Basics of Hydrology: A 45-minute Spiel on Water

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Basic Water Science Seminar
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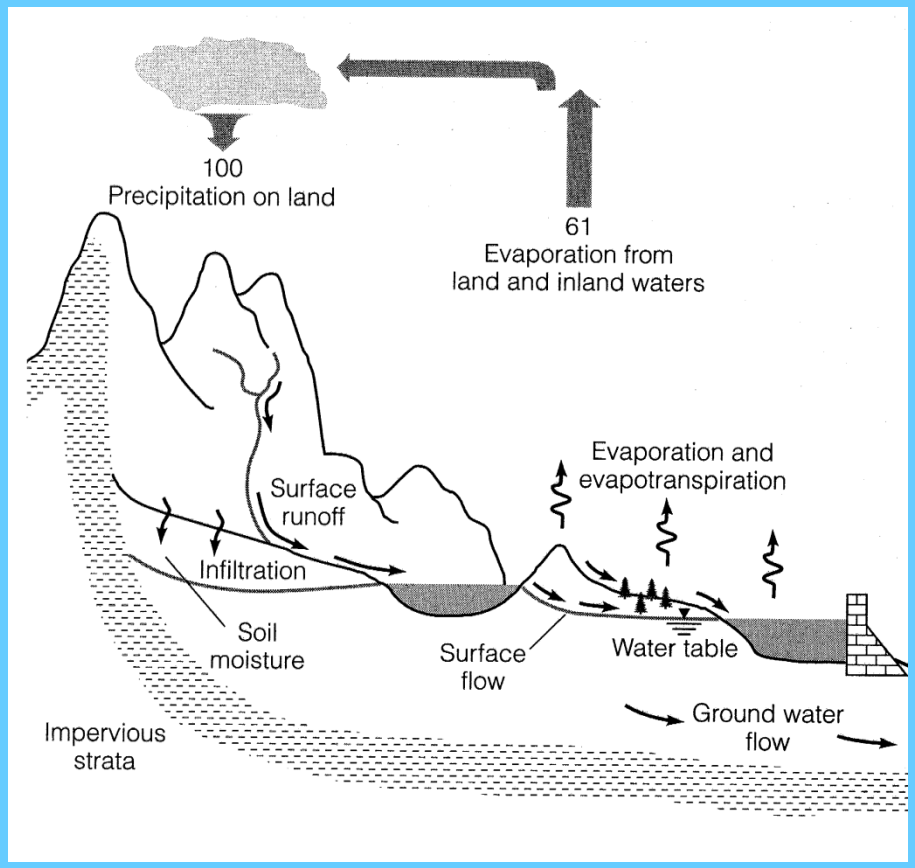
Hydrologic Cycle

Movement of water on and under the earth's land surfaces, and the physical, chemical and biological processes accompanying that movement

Global annual average water balance if **100 units of precipitation fell on land**

(Source: Chow, Maidment, and Mays, *Applied Hydrology*, 1988)



Where is the water?

	% Total Water	% Fresh Water
Oceans	96.5	
Ground Water		
Fresh	0.76	30.1
Saline	0.93	
Soil Moisture	0.0012	0.05
Polar Ice	1.7	68.6
Lakes		
Fresh	0.007	0.26
Saline	0.006	
Rivers	0.0002	0.006

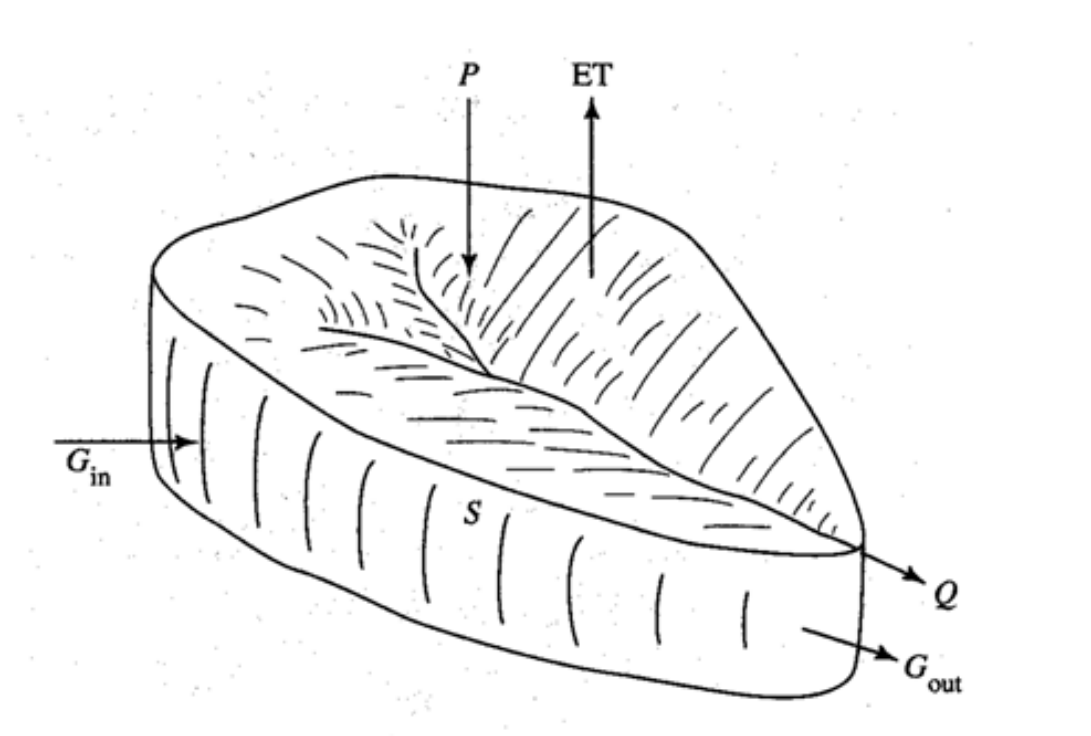
Source: Chin, D.A. Water Resources Engineering, 2000.

Water Balance Equations

- Primary conservation law in hydrology is mass balance:

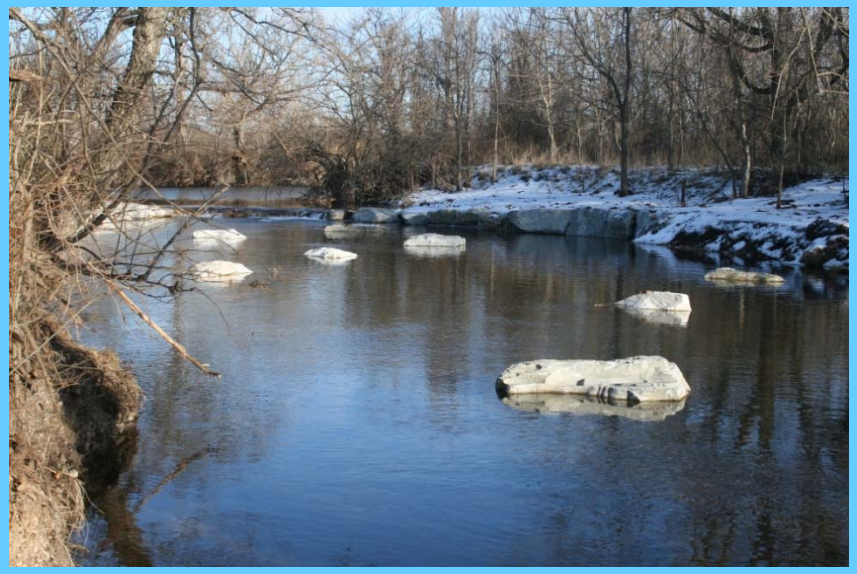
$$I - Q = \Delta S$$

$$P + G_{in} - (Q + ET + G_{out}) = \Delta S$$



Surface Water

- What variables are used to describe surface water?
  - Lakes/Reservoirs:
    - Stage (ft or m)
    - Total Storage (acre-feet or ft^3 or m^3)
  - Rivers/Streams:
    - Stage (ft or m)
    - Discharge, Q (cfs, cms)
    - Velocity (ft/s or m/s)



Honey Creek near Grove, OK

USGS Real-Time Water Data for USGS 07197000 Baron Fork at Eldon, OK - Windows Internet Explorer

http://waterdata.usgs.gov/nwis/uv?07197000

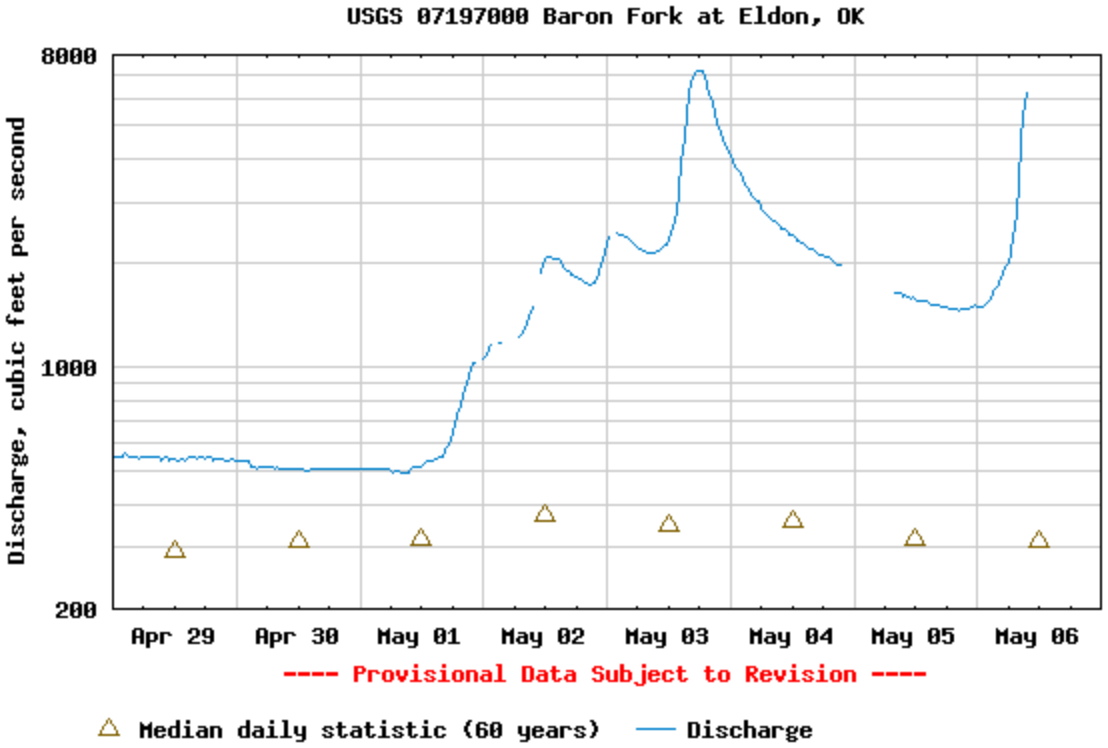
File Edit View Favorites Tools Help

Google Search Bookmarks Check AutoFill

USGS Real-Time Water Data for USGS 07197000 Baro...

