Introduction to the Hydrologic Cycle

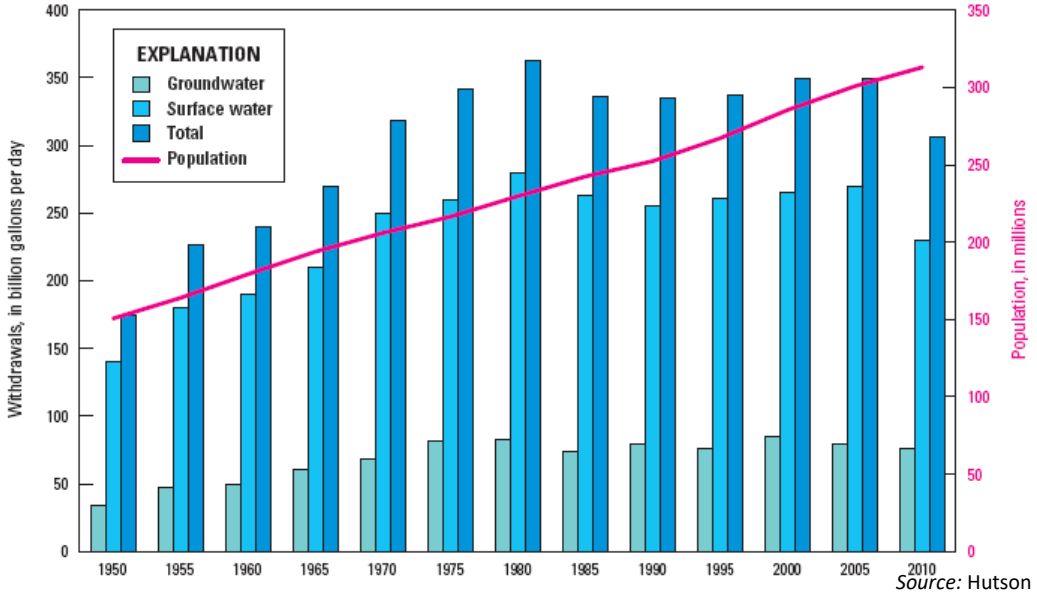
Today's agenda

- Why do we care about groundwater?
- Hydrologic cycle
- Water balance

So what?

Water In the U.S.

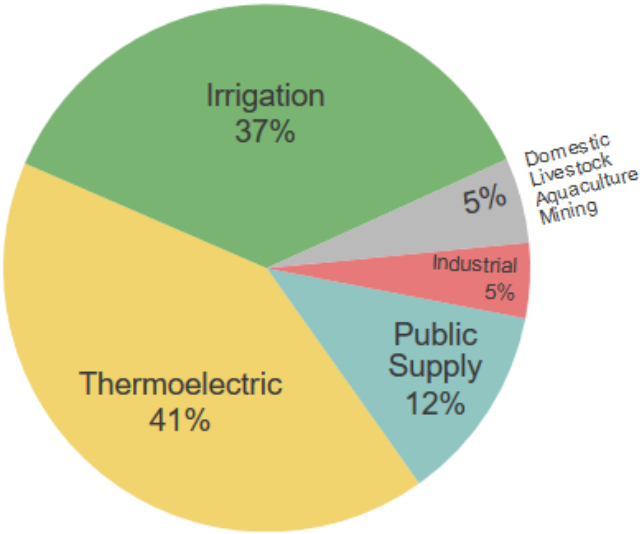
How much are we using?



Trends in population and freshwater withdrawals by source, 1950–2010.

Source: Hutson et al., Estimated use of water in the United States 2000, USGS Circular 1268, 2004.

How is it being used?



Who is using it?

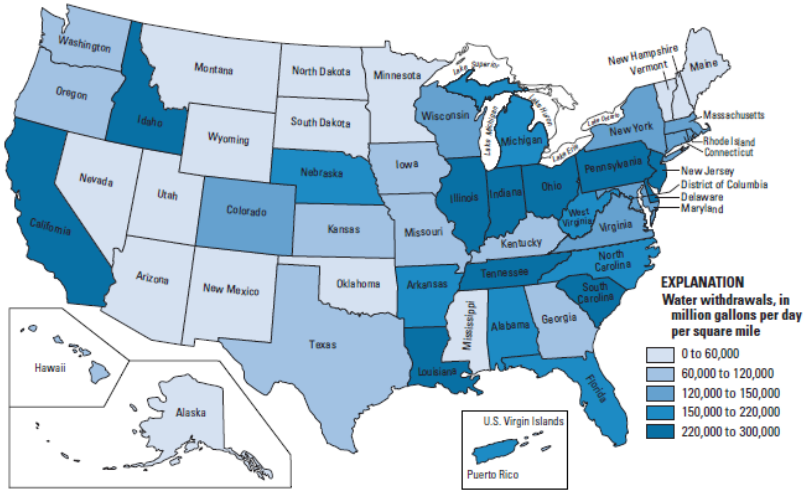
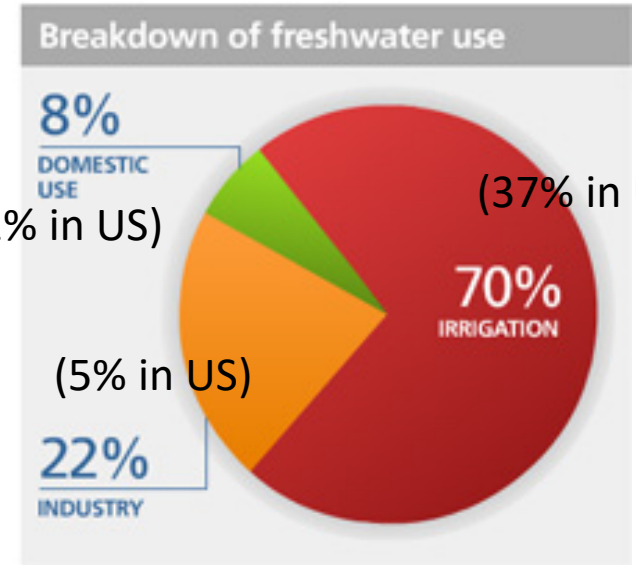


Figure 4. Intensity of freshwater withdrawals, 2000.

Water In the U.S.

How much water do we use?

