Risk Perception, Assessment, and Management II

Today's lecture

- Risk assessment processes
  - Data collection & evaluation
  - Toxicity assessment
  - Exposure assessment
  - Risk characterization

- Risk management

US EPA's human risk assessment process

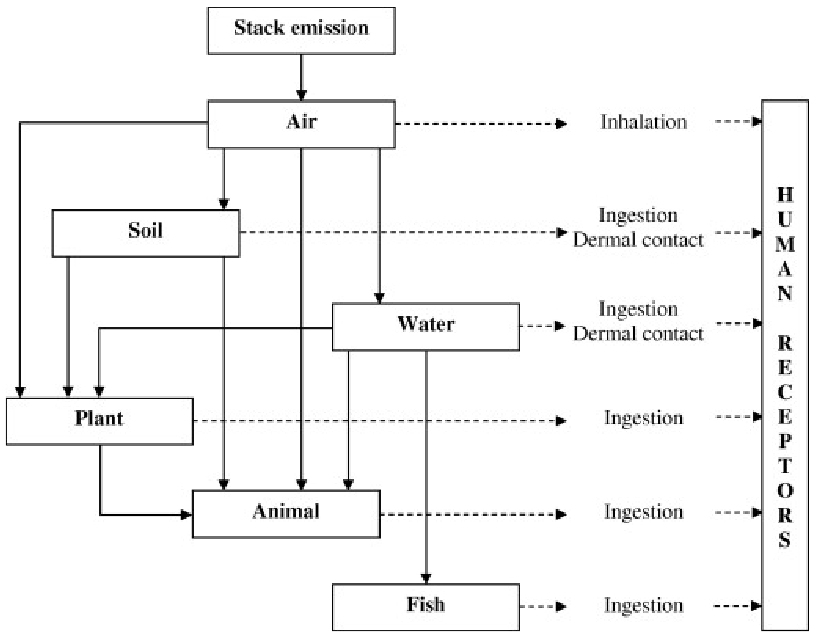
- Data collection and evaluation
- Toxicity assessment
- Exposure assessment
- Risk characterization

Data collection and evaluation

- Collecting background information of a site
  - Possible contaminants
  - Concentrations of the contaminants in key sources and media (air, soil, water, …), characteristics of sources, and information related to the chemical’s release potential
  - Characteristics of the environmental setting that could affect the fate, transport, and persistence of the contaminants

- Form a **“conceptual site model”**:

  initially identify potential exposure pathways and exposure points important for assessing risk



Example conceptual site model

Toxicity assessment

- Determining the relationship between the exposure to a contaminant and the increased likelihood of the occurrence or severity of adverse effects

1. Hazard identification

   determines whether exposure to a contaminant causes increased adverse effects

2. Dose-response evaluation

   describes how the adverse effects are related to the dose provided to humans

Toxicity assessment

2. Dose-response evaluation (continued)

– dose: the mass of chemical received by an exposed individual (mg contaminant / kg body mass)

– response: can be any adverse effects such as reduced body weight, reduced fertility, tumor formation, and death

http://www.dailymail.co.uk

"The dose makes the poison"

- All chemicals can be toxic if too much is eaten, drunk, or absorbed

Q: All chemical can be non-toxic if very little is eaten, drunk, or absorbed?

SCIENTIFIC AMERICAN™

Sign In | Register 0

Search ScientificAmerican.com

Strange but True: Drinking Too Much Water Can Kill

In a hydration-obsessed culture, people can and do drink themselves to death.

Jun 21, 2007 | By Coco Ballantyne

Liquid H_2O is the sine qua non of life. Making up about 66 percent of the human body, water runs through the blood, inhabits the cells, and lurks in the spaces between. At every moment water escapes the body through sweat, urination, defecation or exhaled breath, among other routes. Replacing these lost stores is essential but rehydration can be overdone. There is such a thing as a fatal water overdose.

© ISTOCKPHOTO.COM/GREMLIN

Earlier this year, a 28-year-old California woman died after competing in a radio station's on-air water-drinking contest. After downing some six liters of water in three hours in the "Hold Your Wee for a Wii" (Nintendo game console) contest, Jennifer Strange vomited, went home with a splitting headache, and died from so-called water intoxication.