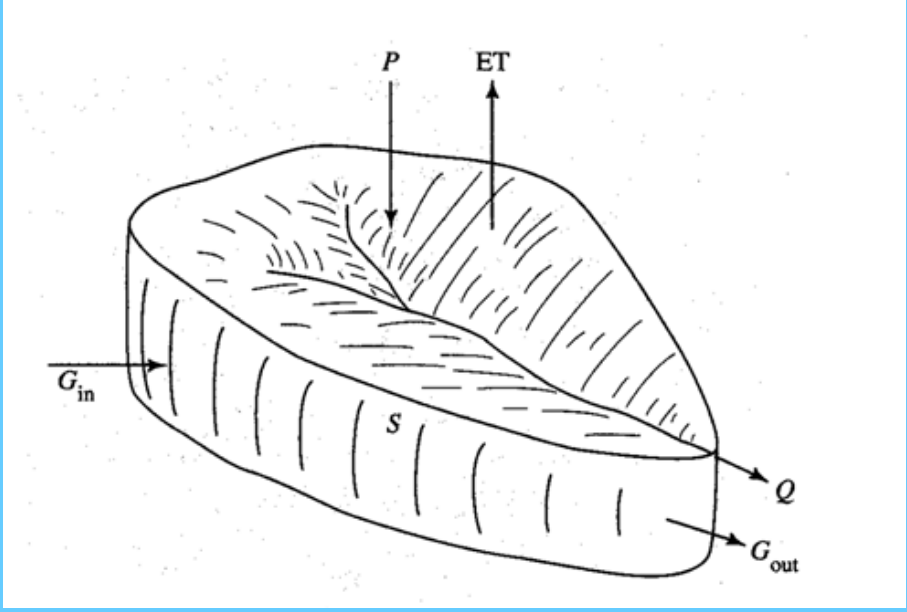
Discharge, cubic feet per second

Most recent instantaneous value: 6,220 05-06-2009 09:30

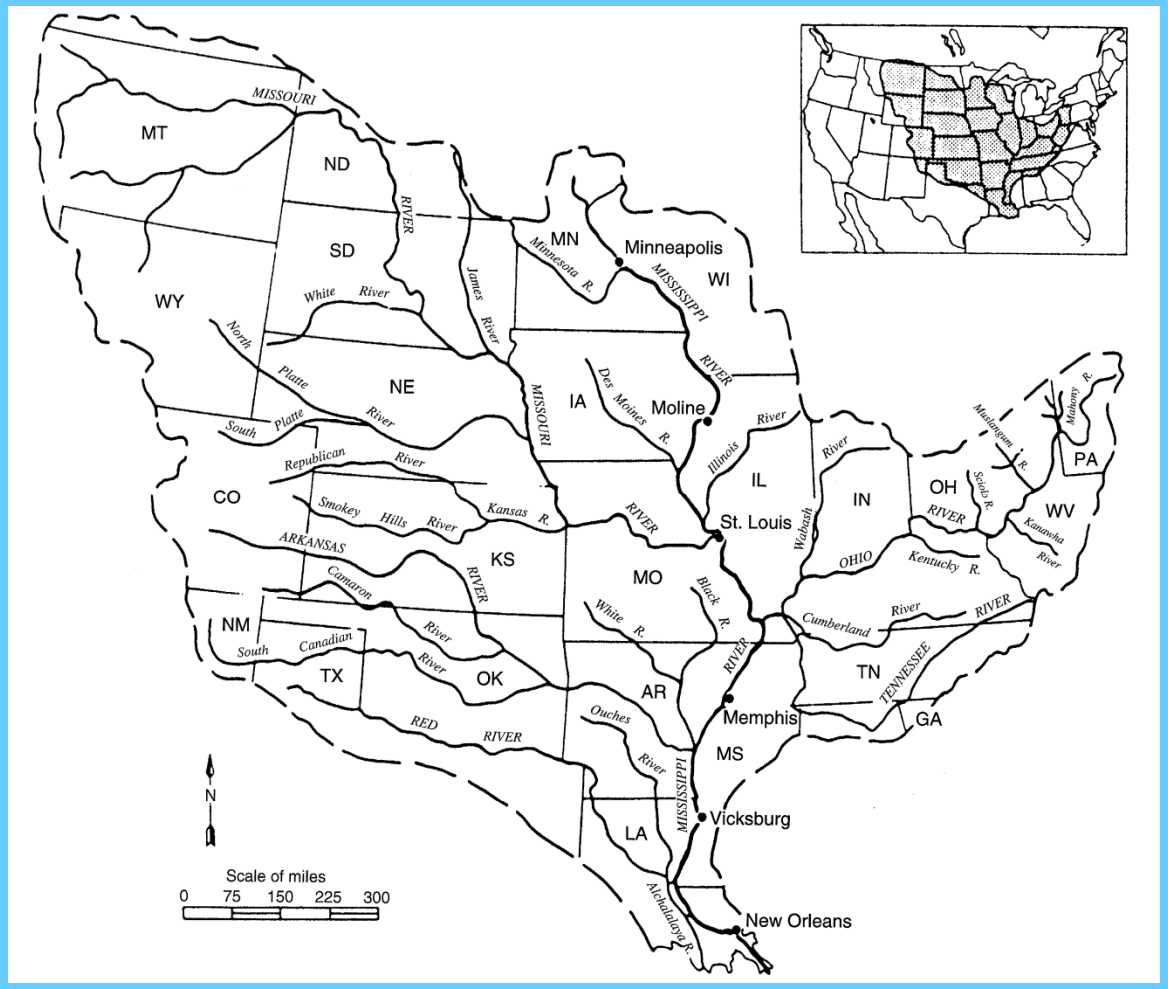


Surface Water

- Surface Water usually managed on basis of watersheds:
  - **Watershed** (**Drainage basin, Catchment**) – topographic area that collects and discharges stream flow through one outlet
  - **Divide**
  - **Basin Outlet**



Surface Water

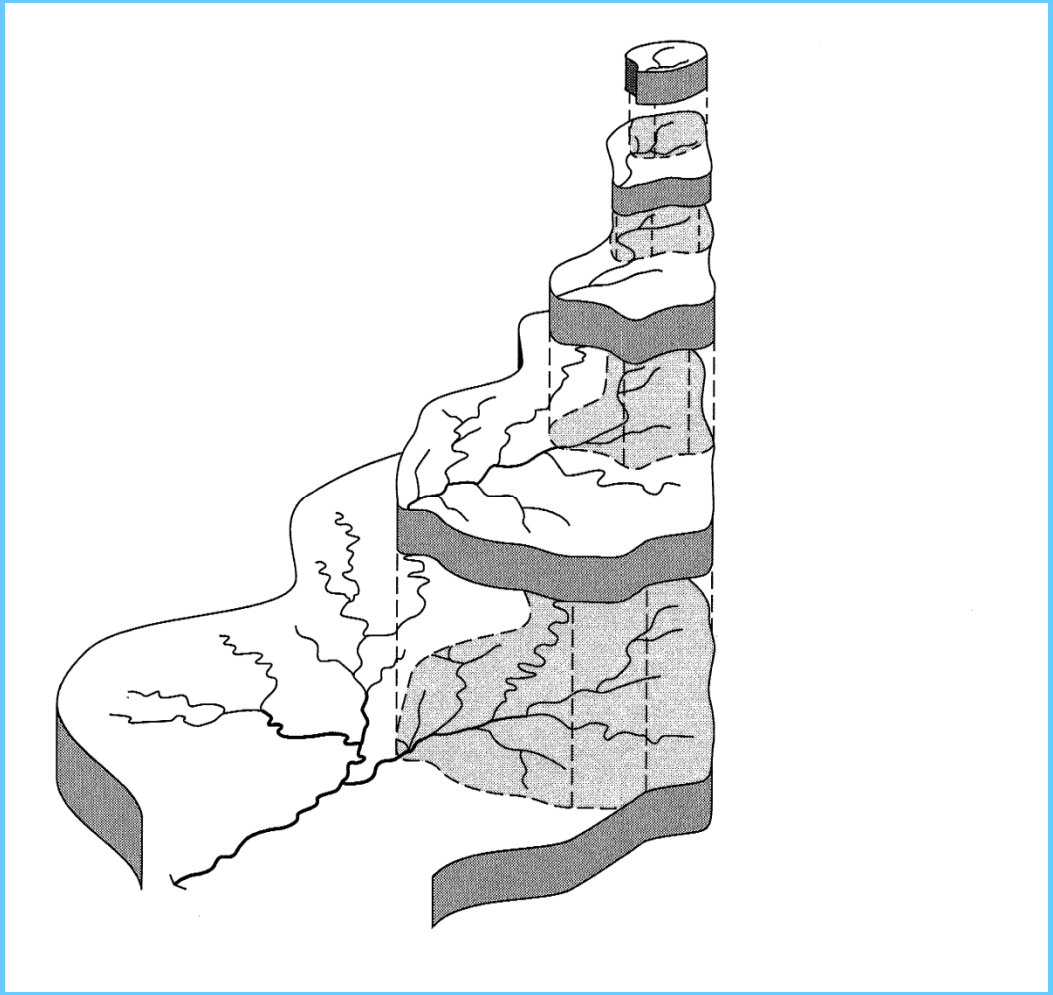


Source:
Mays, *Water Resources Engineering*, 2001

http://www.owrb.state.ok.us/maps/pdf_map/okwater.pdf

Surface Water

- Note the nested hierarchy of lower-order basins within a larger drainage basin…



