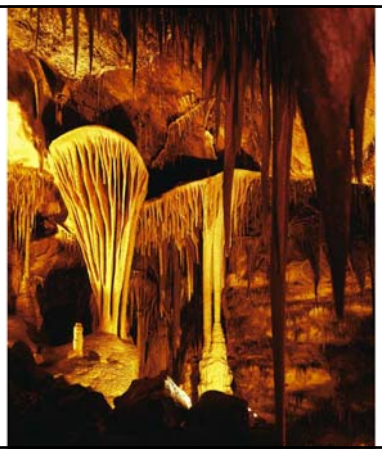
**TABLE 17.1** Fresh Water of the Hydrosphere

| Parts of the Hydrosphere | Volume of Fresh Water ($km^3$) | Share of Total Volume of Fresh Water (percent) | Rate of Water Exchange |
|---|---|---|---|
| Ice sheets and glaciers | 24,000,000 | 84.945 | 8000 years |
| Groundwater | 4,000,000 | 14.158 | 280 years |
| Lakes and reservoirs | 155,000 | 0.549 | 7 years |
| Soil moisture | 83,000 | 0.294 | 1 year |
| Water vapor in the atmosphere | 14,000 | 0.049 | 9.9 days |
| River water | 1,200 | 0.004 | 11.3 days |
| Total | 28,253,200 | 100.000 | |

Source: U.S. Geological Survey Water Supply Paper 2220, 1987





# Some definitions

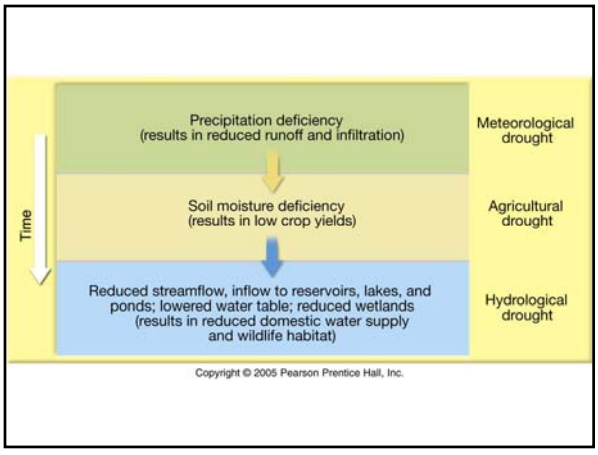
- Groundwater = water in the zone of saturation
- Porosity = the space between solid particles of soil or rock that can be filled by fluids.
- Permeability = the ease with which fluids can pass through a body of soil or rock.
- Infiltration = the movement of water from the surface into the ground.
- Aquifer = a body of soil or rock that can hold a useable amount of water.
- Aquiclude = a body of soil or rock that blocks the flow of water (Aquitard slows the flow).

**TABLE 17.2** Selected Values of Porosity, Specific Yield, and Specific Retention*

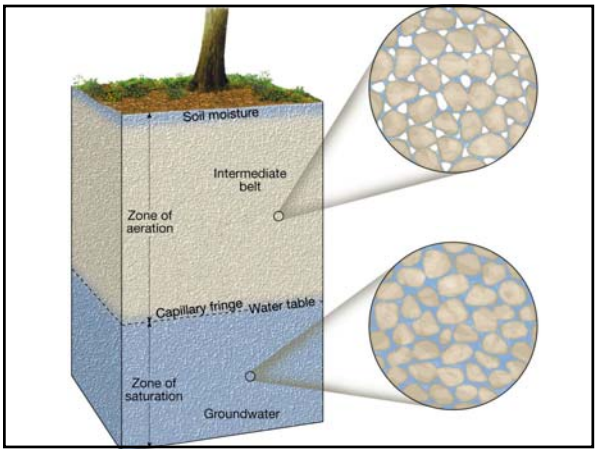
| Material | Porosity | Specific Yield | Specific Retention |
|---|---|---|---|
| Clay | 50 | 2 | 48 |
| Sand | 25 | 22 | 3 |
| Gravel | 20 | 19 | 1 |
| Limestone | 20 | 18 | 2 |
| Sandstone (semiconsolidated) | 11 | 6 | 5 |
| Granite | 0.1 | 0.09 | 0.01 |
| Basalt (fresh) | 11 | 8 | 3 |

