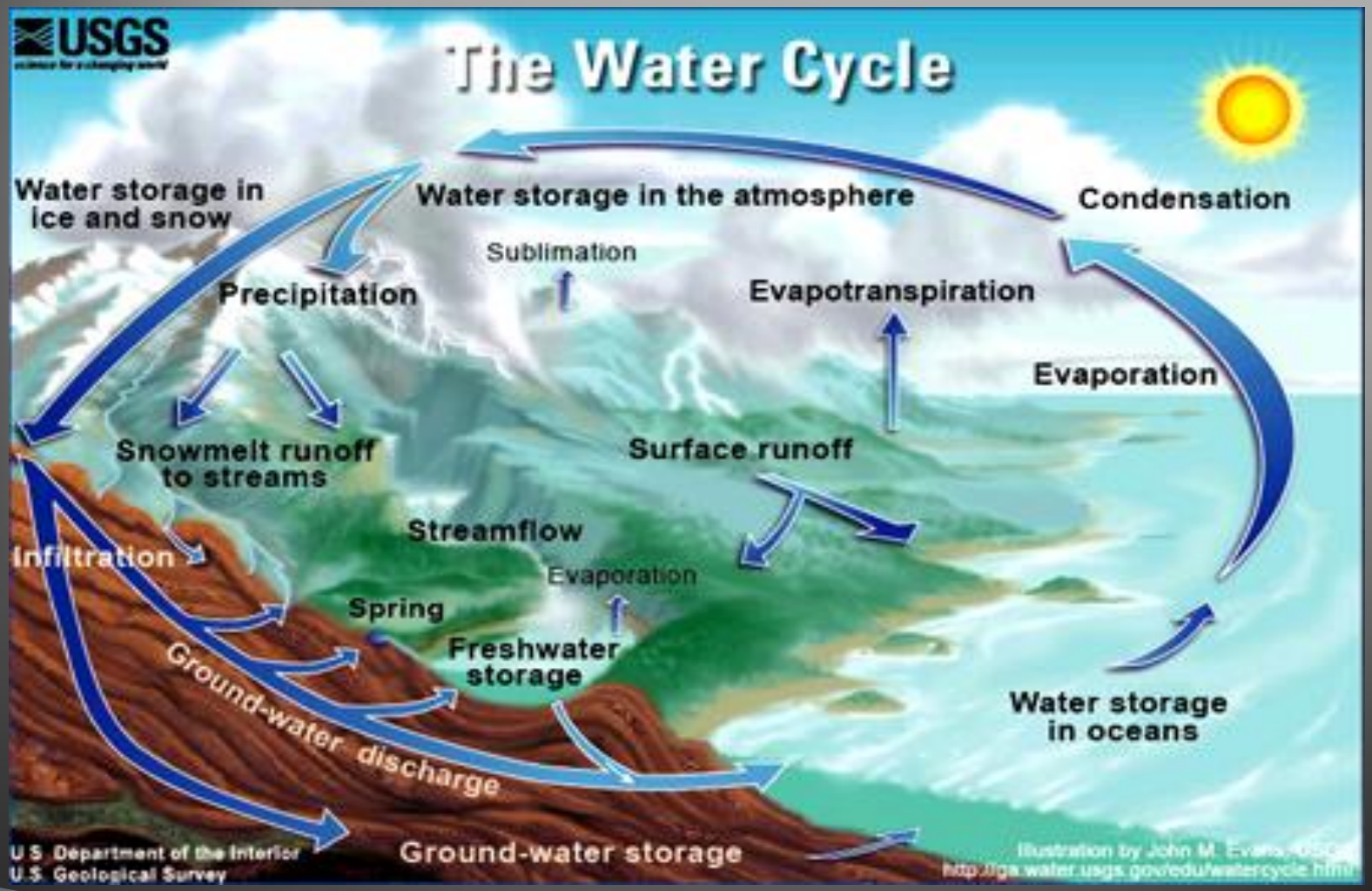
WRIGHT WATER ENGINEERS, INC.

Groundwater Seminar

City of Boulder
June 1, 2017

Presented by: Andrew Earles, Ph.D., P.E., D.WRE

What is groundwater?



