

Earth2Class Workshops for Teachers

The Source and Solution to Groundwater Arsenic Contamination

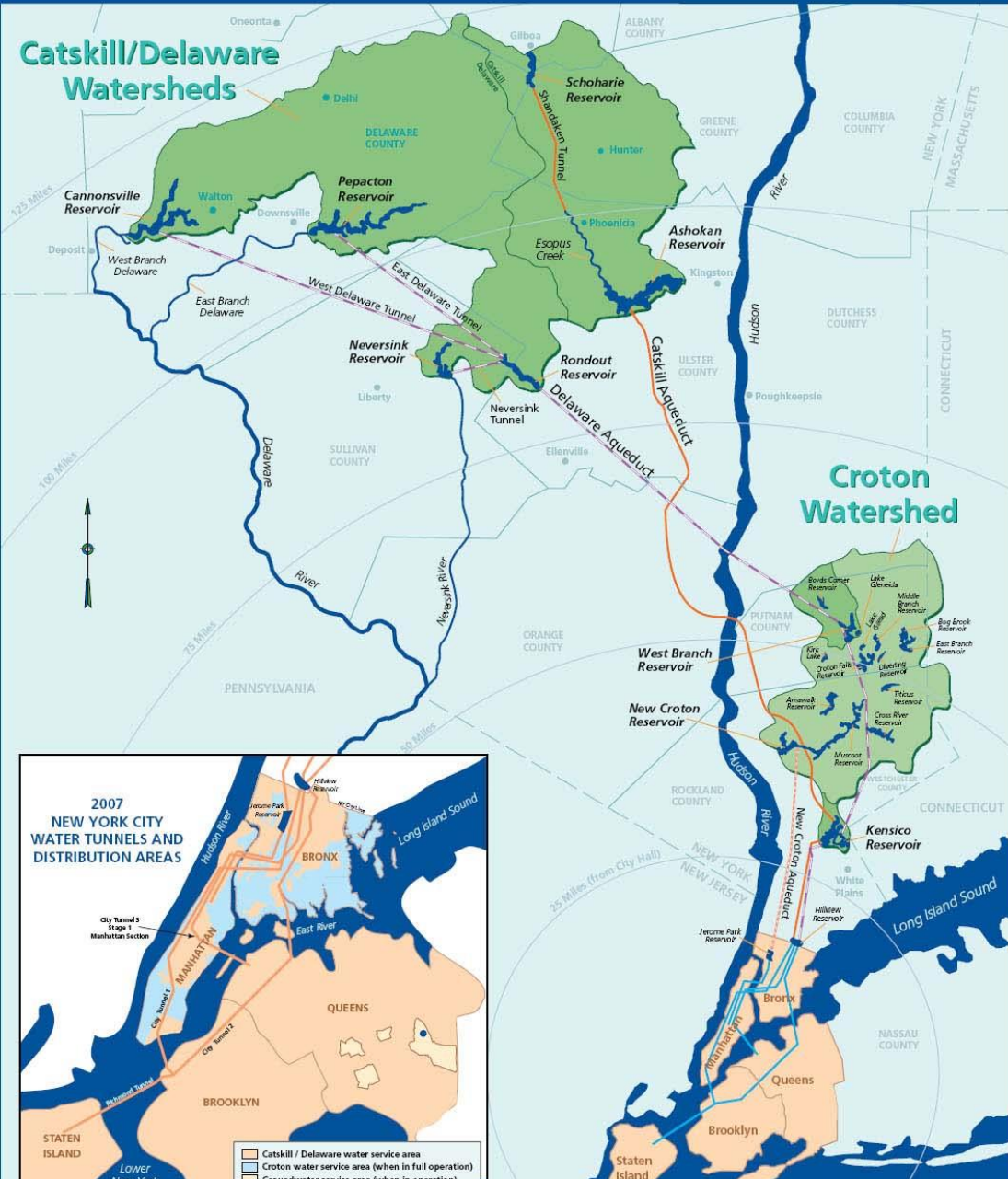
featuring

Dr. Benjamin Bostick

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New York City's Water Supply System



New York City has the greatest water supply system in the world! It can be traced back to the Great Fire of 1835, and even earlier. Each day, approximately 1,300 billion gallons of water flow through the tunnels, mains, and other parts of the NYC system.