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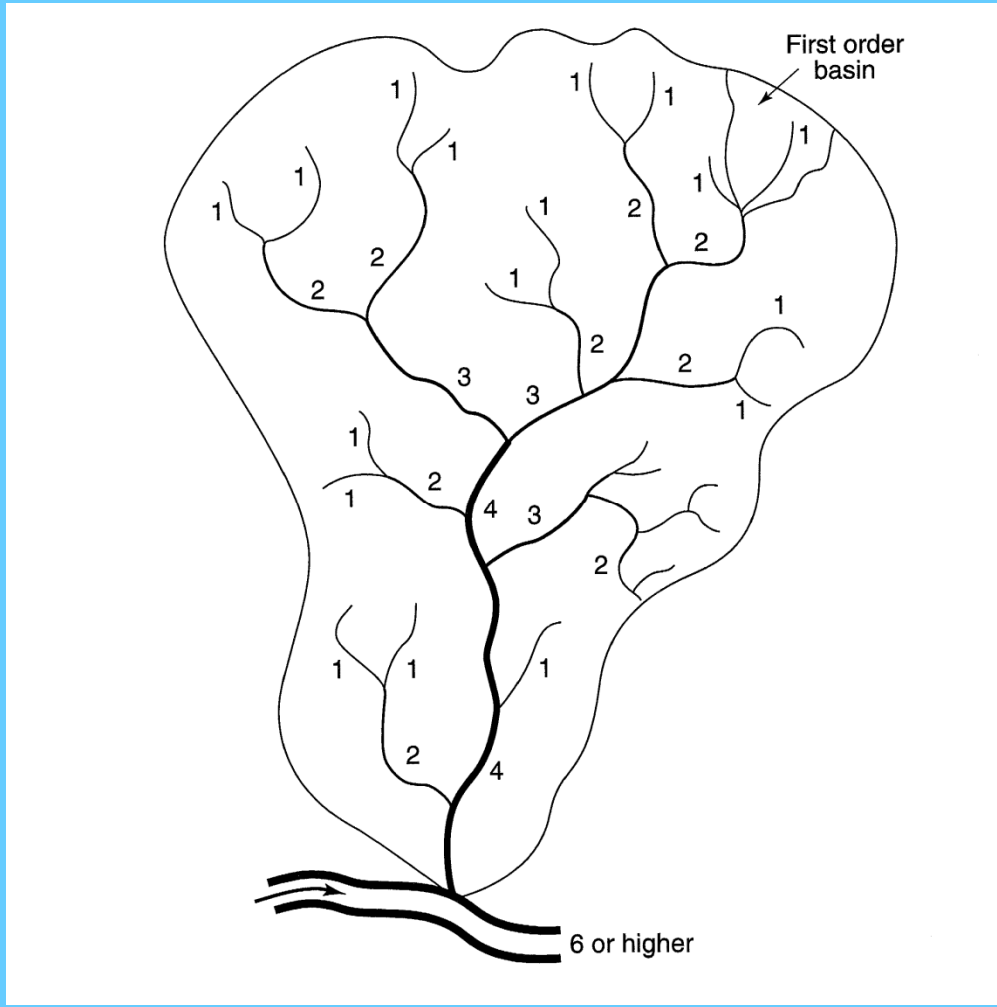
Stream Order

- Streams are classified in a basin by ordering the flow network…



Source:
Mays, *Water Resources Engineering*, 2001

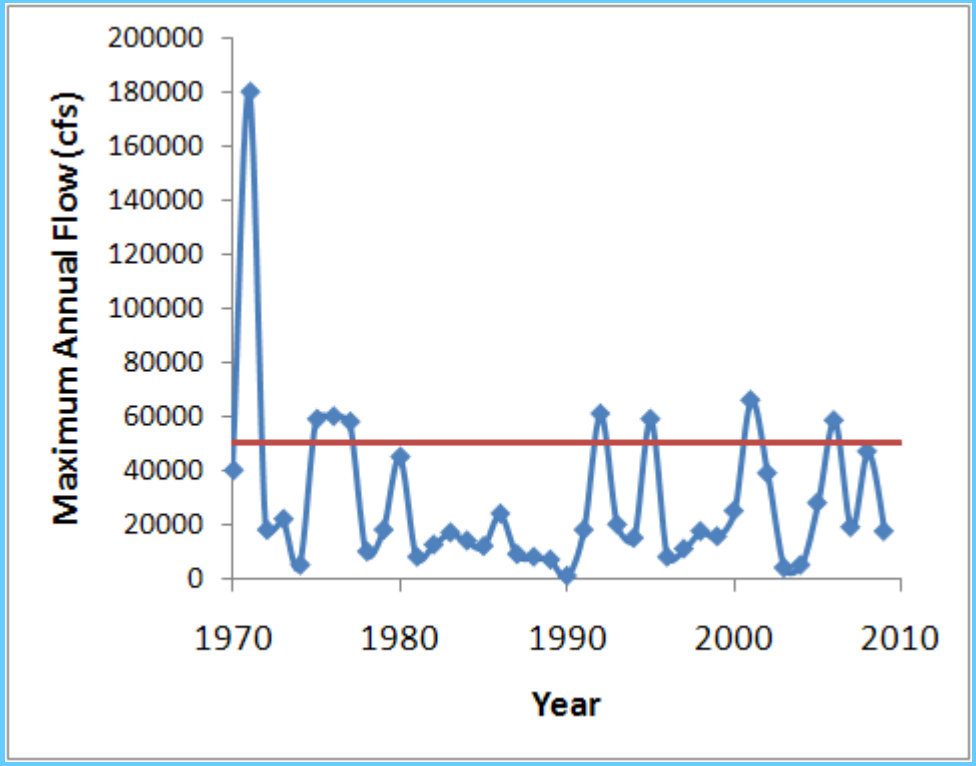
Hydrologists use Statistics…

- Hydrologic statistics → Frequency Analysis

- Hydrologic systems are impacted by extreme events (floods, droughts)
  - Magnitude of extreme event is inversely related to its frequency of occurrence
  - Very extreme events occur less frequently than moderate events

Return Period

- **Return Period (T)** = average recurrence interval between events equaling or exceeding a specific magnitude
  - There is NO REGULARITY expected with a T-year event
  - In a T-year period we may have more than one T-year event



1971 1975 1976 1977 1992 1995 2001 2006

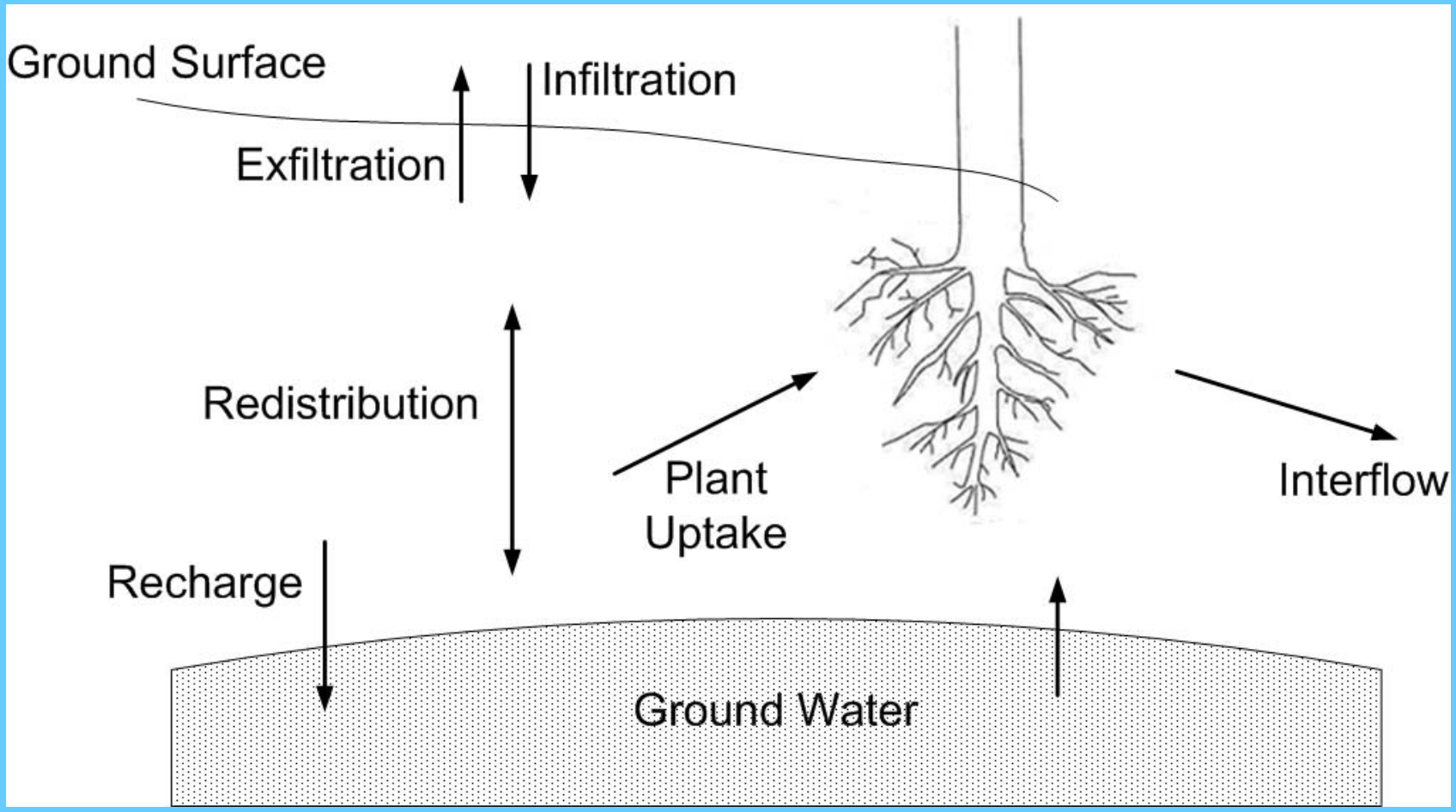
$4\,yrs \quad 1\,yr \quad 1\,yr \quad 15\,yrs \quad 3\,yrs \quad 6\,yrs \quad 5\,yrs \quad = 35$

$$T = \frac{35\ yrs}{7} = 5\ years$$

Infiltration

- **Infiltration** – movement of water from soil surface into the soil
  - 76% of the world's land area precipitation infiltrates
  - Highly dependent on surface cover
  - **Question**: What causes water to infiltrate into the soil?