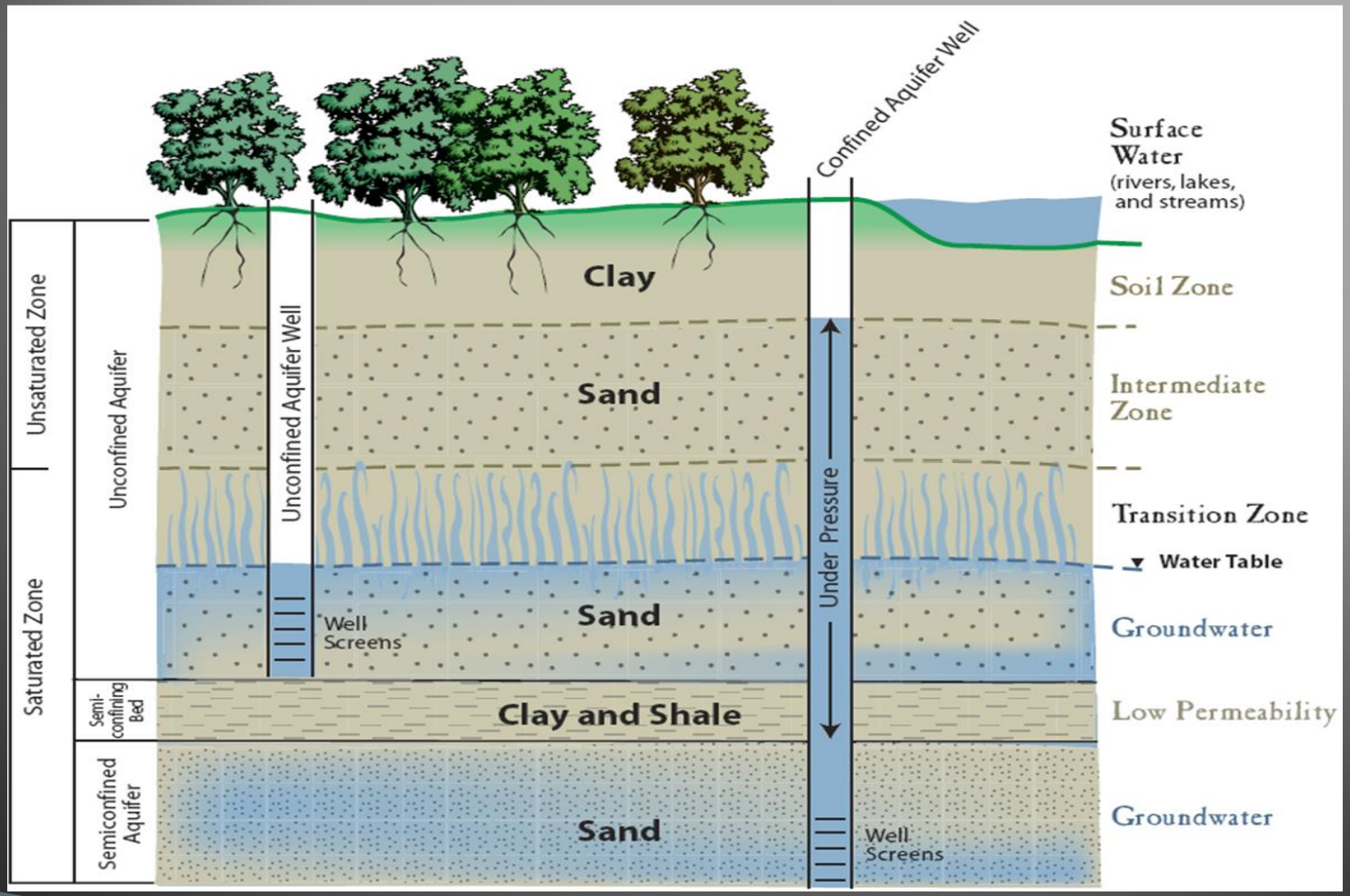
What is groundwater?

