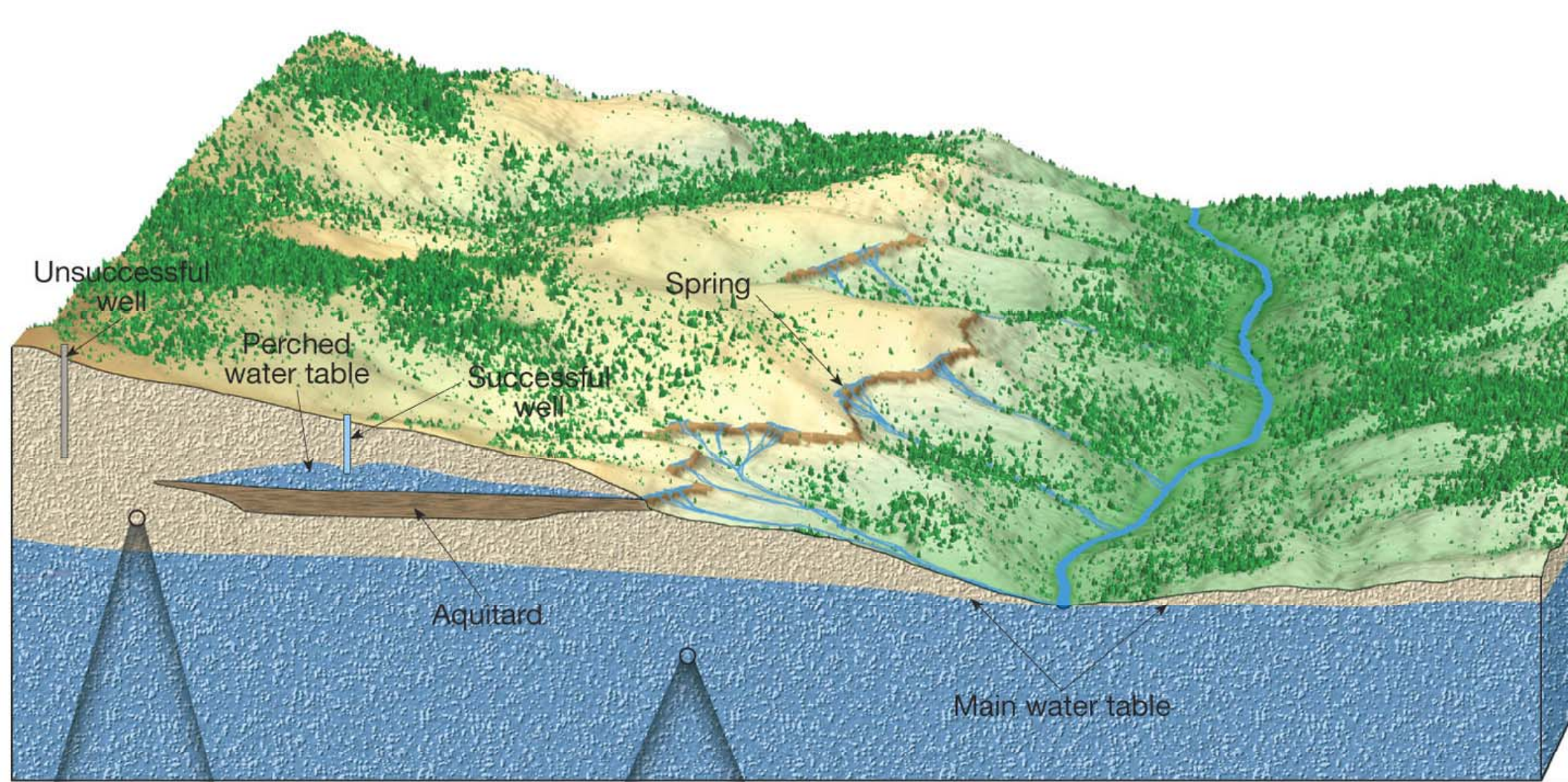


Groundwater, Water Pollution

[click here for 9/page to print](#)



Groundwater Storage

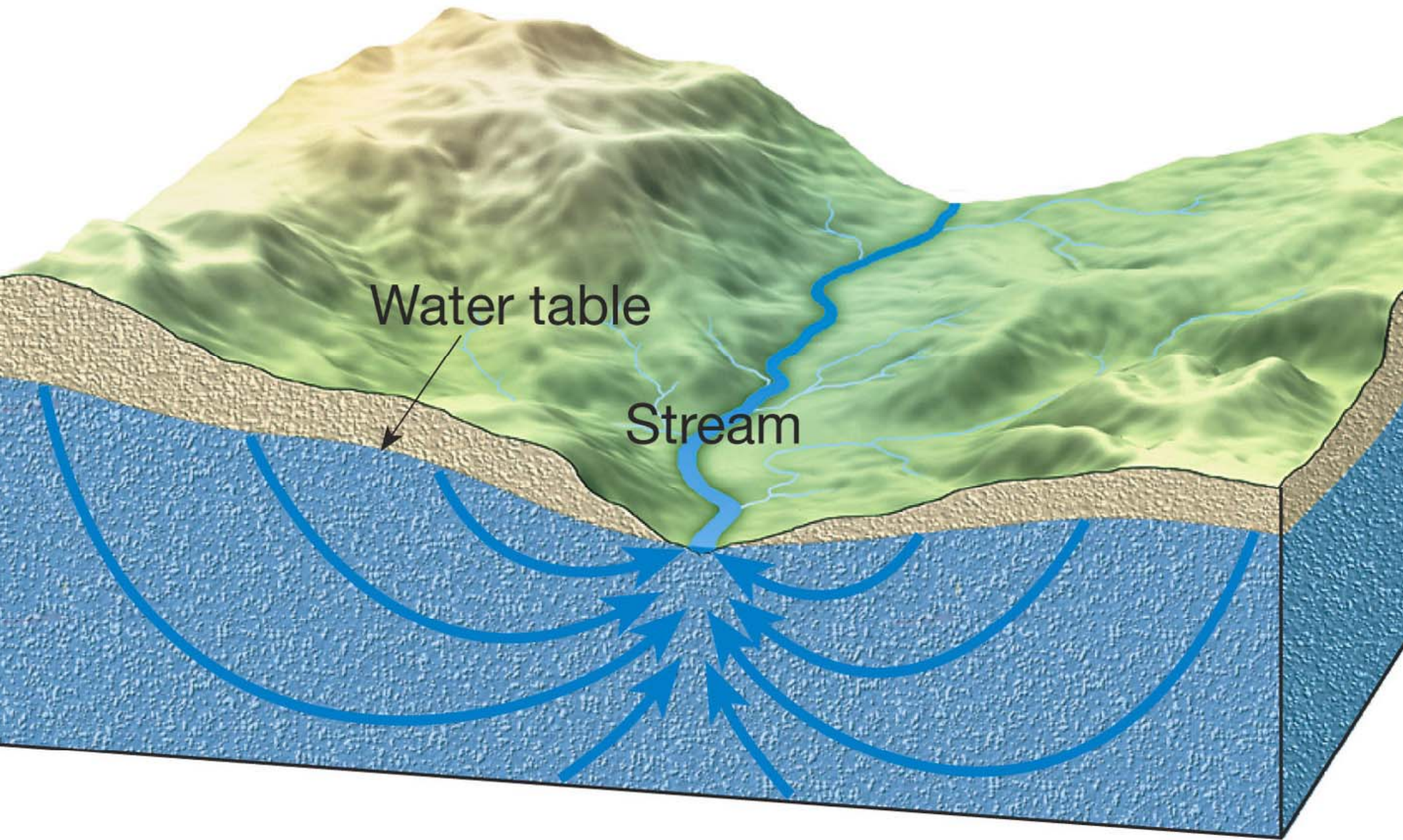
- Porosity of rock
 - Spaces between sand grains
 - Cracks in crystalline rock
 - Dissolved cavities
- Permeability
 - Allows water to move
 - Interconnection of pore spaces