Infiltration

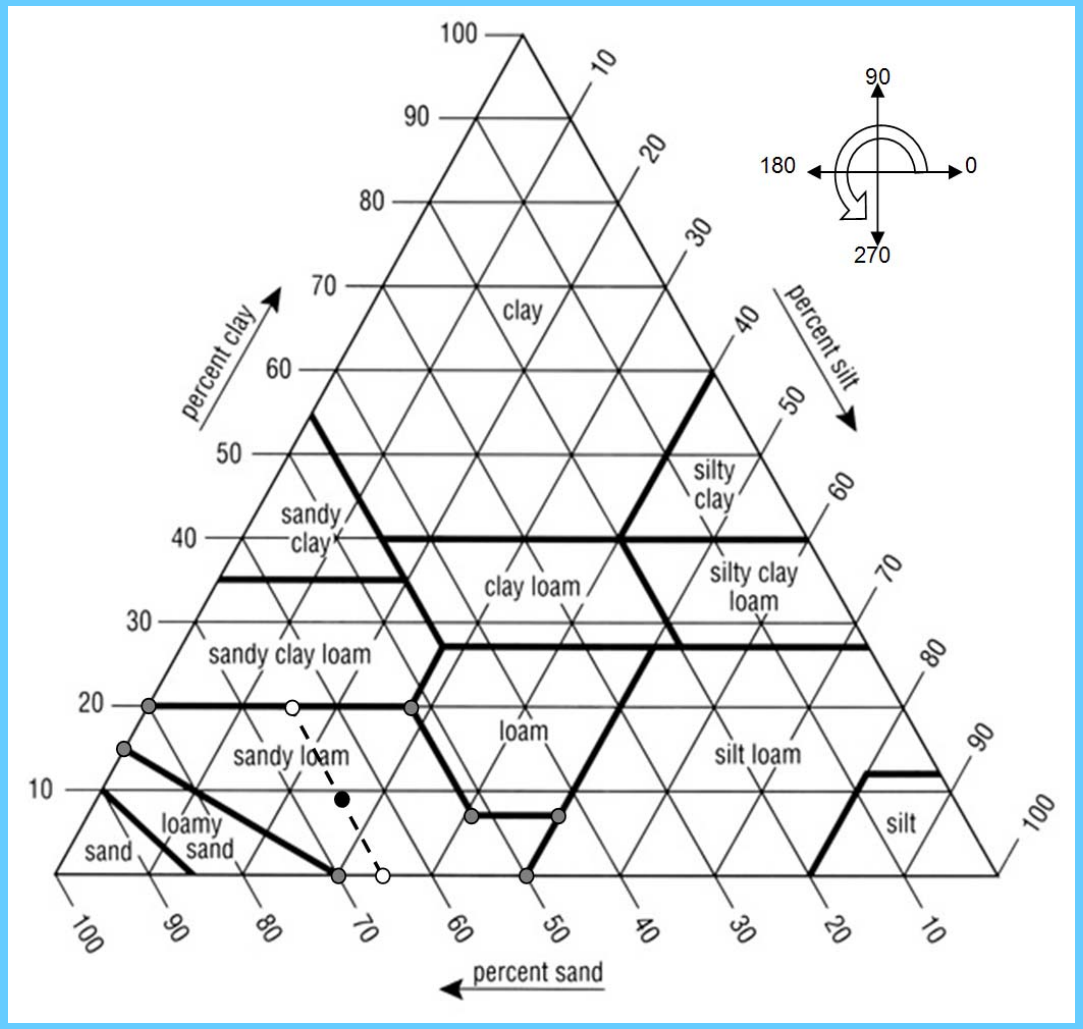


Infiltration

- Infiltration rate in general is governed by:
  - Soil physical properties (Soil Texture, Bulk Density):
    - Hydraulic conductivity
  - Vegetative cover
  - Antecedent moisture content
  - Rainfall intensity
  - Slope
- **True or False?**
  - A wet soil has a lower infiltration rate than a dry soil.

Infiltration

– Soil Texture and Hydraulic Conductivity:



	Typical K (cm/day)
Sand	700
Loamy Sand	346
Loam	17
Silt Loam	8
Silt	4
Clay	3

Evaporation/Evapotranspiration

- Evapotranspiration –
  - Evaporation of liquid water from rivers and lakes, bare soil, and vegetative surfaces
  - Evaporation from within the leaves of plants (transpiration)
- Generally not significant for individual storms but can be over long periods of time…
  - Globally, about 62% of precipitation that falls on continents is evapotranspired

Potential ET

- Potential ET (PET)
  - ET for a well-watered reference crop (turf grass or alfalfa)
- PET depends on the evaporative demand of the atmosphere
  - PET affected by:
    - air temperature
    - relative humidity
    - solar radiation
    - wind speed

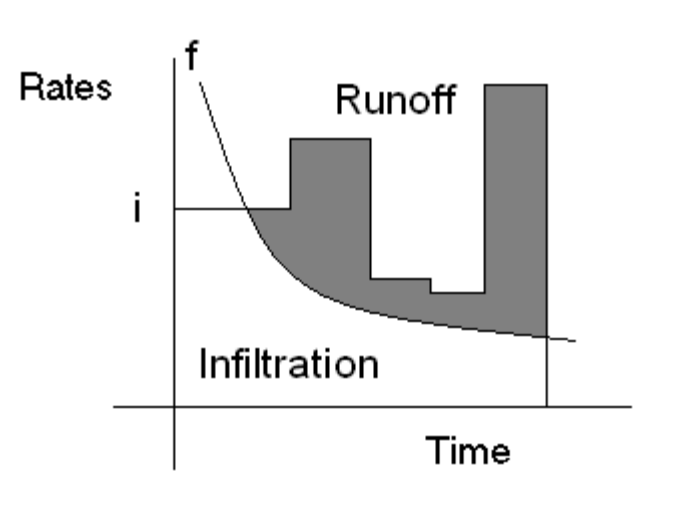
Actual ET

- Actual ET depends on:
  - PET
  - Plant species
  - Plant growth stage
  - Soil moisture
    - In dry conditions, a plant will close its stomata in order to retain water

$$\mathrm{ET} = K_a \times K_c \times \mathrm{ET_r}$$

Runoff

- Rainfall Excess – also called effective rainfall (rainfall neither retained on land surface or infiltrated)



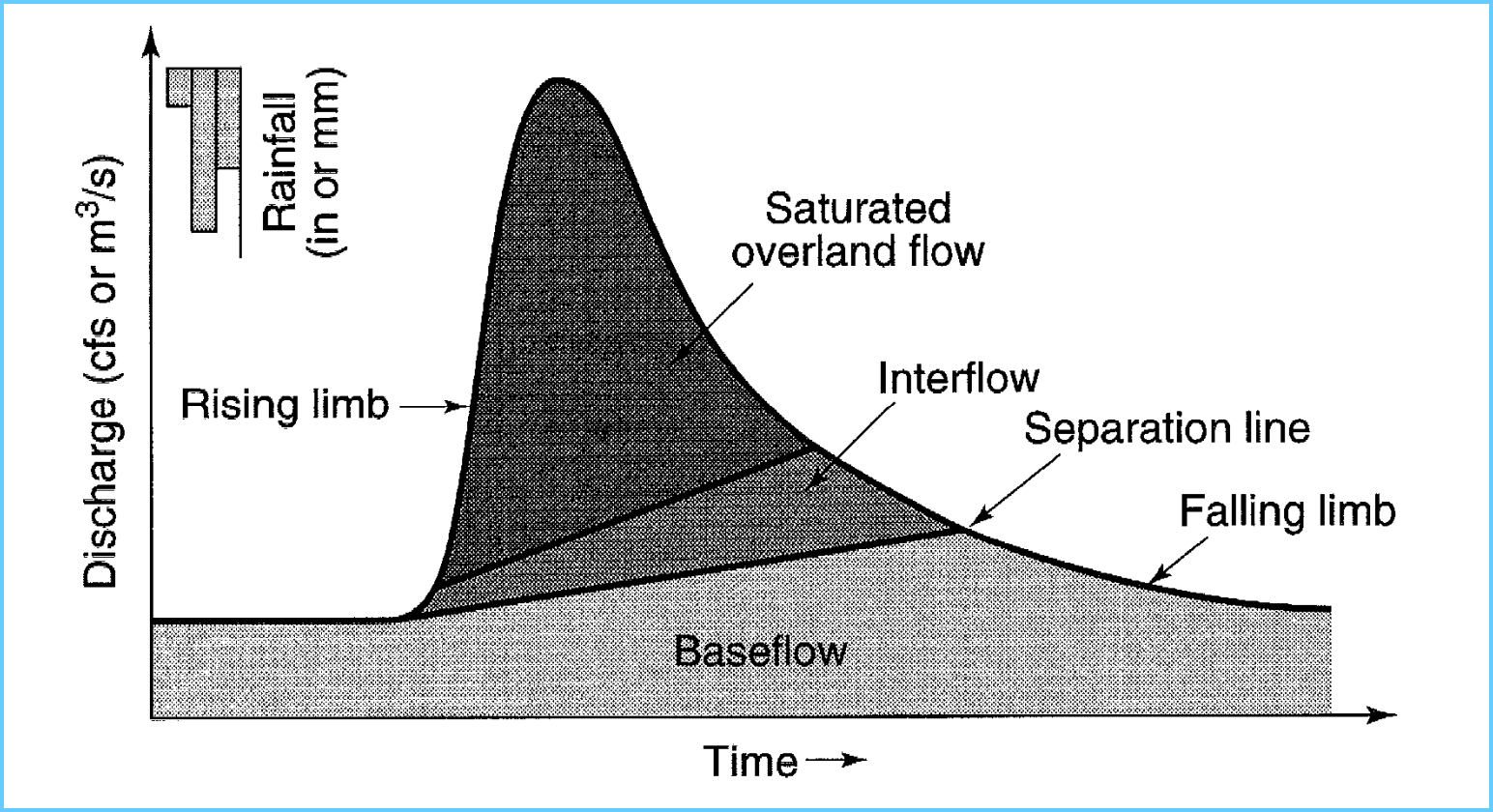
- Goal of runoff models → Determine surface runoff from watersheds due to particular storm
  - Rainfall/runoff Analysis