- Groundwater is:
  - The water that exists beneath the ground surface filling pore spaces in soils and sediments or cracks and crevices in rocks
  - That portion of rain and snow that percolates into the ground
  - That part of the subsurface water that is in the saturated zone

Where is groundwater?

- Groundwater can be found in:
  - pore spaces in soils and sediments or cracks and crevices in rocks beneath the ground surface
    - If water filled - the Saturated Zone (phreatic zone)
    - If air and water -the Unsaturated Zone (vadose zone)
    - The top of the saturation zone is the Water Table
    - Where the saturated zone produces groundwater at a useable rate - it is called an Aquifer

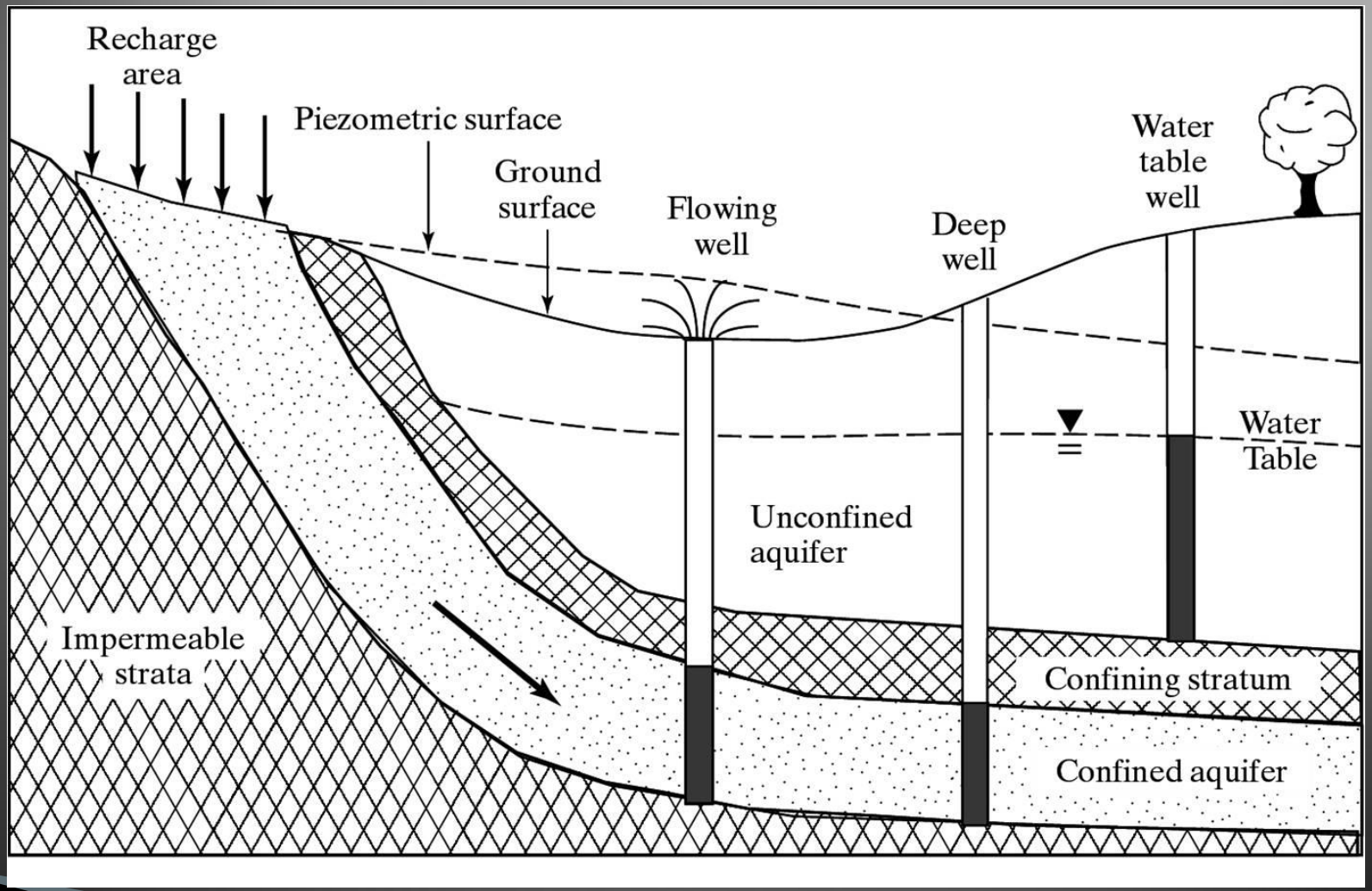
Where is groundwater?