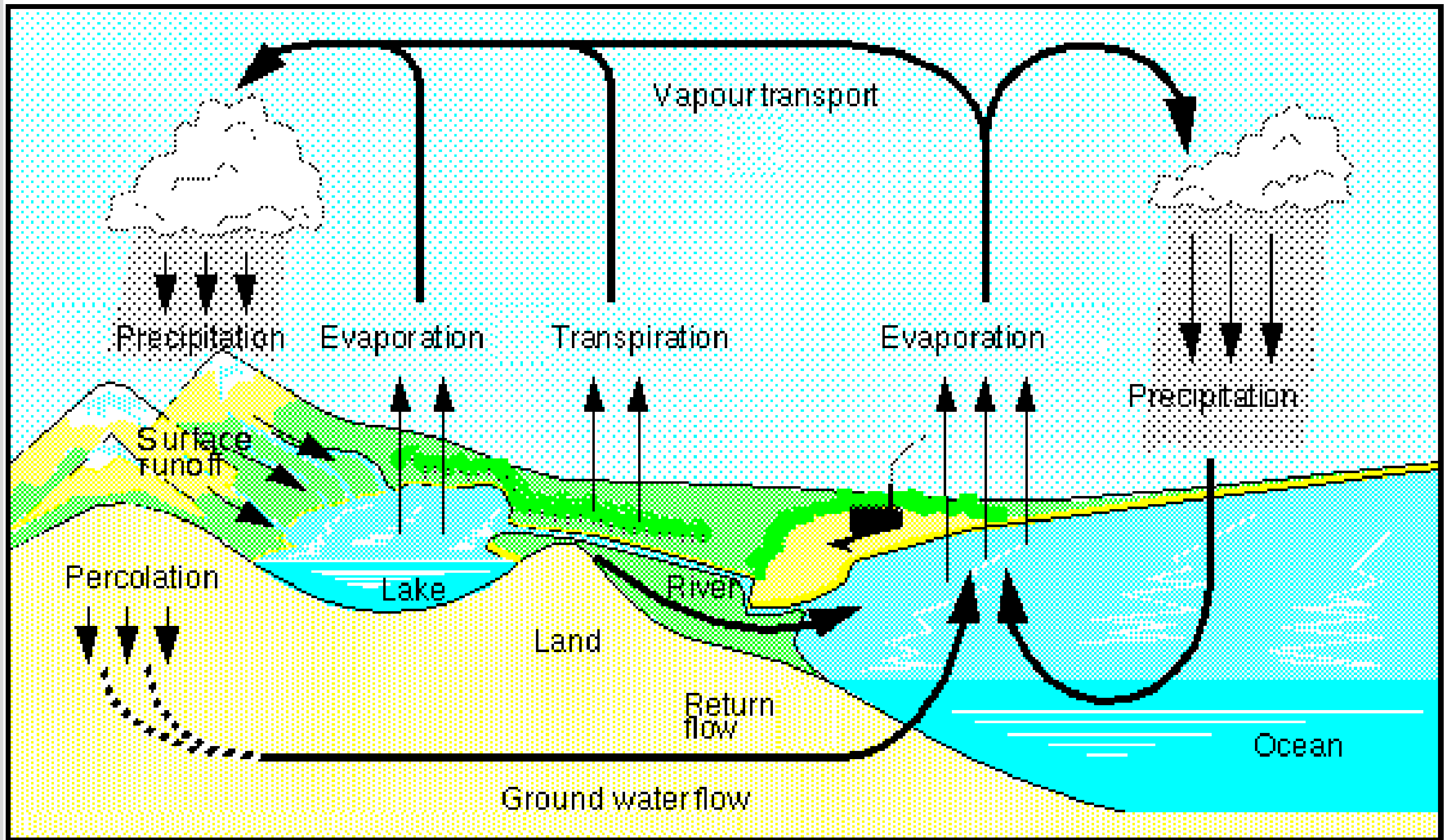
http://www.nyc.gov/html/dep/html/drinkinking_water/history.shtml