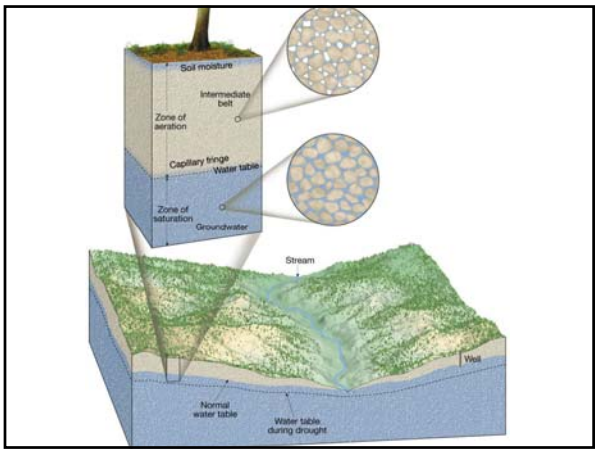
*Values in percent by volume
Source: U.S. Geological Survey Water Supply Paper 2220, 1987

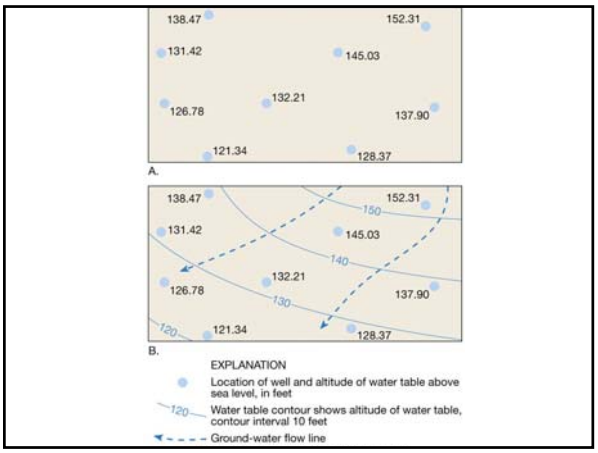


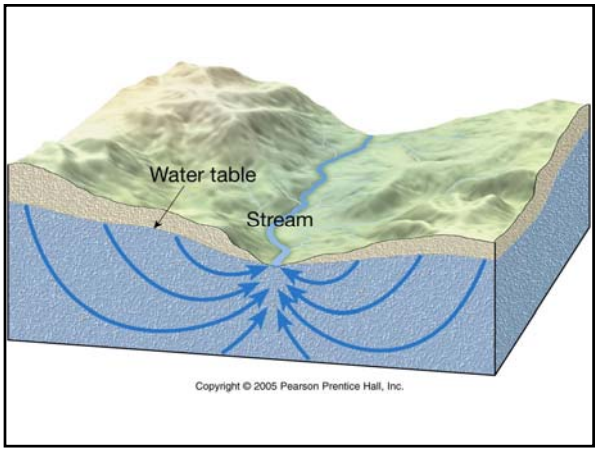


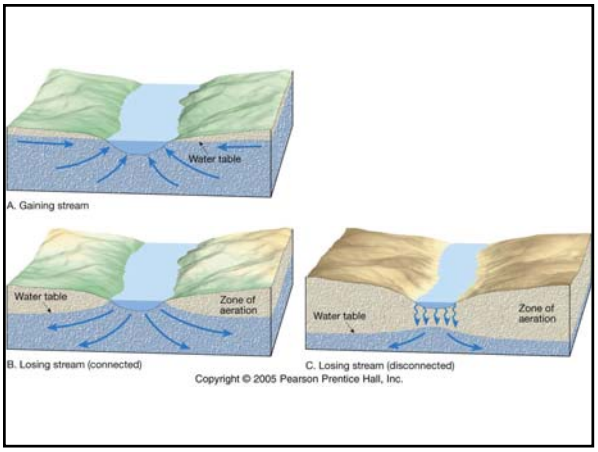




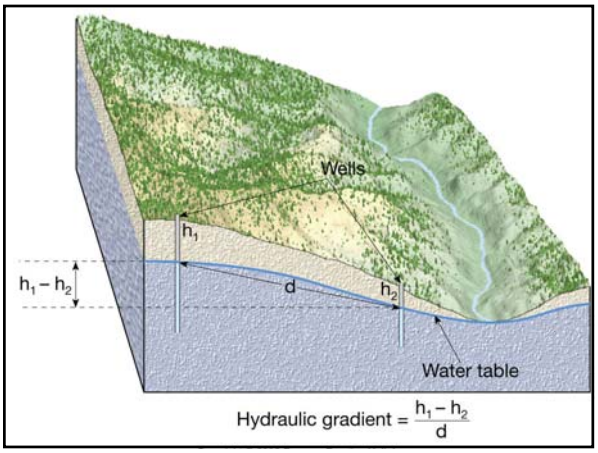