Where is groundwater?

- AQUIFER TYPES
  - Alluvial Aquifer
    - Unconfined – water table conditions
  - Bedrock Aquifer
    - Unconfined – water table conditions
    - Confined – pressurized conditions
      - Artesian – potentiometric surface above aquifer
      - Flowing Artesian – potentiometric surface above land

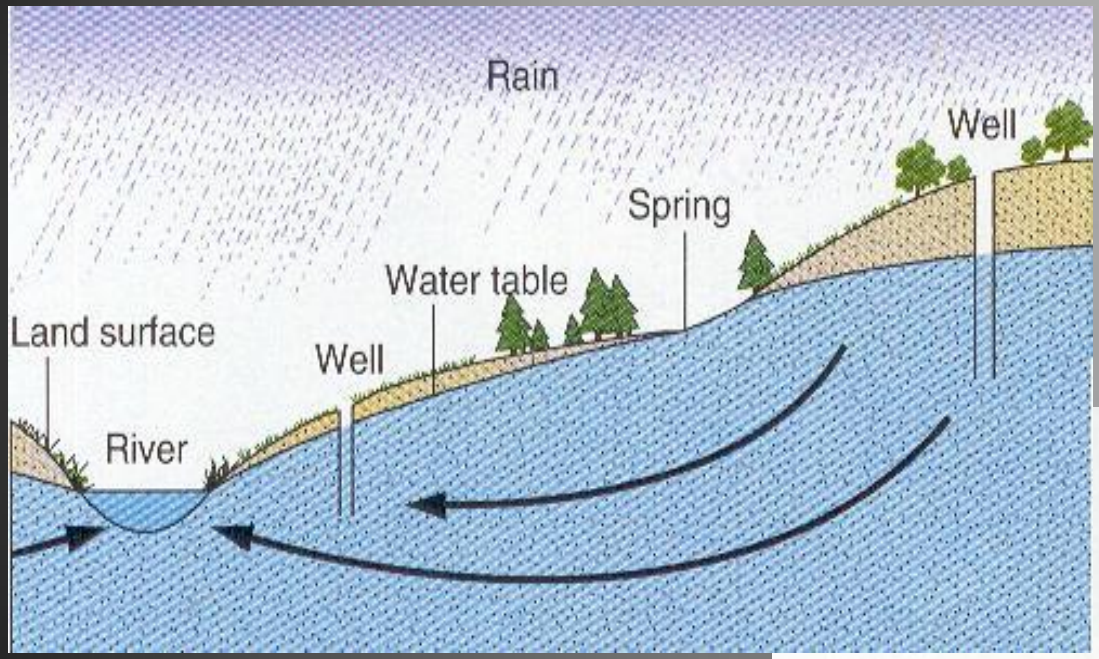
Where is groundwater?