- Rockland County obtains its water from UW-New York, a subsidiary of Suez (French company)
- 70% comes from groundwater aquifers
- 30% comes from surface reservoirs

<https://www.unitedwater.com/newyork/water.aspx>

Groundwater begins with the Water Cycle

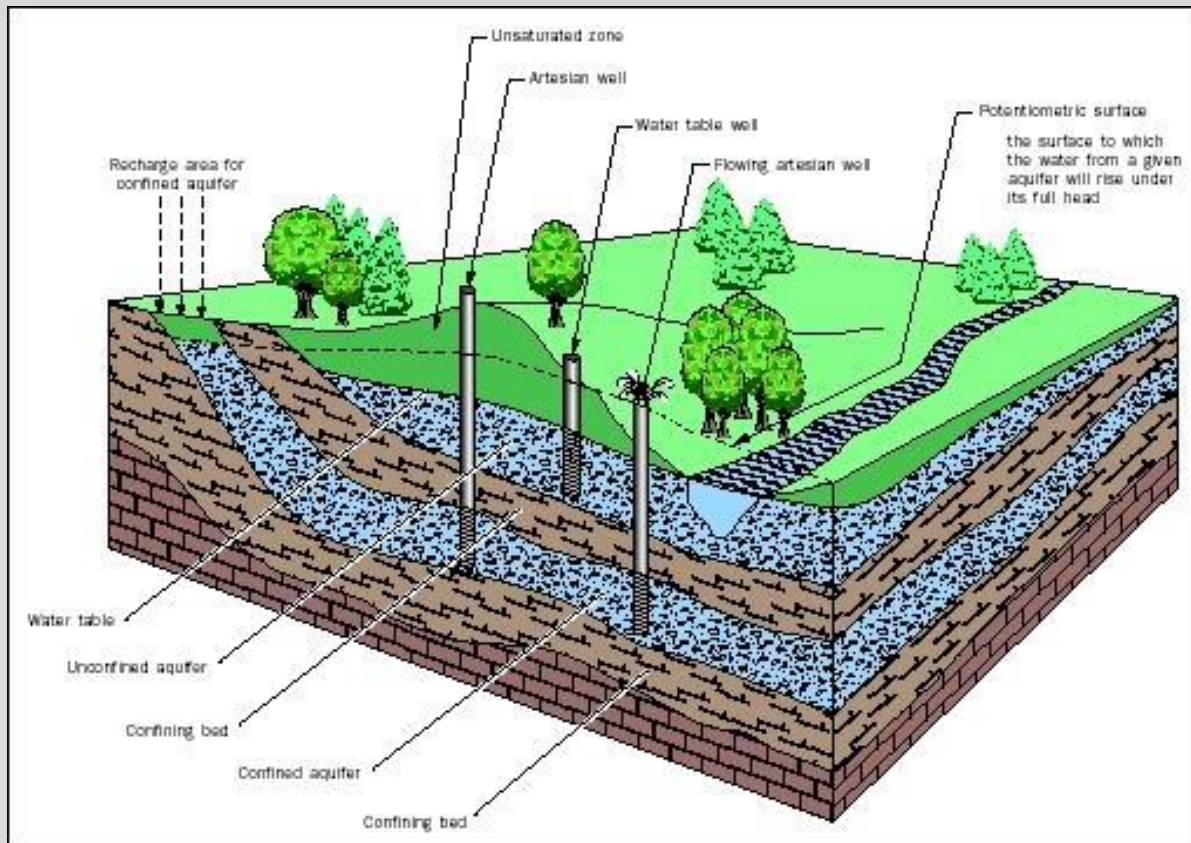


Courtesy Erich Roeckner, Max Planck Institute for Meteorology

Do you know these important groundwater terms?

