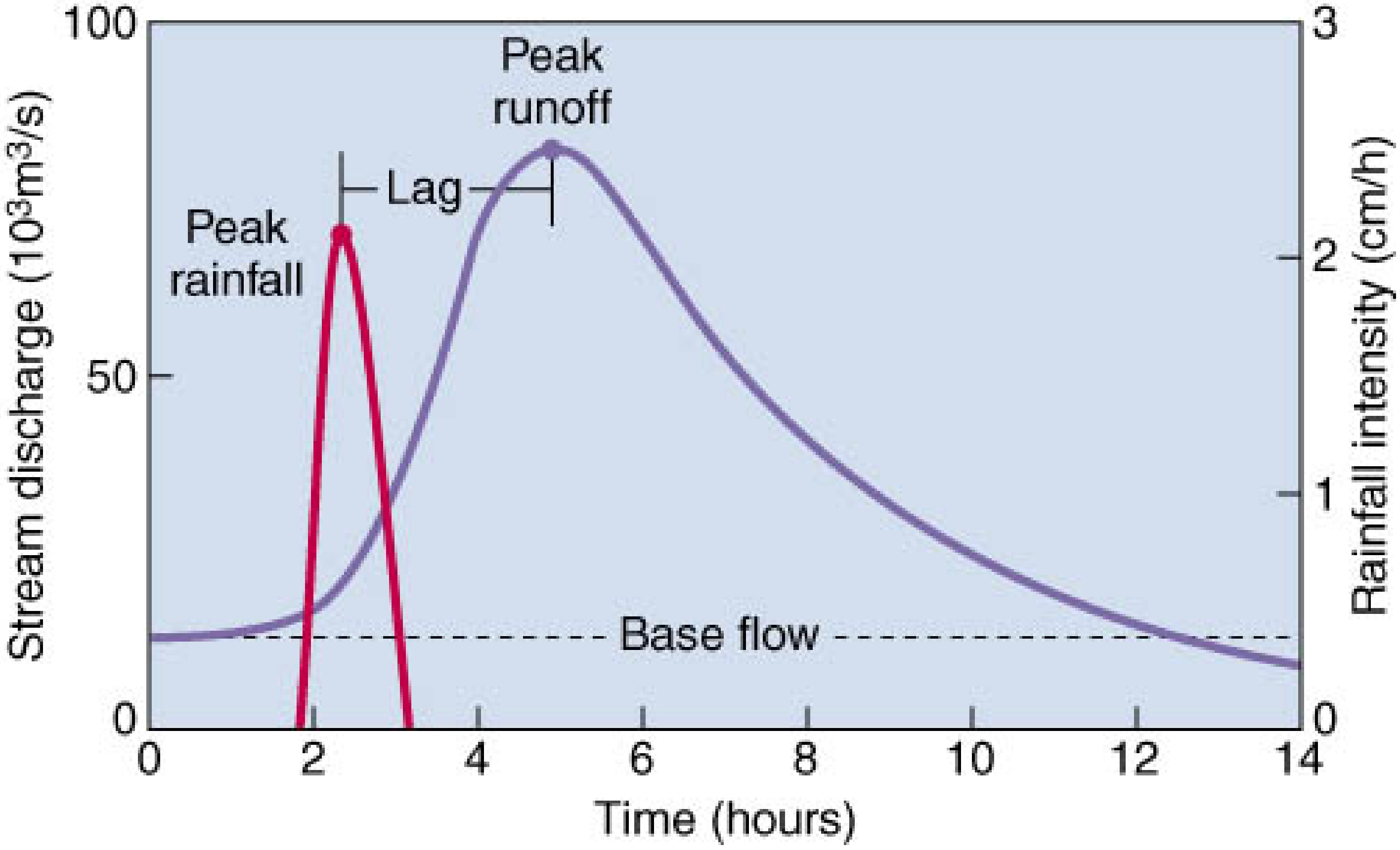
The ratio of channel width to channel depth generally increases down stream.