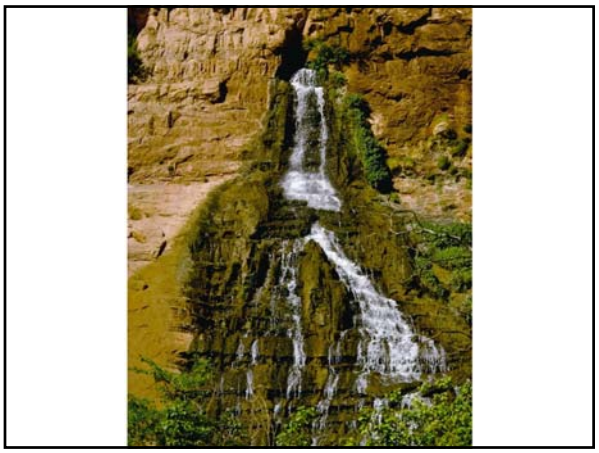

# Darcy's Law

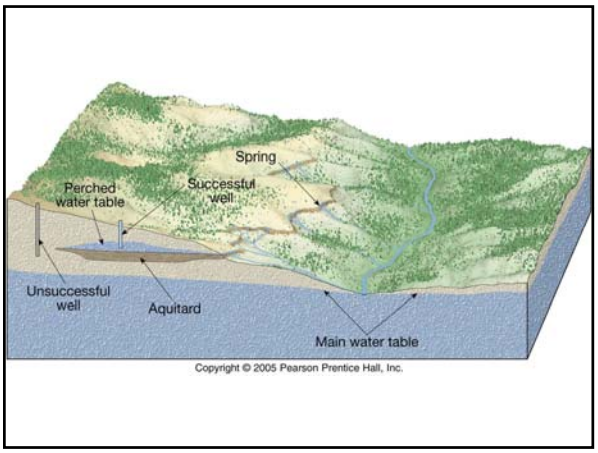
- Just as streams have a discharge, so do aquifers.

## Q=KIA

- Q is the discharge of the aquifer.
- K is the permeability of the aquifer.
- I is the hydraulic gradient.
- A is the cross-sectional area the groundwater is passing through.