- Porosity
- Permeable/
impermeable
- Capillarity
- Infiltration
- Percolation
- Aquifer
- Recharge
- Water Table
- Zone of Saturation
- Zone of Aeration
- Well

Water Table Characteristics



SOIL

- “Residual”—formed by slow weathering of bedrock
- “Transported”—deposited after erosion
 - “Glacial”—much of NY and northern NJ
 - “Loess”—wind-blown, much of mid-West
 - “Flood plain”—Mississippi Valley, Nile

http://soils.usda.gov/soil_survey/main.htm

Soil Horizons

In very generalized terms:

- “O” -- Organic
- “A” – Topsoil
- “B” – Subsoil
- “C” – weathered bedrock
- “D” – unweathered bedrock

Combined with groundwater zones, soils present some of the most complex ecosystems on our planet.

<http://www.mo15.nrcs.usda.gov/Education/wissoil/sld005.htm>

Soils, Zone of Aeration, and Zone of Saturation: “Porous Media”

Three-phase systems consisting of:

- Solid or mineral inorganic phase, often associated with organic matter
- Liquid or solution phase
- Gas phase (subsurface air)

Interact when system disturbed, then move toward equilibrium

Solid Phase

- Typically about 45 – 50% solids on a volume basis
[Simple Mathematical Model of P-P-C]
- Si and O are most abundant, found in most soil minerals
- Weathering produces chemical changes (such as formation of clay) and range of particle size (texture)
[Investigating Sediment Grain Sizes]

Selected aspects of soil chemistry

- Texture and structure affect movements of groundwater, pollutants, and soil micro-organisms
- Clay (mainly Al silicates) add surface area and electrical charge to soils
- Affects water retention capacity, flow through system—bacterial and pollutant

Liquid Phase

- Soil solution chemistry important for microorganisms, nutrient, and pollutant movement
- Soil pH and cations—may be acidic or alkaline
- Horizontal, vertical, and combined flow