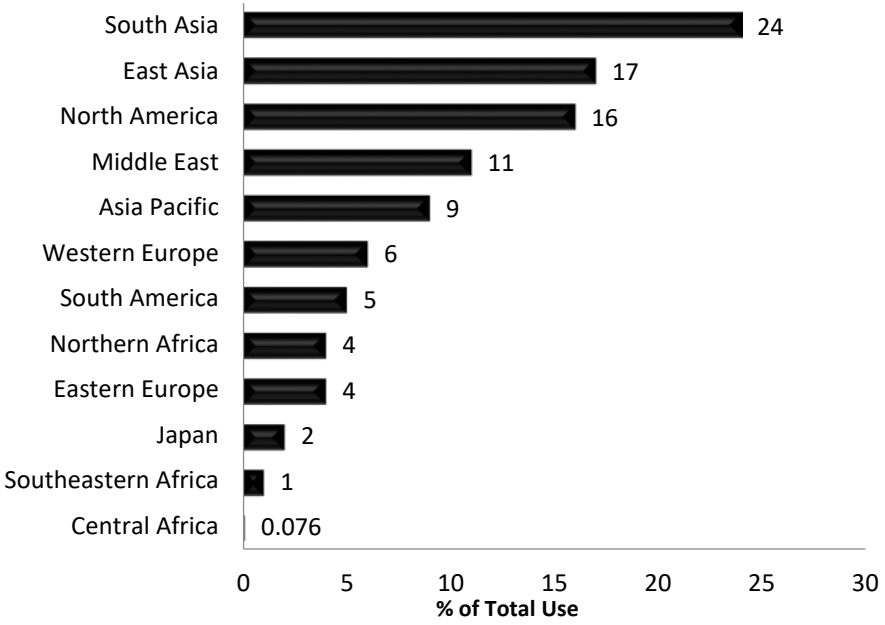
In the World



(12% in US)

(37% in US)

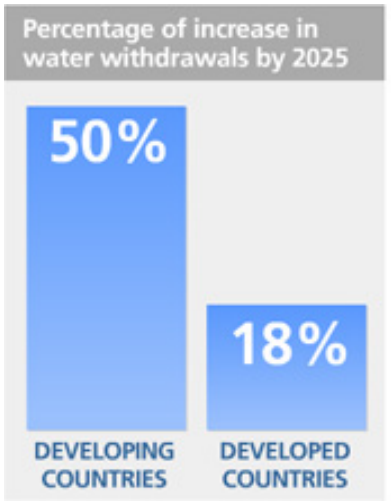
(5% in US)



Domestic Water Use (selected countries)	[Gallons/day]
Canada	209
U.S.	176
South Africa	44
Egypt	40
Costa Rica	23
Honduras	9
Ghana	9
Mozambique	3

www.water.org

Per capita water consumption in developed countries is on average about 10 times more than in developing countries



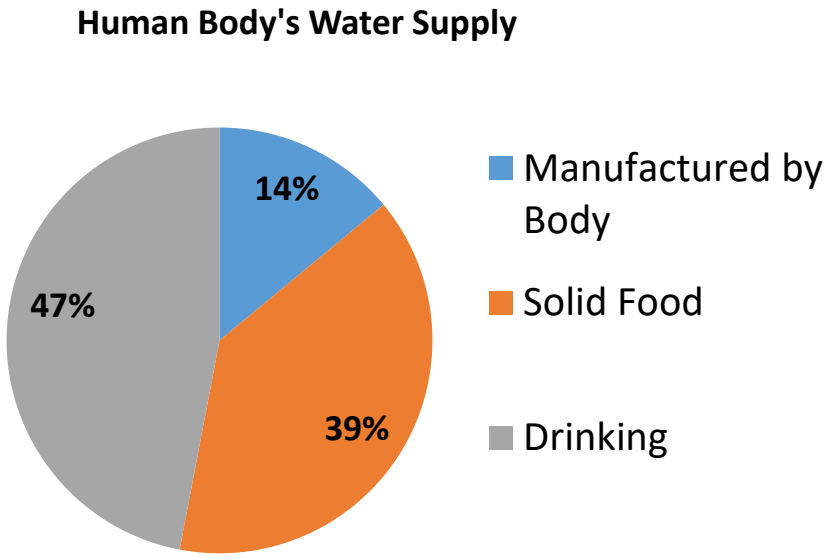
http://www.unwater.org/statistics_use.html

Water Content of Things

You:

- The human body is ~65% water
- Typical consumption is 2-3 liters/day

Note: 1L of water weighs ~1kg



Item	Liters of water
Beverages (per L)	
Glass of water	~1
Bottled water	3-4
Glass of beer	300
Produced Goods (per Kg)	
Roasted coffee	21,000
Tea	9,200
Cotton Textile	11,000
Microchip	16,000
Hamburger	16,000
Crops (per Kg)	
Corn	900
Sugar	1,500
Assorted animals (per Kg meat)	
Goat	4,000
Beef	15,000-70,000
Chicken	3,500-5,700

Source: Gleick et al., The World's Water 2008-2009 The Biennial Report on Freshwater Resources, Island Press, Washington, D.C., 2009.

Relative Merits of Surface and Subsurface Reservoirs

Surface Reservoirs	Subsurface Reservoirs
Disadvantages	**Advantages**
Few new sites free (in USA)	Many large-capacity sites available
High evaporative loss, even in humid climates	Practically no evaporative loss
Need large areas of land	Need very small areas of land
May fail catastrophically	Practically no danger of failure (structural)
Varying water temperature	Water temperature uniform
Easily polluted	Usually high biological purity, although pollution can occur

Surface Reservoirs	Subsurface Reservoirs
Advantages	**Disadvantages**
Water may be available by gravity flow	Water must be pumped
Multiple usage (recreation)	Only uses are storage and conveyance
Usually low mineralization of water	Water may be highly mineralized
Maximum flood control value	Minor flood control value
Large flows	Limited flow at any one point
Relatively easy to investigate and manage	Expensive and difficult to investigate and manage
Low maintenance costs	Maintenance of recharge areas or wells must be continuous and is expensive

Hydrology:

Describes and predicts the occurrence, distribution, movement, and chemistry of all water on earth.

Hydrogeology:

The study of groundwater and its interaction with and through the geologic environment.

Geohydrology:

Sometimes a synonym for hydrogeology. Primarily in engineering fields.