Toxicity assessment: terminologies

- **Acute toxicity**: an adverse effect that has a rapid onset, short course, and pronounced symptoms

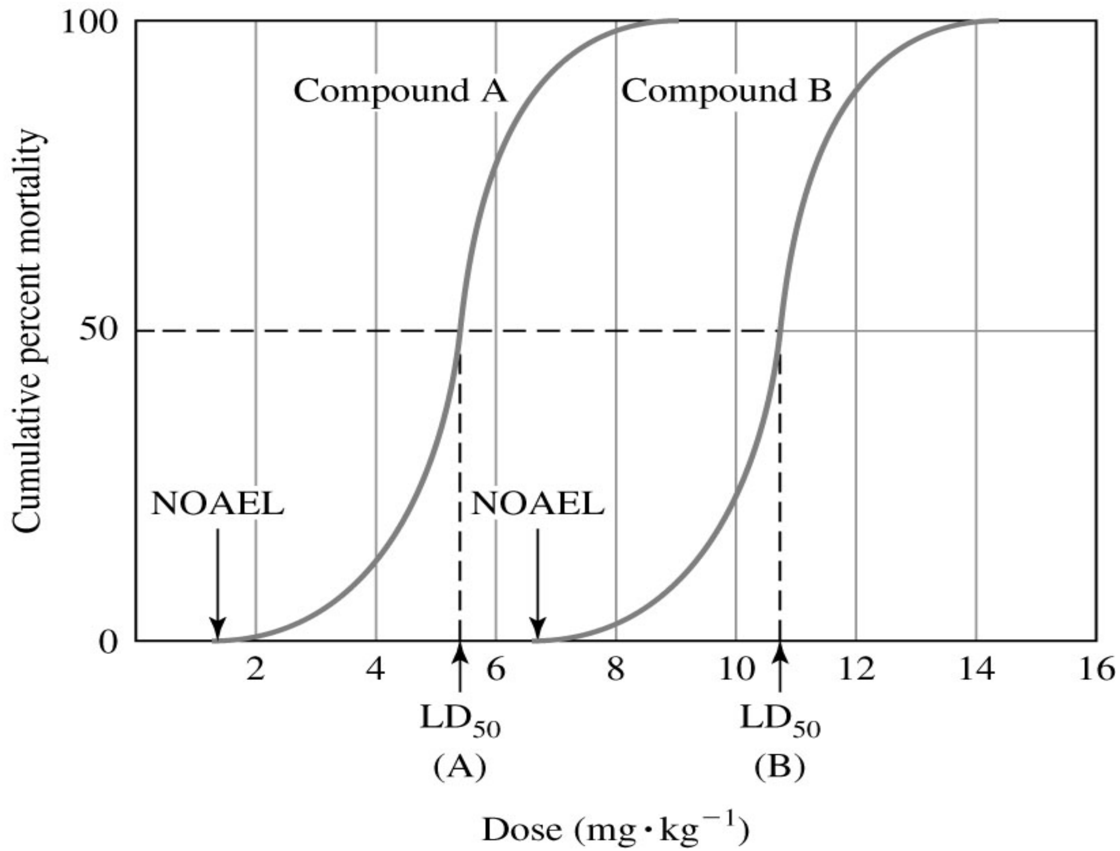
- **Chronic toxicity**: an adverse effect that frequently takes a long time to run its course and initial onset of symptoms may go undetected (ex: carcinogenesis)

- **Carcinogenesis**: creation of cancer (transformation of normal cells into cancer cells)

- **Carcinogen**: a cancer-producing substance

Toxicity assessment

- Dose-response curve



NOAEL:

No **O**bserved **A**dverse **E**ffect **L**evel

LD50:

Lethal **D**ose for **50**% of the population

Toxicity assessment

- Non-carcinogenic vs. carcinogenic risk
  - Non-carcinogenic risk: It is believed that there is a safe dose (*NOAEL* exists), i.e., the body can repair itself. From the *NOAEL* of a dose-response relationship, reference dose (*RfD*) is estimated:

$$RfD = NOAEL/10^x,$$

(1≤*x*≤3; safety factors for animal/human differences & variation within humans)

  - Carcinogenic risk: Assume no safe dose (no *NOAEL*). At low doses, the slope of the dose-response curve is represented by a ***slope factor*** (SF).