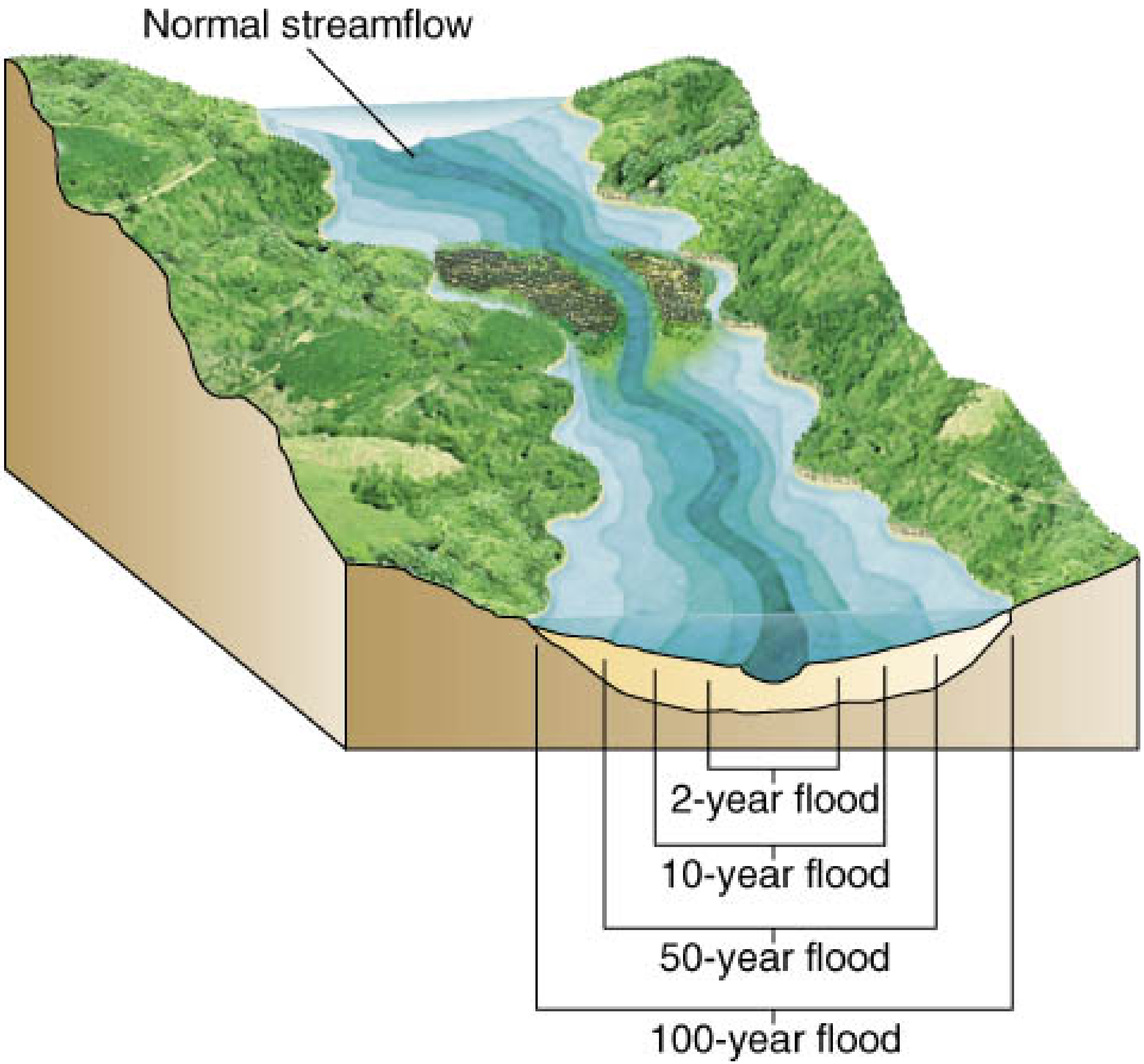
Floods

- A flood occurs when a stream's discharge becomes so great that it exceeds the capacity of the channel, therefore causing the stream to overflow its banks.
- Geologists view floods as normal and expected events.
- Recurrence interval – the average time between floods of a given size