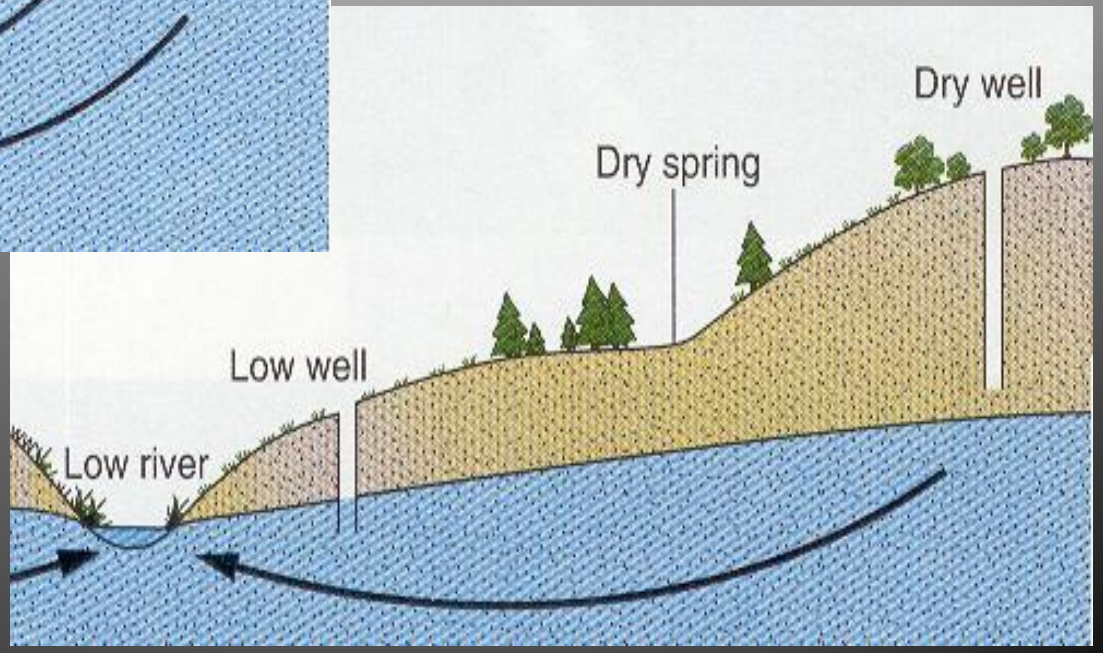


Why is groundwater so enigmatic?

- Groundwater…
  - Is difficult to readily observe over a large area from the surface
  - Moves between pore spaces and in cracks and crevices (therefore not very exciting)
  - Does not exist as underground streams or lakes (except under very specific geologic conditions)
  - Can be variable due to seasonal and hydrologic influences

Why is groundwater so enigmatic?



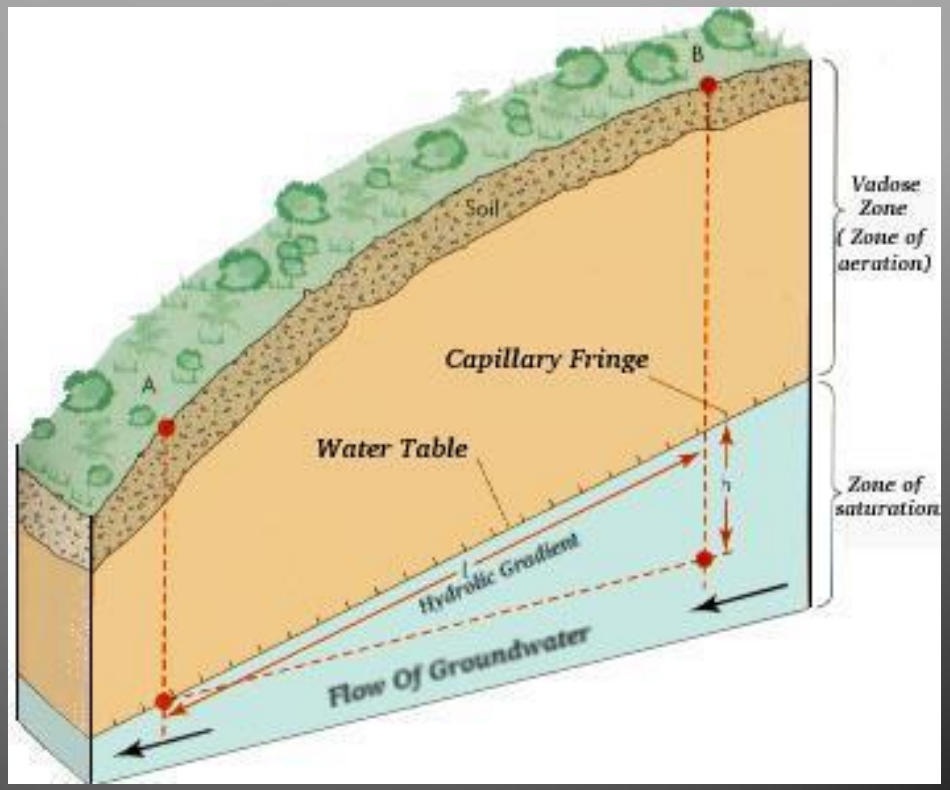


Does groundwater flow and, if so, how?

