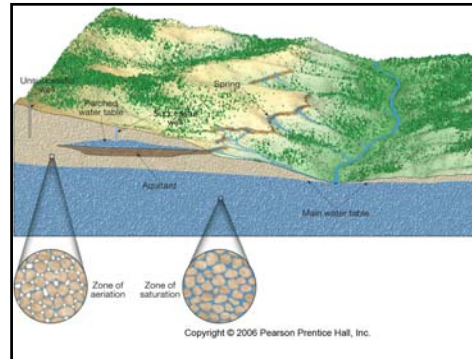


Groundwater, Water Pollution



Groundwater Storage

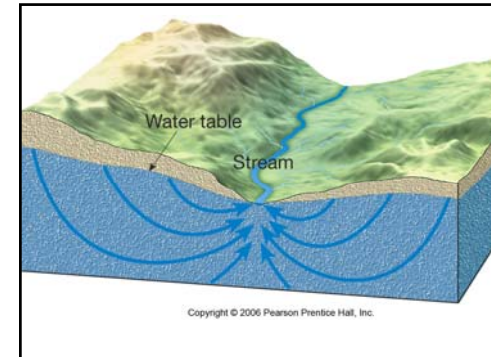
- Porosity of rock
 - Spaces between sand grains
 - Cracks in crystalline rock
 - Dissolved cavities
- Permeability
 - Allows water to move
 - Interconnection of pore spaces

Groundwater Storage

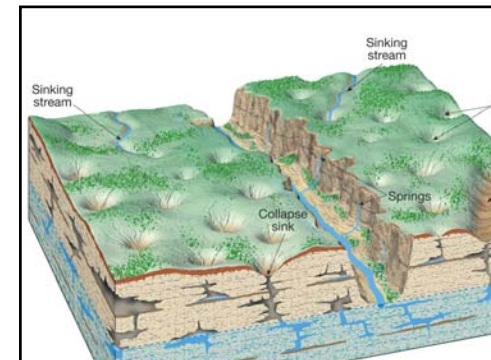
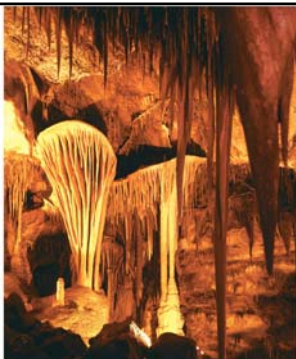
- Stored in AQUIFER
 - Porous and permeable rock
- Trapped by AQUITARD
 - Impermeable rock
 - Clay, shale

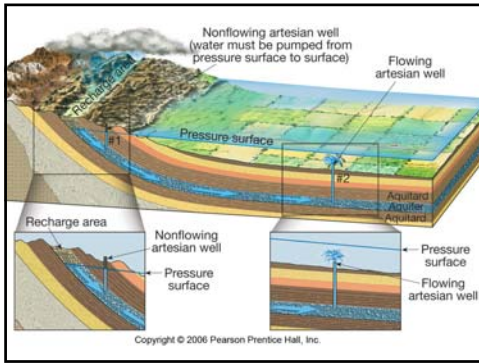
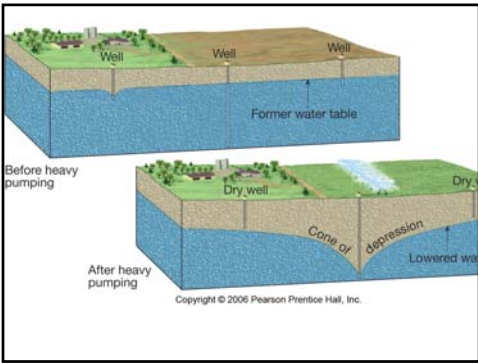
Groundwater Movement

- Very slowly—
 - Small openings
 - High surface tension
- Pressure forces water to areas of lower pressure
 - Hydraulic gradient
 - Hydraulic head