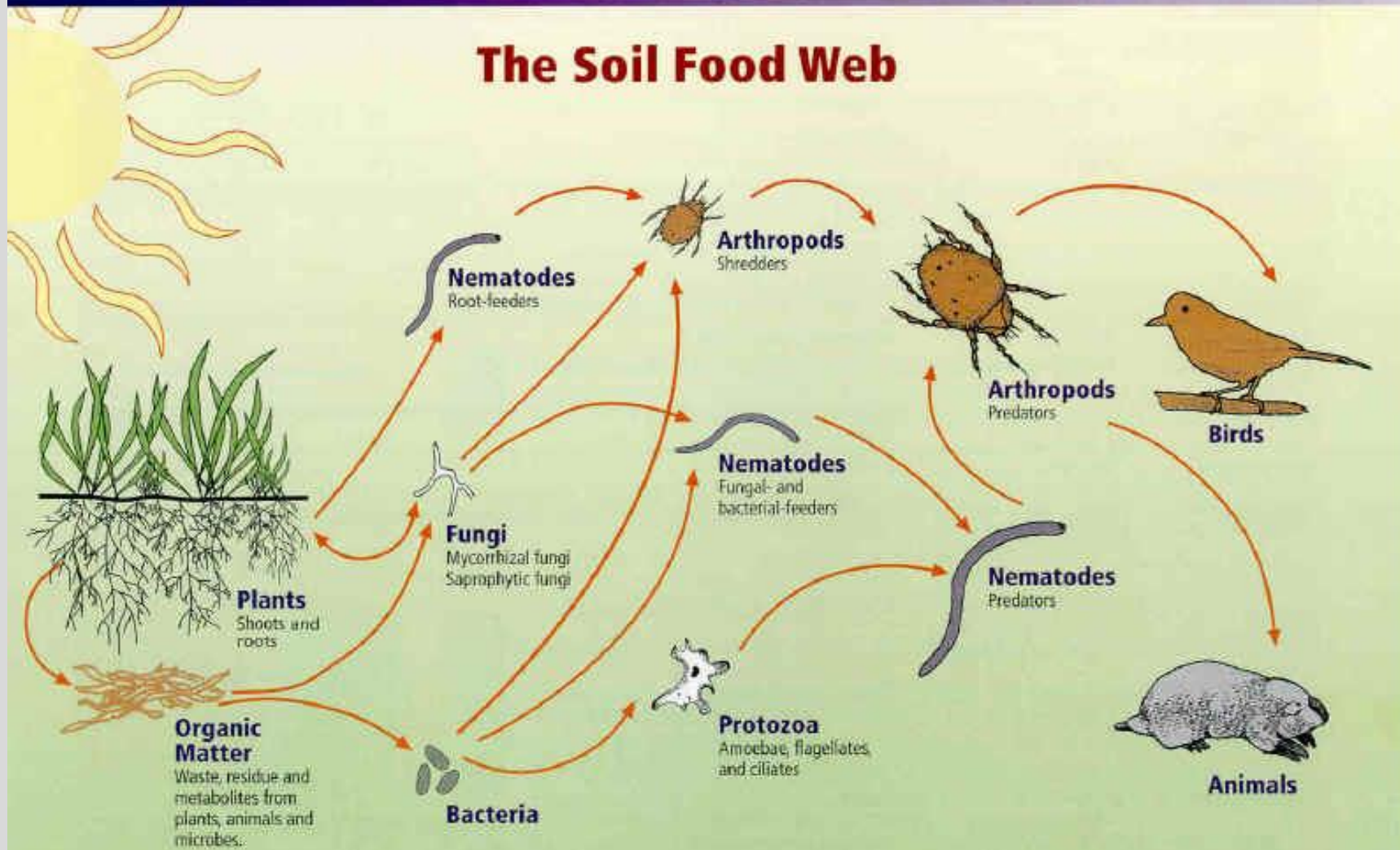
Soil Atmosphere

- Basically similar to air in well-aerated soil
- In fine clay, more N, less O, more CO₂
- Soil microorganisms and plants will greatly affect relative proportions, especially when not well-aerated
- Mainly moved by diffusion, but can also move with porous medium by mass flow due to pressure differences (more water)

Soil Microorganisms

- Viruses
- Bacteria
- Fungi
- Algae
- Protozoa
- Annelids, insects, other animals
- Plants

The Soil Food Web



First trophic level:
Photosynthesizers

Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders

Third trophic level:
Shredders
Predators
Grazers

Fourth trophic level:
Higher level predators

Fifth and higher trophic levels:
Higher level predators

Bacteria: Key to Healthy Soils

A ton of soil bacteria may be in just a few meters beneath a hectare of soil (below)



Bacteria on fungi hyphae (above)

