

# Hydrology I

# Today's lecture

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- What is hydrology?
- Water sources and hydrological cycle
- Water budget
- Surface water topics: Watershed, hydrograph, runoff coefficient

# Hydrology

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- Definition

A multidisciplinary subject that deals with the question of how much water can be expected at any particular time and location

- Application of hydrology

- ensure adequate water supply for drinking, irrigation, industrial uses, etc.
- prevent flooding

# Issues of hydrology

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- Flood and droughts



# Issues of hydrology

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- Climate change



# Issues of hydrology

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- Water use sustainability



Aral Sea, Kazakhstan & Uzbekistan, change from 1989 to 2008



# Issues of hydrology

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- Water use sustainability



Land  
subsidence due  
to groundwater  
pumping

# Issues of hydrology

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- Hot in Korea - sinkholes





# Water balance and residence time

Table 1.1 Estimate of the Water Balance of the World

Parameter	Surface area (km <sup>2</sup> ) × 10 <sup>6</sup>	Volume (km <sup>3</sup> ) × 10 <sup>6</sup>	Volume (%)	Equivalent depth (m)*	Residence time
Oceans and seas	361	1370	94	2500	~4000 years
Lakes and reservoirs	1.55	0.13	<0.01	0.25	~10 years
Swamps	<0.1	<0.01	<0.01	0.007	1–10 years
River channels	<0.1	<0.01	<0.01	0.003	~2 weeks
Soil moisture	130	0.07	<0.01	0.13	2 weeks–1 year
Groundwater	130	60	4	120	2 weeks–10,000 years
Icecaps and glaciers	17,8	30	2	60	10–1000 years
Atmospheric water	504	0.01	<0.01	0.025	~10 days
Biospheric water	<0.1	<0.01	<0.01	0.001	~1 week

SOURCE: Nace, 1971.

\*Computed as though storage were uniformly distributed over the entire surface of the earth.

- Water useful for humans: i) lakes & reservoirs, ii) rivers iii) (shallow) groundwater
- These waters constitute only a small fraction

# Water balance and residence time

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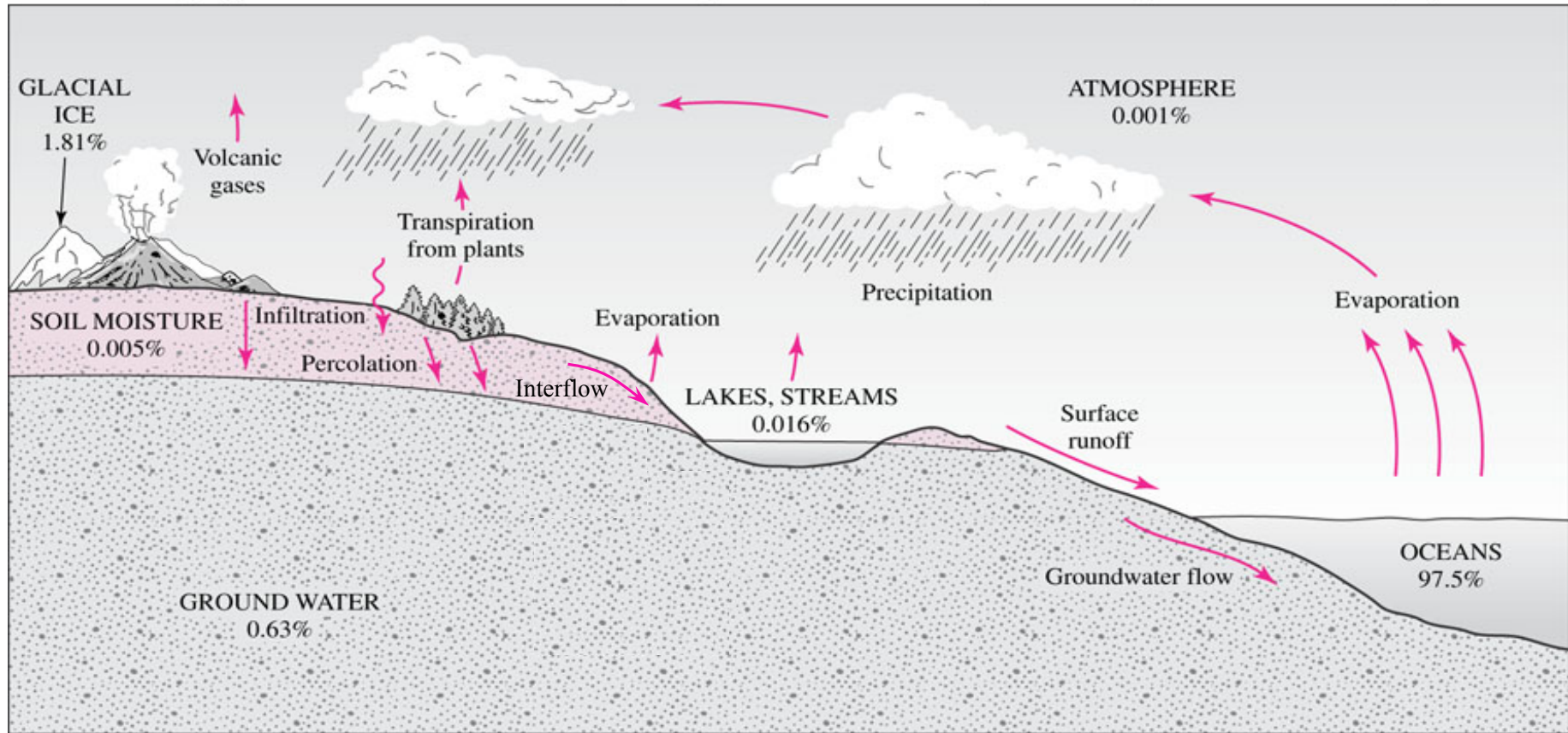
SOURCE: Nace, 1971.