Exposure assessment

- Estimate the magnitude of exposure to chemicals of potential concern
- The exposure concentrations are predicted, then the <u>pathway-specific intakes</u> are calculated as:

$$CDI = C\left[\frac{CR \times EFD}{BW}\right] \times \frac{1}{AT}$$

* This is a simplified & generalized version; you may find more complicated forms in textbooks

CDI = chronic daily intake (mg/kg body weight/day)
C = chemical concentration (ex: mg/L water);
CR = contact rate (ex: L/day)
EFD = exposure frequency and duration (= EF x ED)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days)

Exposure assessment

Q: Estimate the lifetime average chronic daily intake of benzene from exposure to a city water supply that contains a benzene concentration of 0.005 mg/L. Assume the exposed individual is an adult male who drinks 2 L of water every day for 63 years and ingestion of benzene in drinking water is the only exposure pathway. The averaging time (AT) is 75 years (=27375 days).

Risk characterization

- For **carcinogenic risk** (risk below 0.01),

  Risk = (CDI)(slope factor)

  For multiple substances and multiple pathways,

  Total exposure risk = $\sum \text{Risk}_{ij}$

  i = compounds; j = pathways

  * Goal: ensure risk < 10^{-4} to 10^{-6}

Risk characterization

- For non-carcinogenic risk,

  calculate Hazard Index (HI):

  $HI = (CDI)/(RfD)$

  For multiple substances and multiple pathways,

  $HI_T = \sum HI_{ij}$ $\quad$ i = compounds; j = pathways

* Goal: ensure $HI_T < 1$

Risk characterization

Q: Using the previous example, estimate the carcinogenic risk by ingestion of benzene in drinking water.

(benzene slope factor for oral ingestion = 0.015 kg·day/mg)

Risk management

- Based on the risk assessment result, decision is made whether actions are needed & what actions should be taken if the existing risk should be reduced to an acceptable level

- Strategies to reduce risk
  - Lower the concentration

    apply engineering techniques to reduce concentrations in the environmental media (contaminant source or medium of significant contaminant exposure)

  - Engineering control for the exposure

    ex) solidification of contaminated soil; placing barriers to prevent release of contaminated water (e.g., surface runoff, groundwater) from the site

  - Institutional control for the exposure

    ex) restrict public access to a contaminated site

Suggested readings

[ENG] pp. 246 – 259

[KOR] pp. 238 – 254

Next class

Hydrology I

- Hydrology and issues involved with water
- Water sources and water cycle
- Water mass balance
- Basic concepts/tools: watershed, hydrograph, runoff coefficient

Slide#12 solution

$$CDI = C\left[\frac{CR \times EFD}{BW}\right] \times \frac{1}{AT}$$

C = benzene conc. = 0.005 mg/L

CR = contact rate = 2 L/day

EFD = exposure frequency and duration = EF x ED

= (365 days/year) x (63 years) = 22995 days

BW = body weight = 70 kg

AT = averaging time = 75 years = 27375 days

$$CDI = 0.005\, mg/L \times \frac{2\, L/day \times 22995\, days}{70\, kg} \times \frac{1}{27375\, days} = \mathbf{1.2 \times 10^{4}\, mg/kg - day}$$

Slide#15 solution

$CDI = 1.2 \times 10^4 \; mg/kg - day$

Carcinogenic risk = (CDI) x (slope factor)

= (1.2 x 10^{-4} mg/kg-day) x (0.015 kg-day/mg)

= ***1.8 x 10^{-6}***

→ *The man has a 1.8/1,000,000 chance of developing cancer because of benzene ingestion by drinking water.*

Hydrology I

Today's lecture

- Hydrology and its issues
- Water sources and hydrological cycle
- Water budget: water mass balance
- Surface water topics: Watershed, hydrograph, runoff coefficient