Runoff

- Amount of runoff depends on land cover
  - Can be quantified through runoff coefficient…

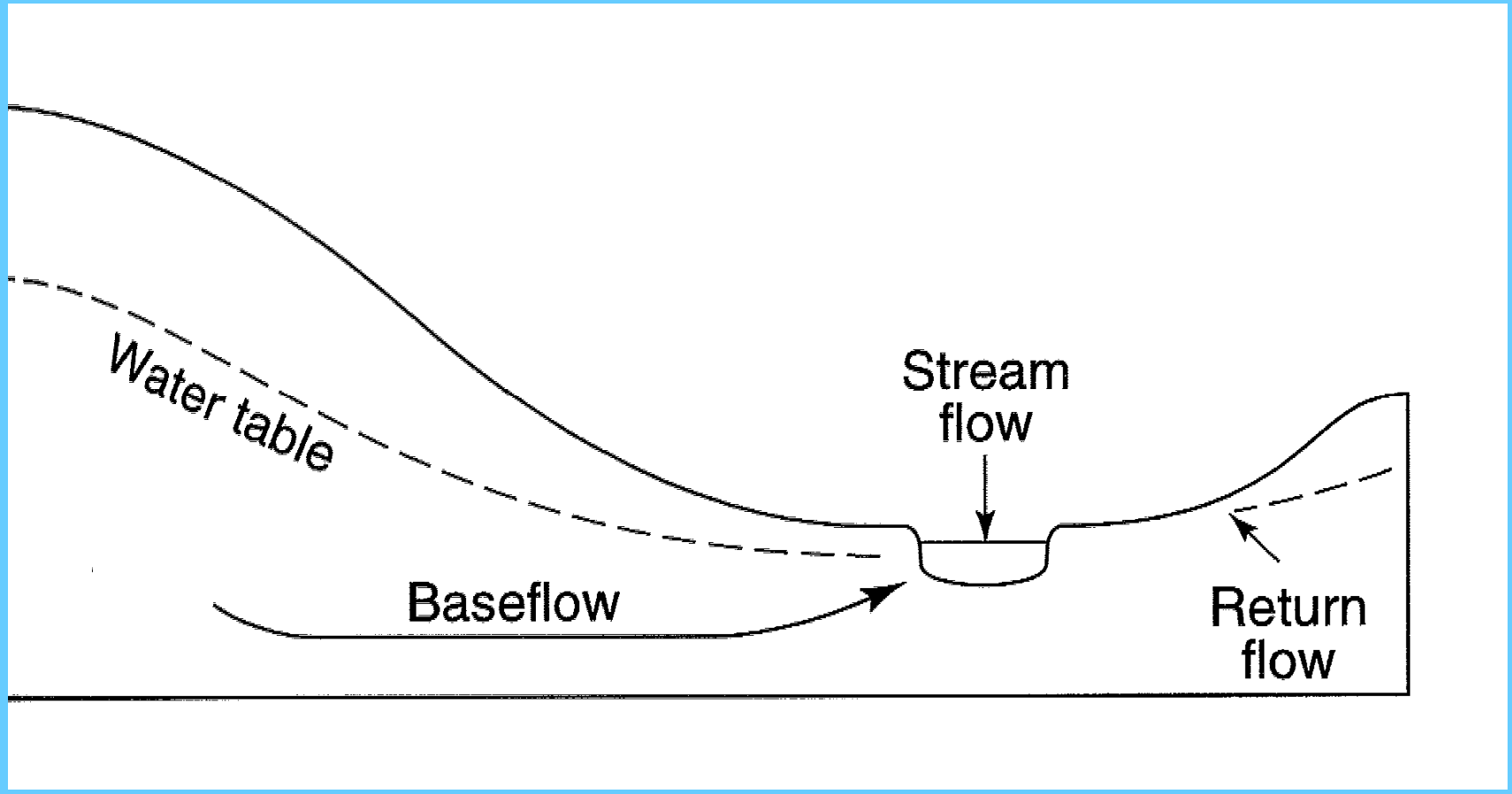
Description	Runoff Coefficient
Pavement: Asphalt, Concrete	0.70-0.95
Lawns, sand soil: 2% (Flat) >7% (Steep)	 0.05-0.10 0.15-0.20
Residential: Single Family Apartments	 0.30-0.50 0.50-0.70

Hydrographs



Source:
Mays, *Water Resources Engineering*, 2001

Hydrographs



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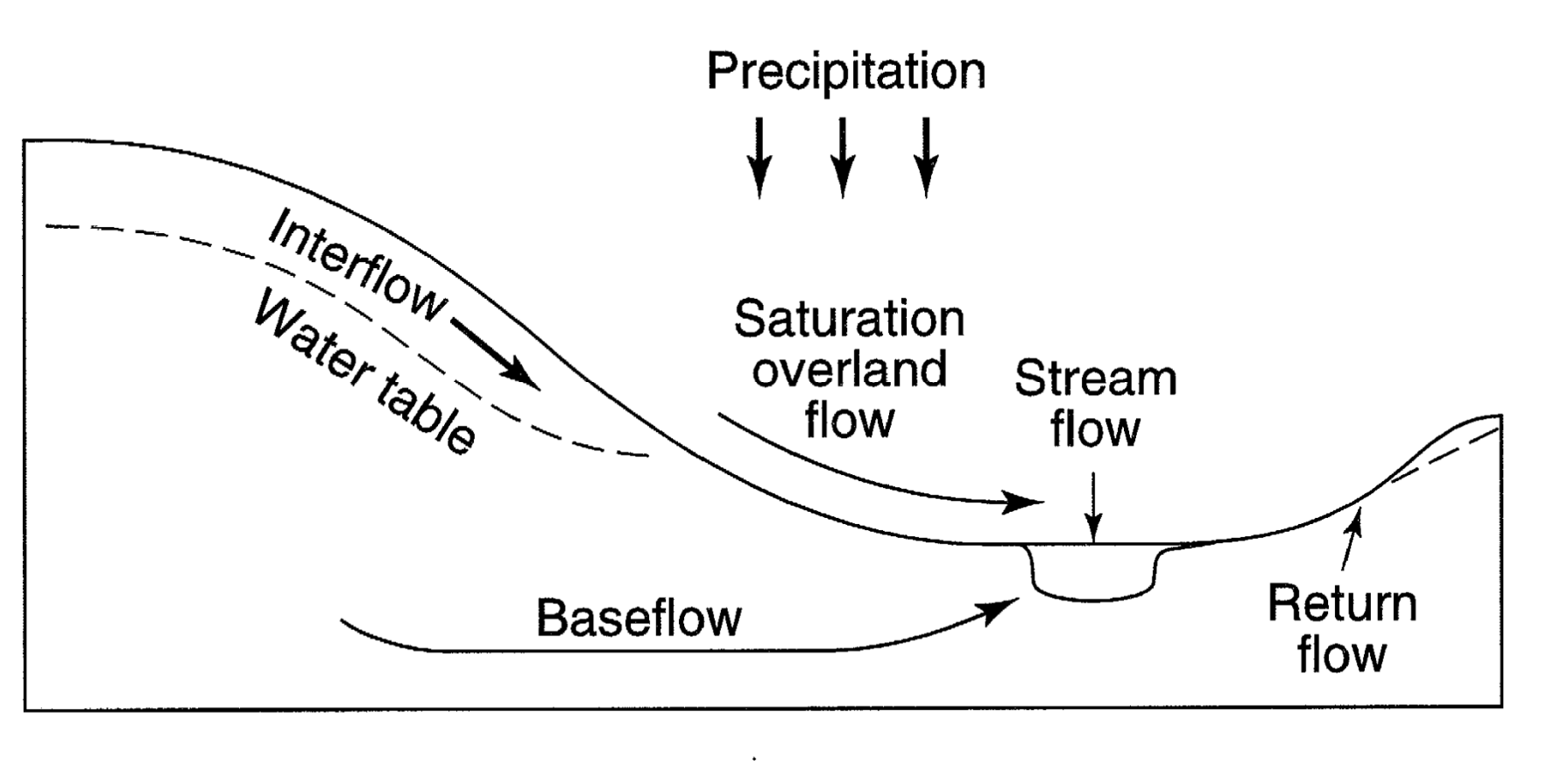