Underground Water or Subsurface Water:

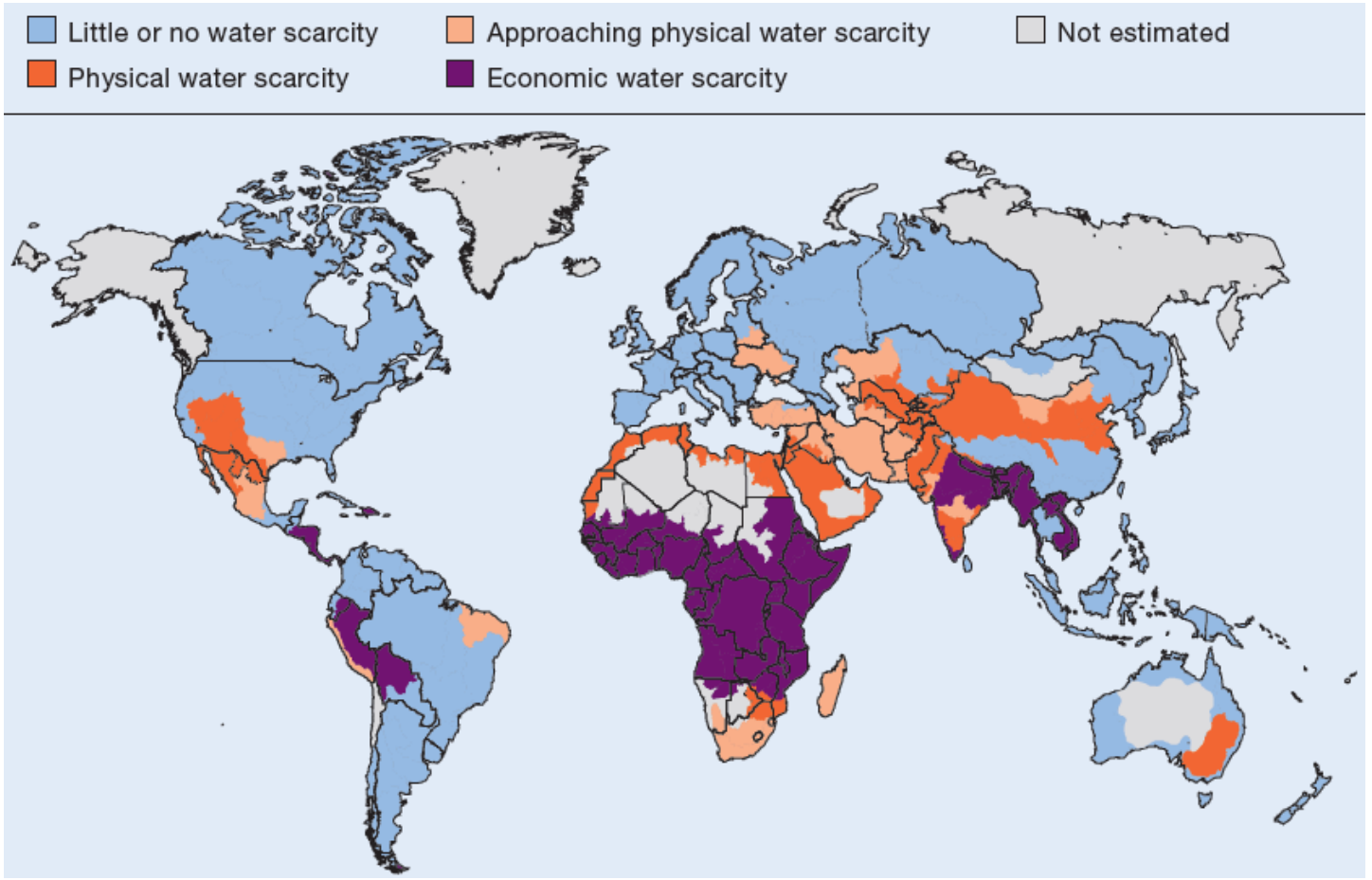
- All water below the surface of the earth
- Groundwater hydrology deals primarily with the water in the saturated zone (groundwater occurs beneath the water table) and in the upper few km
- There is also water in the unsaturated zone (soil moisture)
- We will discuss both groundwater flow in the saturated and unsaturated zones

Hydrogeologists deal with 2 primary issues:

Water Supply
Water Quality

Supply:

- How much water can we extract? (sustainably?)
- Where should we pump from to extract the most with the least impact?



Problems: Water Supply
Water Quality

Source:
International Water Management Institute, A Comprehensive Assessment of Water Management in Agriculture, 2007

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Quality:

- How much and where should we pump in order to ensure good water quality?
- Contaminant transport: if there's a spill, where is it going? How can we clean it up (remediation)?

All water bodies are vulnerable to contamination

These include:

- Oceans
- Estuaries
- Lakes
- Rivers/streams
- Wetlands
- Groundwater

Major sources of contamination (mostly anthropogenic):