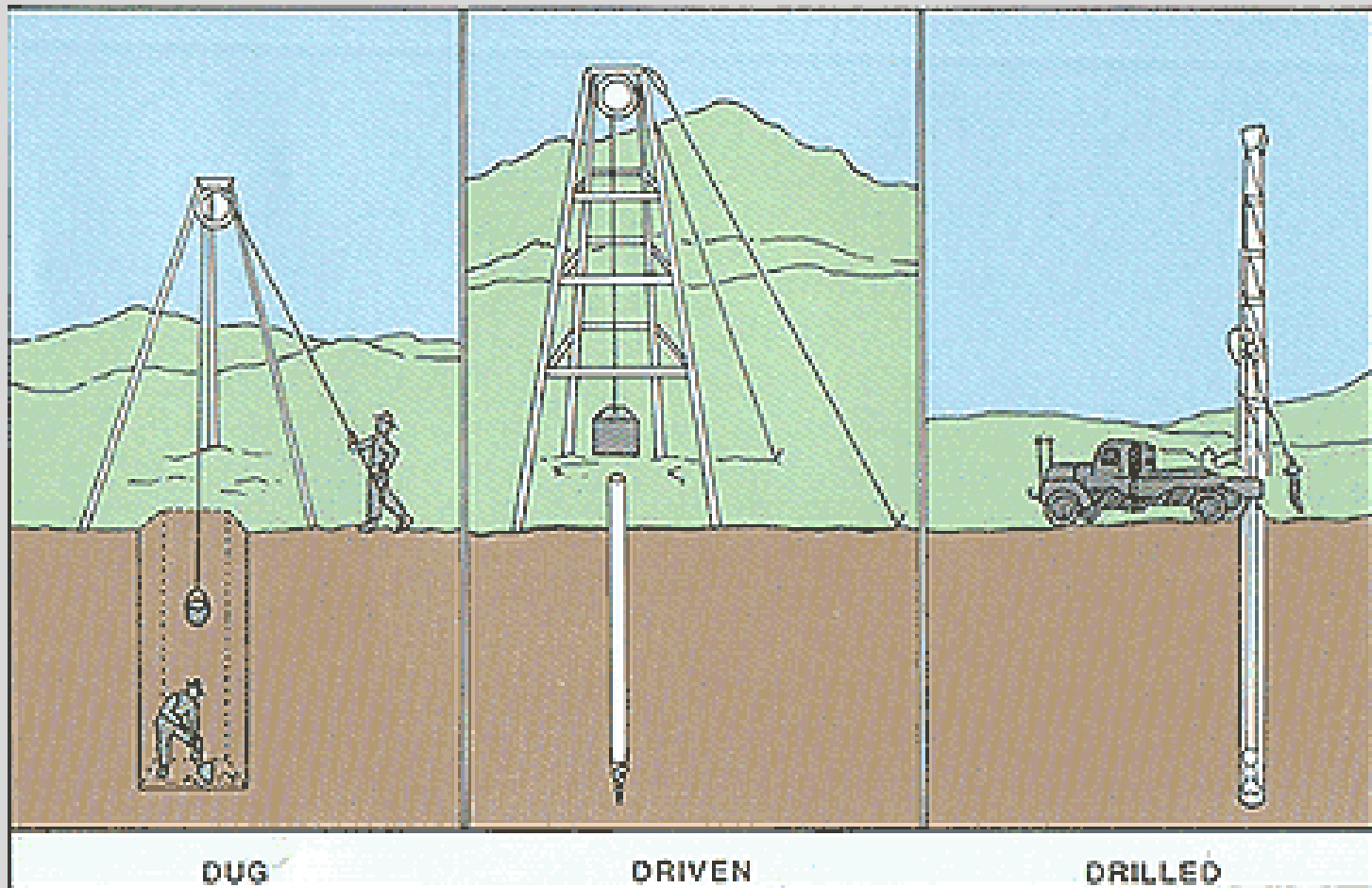
BIOGEOCHEMICAL CYCLES

- Carbon Cycle
 - Carbon Dioxide—Oxygen cycle of photosynthesis and respiration
- Nitrogen Cycle
- Sulfur Cycle
- “Reservoirs”—sources and sinks