Spring
Perched water table
Successful well
Unsuccessful well
Aquitard
Main water table
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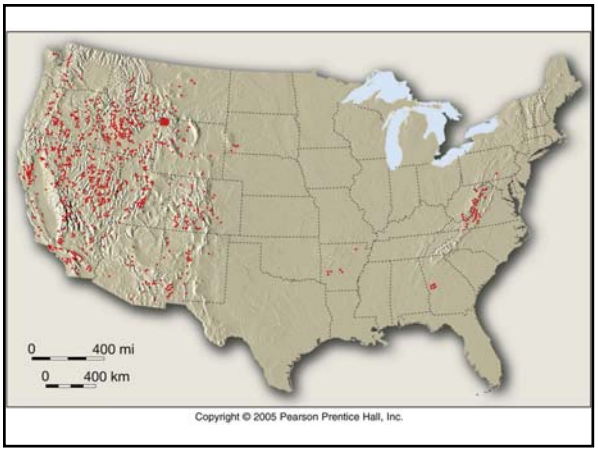
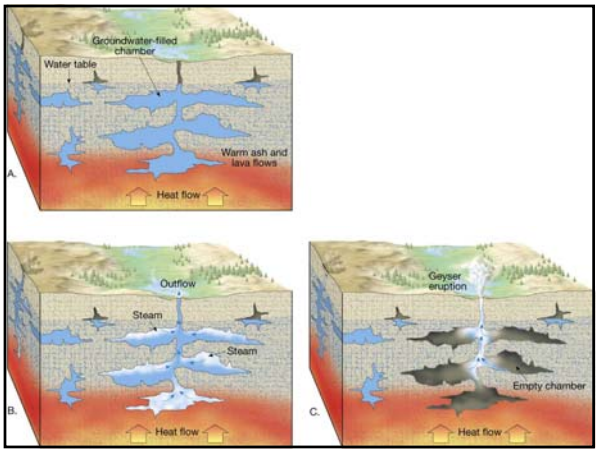
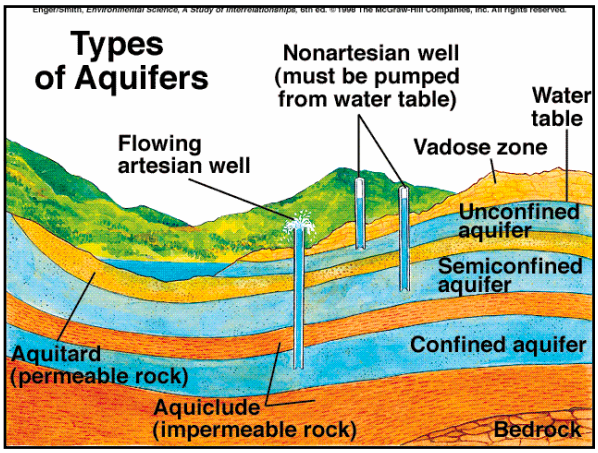
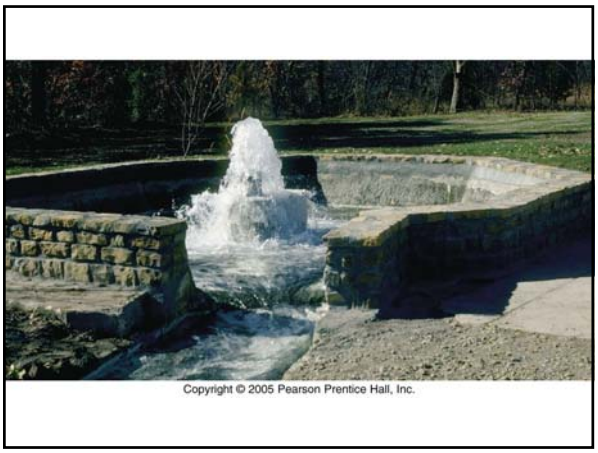

0 400 mi
0 400 km
Copyright © 2005 Pearson Prentice Hall, Inc.


Groundwater-filled chamber
Water table
Warm ash and lava flows
Heat flow
A.
Outflow
Steam
Steam
Heat flow
B.
Geyser eruption
Empty chamber
Heat flow
C.