Hydrograph



100
50
0
3
2
1
0
Peak
runoff
Lag
Peak
rainfall
Base flow
0
2
4
6
8
10
12
14
Time (hours)
Stream discharge (10³m³/s)
Rainfall intensity (cm/h)


Normal streamflow
2-year flood
10-year flood
50-year flood
100-year flood

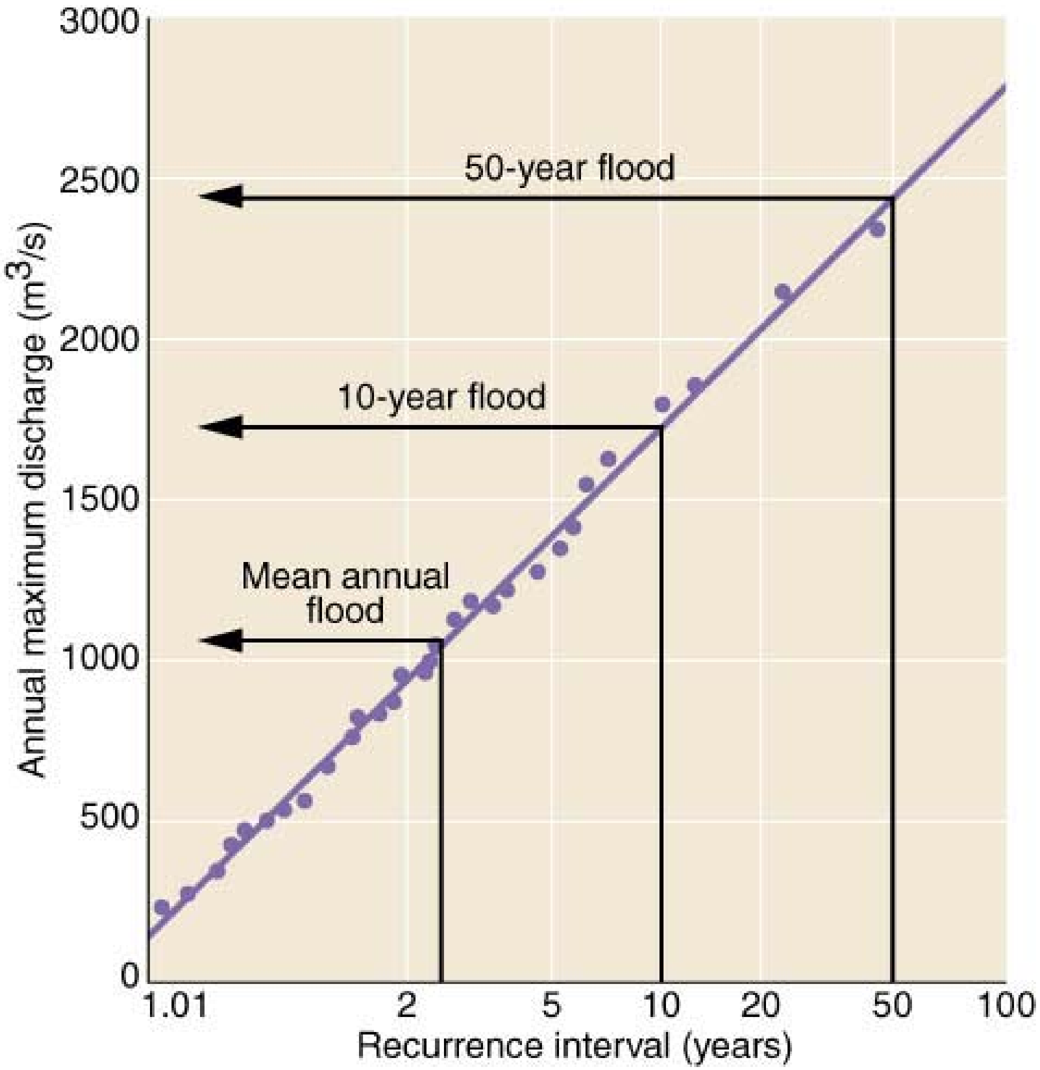
Flood Frequency

- A flood-frequency curve is produced by plotting the occurrence of past floods of different sizes on a probability graph.
- The measure of how often a flood of a given magnitude is likely to occur is called the **recurrence interval**.
- A flood having a recurrence interval of 10 years is called a "10-year flood."