Carlsbad Caverns





Ogallala Aquifer

- Exploited in Great Plains agriculture
- Water table dropped
- Recharge rate low

San Joaquin Valley subsidence

Not able to recover due to aquifer compaction

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Hot Springs

- Water heated by hot rock (cooling magma)
- Temperature increases solvent capabilities
- May contain acids from magmatic water

Geysers

- Special type of hot spring
- Pressure of water column suppresses boiling
- Heat added eventually overcomes pressure
- Sudden rise of water, increase pressure release on rising

Old Faithful webcam link

<http://www.nps.gov/oldfaithful/yellowstone.htm>

Geyser Eruption

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Geyser eruption stages

http://www.wested.org/p2p/netexp_projects/H2O.html

Impurities in Runoff

- Atmosphere
- Dissolved substances
- Silt, etc.
- Radon

TABLE 13.2 Some Substances Found in Natural Waters

| Substance | Formula | Source |
|-----------------------------|-------------------------------|-------------------|
| Carbon dioxide | CO ₂ | Atmosphere |
| Dust | — | Atmosphere |
| Nitrogen | N ₂ | Atmosphere |
| Oxygen | O ₂ | Atmosphere |
| Nitric acid (thunderstorms) | HNO ₃ | Atmosphere |
| Sand and soil particles | — | Soil and rocks |
| Sodium ions | Na ⁺ | Soil and rocks |
| Potassium ions | K ⁺ | Soil and rocks |
| Calcium ions | Ca ²⁺ | Limestone rocks |
| Magnesium ions | Mg ²⁺ | Dolomite rocks |
| Iron(II) ions | Fe ²⁺ | Soil and rocks |
| Chloride ions | Cl ⁻ | Soil and rocks |
| Sulfate ions | SO ₄ ²⁻ | Soil and rocks |
| Bicarbonate ions | HCO ₃ ⁻ | Soil and rocks |
| Radon | Rn | Radioactive decay |

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TABLE 13.5 National Drinking Water Standards for Selected Substances (U.S. EPA)*

| Substance | Maximum Contaminant Level (mg/L) [†] |
|--|---|
| Primary standards: inorganic compounds | |
| Arsenic | 0.01 [‡] |
| Barium | 2 |
| Copper | 1.3 |
| Cyanide | 0.2 |
| Fluoride | 4 |
| Lead | 0.015 |
| Nitrate | 10 [§] |
| Primary standards: organic compounds | |
| Atrazine | 0.003 |
| Benzene | 0.005 |
| p-Dichlorobenzene | 0.075 |
| Dichloromethane | 0.005 |
| Heptachlor | 0.0004 |
| Lindane | 0.0002 |
| Toluene | 1 |
| Trichloroethylene | 0.005 |
| Secondary standards (nonenforceable) | |
| Chloride | 250 |
| Iron | 0.3 |
| Manganese | 0.05 |
| Silver | 0.10 |
| Sulfate | 250 |
| Total dissolved solids | 500 |
| Zinc | 5 |

*A more detailed list and a more detailed explanation of the rules can be found at <http://www.epa.gov/OGWDW/nacl.html>.

Parts per Million

- ppm
- Change 1,000,000 mg to liters

$$1,000,000 \text{ mg} \times \frac{1 \text{ g}}{1,000 \text{ mg}} \times \frac{1 \text{ mL}}{1 \text{ g}} \times \frac{1 \text{ L}}{1,000 \text{ mL}} = 1 \text{ L}$$