\*Computed as though storage were uniformly distributed over the entire surface of the earth.

- Long residence time for groundwater – once depleted, it takes a long time to recover (effectively nonrenewable)
- Significant temporal and spatial variation of freshwater availability & water needs → dams, reservoirs, pipelines, etc. needed

# Hydrological cycle

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# Processes in the hydrological cycle

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- Earth's surface → atmosphere
  - evaporation: conversion of liquid water from lakes, streams, and other bodies of water to water vapor
  - transpiration: the process by which water is emitted from plants through the stomata
    - \* evapotranspiration = evaporation + transpiration

# Processes in the hydrological cycle

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- Earth's atmosphere → surface
  - precipitation (rain+snow+hail+...)
- Within Earth's surface
  - surface (direct) runoff: water running over the ground into streams and rivers
  - interflow: portion of precipitation that infiltrates into the soil and moves horizontally through the shallow soil horizon without ever reaching the water table
  - infiltration (percolation): vertical movement of water from the surface into the soil



# Water budget

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- Water budget: mass balance for water  
*(rate of accumulation) = (rate in) – (rate out)*

\*All written in units of [vol./time]

ex) For a lake,

$$\Delta S = \sum(\text{rate in}) - \sum(\text{rate out})$$

- $\Delta S$  = change in storage over time
- possible “in” processes: flow of streams entering the lake, precipitation, runoff, seepage into the lake
- possible “out” processes: flow of streams exiting the lake, evapotranspiration, seepage out of the lake

# Water budget

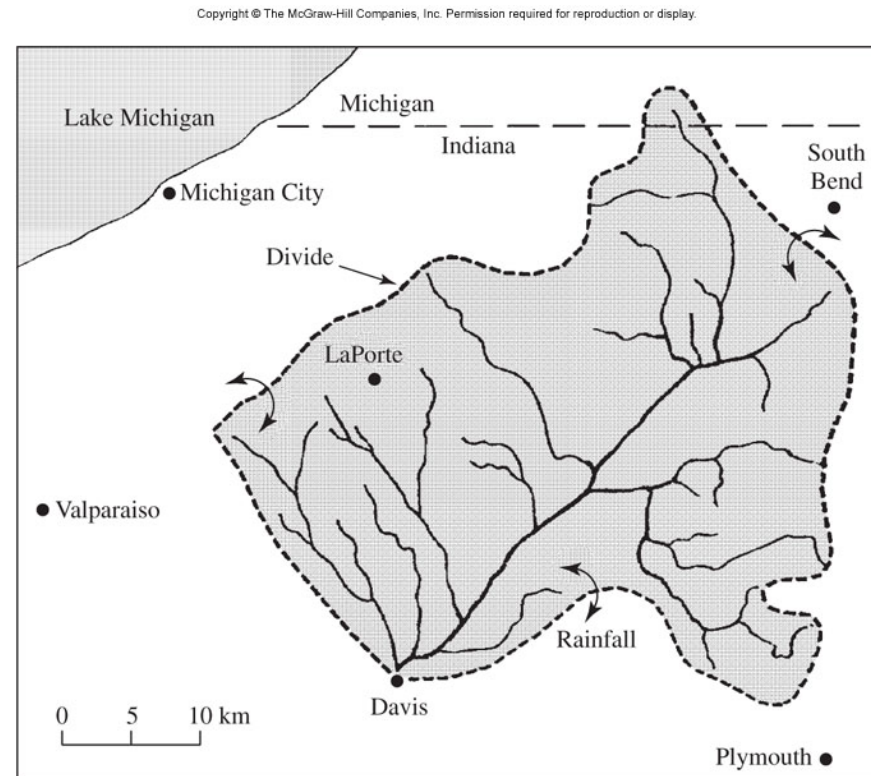
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Q: Sulis Lake has a surface area of  $708,000 \text{ m}^2$ . Okemos Brook flows into the lake at a flow rate of  $1.5 \text{ m}^3/\text{s}$  and the Tamesis River flows out of the lake at a flow rate of  $1.25 \text{ m}^3/\text{s}$  during the month of June. The evaporation rate was measured as  $19.4 \text{ cm/month}$ . Transpiration is ignored because there are few water plants. A total of  $9.1 \text{ cm}$  of precipitation fell this month. Seepage and runoff is negligible. The average depth in the lake at the beginning of the month was  $19 \text{ m}$ . Calculate the **average depth at the end of the month.**