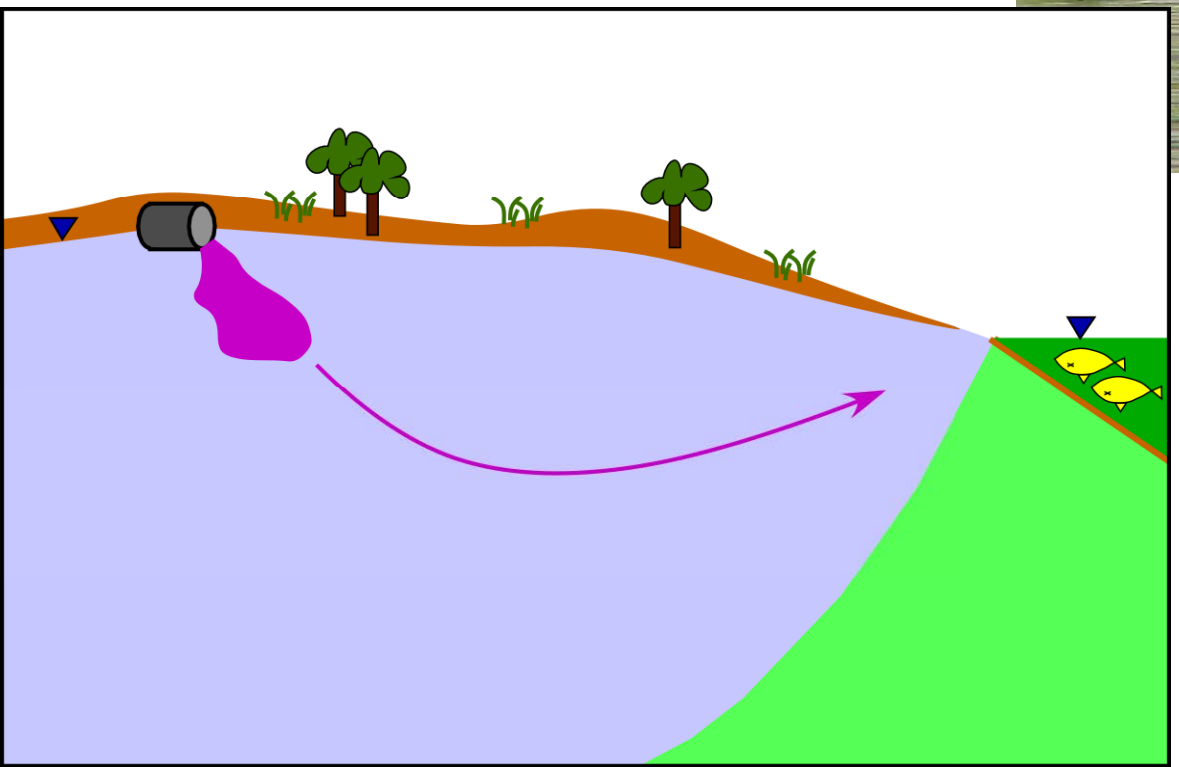
- Municipal
- Industrial
- Agricultural

Major types of contamination:

- Chemicals
- Nutrients
- Pathogens
- Sediment and debris
- Temperature

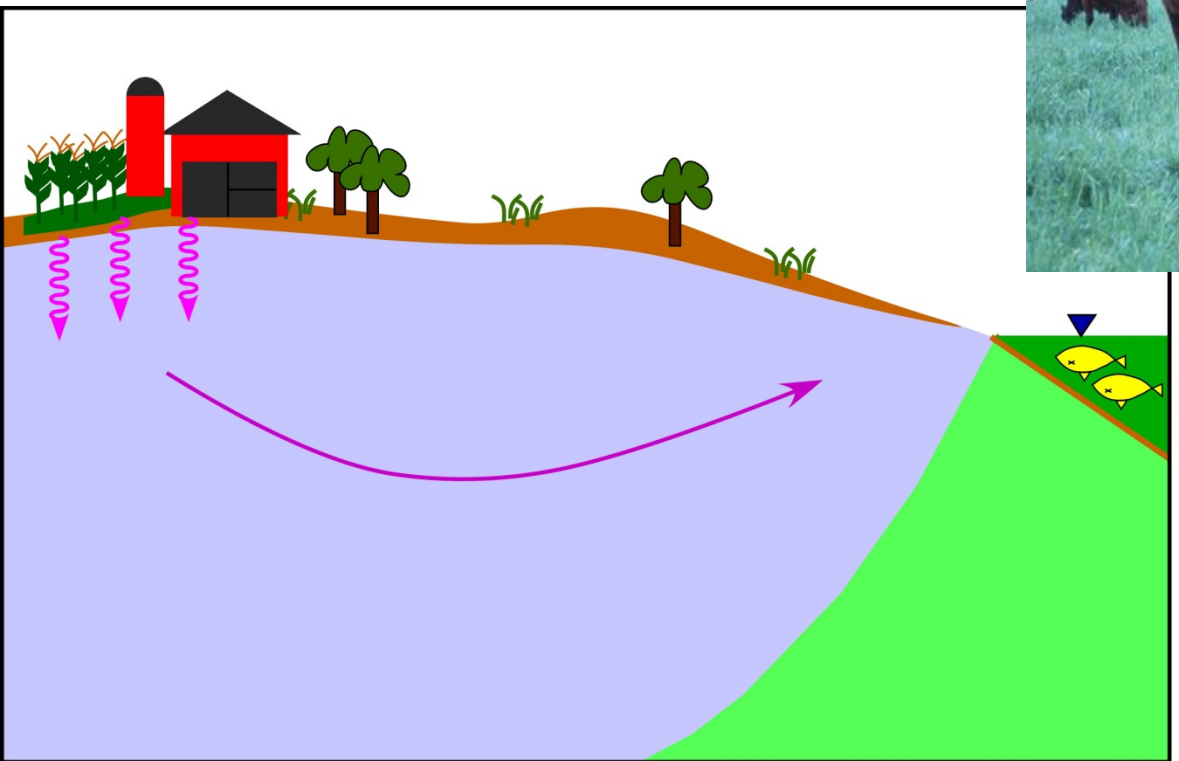
Point-Source Pollution:

- Industrial Effluent
- Wastewater treatment plants
- Oil and chemical spills
- Leaky underground storage tanks
- Leaky or unlined landfills



Nonpoint-Source Pollution:

- Agriculture: fertilizers, herbicides, insecticides (also lawns)
- Urban runoff and energy production: oil, grease, chemicals
- Human disturbance: excess sediment
- Acid mine drainage
- Road salt
- Livestock, septic systems:
  bacteria and nutrients
- Atmospheric deposition



Groundwater Contamination In the U.S.