FLOOD FREQUENCY

Bankfull flood occurs on average about every 1 to 2 years

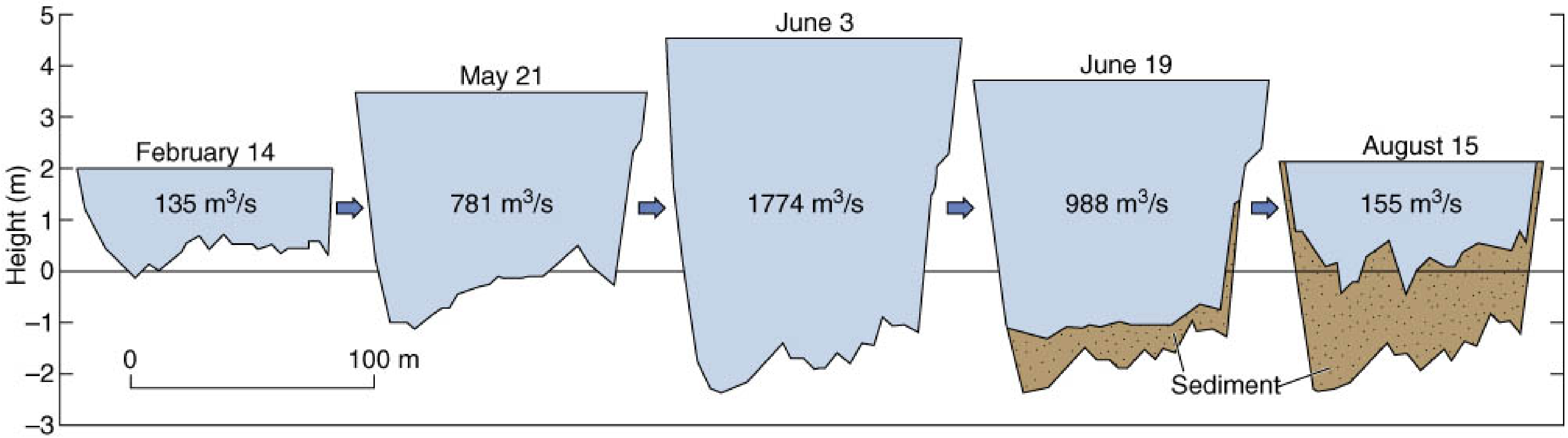
100 year flood occurs on average about every 100 years.



Floods

- With an increased discharge and velocity during a flood, a channel can carry a greater load.
- As discharge falls, the stream is unable to transport as much sediment.
  - At the end of the flood it returns to its pre-flood dimensions.