- Yes, groundwater flows…
  - Relatively slowly through bedrock and somewhat faster through soils and sediments (there are exceptions)
  - In response to differences in water pressure and elevation (i.e., water flows downhill)
  - Roughly in a direction and rate represented by the general slope of the overlying surface topography

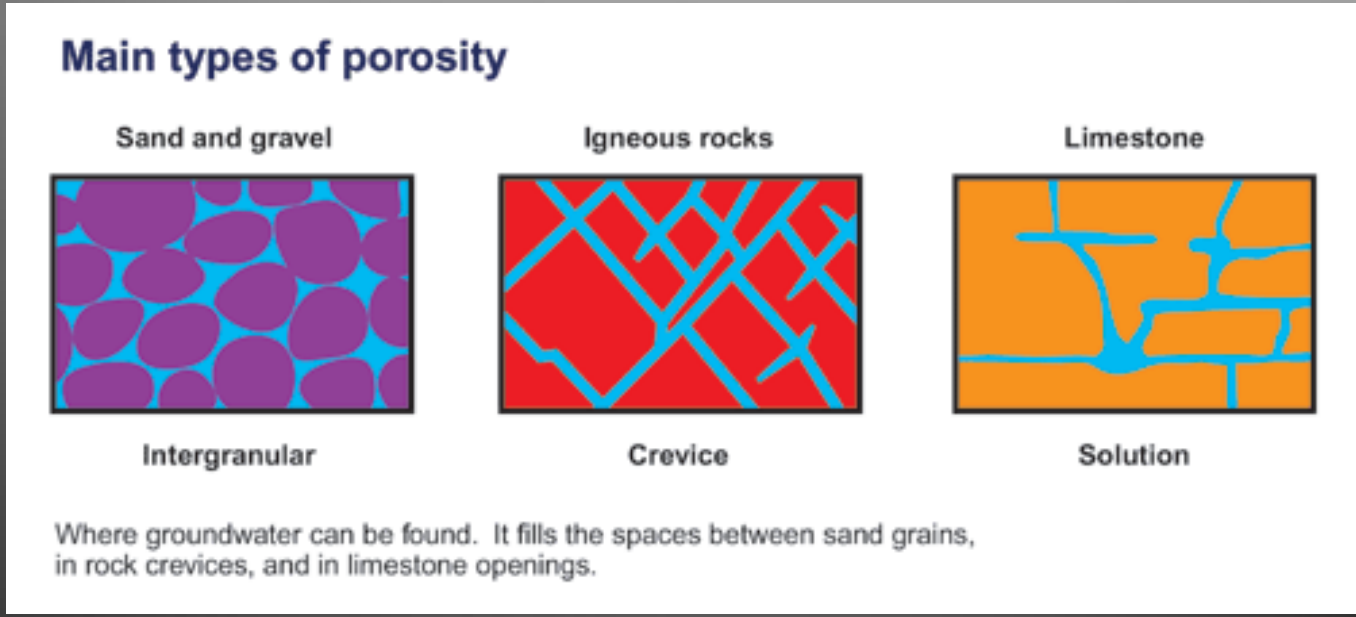
Does groundwater flow and, if so, how?