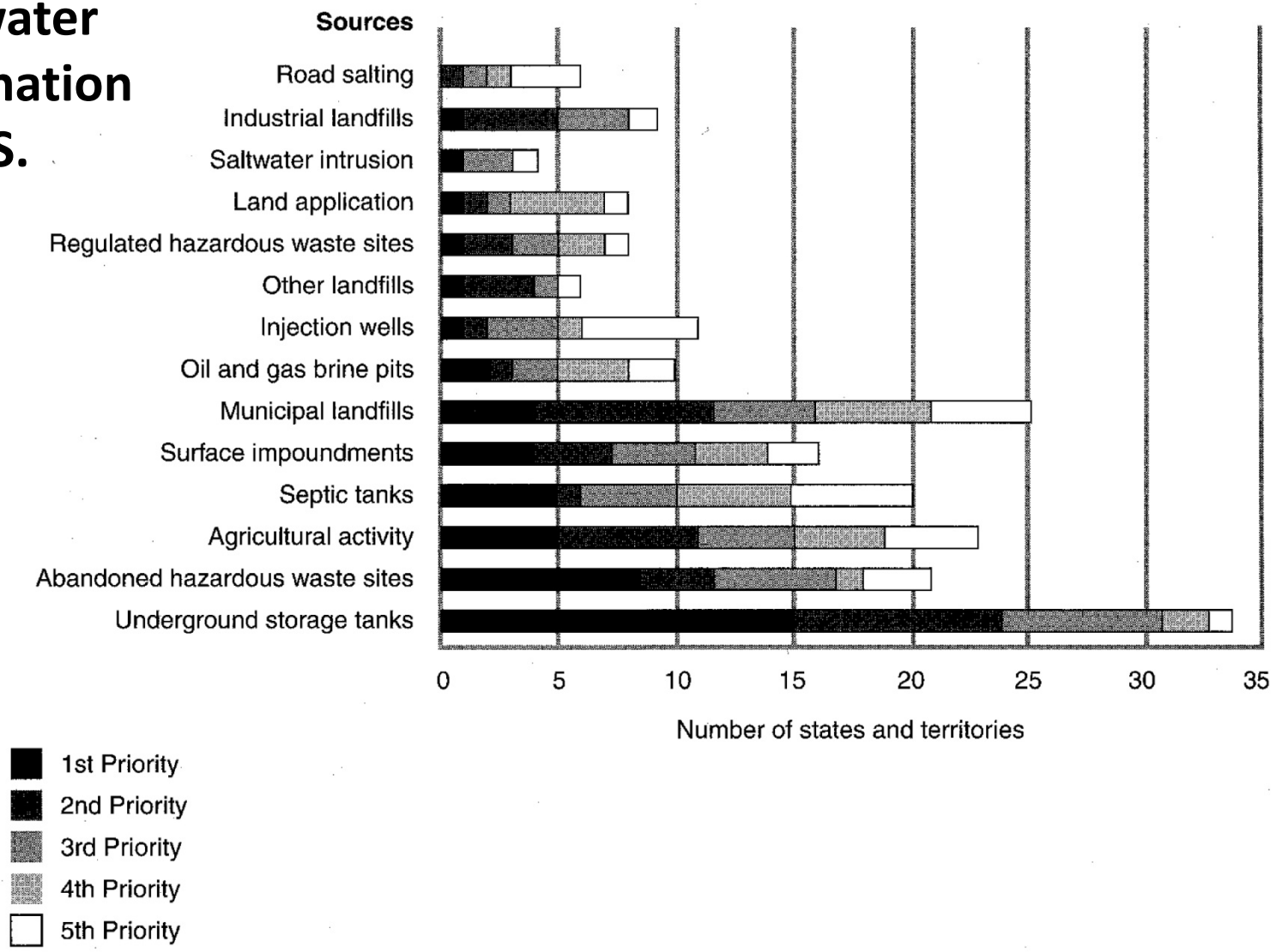
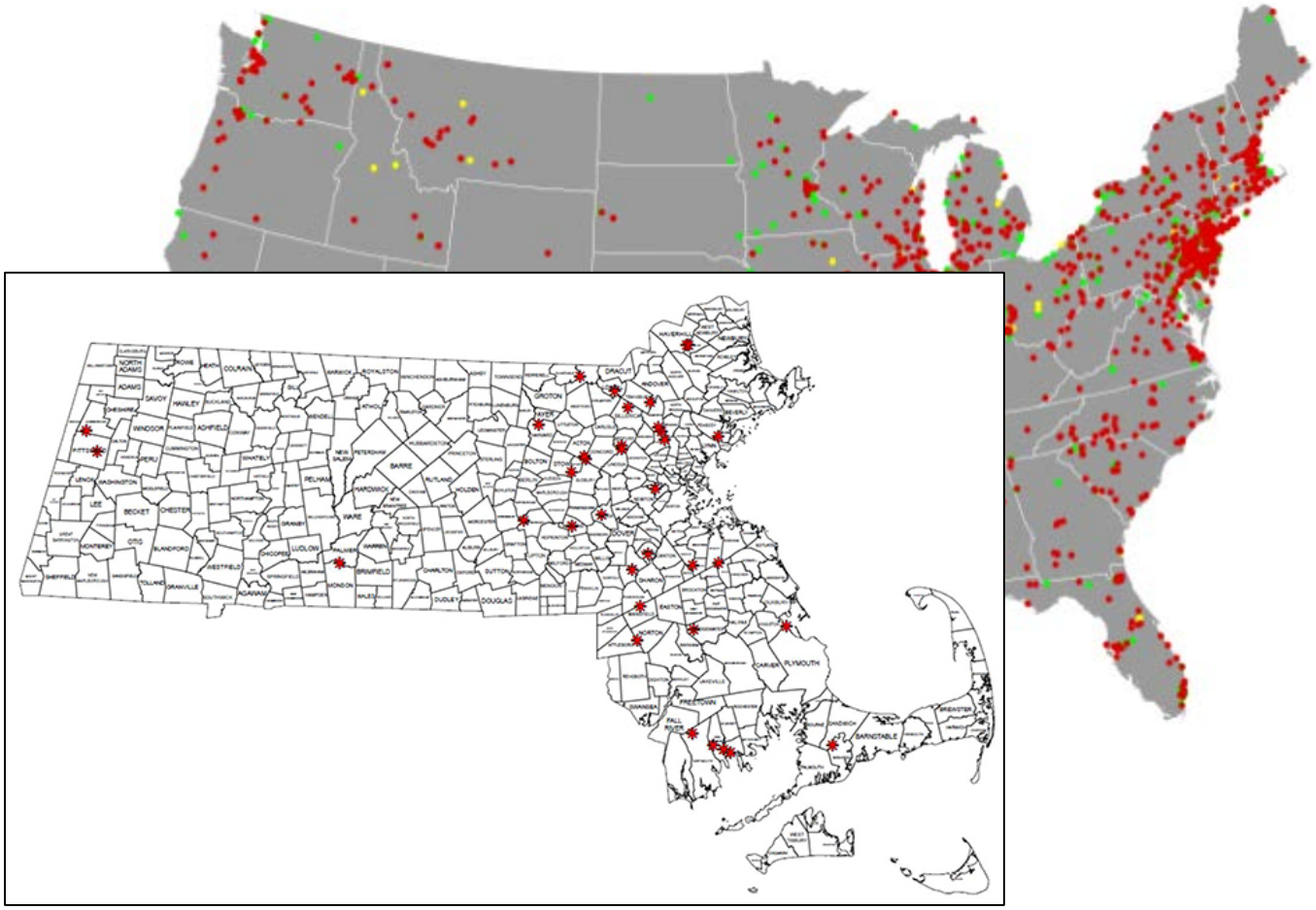
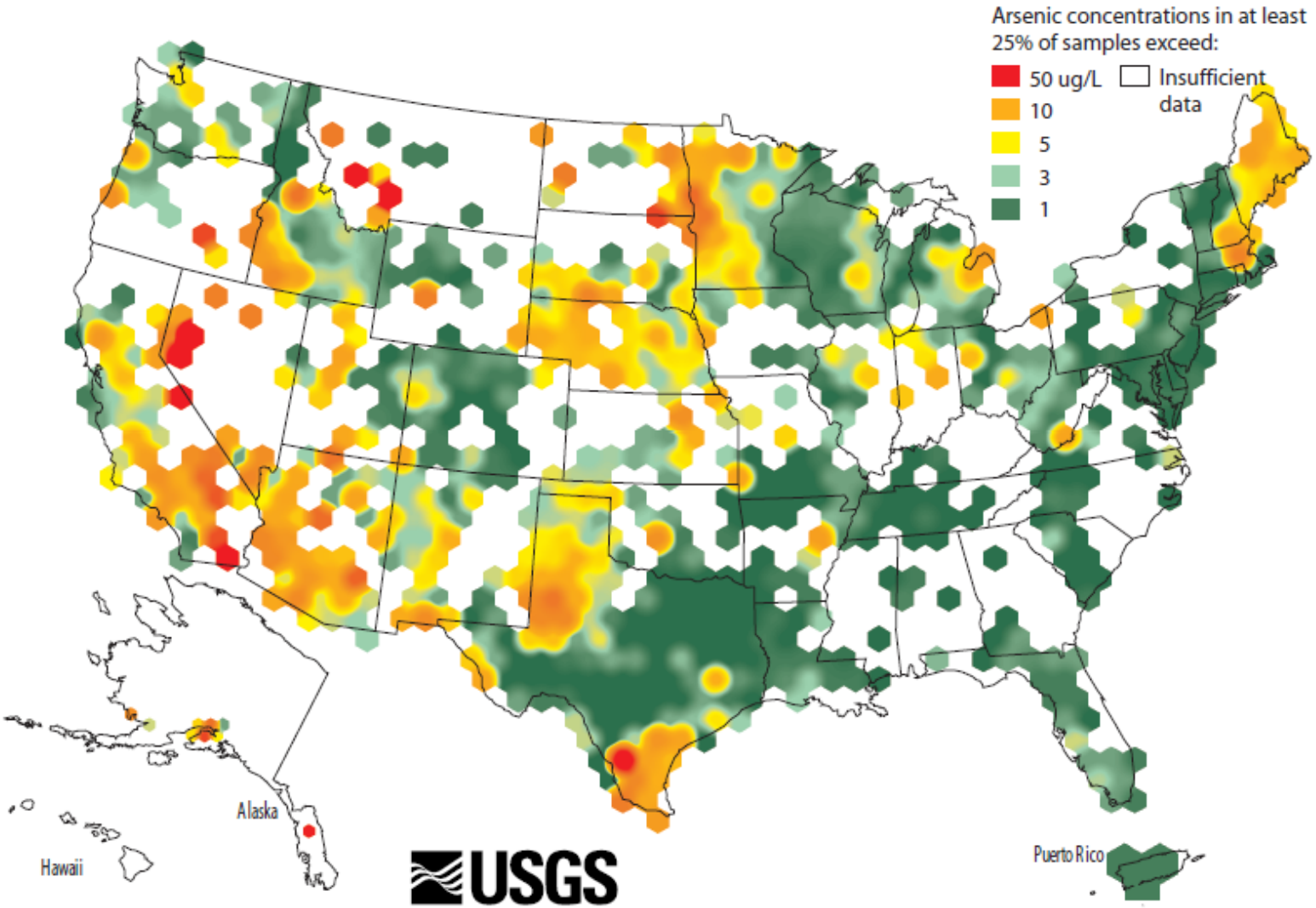