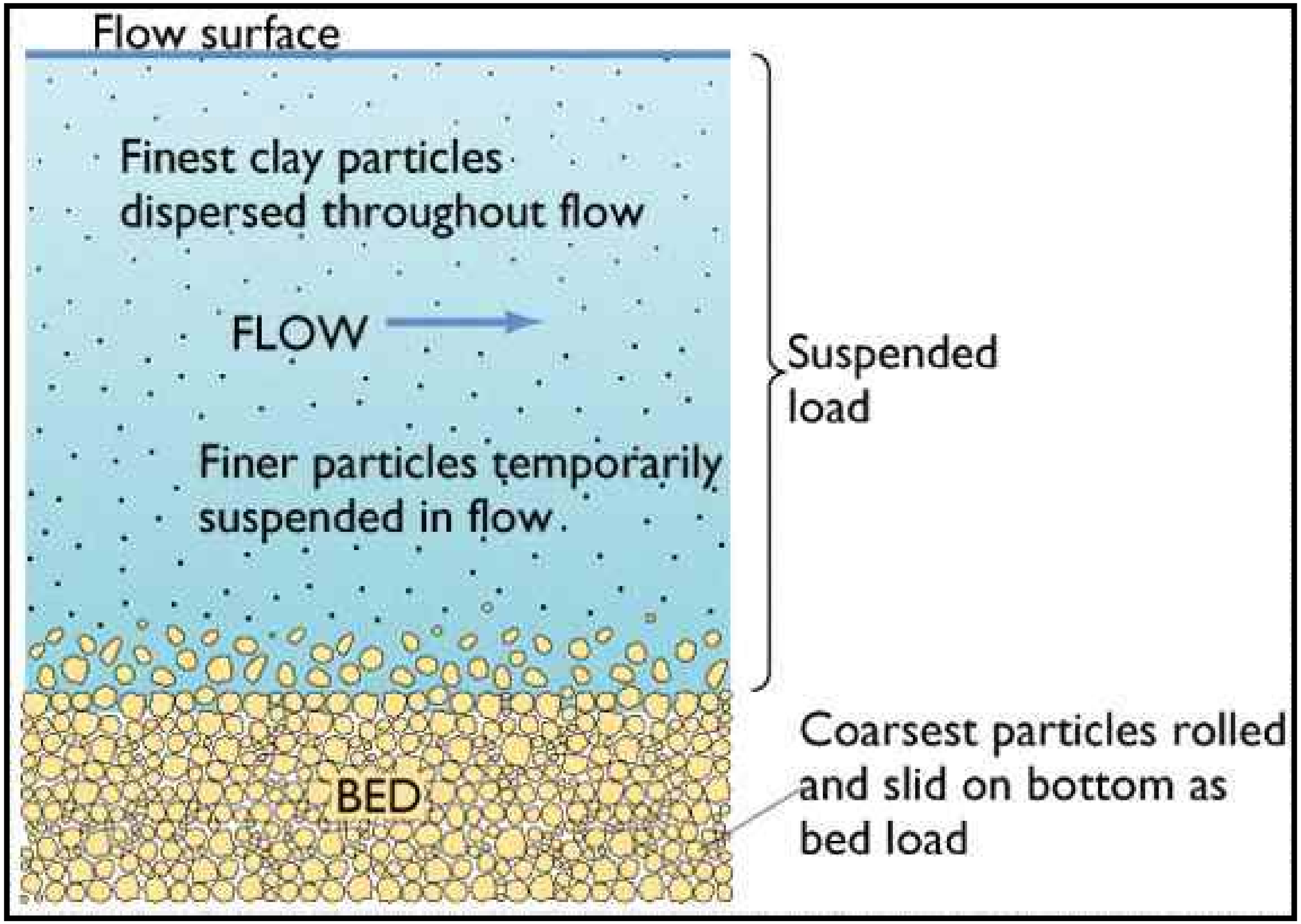
As discharge increases the water rises in the channel and erosion scours the bed.