Types of Aquifers
Nonartesian well (must be pumped from water table)
Water table
Flowing artesian well
Vadose zone
Unconfined aquifer
Semiconfined aquifer
Confined aquifer
Aquitard (permeable rock)
Aquiclude (impermeable rock)
Bedrock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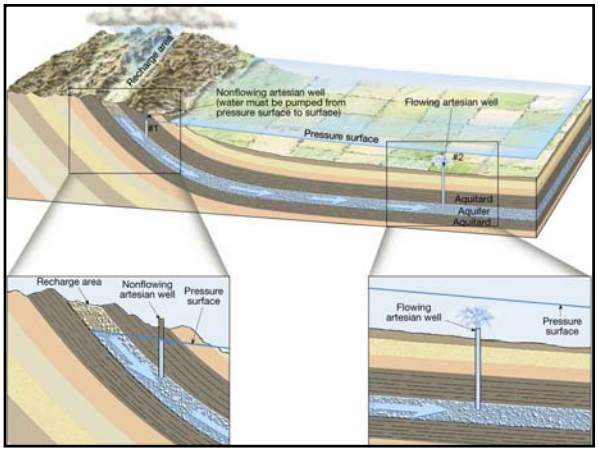
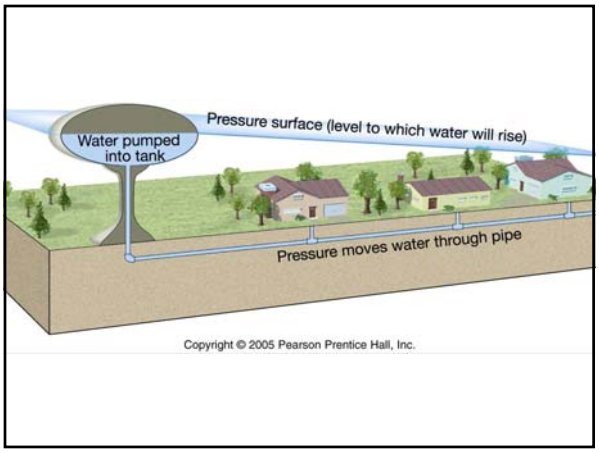

Recharge area
Nonflowing artesian well (water must be pumped from pressure surface to surface)
Flowing artesian well
Pressure surface
#1
#2
Aquitard
Aquifer
Aquitard
Recharge area
Nonflowing artesian well
Pressure surface
Flowing artesian well
Pressure surface


Pressure surface (level to which water will rise)
Water pumped into tank
Pressure moves water through pipe
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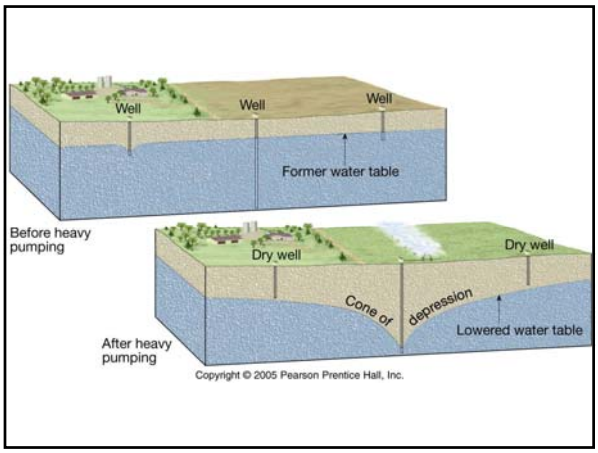
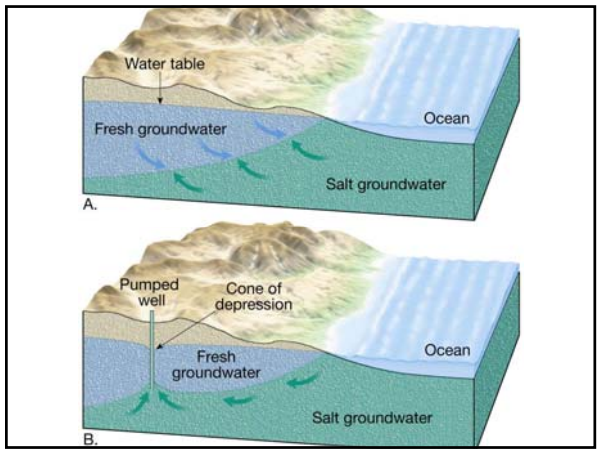
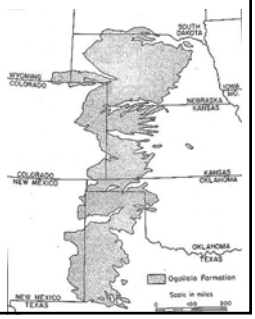