Groundwater Storage

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

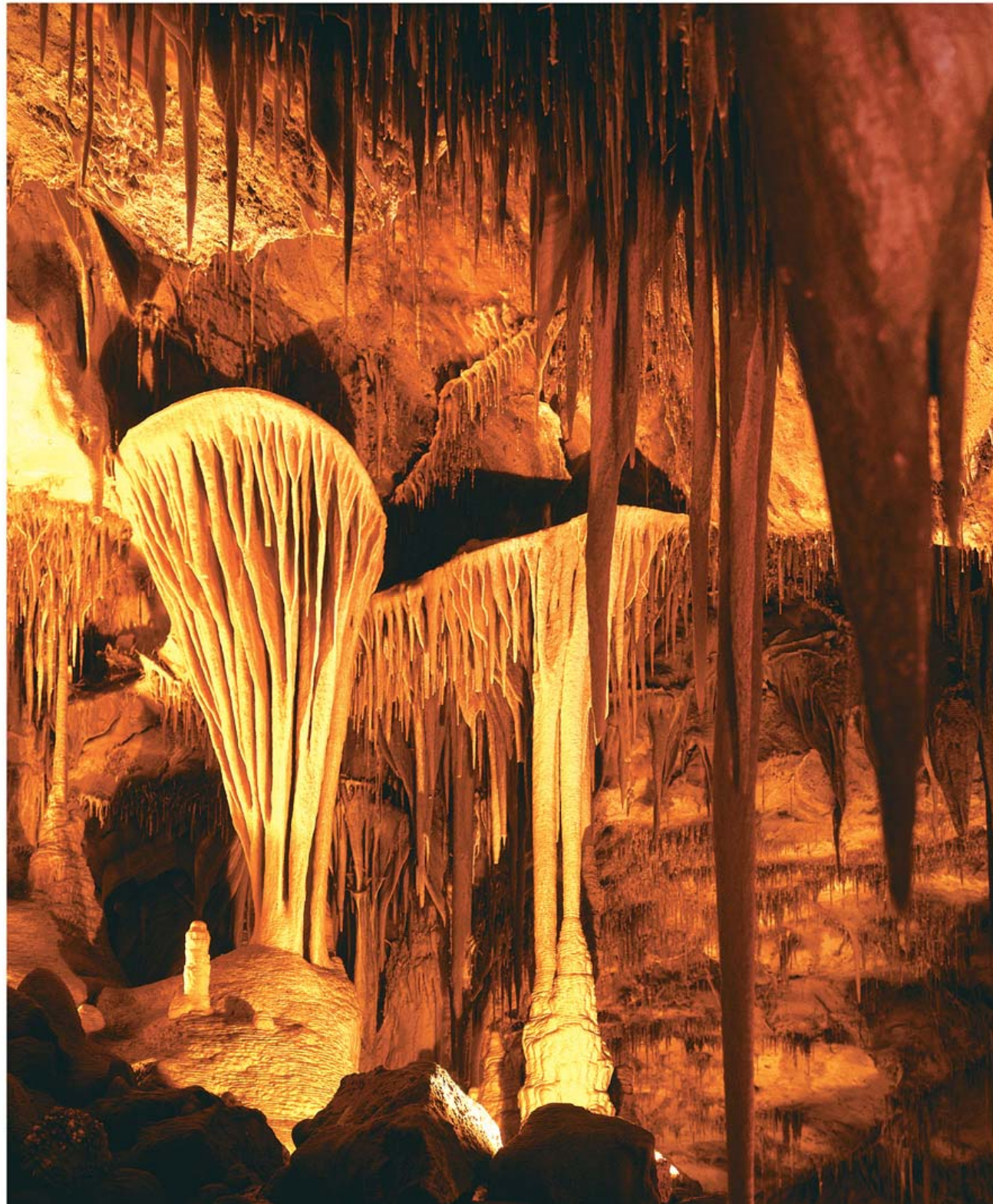
Groundwater Movement

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

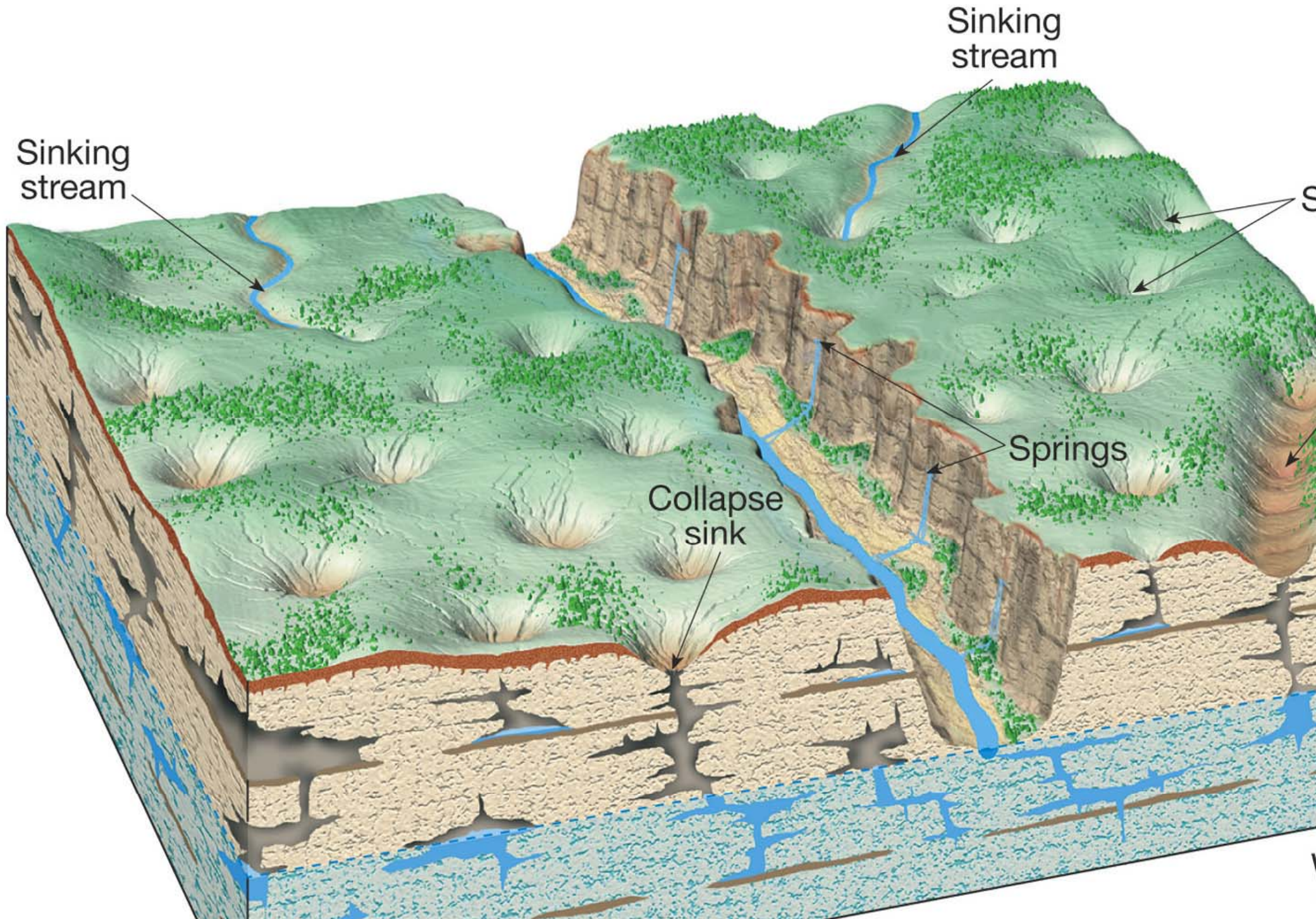


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Carlsbad Caverns