Hydrology

- 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 hydrology1: flood and droughts

- Flood and droughts

Issues of hydrology2: climate change

- Climate change

Issues of hydrology3: water use sustainability

1973 1989 2003 2010

Aral Sea,
Kazakhstan & Uzbekistan

Sustainability problem particularly significant

- For dry regions
- In regions with high water demand (high population, significant agricultural activities, etc.)
- When the residence time for the water sources is long
- When the water sources are shared by multiple countries

Issues of hydrology3: water use sustainability

Land subsidence due to unsustainable groundwater pumping

Issues of hydrology4: sinkholes

Water balance and residence time

Table 1.1 Estimate of the Water Balance of the World

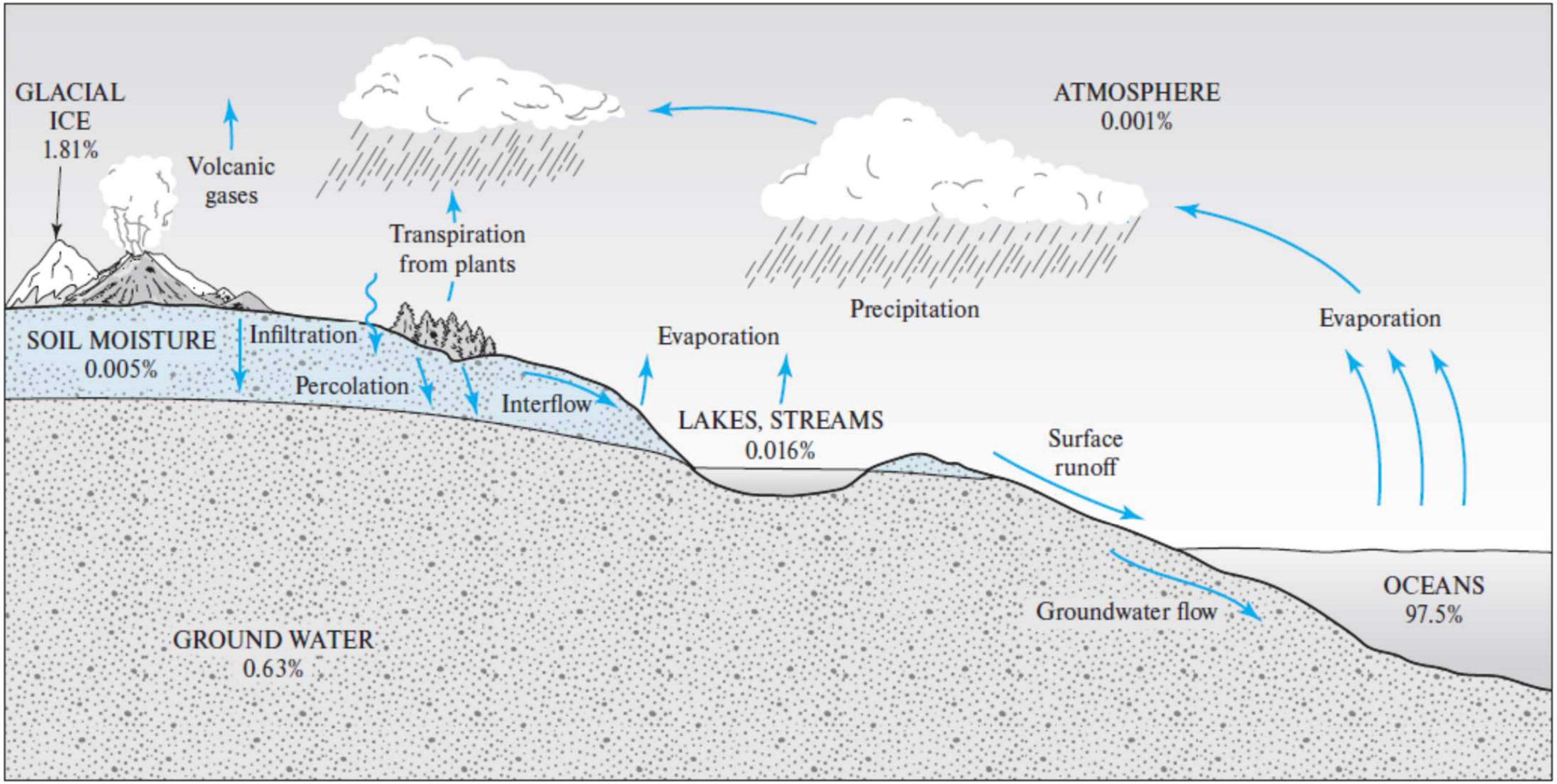
Parameter	Surface area $(km^2) \times 10^6$	Volume $(km^3) \times 10^6$	Volume (%)	Equivalent depth (m)*	Residence time
Oceans and seas	361	1370	94	2500	~4000 years
Lakes and reservoirs	1.55	0.13	<0.01	0.25	~10 years
Swamps	<0.1	<0.01	<0.01	0.007	1–10 years
River channels	<0.1	<0.01	<0.01	0.003	~2 weeks
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
  → only a small fraction of total water volume on the Earth
- Long residence time for groundwater
  → once depleted, long time required for recovery (often effectively nonrenewable)
- Significant temporal and spatial variation of freshwater availability & water needs
  → dams, reservoirs, pipelines, etc. needed