# Watershed

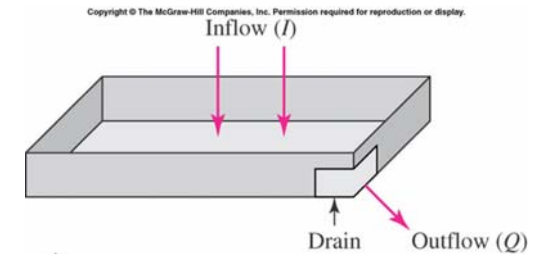
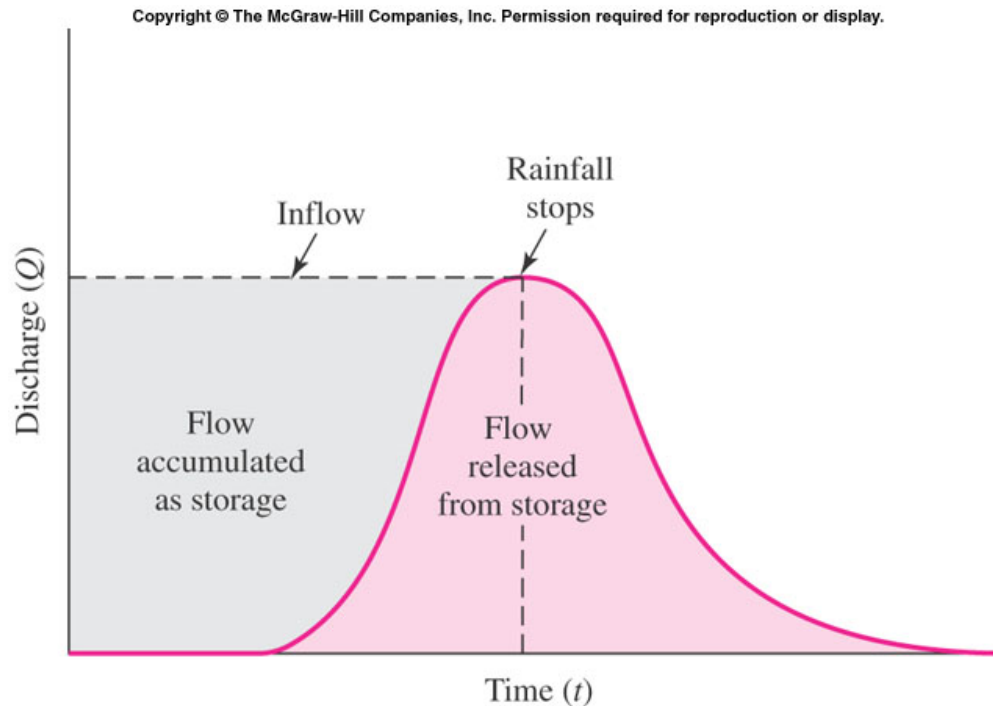
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- Watershed (basin): the area of land where all of the water that is under it or drains off of it goes to the same place
- Divide: the boundary of the watershed