Selected other soil and groundwater quality parameters often measured

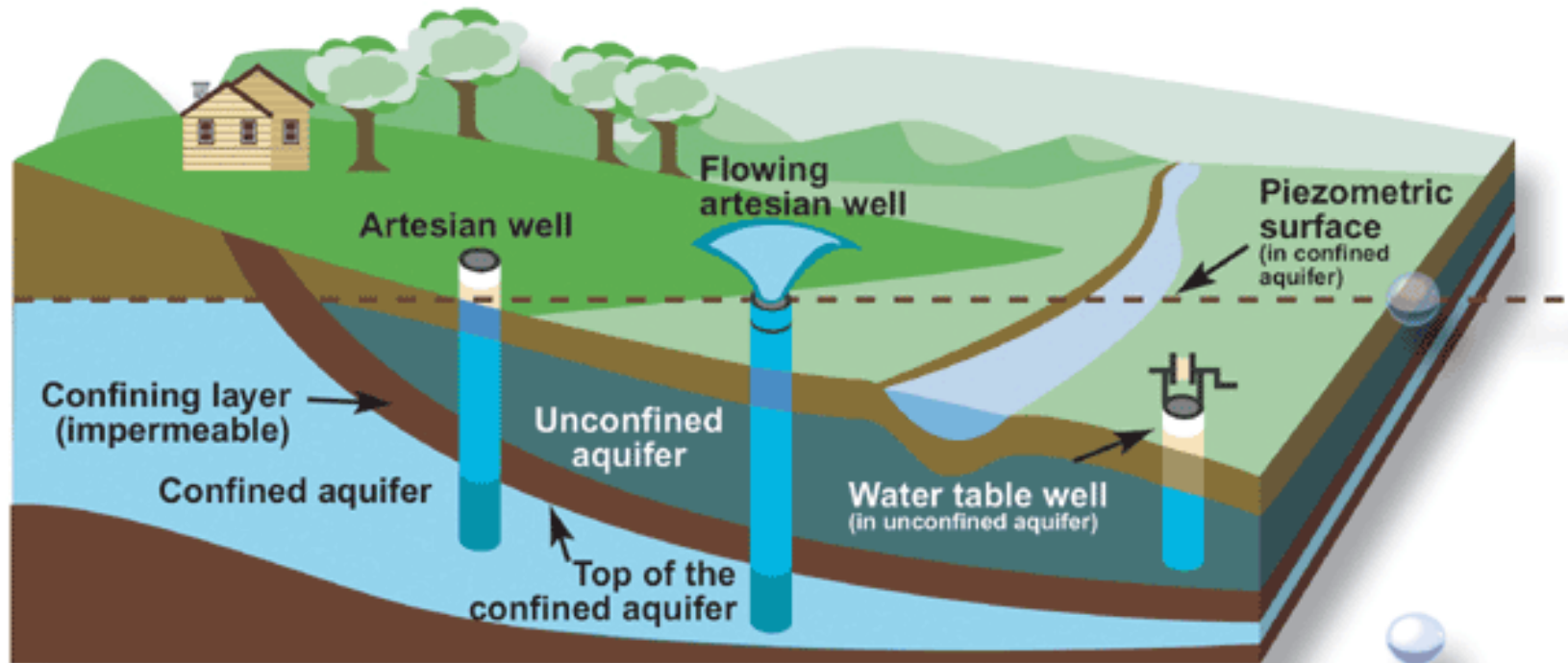
- BOD “Biological Oxygen Demand” Biochemical Oxygen Demand (BOD) refers to the amount of oxygen that would be consumed if all the organics in one liter of water were oxidized by bacteria and protozoa (ReVelle and ReVelle, 1988).
[http://hermes.ecn.purdue.edu/http_dir/ced/ccw/crc/agen521/agen521/epadir/wetlands/oxygen_demand.html]
- Coliform bacteria
- Heavy metals (such as As, Fe, Mn, Pb)
- Hardness
- Sulfates and Hydrogen Sulfide
- Organics