Sinking stream

Sinking stream

Collapse sink

Springs



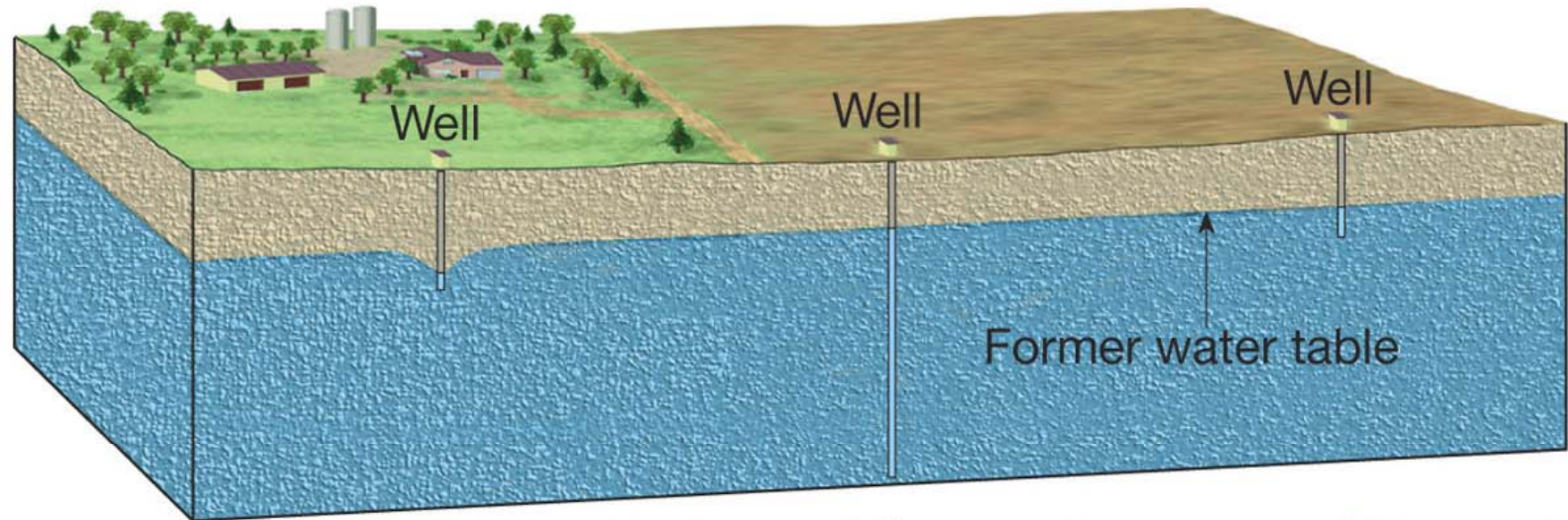




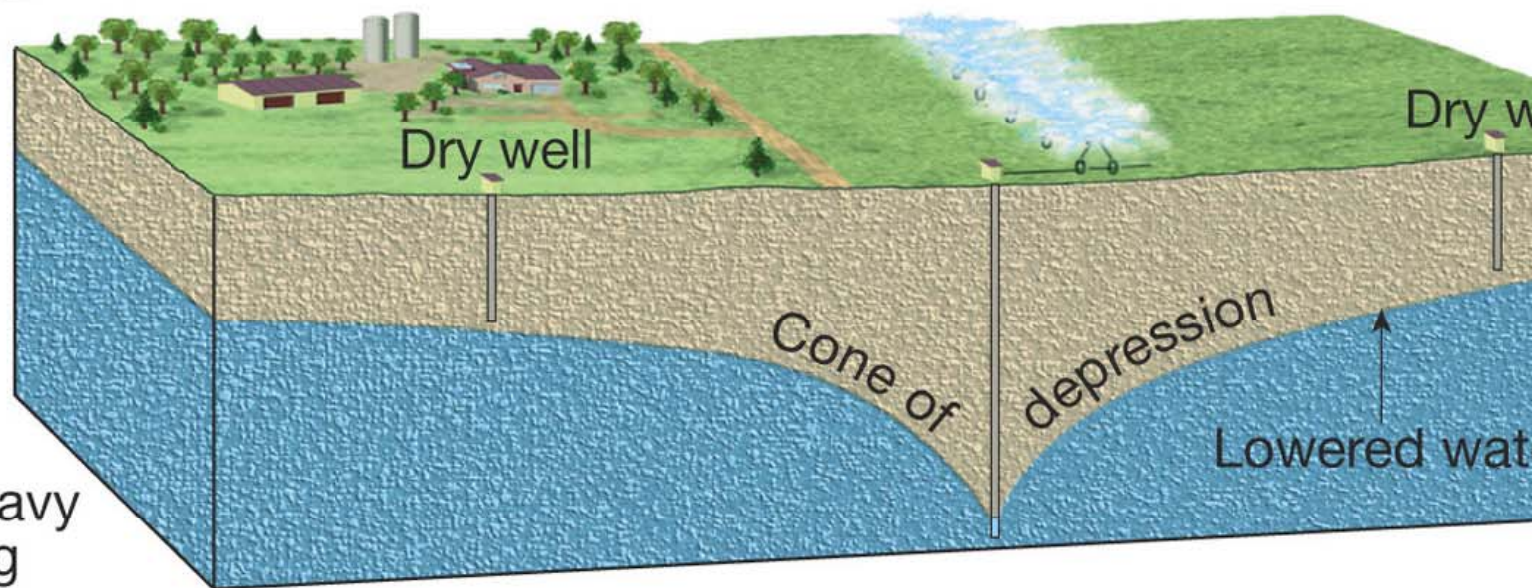




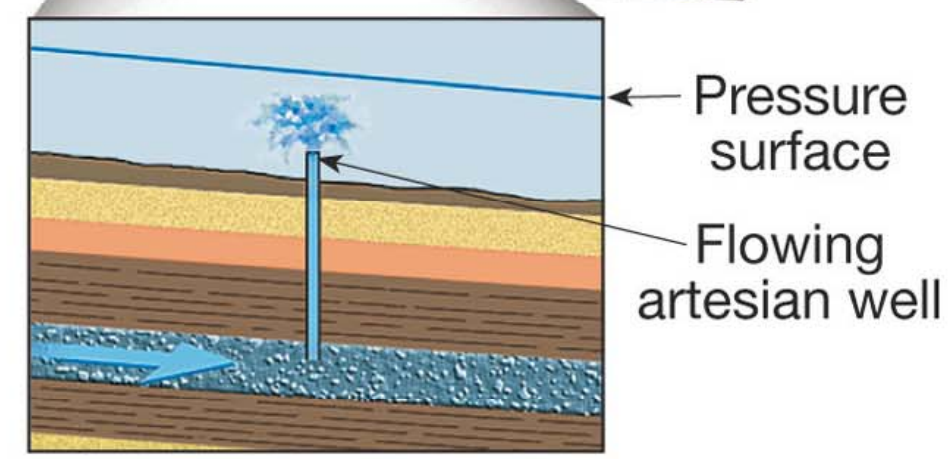
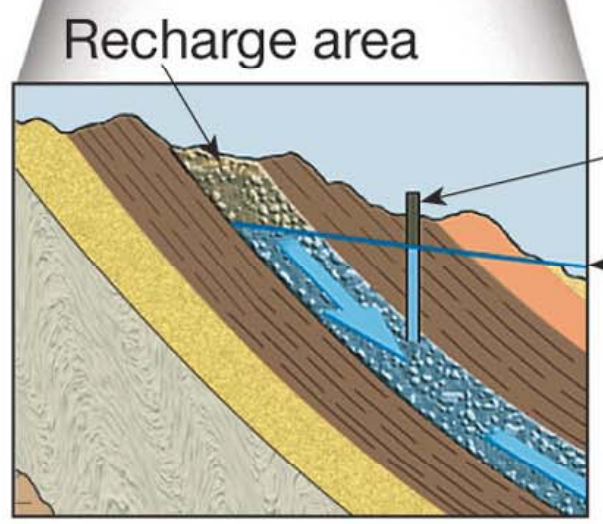
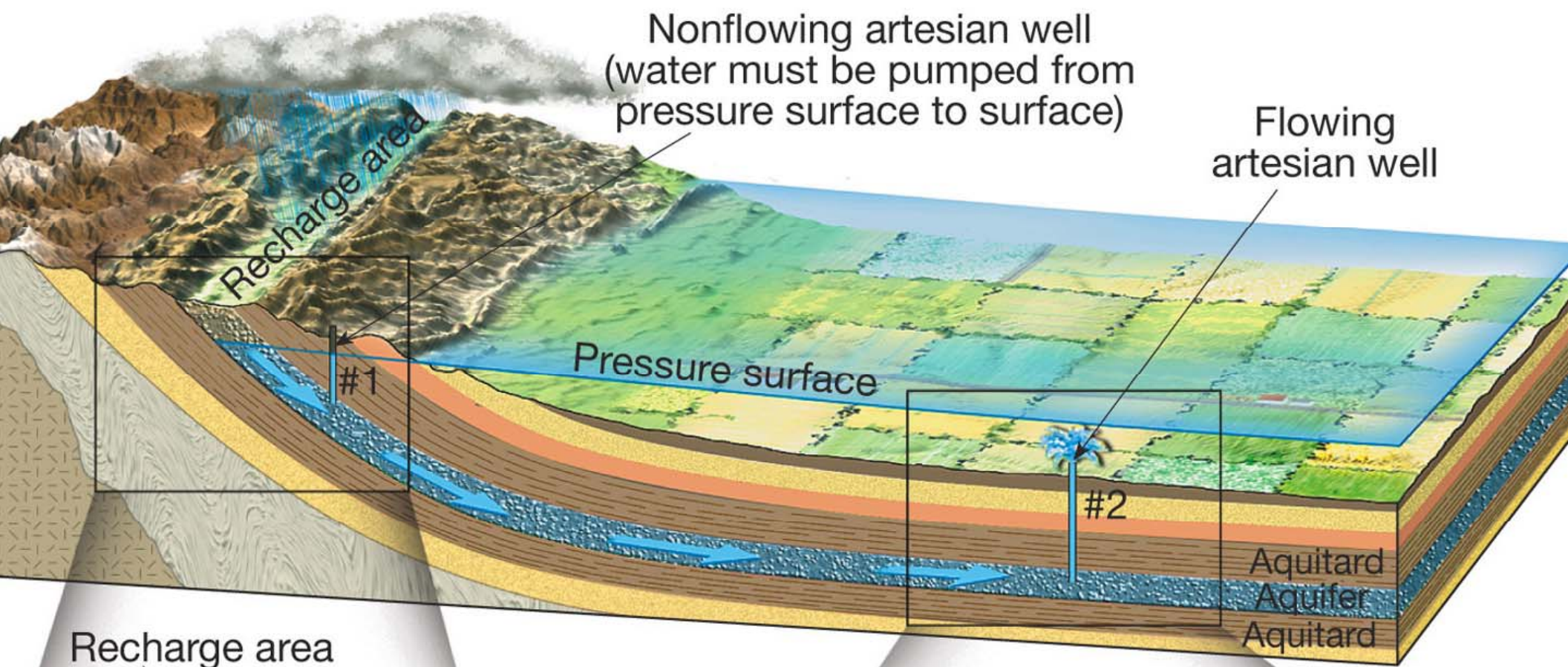