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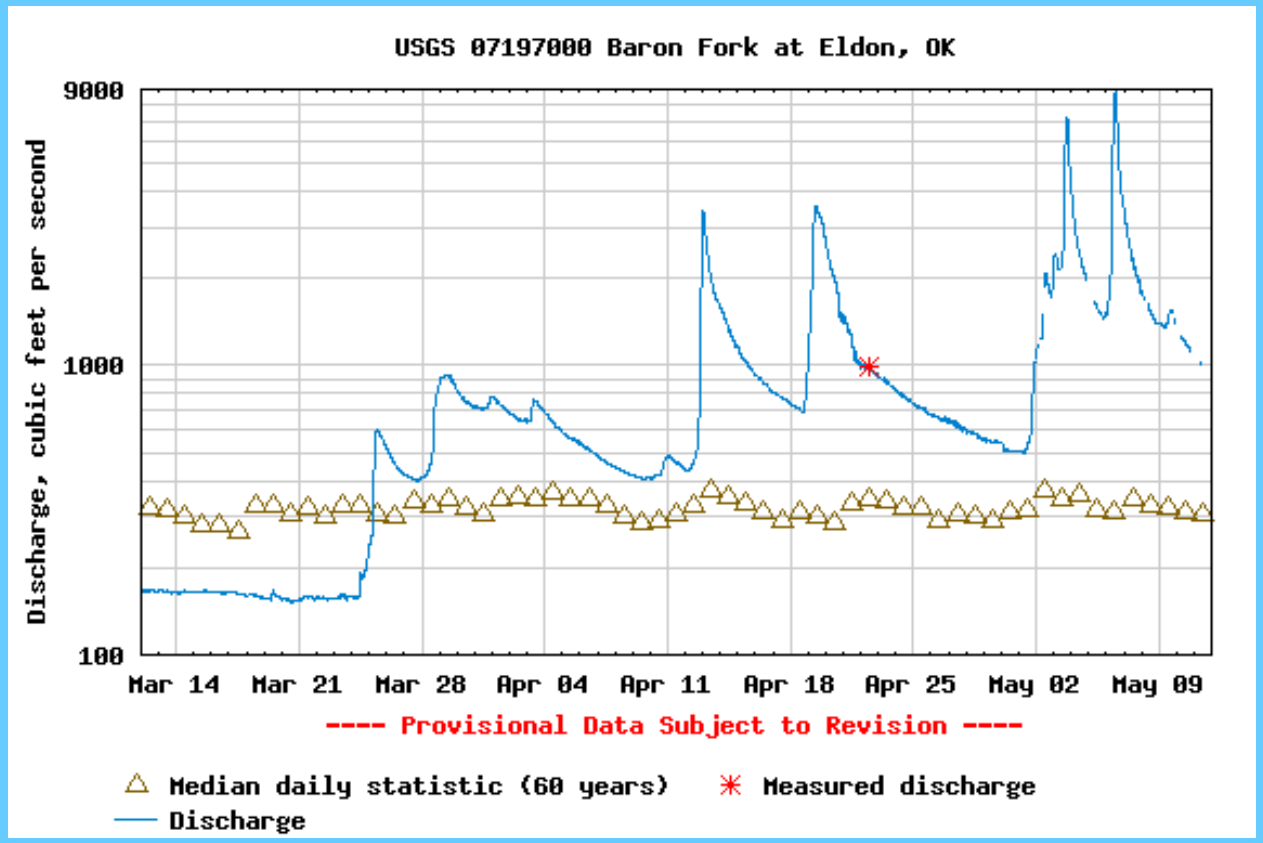
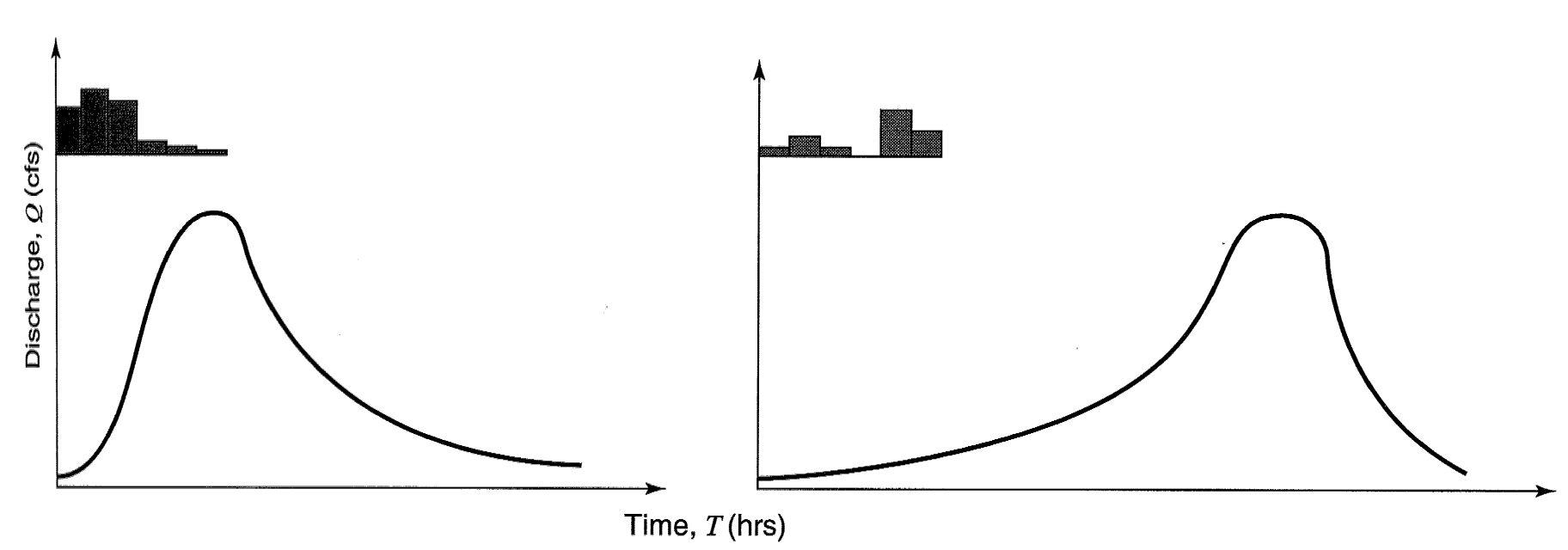


Mid and Large-Size Watersheds

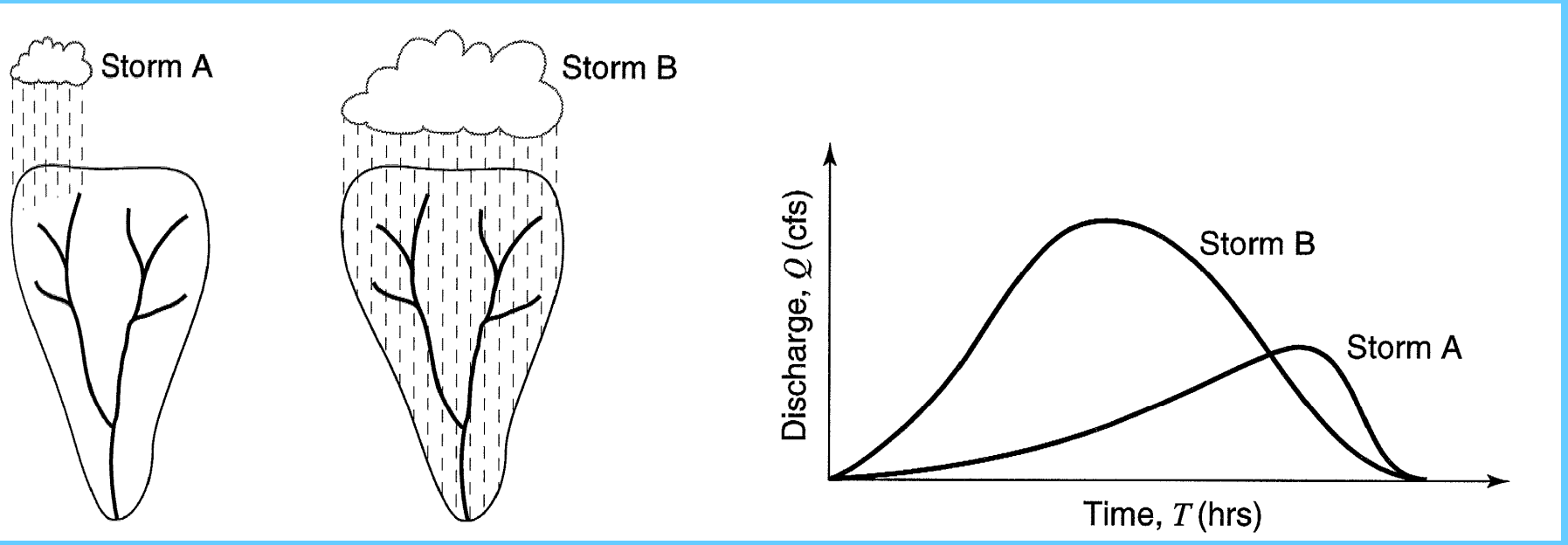
- Shape of the hydrograph depends on the temporal distribution of rainfall…



Source:
Mays, *Water Resources Engineering*, 2001

Mid and Large-Size Watersheds

- Shape of the hydrograph depends on the spatial distribution of rainfall…



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Mid and Large-Size Watersheds