## Ogallala ("High Plains") Aquifer

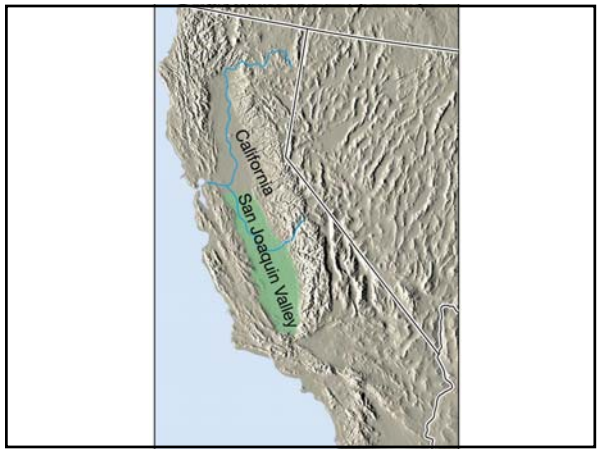
- Buried erosional remnant of Rocky Mts.
- Largest single water bearing unit in North America.
- Holds enough water to fill Lake Huron.



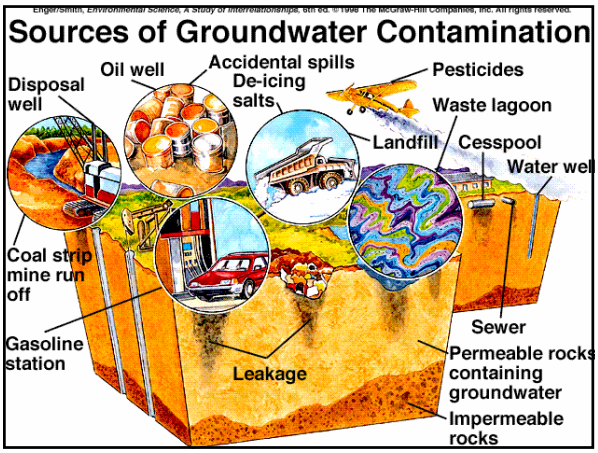


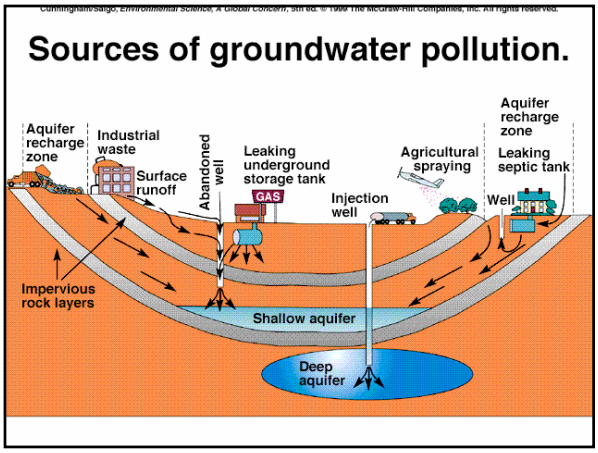
## Ogallala Aquifer Depletion

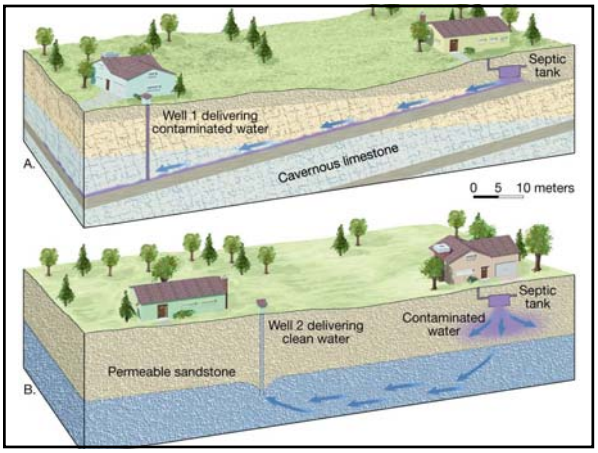
- Most water pumped for irrigation of crops principally used to feed livestock.
- From 1940 to 1980 aquifer water table fell an average of 10 ft/decade (up to 100 ft in some places).
- 1980's only fell another foot due to improved irrigation techniques.