Before heavy pumping



After heavy pumping

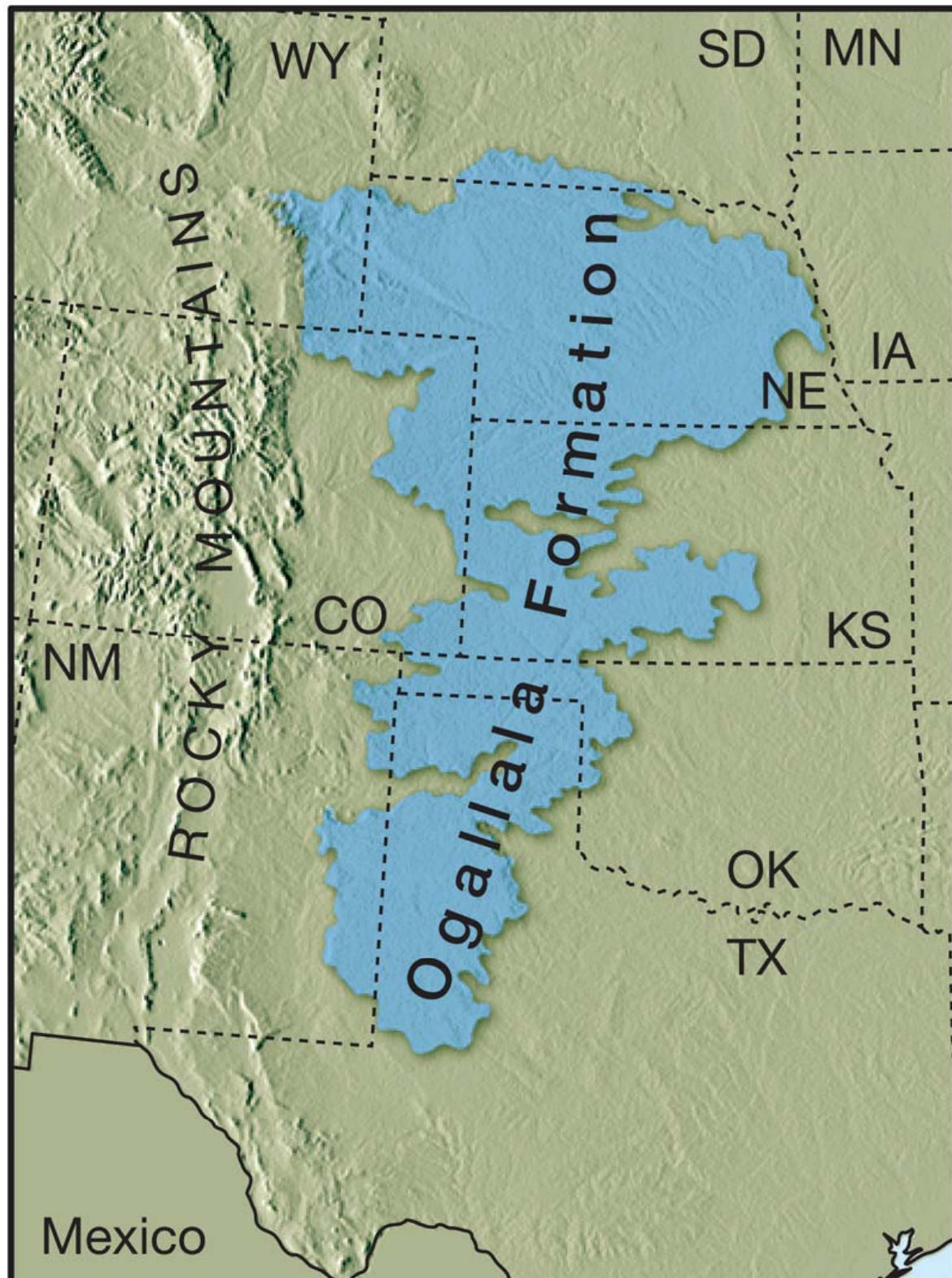




B.

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



Hot Springs

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

Geysers

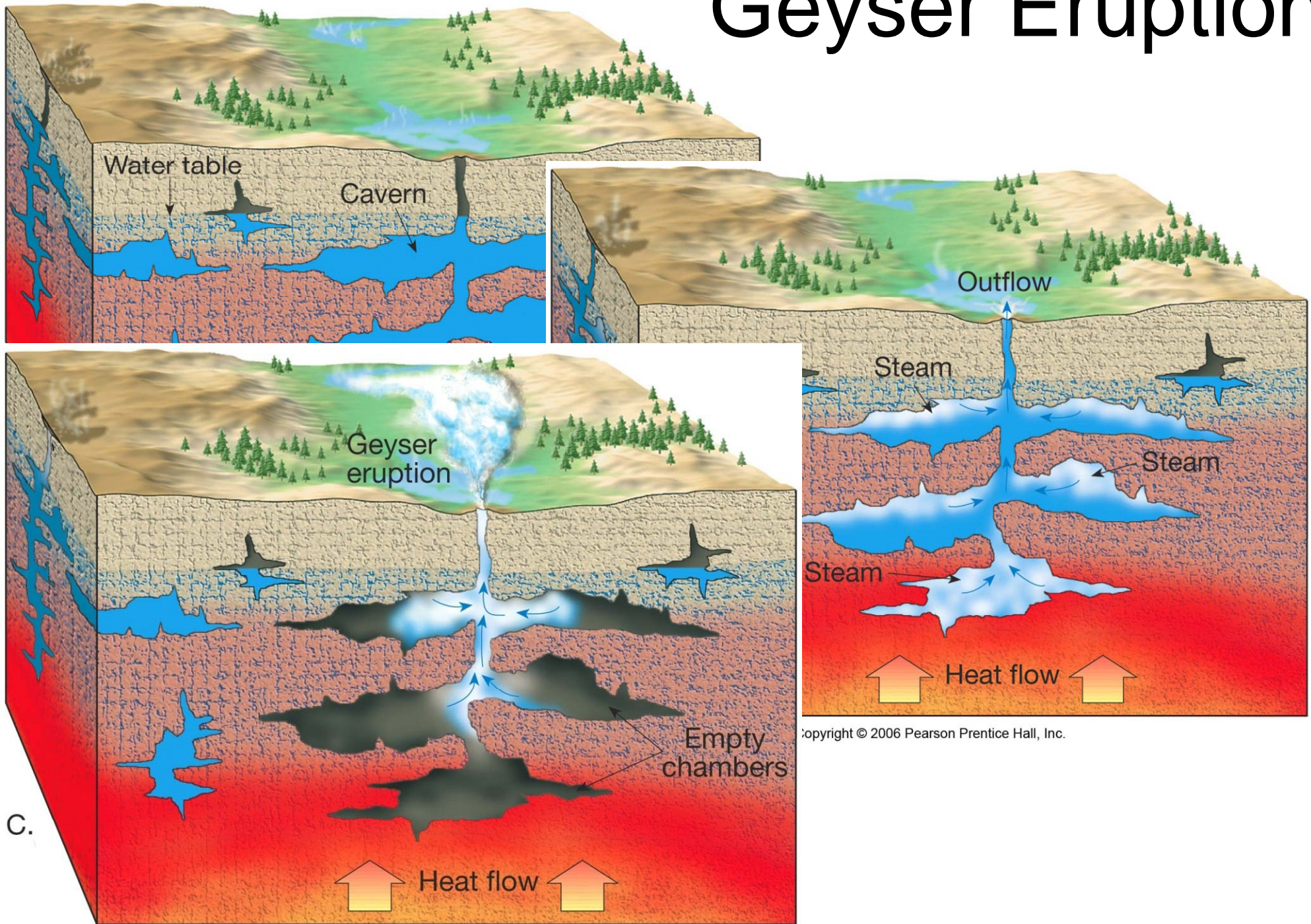
- Special type of hot spring
- Pressure of water column suppresses boiling
- Heat added eventually overcomes pressure
- Sudden rise of water, increase pressure release on rising



Old Faithful webcam link

[http://www.nps.gov/archive/
yell/oldfaithfulcam.htm](http://www.nps.gov/archive/yell/oldfaithfulcam.htm)