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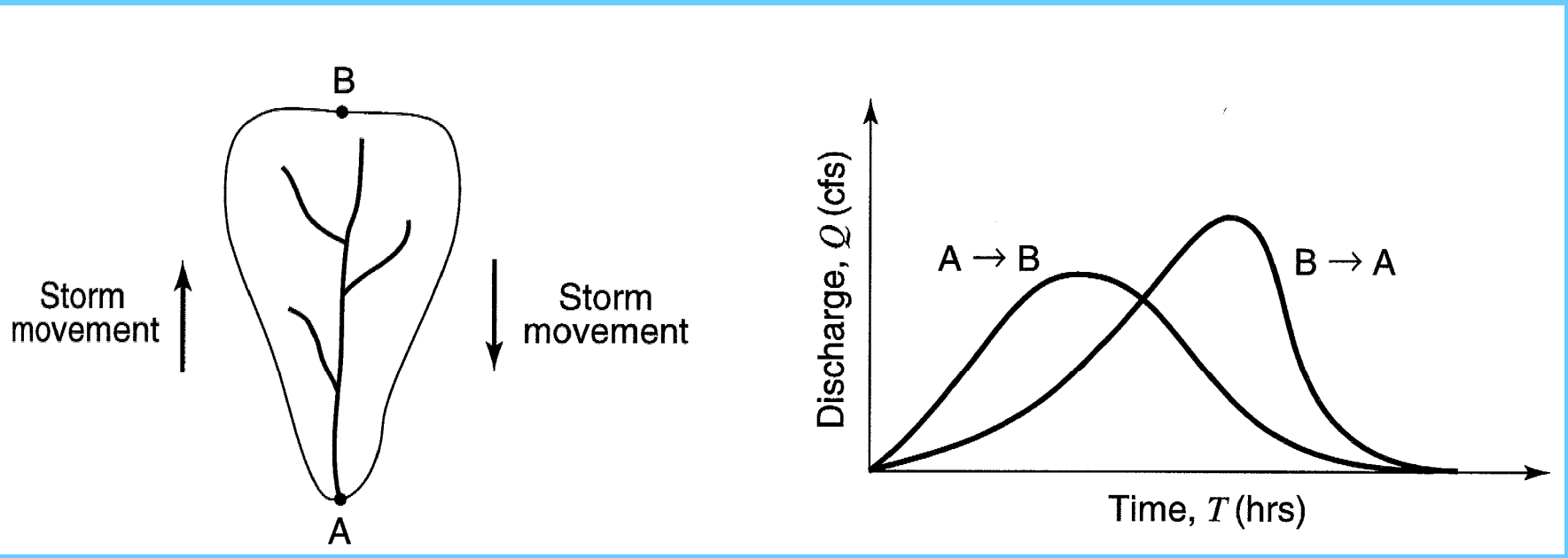

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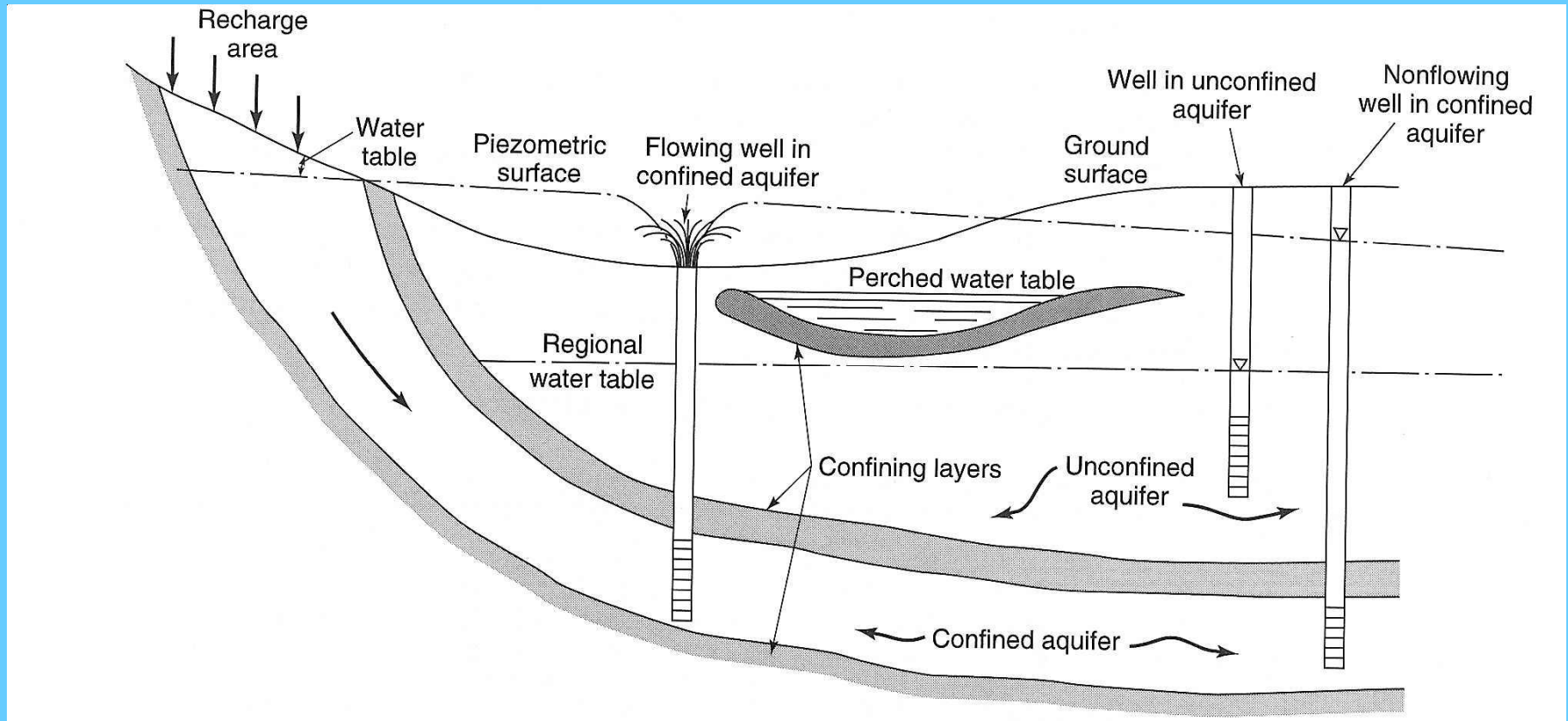
Ground Water

- Aquifer - geologic formation that ***CONTAINS*** sufficient saturated porous material and ***CONDUCTS*** water in useable quantities



Ground Water

- Ground water usually managed as basins:
  - **<u>Ground Water Basin</u>** – group of aquifers linked together in a larger flow system

About 30% of world's total freshwater

About ¼ of all water used for domestic water use, irrigation and industrial uses is from ground water

Ground water is the source of most water in rivers and lakes (base flow)

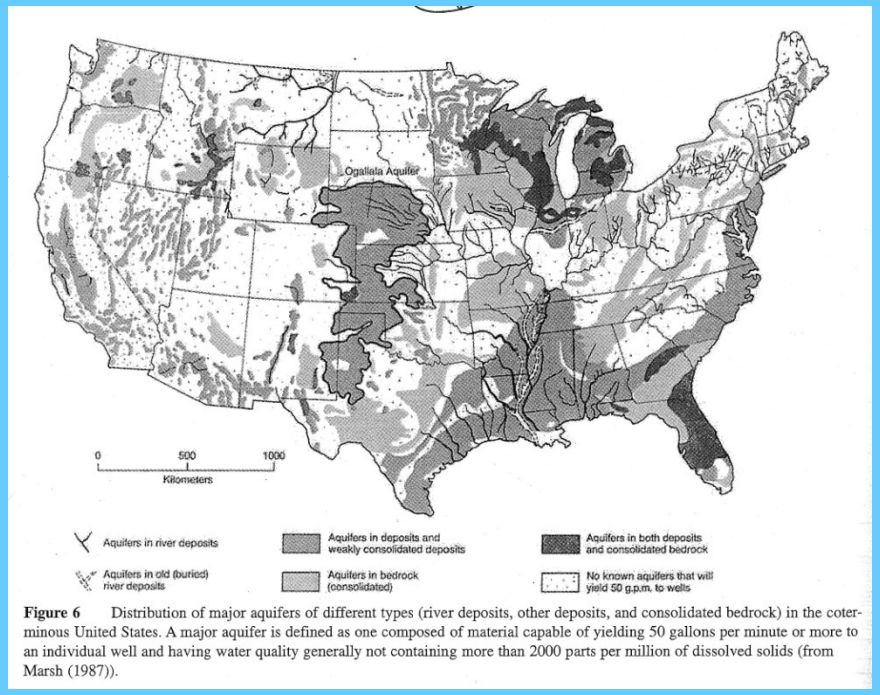


Figure 6 Distribution of major aquifers of different types (river deposits, other deposits, and consolidated bedrock) in the coterminous United States. A major aquifer is defined as one composed of material capable of yielding 50 gallons per minute or more to an individual well and having water quality generally not containing more than 2000 parts per million of dissolved solids (from Marsh (1987)).

http://www.owrb.state.ok.us/maps/pdf_map/major_aquifers.pdf

Aquifer Properties

- ***CONDUCTS*** – how fast can water move through the porous media?
  - Hydraulic Conductivity
    - Rate of flow of water through a unit area of porous material under a unit hydraulic gradient
    - **Question:** Which has the higher hydraulic conductivity?

      (a) Sand

      (b) Clay

Aquifer Properties

- ***STORAGE*** - how much water can an aquifer hold?
  - **Question:** Which has the higher storage capacity?