Hydrological cycle

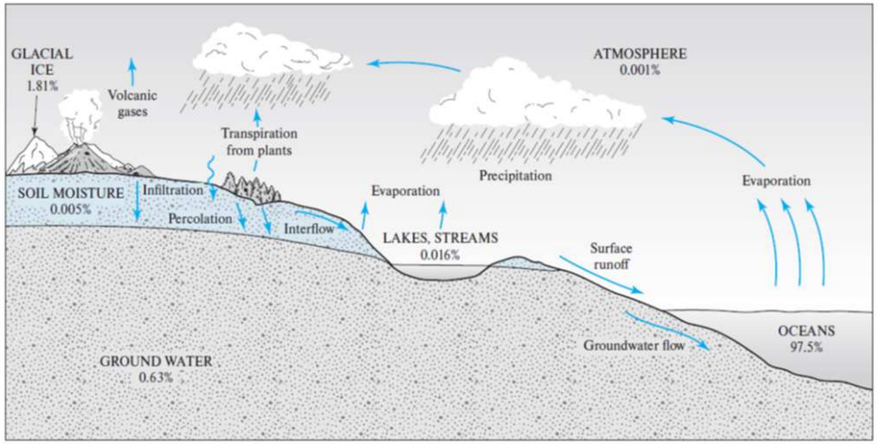


Processes in the hydrological cycle

- 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

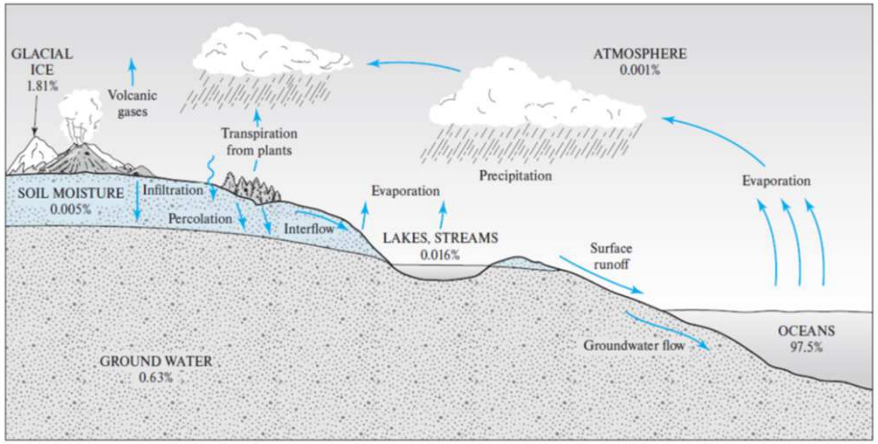
    * evapotranspiration = evaporation + transpiration