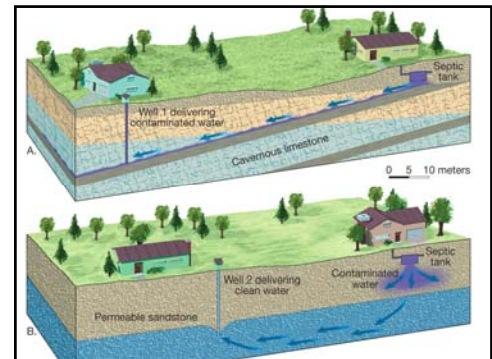
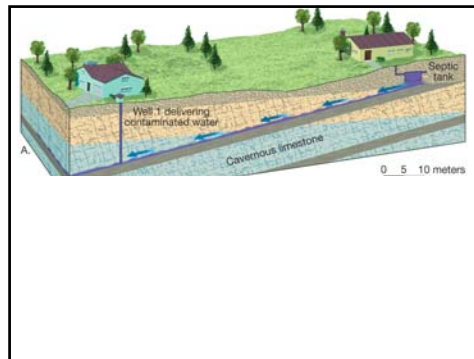
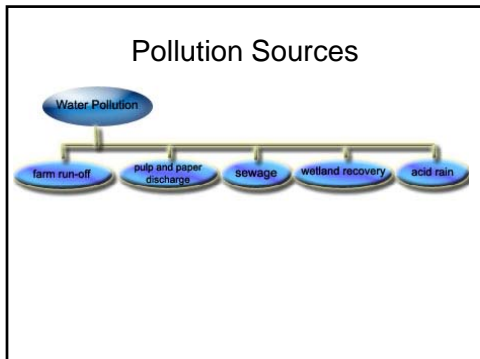
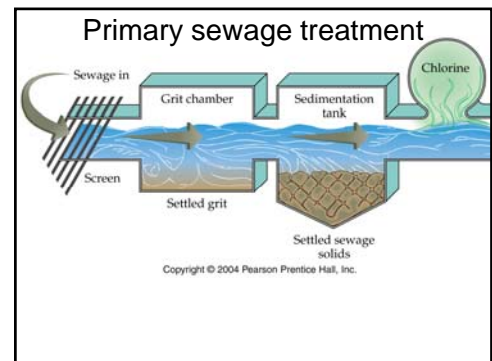
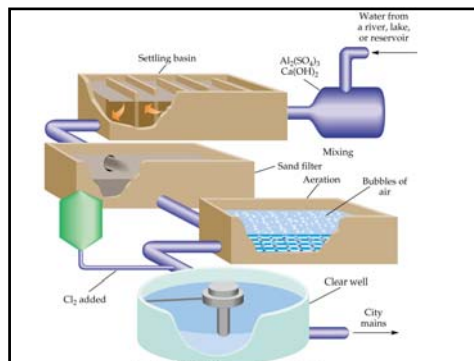
$$1 \text{ ppm} = \frac{1 \text{ mg}}{1 \text{ L}}$$


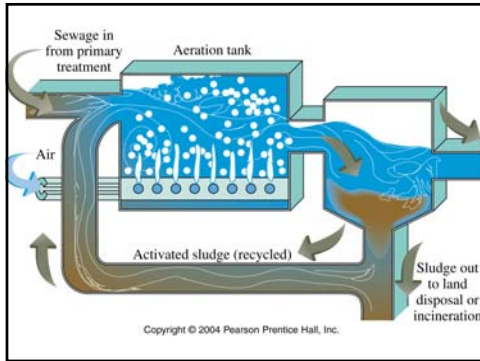
TABLE 13.3 Some Substances Added to Water by the Breakdown of Organic Matter

| Substance | Formula |
|----------------------|-------------------------------|
| Aerobic conditions | |
| Carbon dioxide | CO ₂ |
| Nitrate ions | NO ₃ ⁻ |
| Phosphate ions | PO ₄ ³⁻ |
| Sulfate ions | SO ₄ ²⁻ |
| Bicarbonate ions | HCO ₃ ⁻ |
| Anaerobic conditions | |
| Methane | CH ₄ |
| Ammonia | NH ₃ |
| Amines | RNH ₂ ⁺ |
| Hydrogen sulfide | H ₂ S |
| Methanethiol | CH ₃ SH |

*See Chapter 9.

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- ### Contamination of Water
- Micro-organisms
 - Decay products
 - Plant nutrients
 - Petroleum compounds
 - Acid
 - Industry
 - Mining