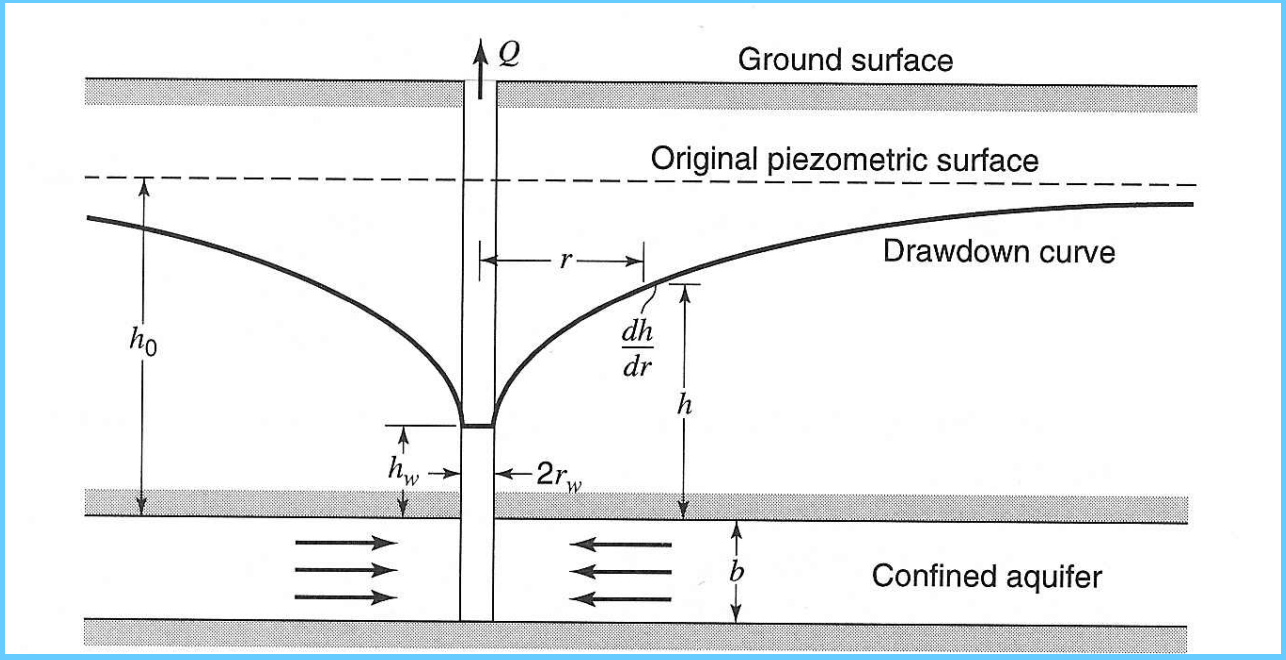
    (a) Sand

    (b) Clay

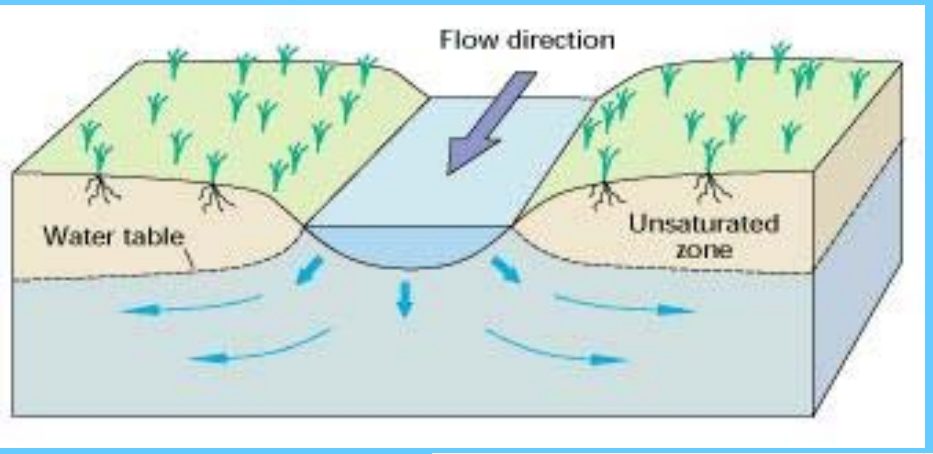
  - Specific Yield – volume of water drained from a saturated sample by gravity
    - Generally only applies to an unconfined aquifer
  - Storage Coefficient – volume of water the aquifer releases from storage per unit decline in head
    - Applies to both confined and unconfined aquifers

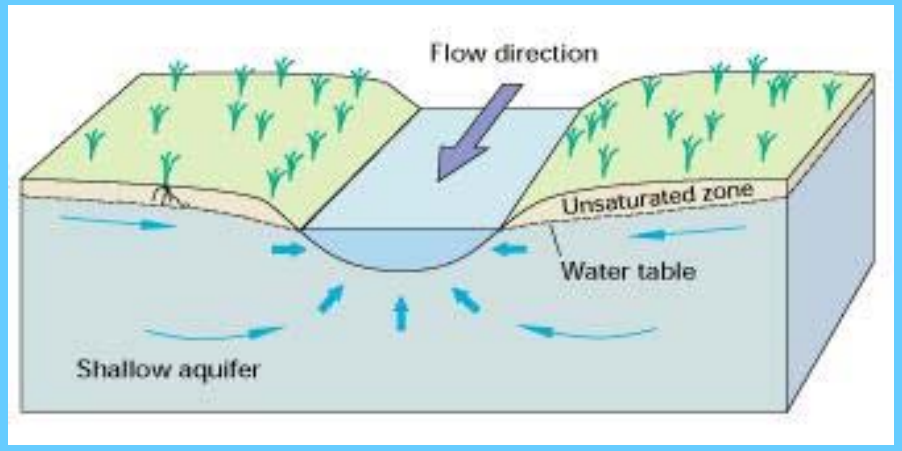
Well Pumping

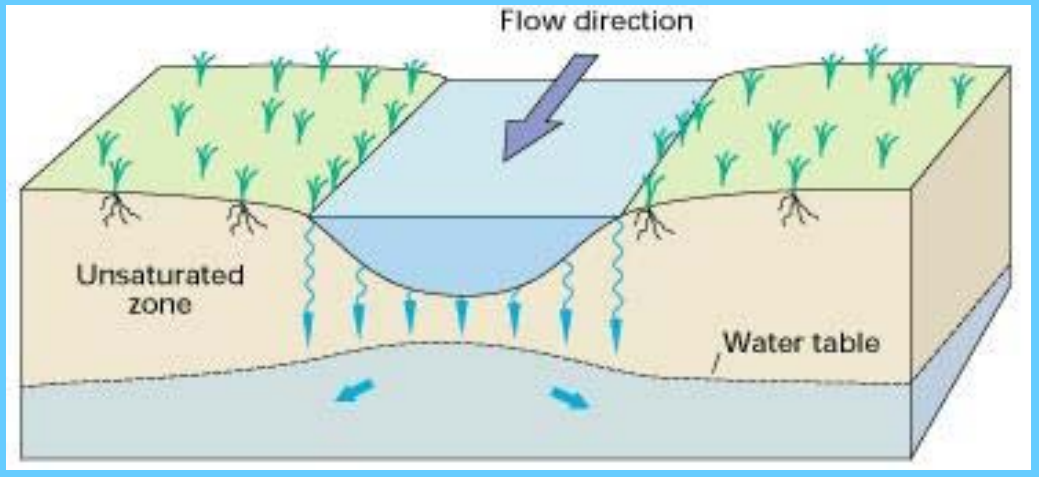
- Drawdown – distance water level or piezometric surface is lowered



Alluvial Aquifers



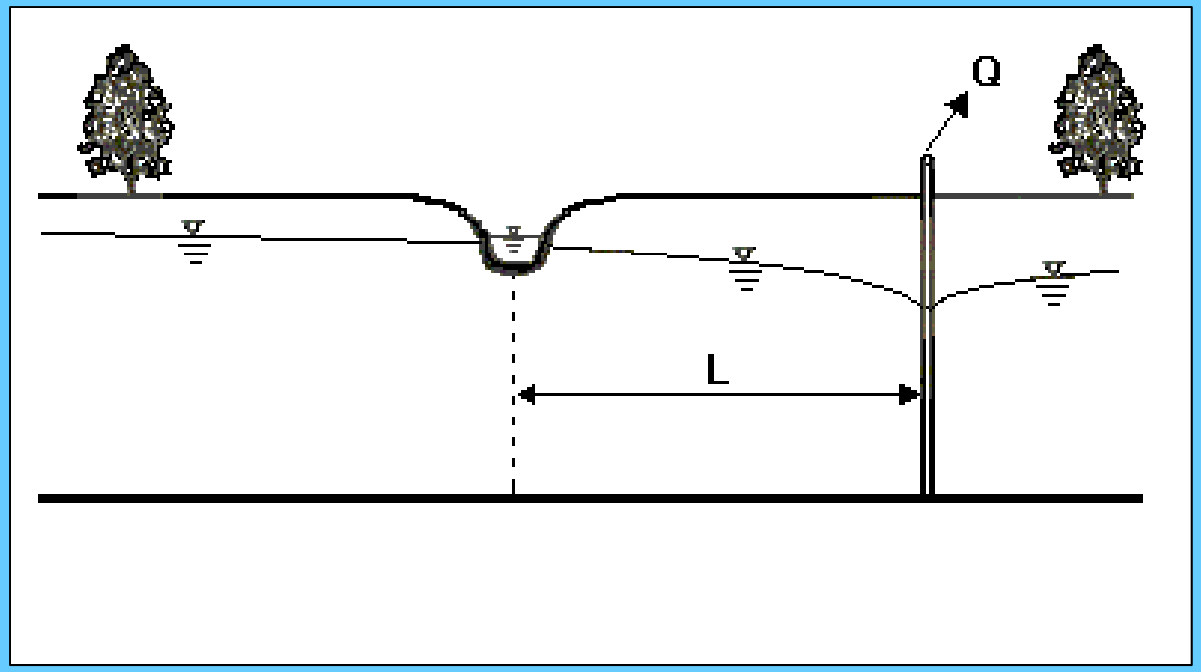




Pumping next to River

Water pumped from ground can capture…

1. Water that would have contributed base flow to a stream
2. Create leakage from the stream into the aquifer



Key U.S. Water Resources Agencies

- U.S. Geological Survey (USGS) – primary source for streamflow and ground water data in the United States (www.usgs.gov)
- U.S. Environmental Protection Agency (EPA) – responsible for implementation and enforcement of environmental laws (www.epa.gov)
- U.S. Natural Resources Conservation Service (NRCS) – works with landowners on private lands to conserve natural resources (www.nrcs.usda.gov)
- U.S. Army Corps of Engineers (USACE) – responsible for planning, construction, operation, and maintenance of a variety of water-resource facilities (www.usace.army.mil)
- U.S. Bureau of Reclamation (USBR) – manages water-related resources west of the Mississippi River (www.usbr.gov)

Questions?

It is always a great day to be a hydrologist!