Geyser Eruption

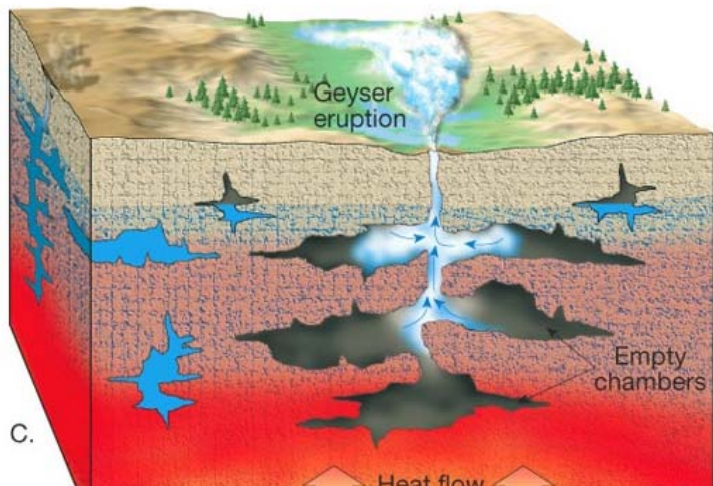
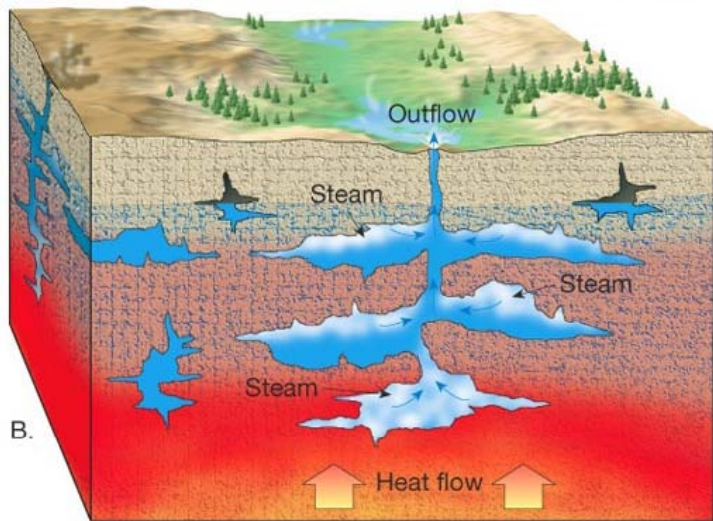
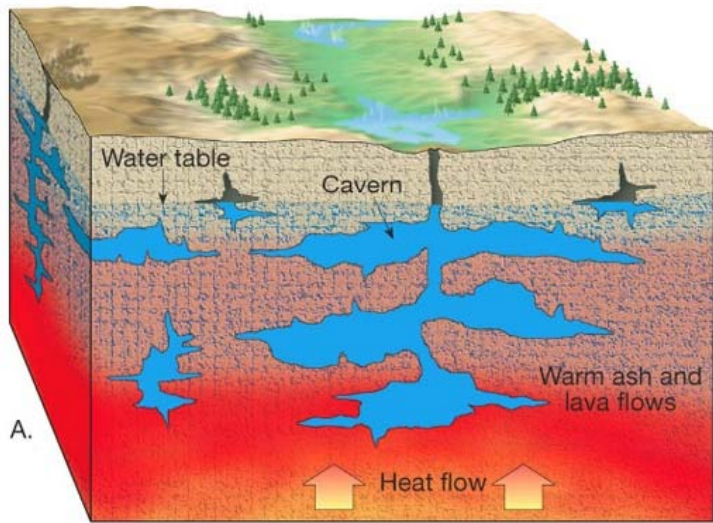


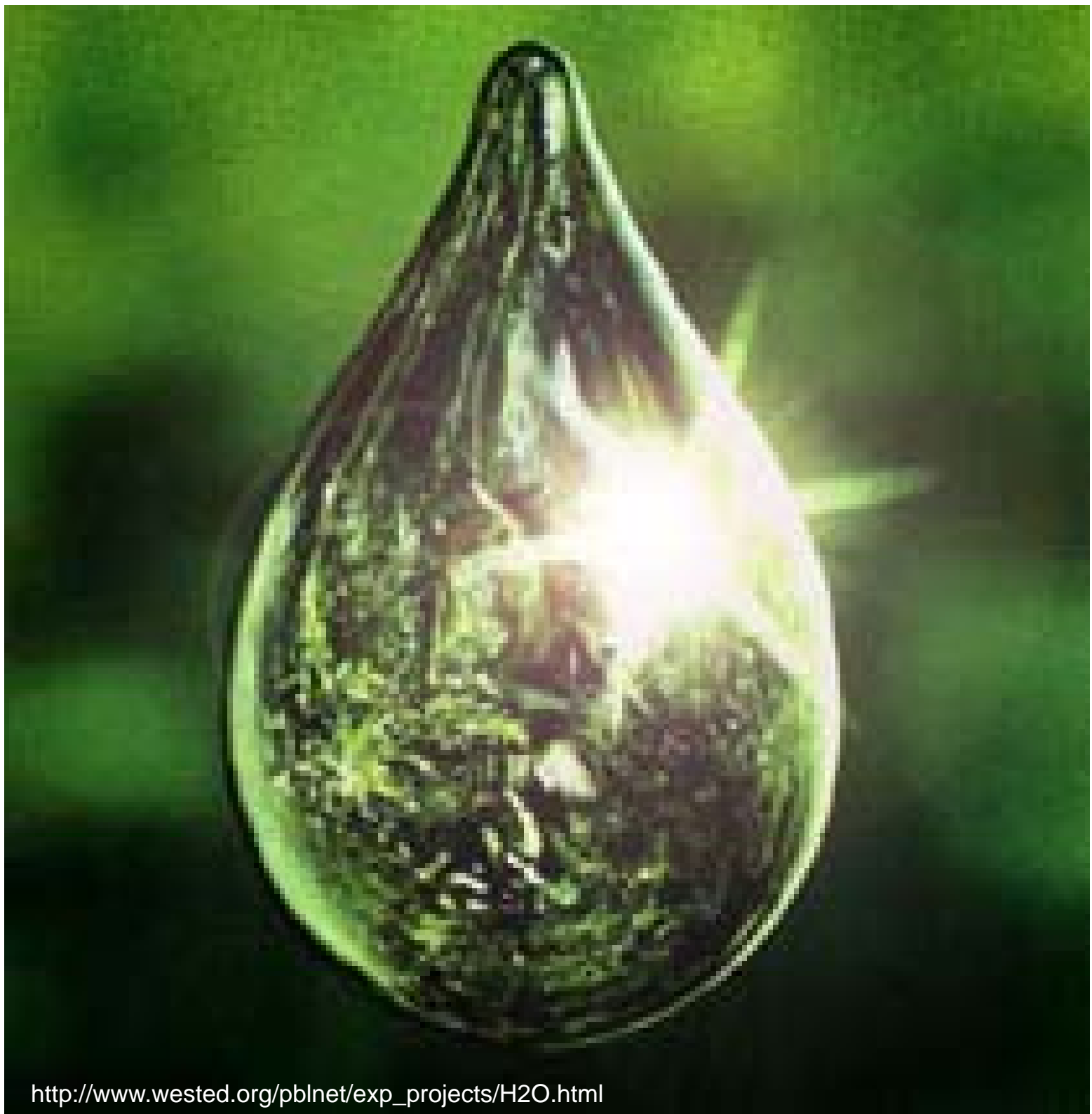
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C.

Geyser eruption stages





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

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
<i>p</i> -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/mcl.html>.

[†] 1 mg/L is often called 1 part per million (1 ppm)