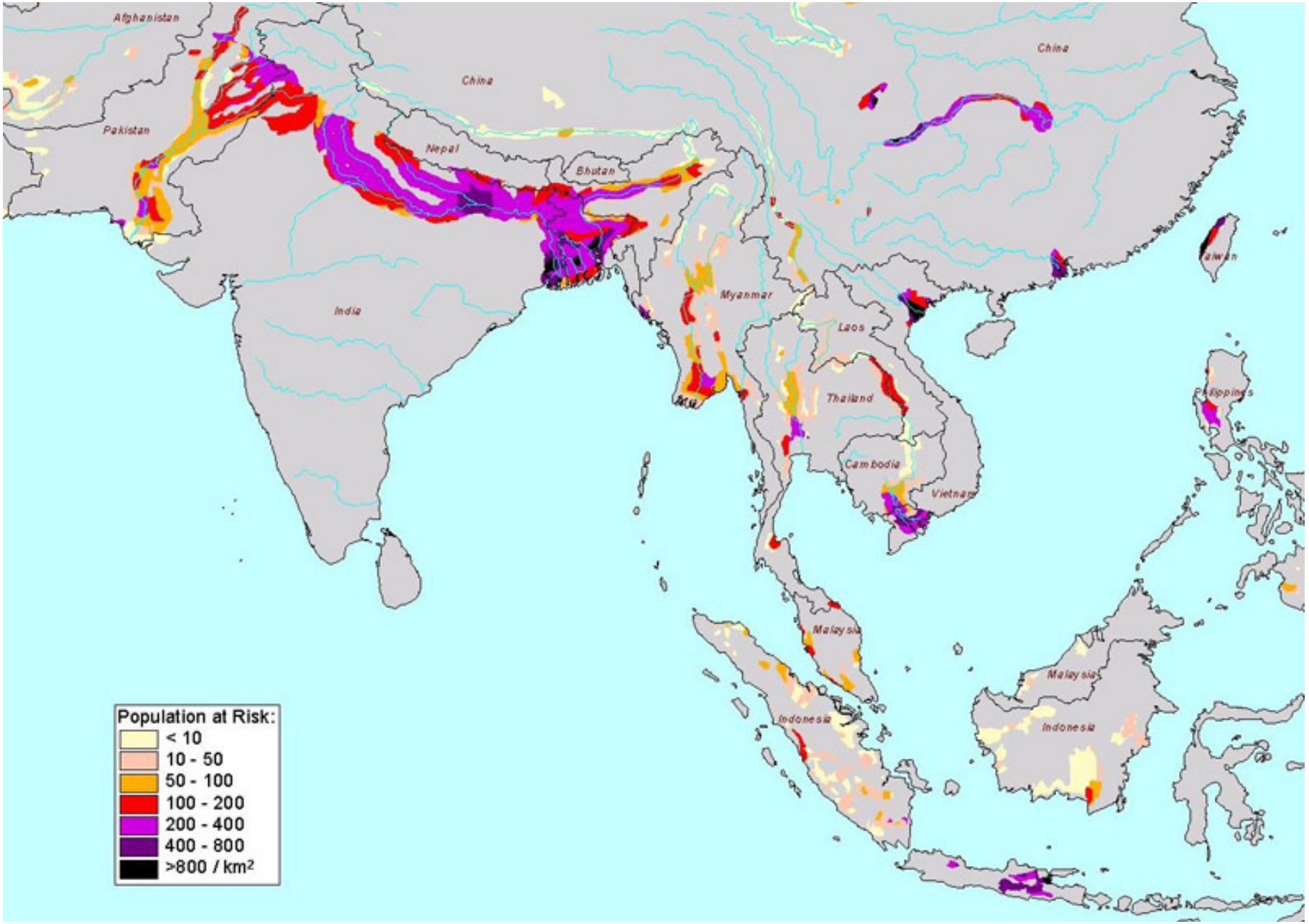
Figure 9.20 Sources of groundwater contamination ranked in terms of priority by states and territories of the United States.
(From EPA, 1990a.)