Carrying the Load

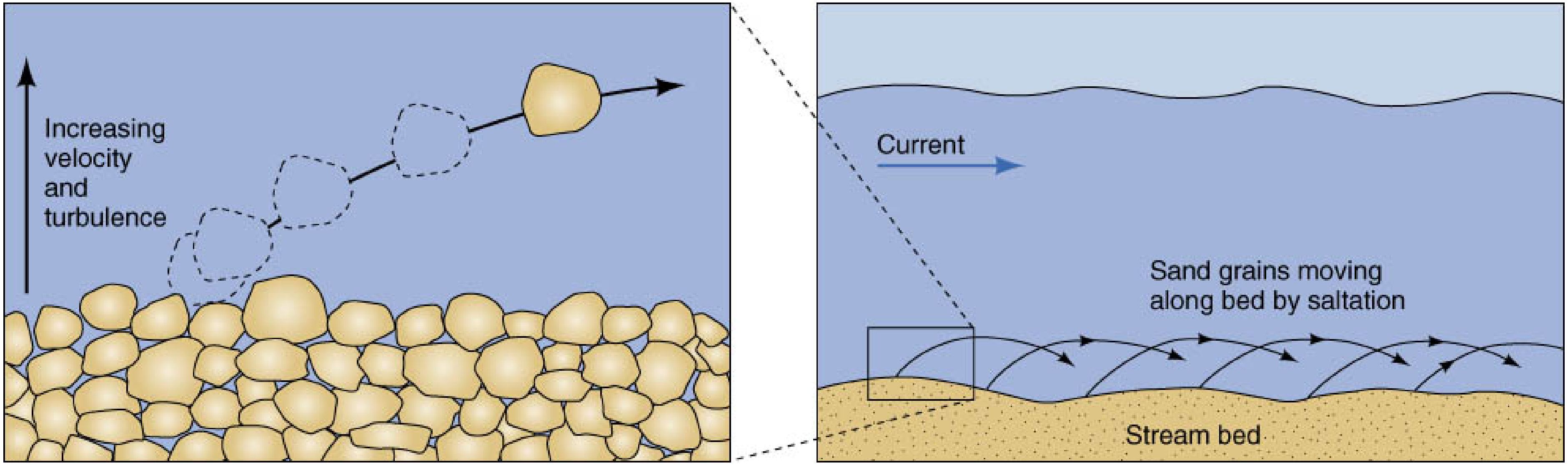
- The material transported by a river is called its load.
- There are three basic classes of load
  - Bed load: sediment rolling, bouncing, and creeping along the river bed
  - Suspended load: sediment that is fine enough to remain in suspension in stream (size depends on velocity and turbulence)
  - Dissolved load: the invisible load of dissolved ions (e.g. Ca, Mg, K, HCO_3)

Sediment Load



Bed Load

- The bed load generally constitutes between 5 and 20 percent of the total load of a stream.
- Particles move discontinuously by rolling or sliding at a slower velocity than the stream water.
- The bed load may move short distances by saltation (series of short intermittent jumps).



Suspended Load

- Particles tend to remain in suspension when upward-moving currents exceed the velocity at which particles of silt and clay settle toward the bed under the pull of gravity.

- They settle and are deposited where velocity decreases, such as in a lake or in the oceans.