- Earth’s atmosphere → surface
  - precipitation (rain+snow+hail+…)



Processes in the hydrological cycle

- Within Earth's surface
  - surface 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

- Water budget: mass balance for water

  (rate of accumulation) = (rate in) – (rate out)

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

ΔS/Δt = change in storage over time [L^3/T]

ex) For a lake: define the control volume as the lake itself

- 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

$$\frac{\Delta S}{\Delta t} = (Q_{in} + P + R + I_{in}) - (Q_{out} + E_T + I_{out})$$

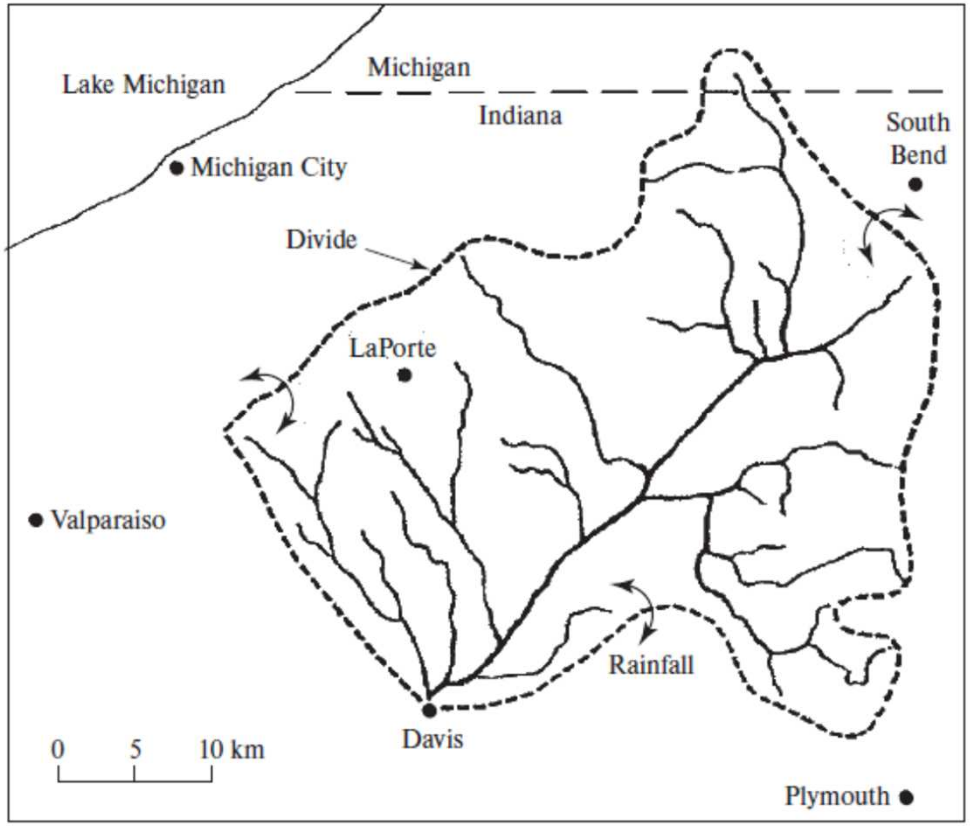