Parts per Million

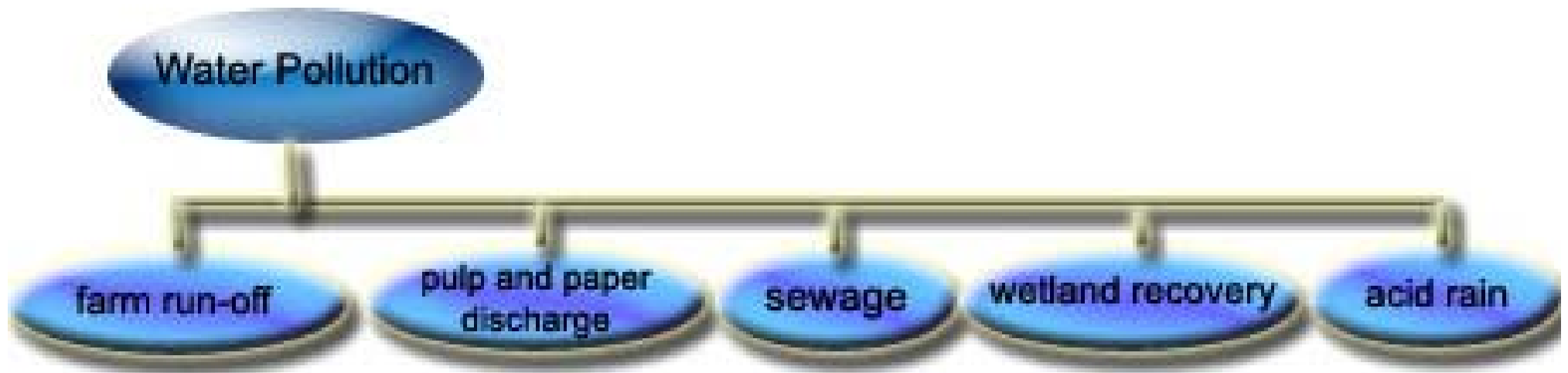
- ppm
- Change
1,000,000 mg to liters

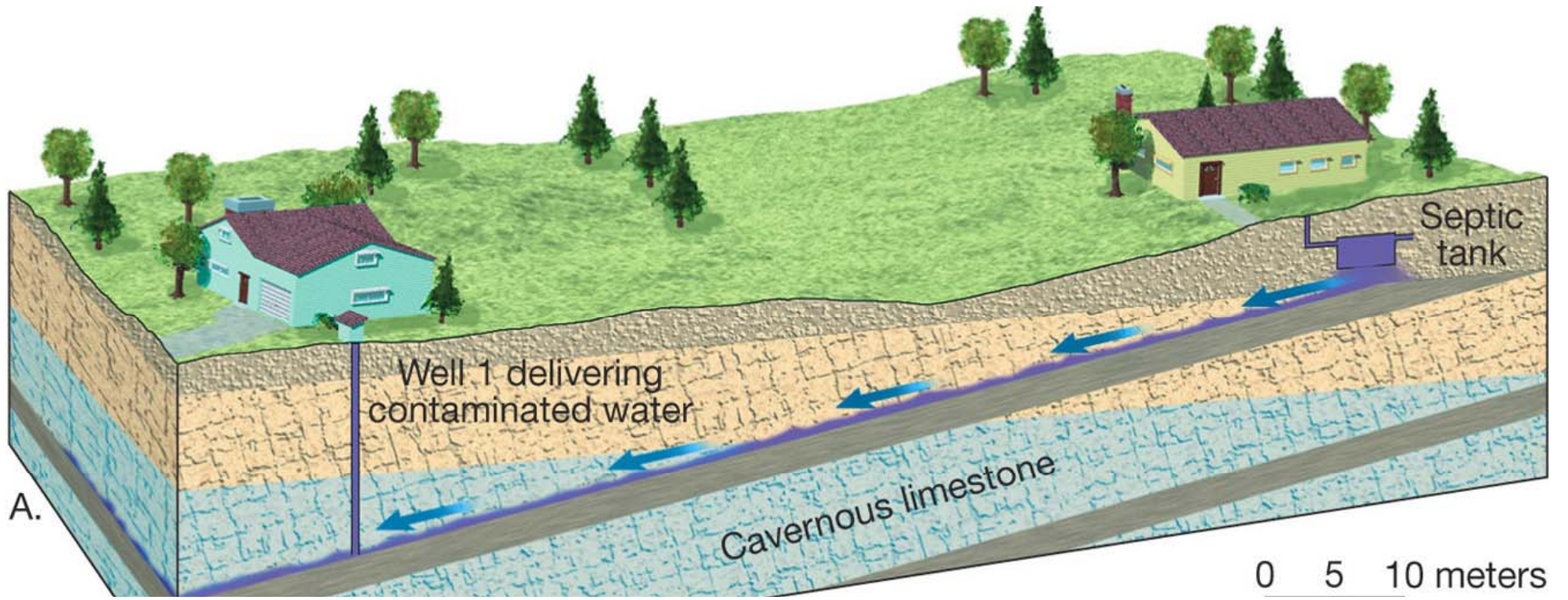
$$\frac{1 \text{ mg}}{1,000,000 \text{ mg}}$$