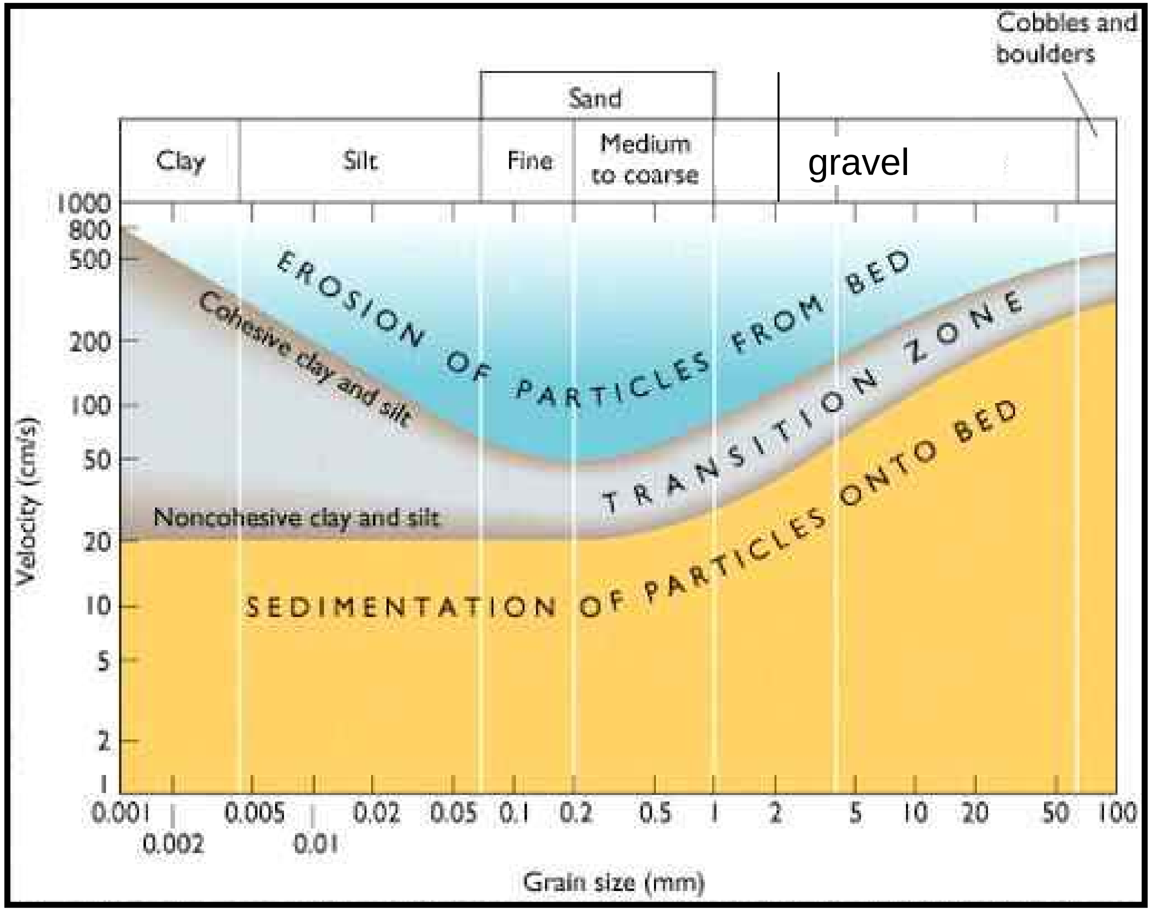
Dissolved Load

- All stream water contains dissolved ions and anions
- The bulk of the dissolved content of most rivers consists of seven ionic species:
  - Bicarbonate (HCO_3^-)
  - Calcium (Ca^{++})
  - Sulfate (SO_4^{--})
  - Chloride (Cl^-)
  - Sodium (Na^+)
  - Magnesium (Mg^{++})
  - Potassium (K^+)
  - Dissolved silica as $Si(OH)_4$

Sediment Size

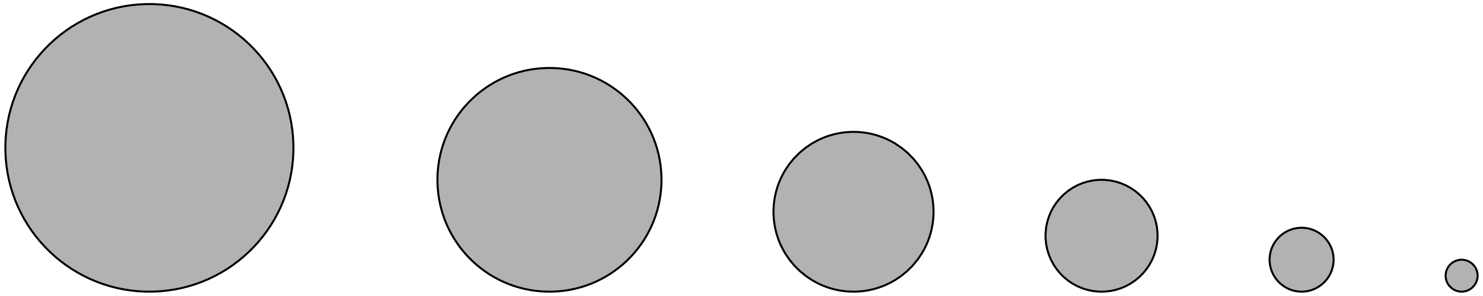
- Boulders > 256 mm
- Cobbles 80 mm - 256 mm
- Gravel 2 mm - 80 mm
- Sand 0.05 mm - 2 mm
- Silt 0.002 mm - 0.05 mm
- Clay <0.002 mm

The ability of a stream to pick up particles of sediment from its channel and move them along depends on the velocity of the water.