Types of Wells in the US



<http://water.usgs.gov/edu/earthgwwells.htm>

Aquifers and wells



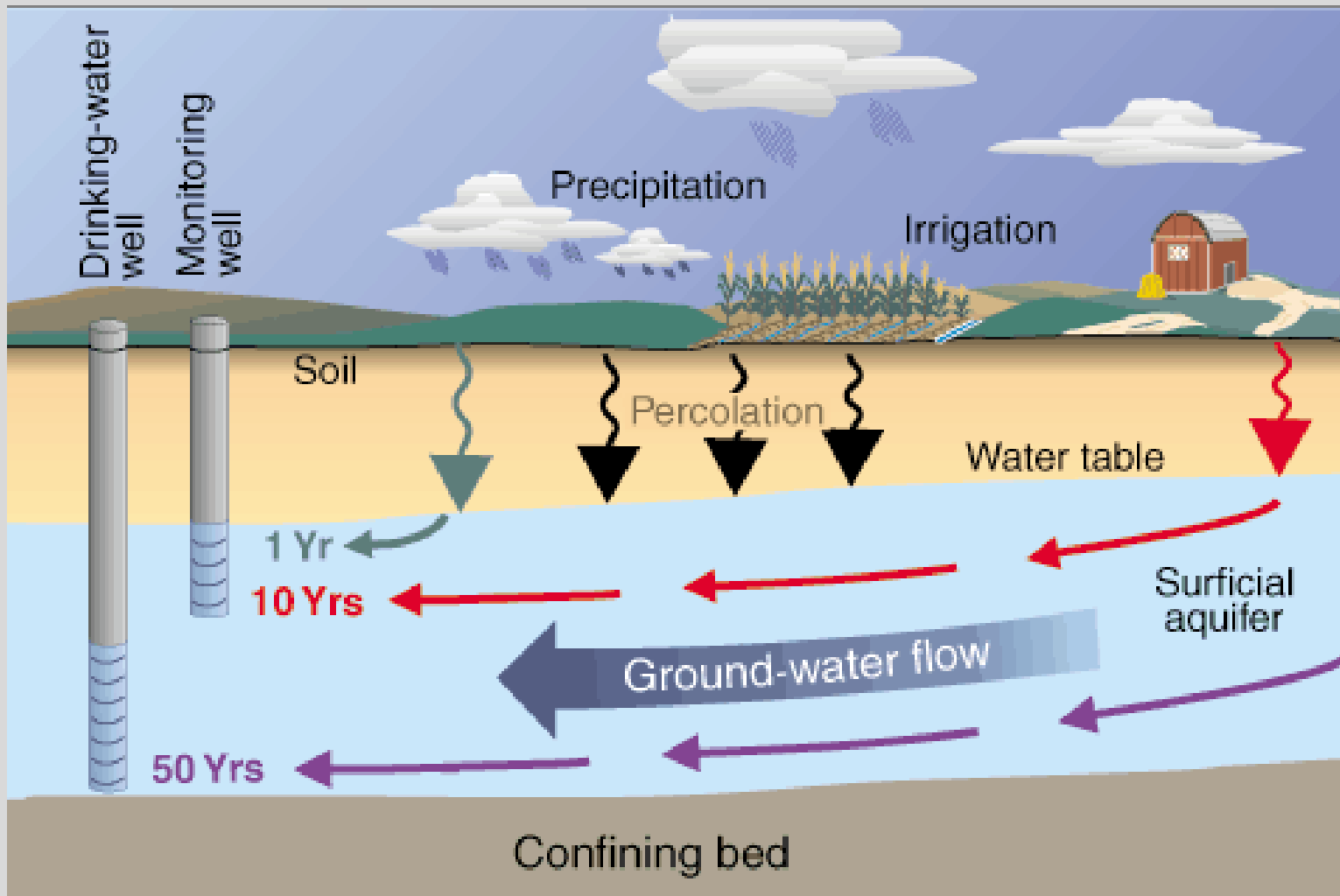
Source: Environment Canada

<http://water.usgs.gov/edu/earthgwwells.htm>

Groundwater contamination from a waste disposal site



<http://water.usgs.gov/edu/earthgwquality.html>



<http://water.usgs.gov/edu/pesticidesgw.html>