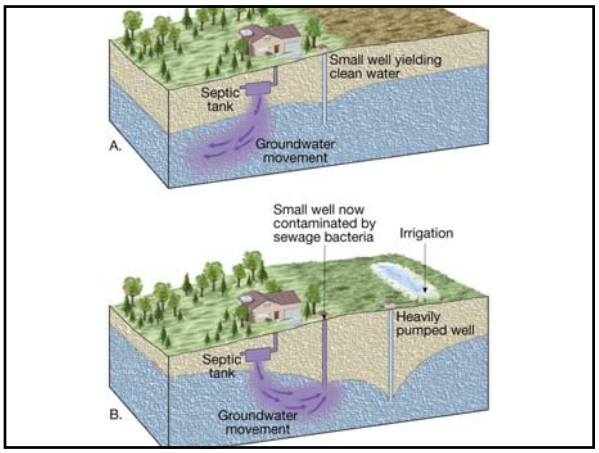


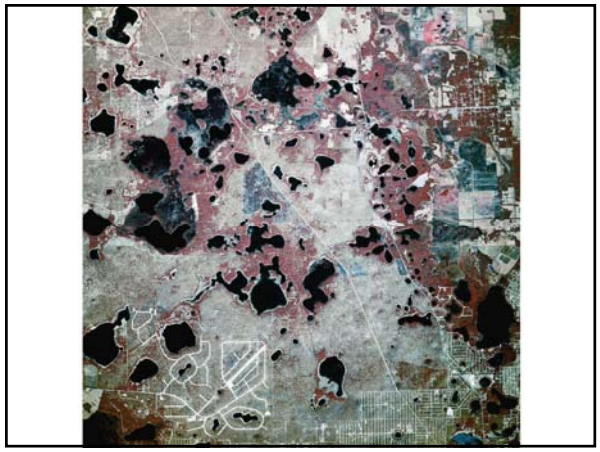

1925
1955
1977

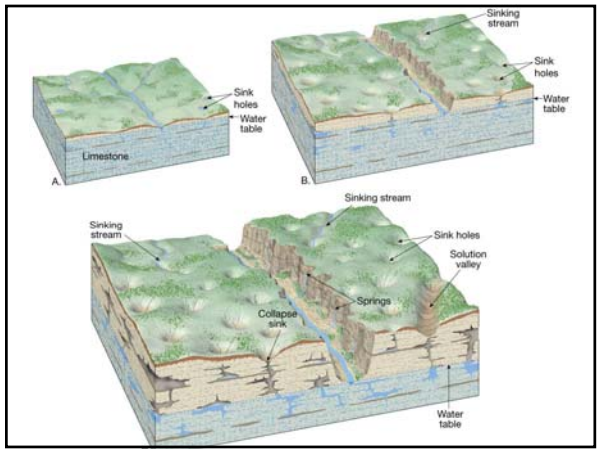

Sources of Groundwater Contamination
Disposal well
Oil well
Accidental spills
De-icing salts
Pesticides
Waste lagoon
Landfill
Cesspool
Water well
Coal strip mine run off
Gasoline station
Leakage
Sewer
Permeable rocks containing groundwater
Impermeable rocks


Sources of groundwater pollution.
Aquifer recharge zone
Industrial waste
Surface runoff
Abandoned well
Leaking underground storage tank
GAS
Injection well
Agricultural spraying
Aquifer recharge zone
Leaking septic tank
Well
Impervious rock layers
Shallow aquifer
Deep aquifer


Septic tank
Well 1 delivering contaminated water
A.
Cavernous limestone
0 5 10 meters
Septic tank
Well 2 delivering clean water
Contaminated water
Permeable sandstone
B.


Small well yielding clean water
Septic tank
Groundwater movement
A.
Small well now contaminated by sewage bacteria
Irrigation
Heavily pumped well
Septic tank
Groundwater movement
B.




Sinking stream
Sink holes
Water table
Limestone
A.
B.
Sinking stream
Sinking stream
Sink holes
Solution valley
Springs
Collapse sink
Water table