Water budget

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

Watershed

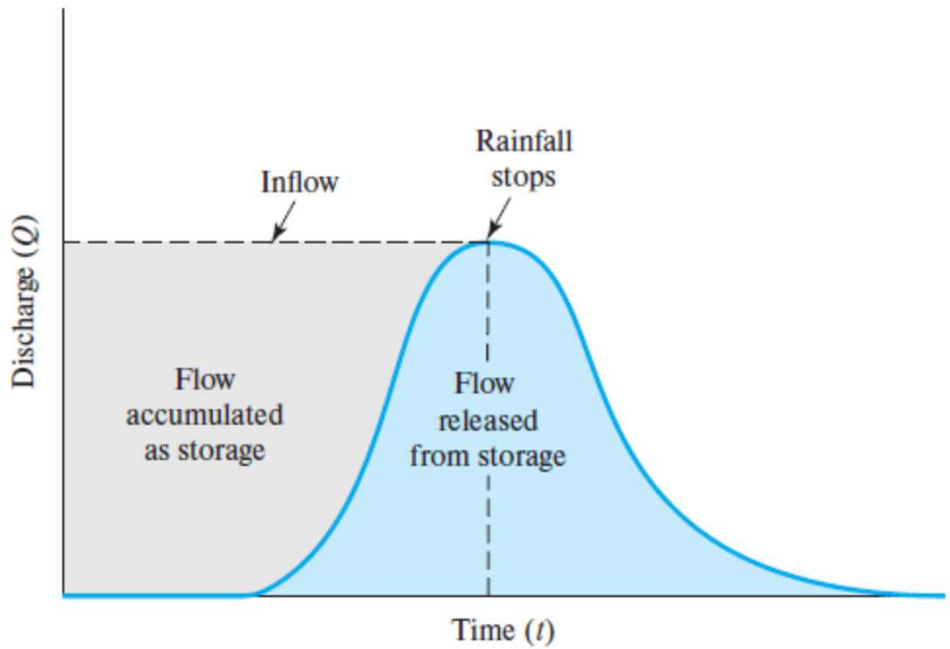
- **Watershed (basin)**: the area of land where all of the water that is under it or drains off of it goes to the same place

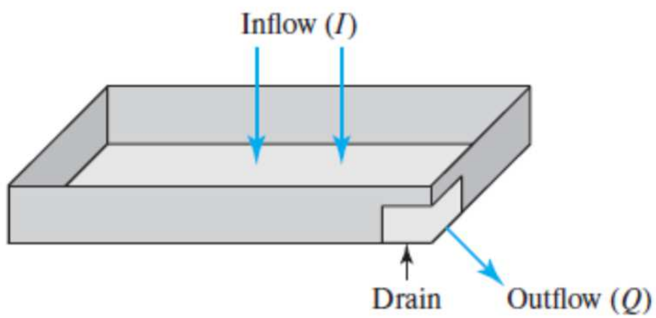
- **Divide**: the boundary of the watershed



Hydrograph

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





An example hydrograph for a simple parking lot

FIGURE 7–8a

Ten-year hydrograph for Convict Creek near Mammoth Lakes, California.

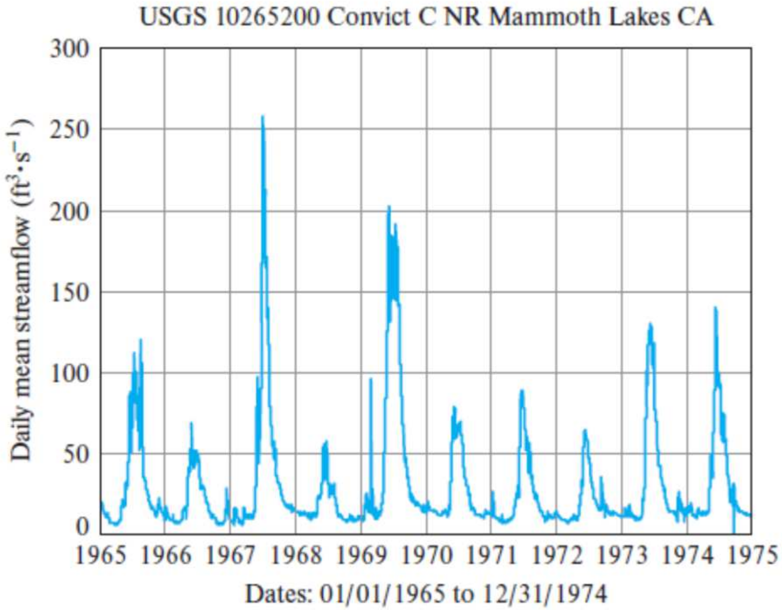
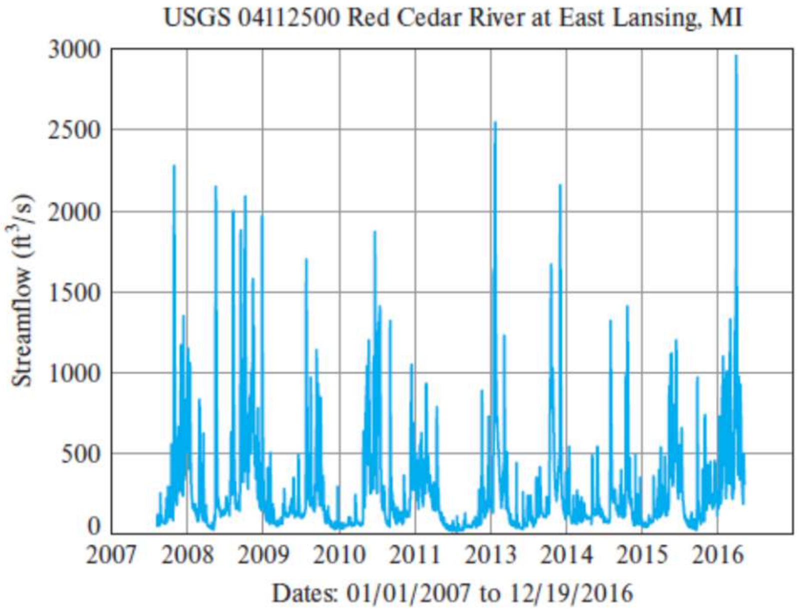