Superfund site locations

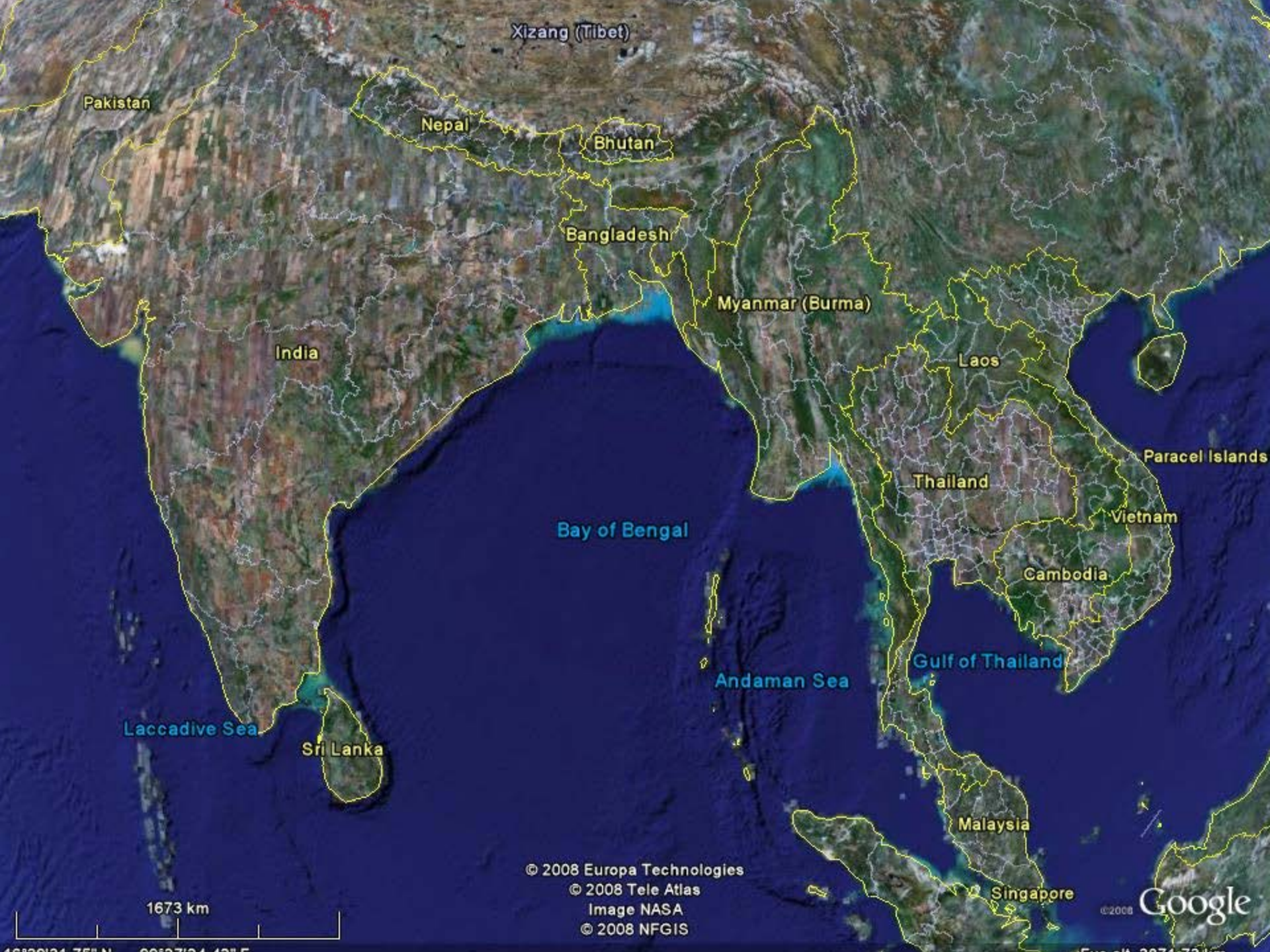




Source: Ryker, S.J., Nov. 2001, Mapping arsenic in groundwater: Geotimes v.46 no.11, p.34-36.