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

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

Pollution Sources





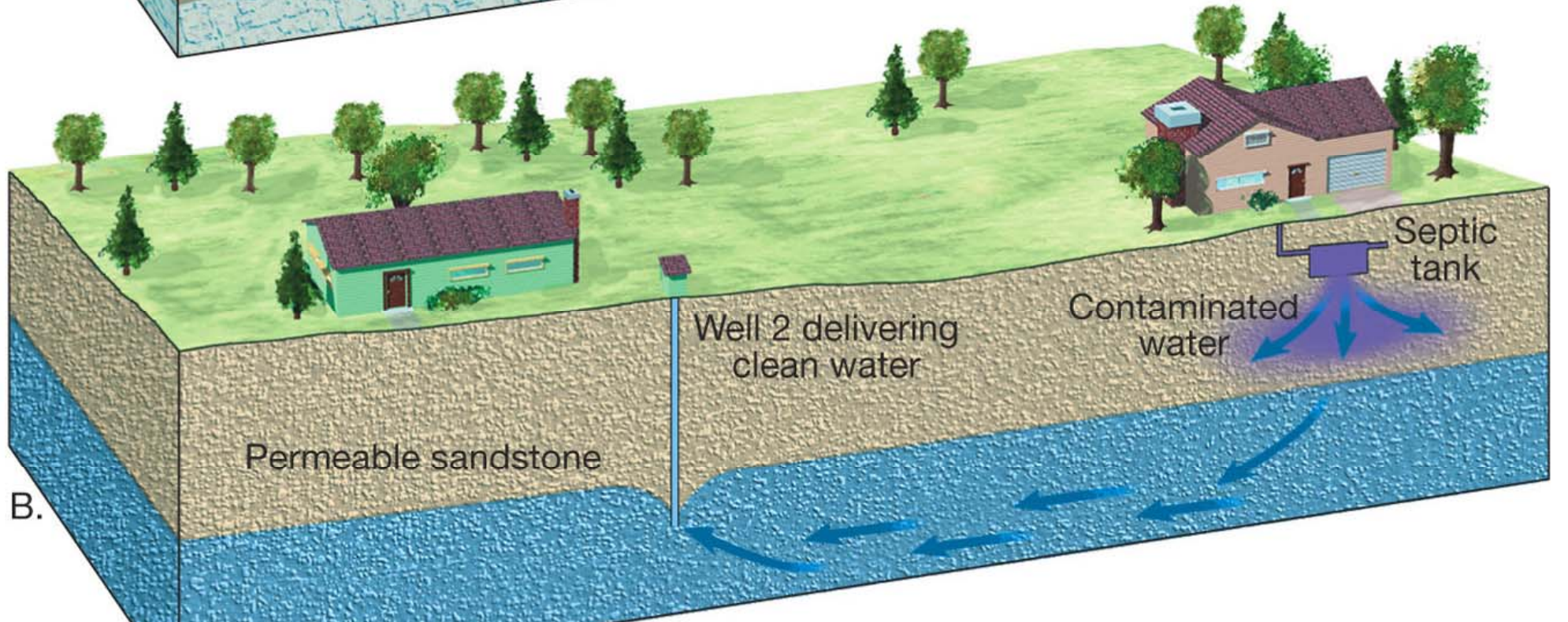
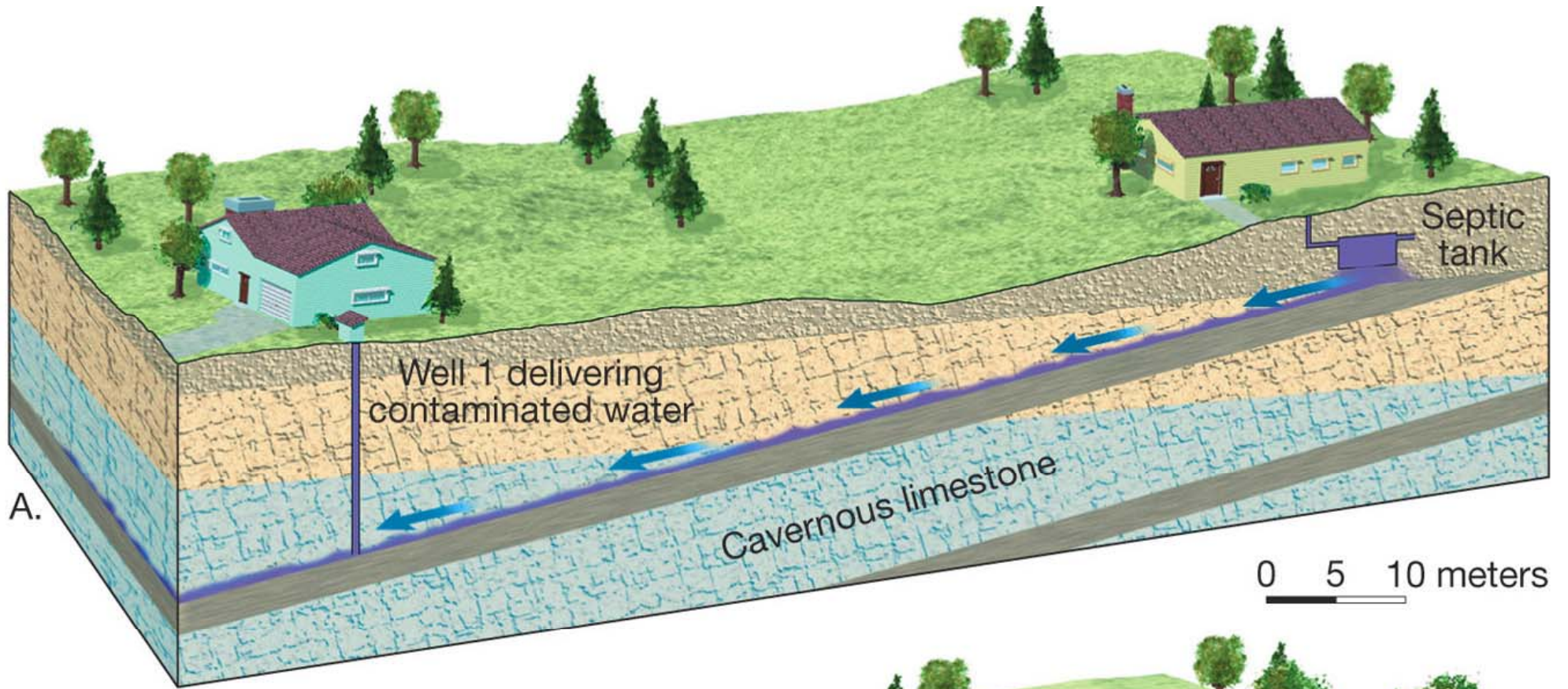
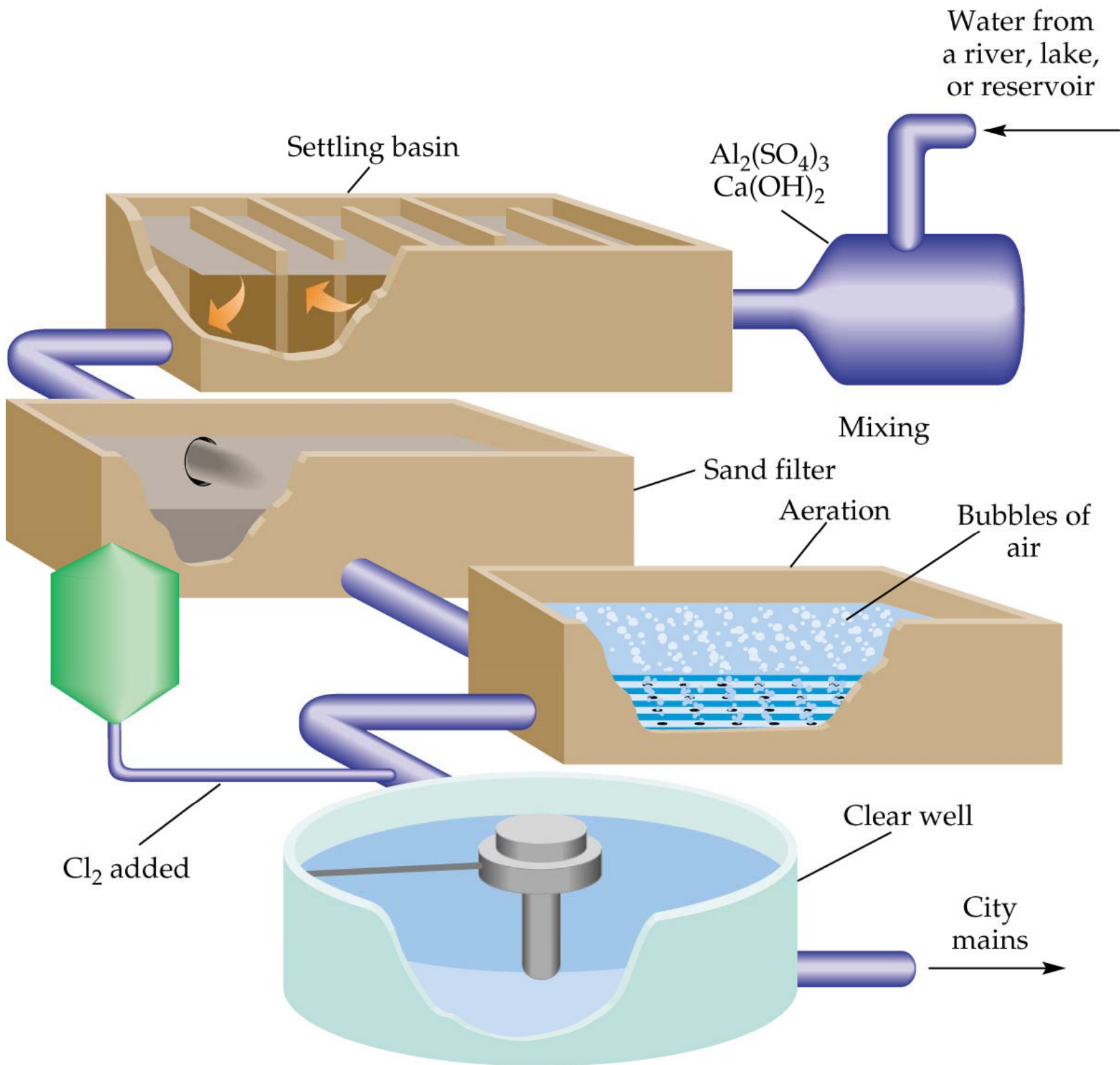


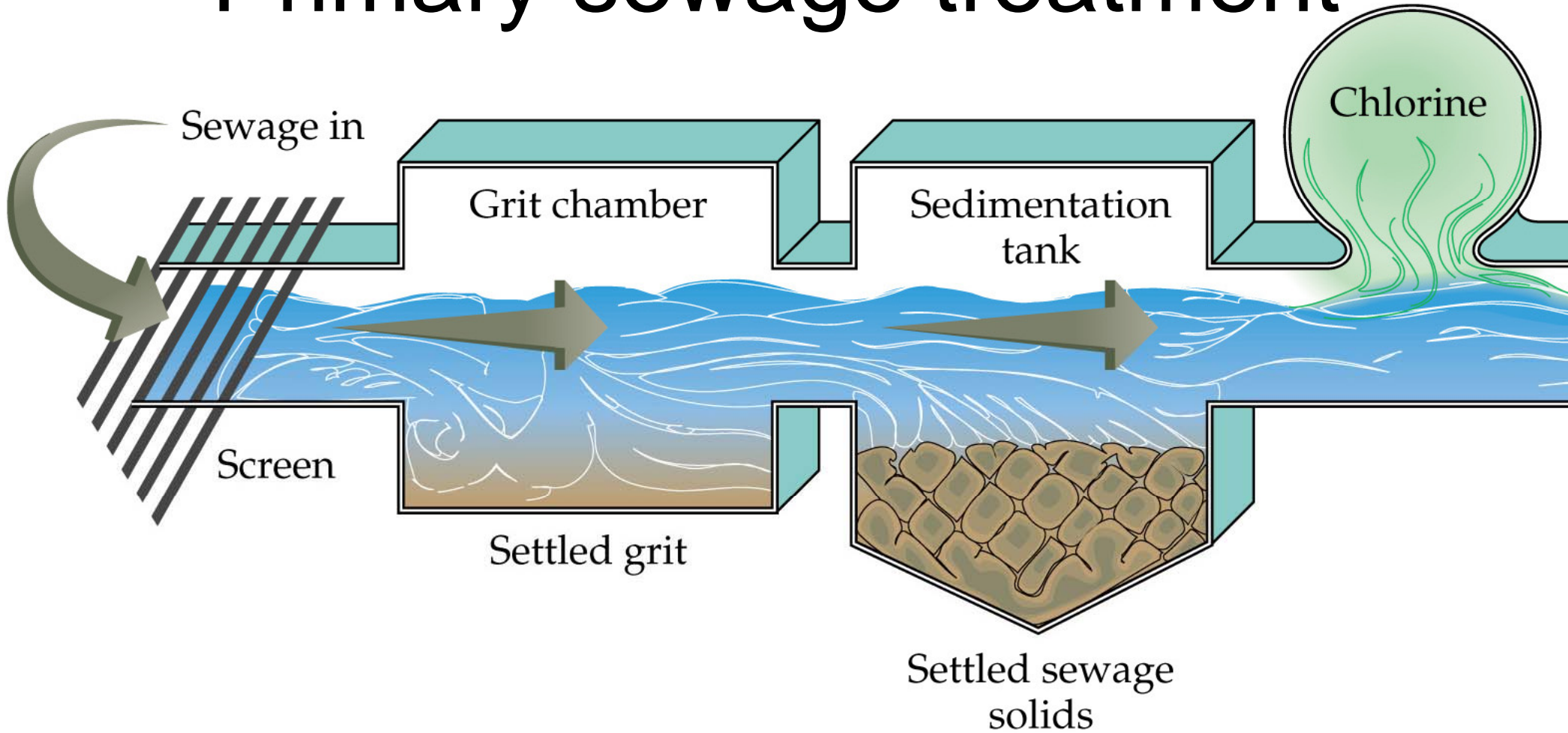
TABLE 13.3 Some Substances Added to Water by the Breakdown of Organic Matter