FIGURE 7–8b

Hydrograph for the Red Cedar River at East Lansing, Michigan.



of the watershed, density and type of ground cover, …

Runoff coefficient

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

TABLE 7–1 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.

Runoff coefficient

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

Suggested readings

[ENG] pp. 267 – 277

[KOR] pp. 259 – 269

Next class

Hydrology II

- Impact of urban development on hydrology
- Ways to reduce the impact
- Groundwater hydrology

Slide #14 solution

The control volume is the lake.

Input processes

$Q_{in} = 1.5\ m^3/s$

$P = 9.1\ cm/month$

No seepage in, no runoff into the lake

Output processes

$Q_{out} = 1.25\ m^3/s$

$E = 19.4\ cm/month$

No transpiration, no seepage out

$$\frac{\Delta S}{\Delta t} = (Q_{in} + P) - (Q_{out} + E)$$

Need a unit of m/month

$$\frac{\Delta h}{\Delta t} = \frac{\Delta S}{A_{lake}\Delta t}$$

$$= \frac{(1.5-1.25)\ m^3/s \times 86400\ s/day \times 30\ days/month}{708000\ m^2} + (9.1 - 19.4)\ cm/month\ \times 10^{-2}\ m/cm$$

$$= 0.8\ m$$

$$h = h_0 + \frac{\Delta h}{\Delta t} \cdot \Delta t = 19.0\ m + 0.8\ m = \mathbf{19.8\ m}$$

Slide#19 solution

The control volume is the watershed.

Input processes

P = 77.7 cm/year

No other input processes for a watershed

Output processes

$Q_{out} = 39.6\ m^3/s$ (this is the "runoff" from the watershed!)

$I_{out} = 9.2 \times 10^{-7}\ m/s$

$E_T = 45$ cm/year

$$\frac{\Delta S}{\Delta t} = P - (Q_{out} + I_{out} + E_T) = (P - I_{out} - E_T) - Q_{out}$$

$$= (77.7\ cm/year - 9.2 \times 10^{-7}\ cm/s\ \times 86400\ s/day\ \times 365\ days/year - 45\ cm/year)$$

$$\times 10^{-2}\ m/cm \times 4530\ km^2\ \times\ 10^6\ m^2/km^2 - 39.6\ m^3/s\ \times\ 86400\ s/day\ \times 365\ days/year$$

$$= \boldsymbol{-1.08 \times 10^9\ m^3/year}$$

Converting the Q_{out} into cm/year:

$$\frac{39.6\ m^3/s \times 86400\ s/day \times 365\ days/year}{4530\ km^2 \times 10^6\ m^2/km^2} \times 10^2\ cm/m = 27.6\ cm/year$$

Runoff coefficient = $\frac{27.6\ cm/year}{77.7\ cm/year} = \boldsymbol{0.36}$