Source: Royal Geographical Society, www.rgs.org


Xizang (Tibet)
Pakistan
Nepal
Bhutan
Bangladesh
Myanmar (Burma)
India
Laos
Paracel Islands
Thailand
Vietnam
Bay of Bengal
Cambodia
Gulf of Thailand
Andaman Sea
Laccadive Sea
Sri Lanka
Malaysia
Singapore
1673 km
© 2008 Europa Technologies
© 2008 Tele Atlas
Image NASA
© 2008 NFGIS
©2008 Google


Assam
Bihar
Rajshahi
Sylhet
Dhaka
Bangladesh
Tripura
Bangladesh
West Bengal
Jharkhand
Khulna
Chittagong
Orissa
Image © 2008 DigitalGlobe
Image © 2008 TerraMetrics
© 2008 Europa Technologies
© 2008 Tele Atlas
23°11'48.91" N 90°19'25.04" E

https://en.wikipedia.org/wiki/Sundarbans

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Other issues:

- engineering: dams, levees, basements!

Dam failure

This 700 ft section of levee slid into the east side of the Mississippi River on August 23, 1983 at Darrow, in Ascension Parish, Louisiana. Groundwater flow processes likely contributed to this failure.

http://web.mst.edu/~rogersda/levees/

My Ph.D. Adviser's basement

Hydrologic Cycle

- List of reservoirs
- List of pathways “Fluxes”

Some Definitions:

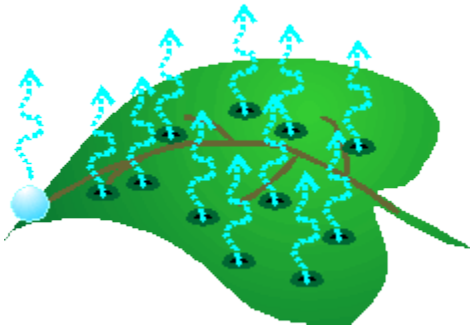
Runoff- That part of the precipitation that appears in surface streams. It is the same as streamflow

Some Definitions:

Precipitation- All water that falls from the atmosphere

Evapotranspiration (ET)- A collective term -> includes evaporation, transpiration, and sublimation.

- Of precipitation on the continents, most (62%) is evapotranspired



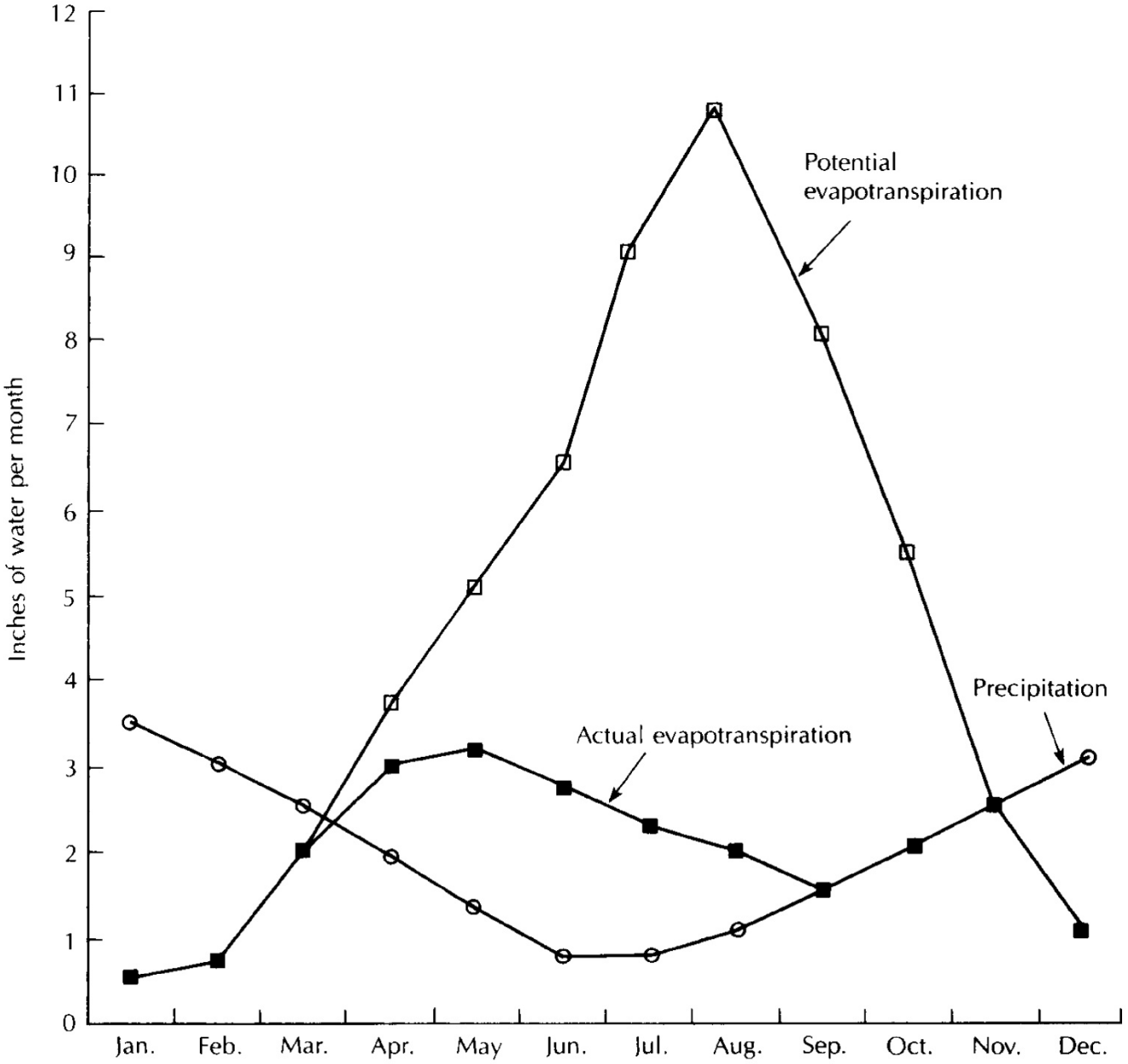
Some Definitions:

Precipitation- All water that falls from the atmosphere to the earth's surface.

Evapotranspiration (ET)- A collective term -> includes evaporation, transpiration, and sublimation.

- Of precipitation on the continents, most (62%) is evapotranspired

Potential Evapotranspiration (PE)- Water loss that will occur if there is no deficiency of water (a function of the energy of the environment under maximum water conditions).



▲ FIGURE 2.2
Diagram of potential and actual evapotranspiration in an area that has coarse soil with limited soil-moisture storage; warm, dry summers; and cool, moist winters.