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

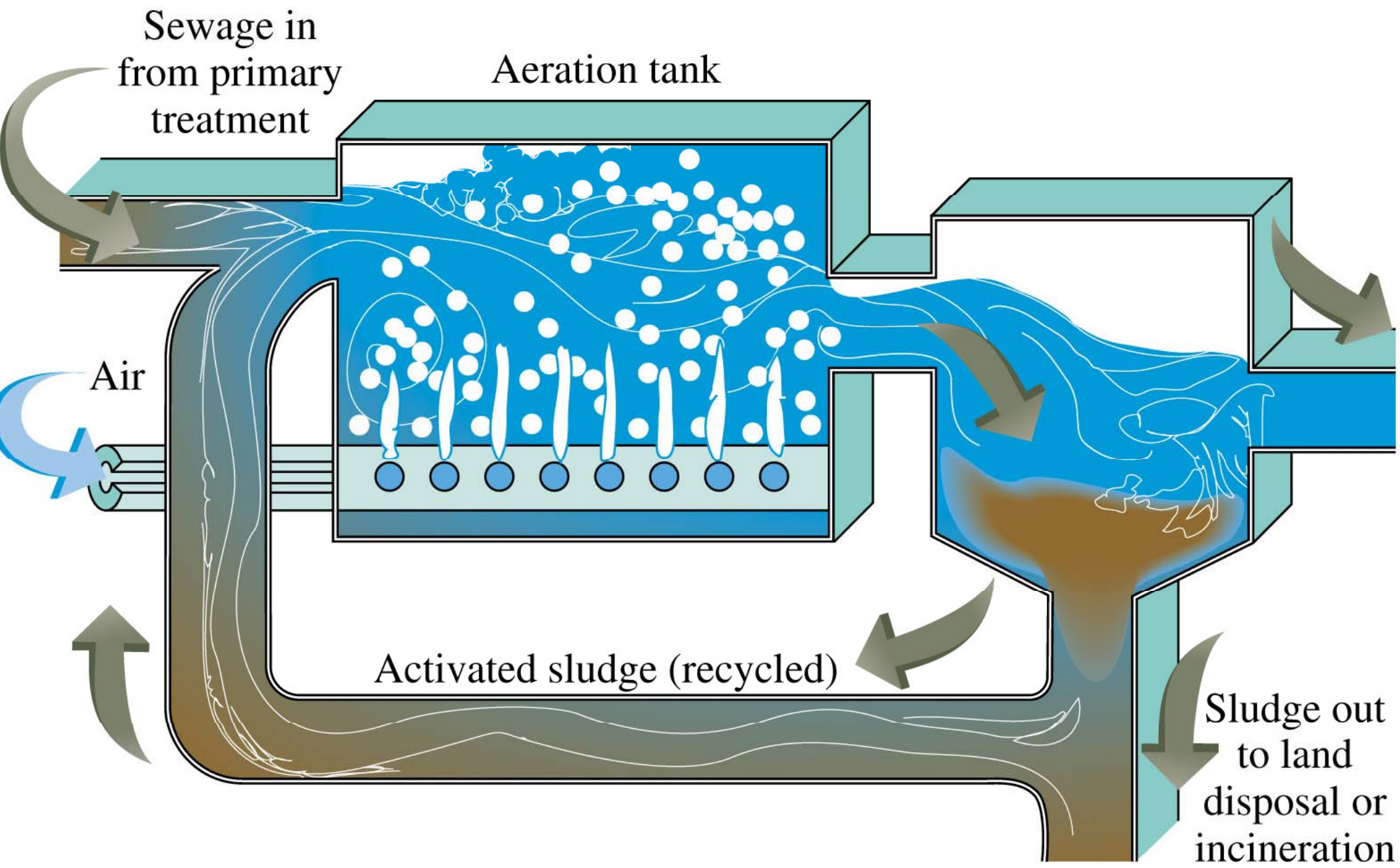
*See Chapter 9.



Primary sewage treatment



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Agriculture sources of groundwater contamination



Contamination of Water

- Micro-organisms
- Decay products
- Plant nutrients
- Petroleum compounds
- Acid
- Industry
- Mining





 ***Dense algal growth from excess nutrients blocks sunlight, causing plants to die.***

Jeff Horan Maryland Dept of Natural Resources

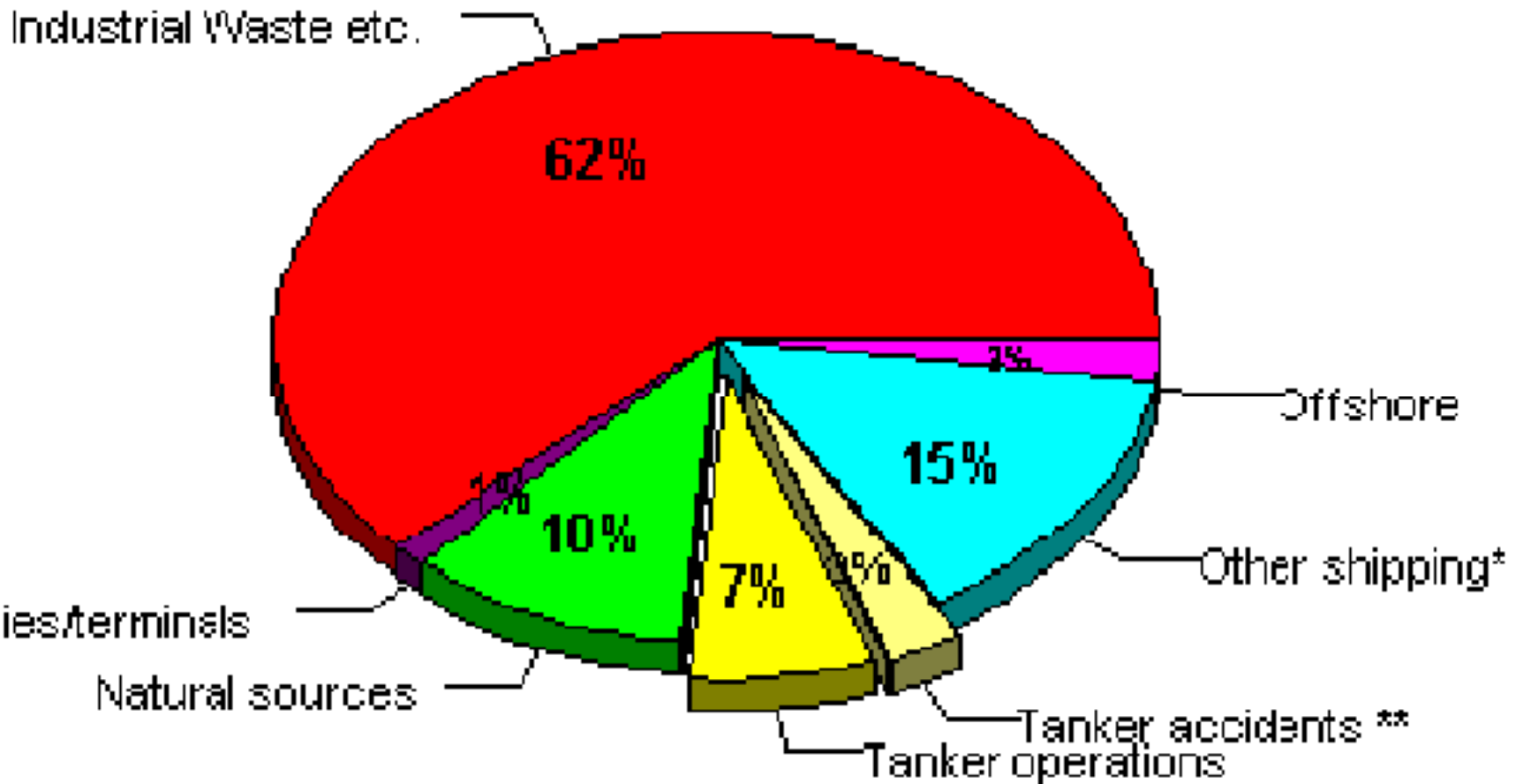


 ***Agricultural runoff can carry sediment, nutrients and pesticides to surface waters.***

USDA Soil Conservation Service

http://www.na.fs.fed.us/SPFO/pubs/n_resource/riparianforests/Tab%20I.htm

Source of oil pollution into the sea



** 1997

Source: UN Environmental Programme (UNEP), 1990.

* Non-tanker accidents, Bilge and Fuel oil, Dry-docking



<http://www.ew.govt.nz/enviroinfo/hscs/contam/>

Iron rich mine leachate