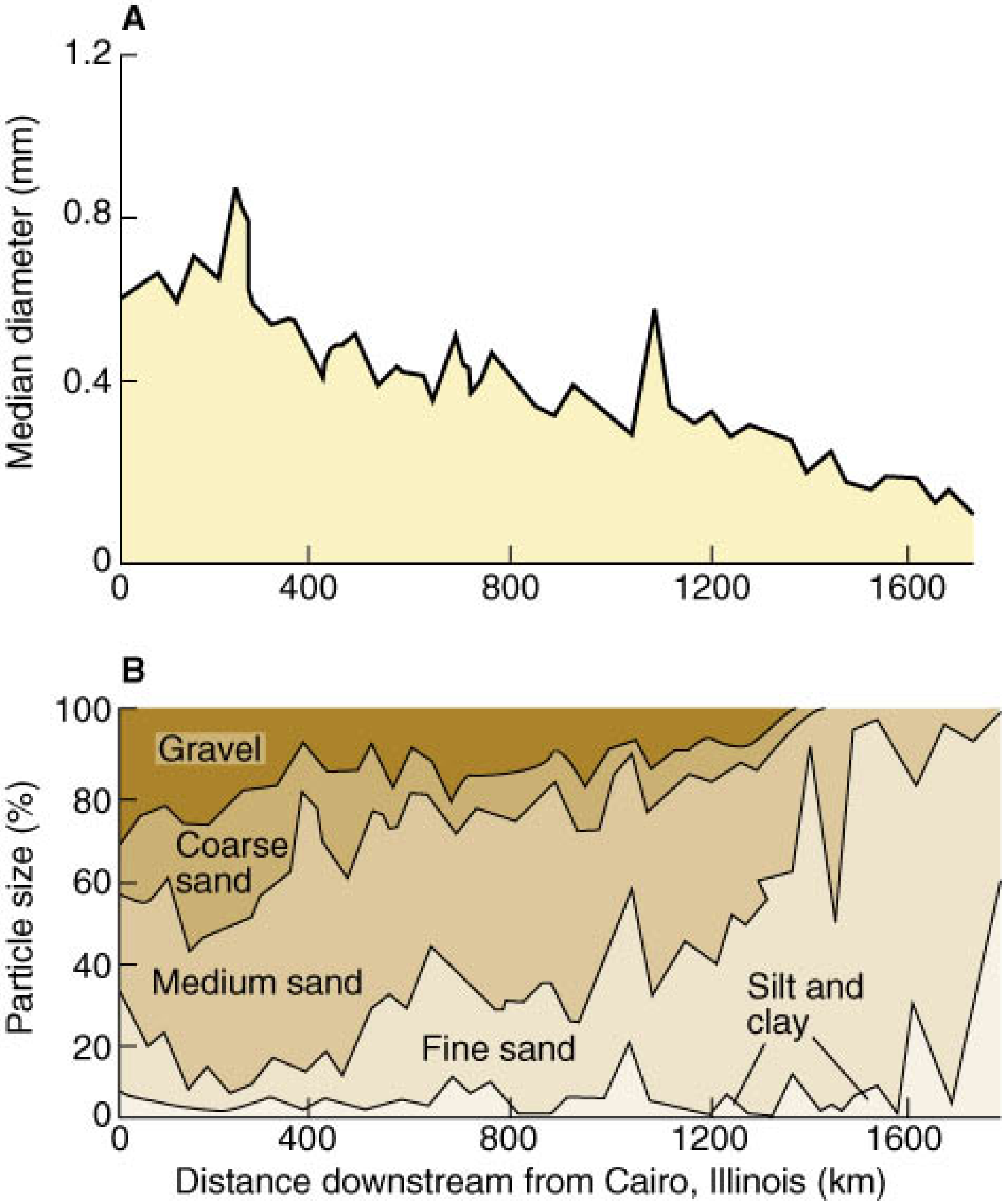


Downstream Changes in Particle Size

The size of river sediment normally decreases in size downstream, from boulders in mountain streams to silt and sand in major rivers because the coarse bed load is gradually reduced in size by abrasion.



When a river eventually reaches the sea, its bed load may consist mainly of sand and silt.



In rivers and bad governments, the lightest things swim at the top.

- Benjamin Franklin