# Hydrograph

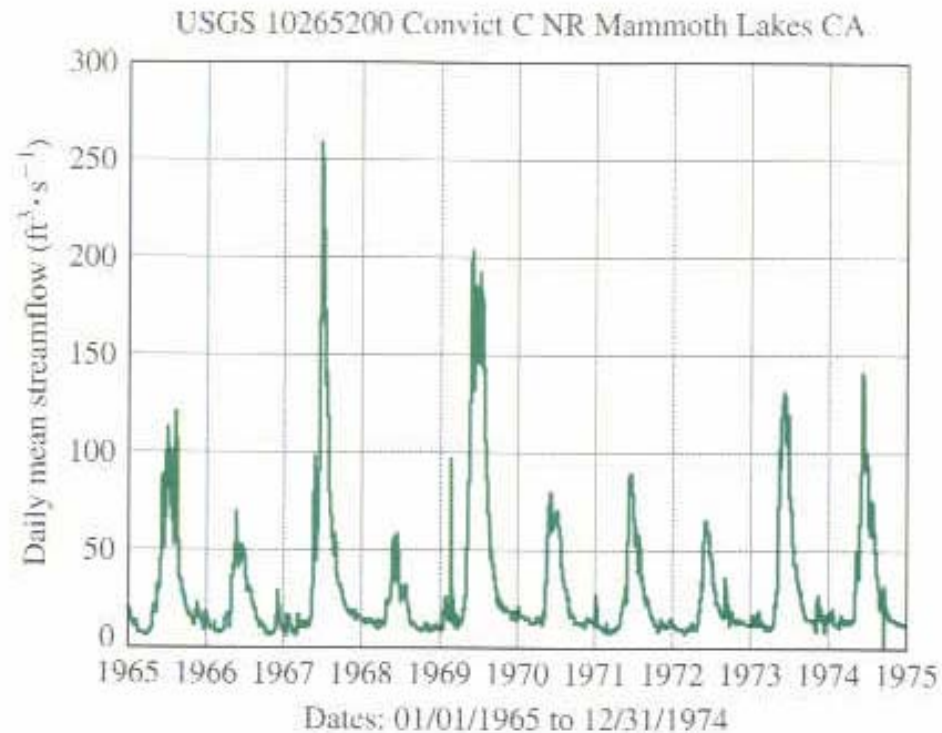
- A chart in which flow rate is plotted vs. time



An example hydrograph for a simple parking lot

# Hydrograph

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10-year hydrograph for  
a creek (example)

- The shape of the hydrograph is affected by various factors such as: precipitation, weather, topography of the watershed, density and type of ground cover, ...



# Runoff coefficient

- Runoff coefficient

$$= \{ \text{rate of runoff } (R) \} / \{ \text{rate of precipitation } (P) \}$$

Typical Runoff Coefficients			
Description of Area or Character of Surface	Runoff Coefficient	Description of Area or Character of Surface	Runoff Coefficient
Business		Railroad yard	0.20–0.35
Downtown	0.70–0.95	Natural grassy land	0.10–0.30
Neighborhood	0.50–0.70	Pavement	
Residential		Asphalt, concrete	0.70–0.95
Single-family	0.30–0.50	Brick	0.70–0.85
Multi-units, detached	0.40–0.60	Roofs	0.75–0.95
Multi-units, attached	0.60–0.75	Lawns, sandy soil	
Residential, suburban	0.25–0.40	Flat (< 2%)	0.05–0.10
Apartment	0.50–0.70	Average (2–7%)	0.10–0.15
Industrial		Steep (> 7%)	0.15–0.20
Light	0.50–0.80	Lawns, heavy soil	
Heavy	0.60–0.90	Flat (< 2%)	0.13–0.17
Parks, cemeteries	0.10–0.25	Average (2–7%)	0.18–0.22
Playgrounds	0.20–0.35	Steep (> 7%)	0.25–0.35

Source: Joint Committee of the American Society of Civil Engineers and the Water Pollution Control Federation, 1969.

The more developed, the bigger runoff coefficient

# Runoff coefficient

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**Q:** A watershed with an area of  $4530 \text{ km}^2$  received  $77.7 \text{ cm}$  of precipitation in 2013. The average rate of flow measured in a river which drained the watershed was  $39.6 \text{ m}^3/\text{s}$ . Infiltration occurred at an average rate of  $9.2 \times 10^{-7} \text{ m/s}$  and evapotranspiration was estimated to be  $45 \text{ cm/year}$ . What was the change in storage in the watershed in 2013? What was the runoff coefficient?

# Reading assignment

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- Textbook Ch 7, p. 258-267