- Factors affecting groundwater flow:
  - Gradient (i) – the slope of the water table ($i=\Delta h/\Delta l$); the steeper the gradient, the faster the movement



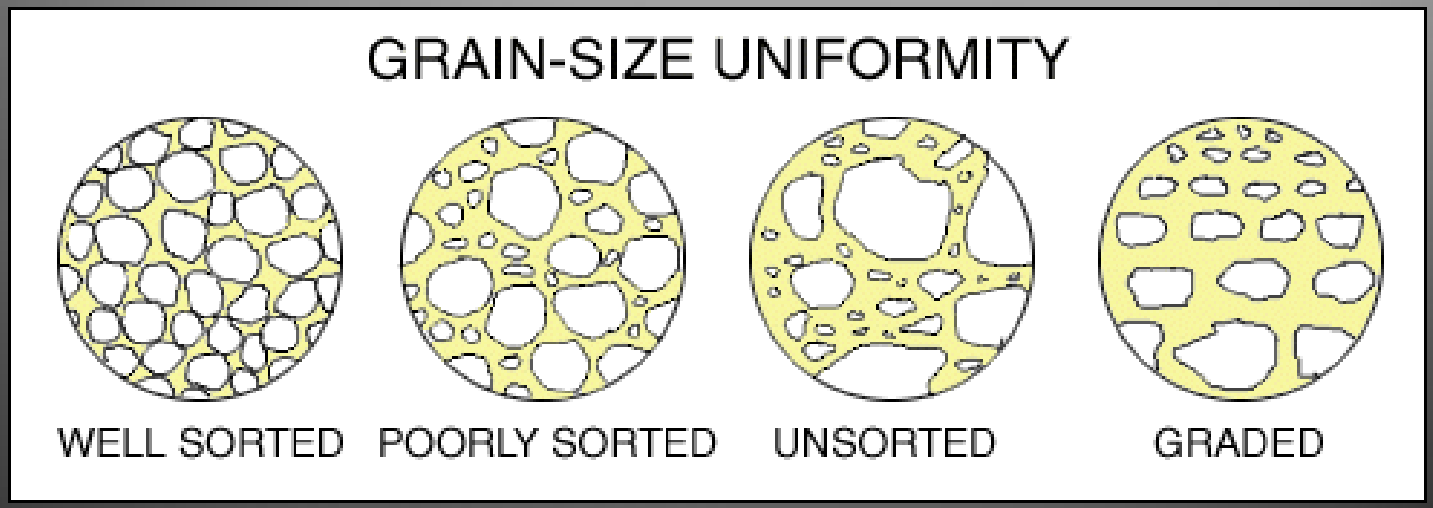
Does groundwater flow and, if so, how?

- Factors affecting groundwater flow:
  - Porosity (Φ) - the space between solid particles of soil or rock that can be filled with fluid



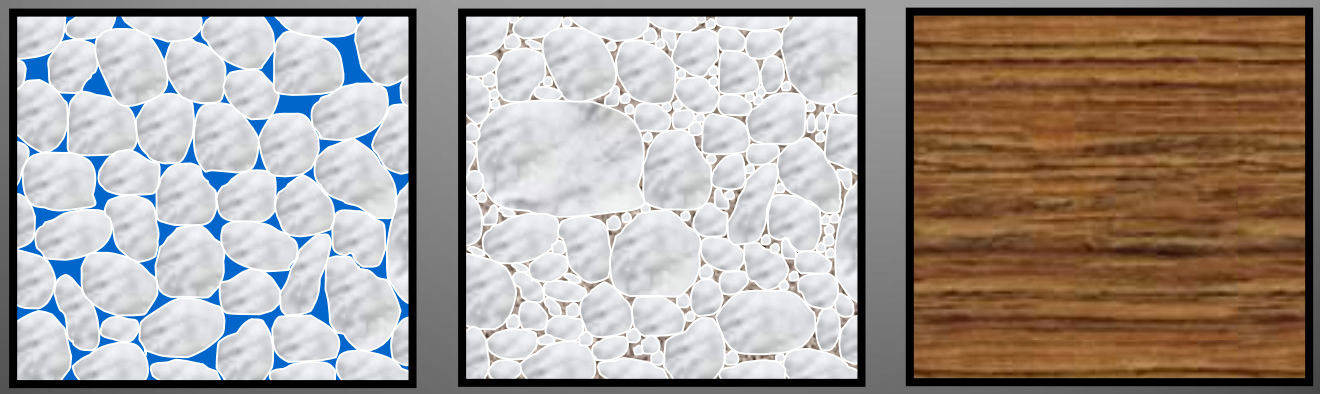
Does groundwater flow and, if so, how?

- Factors affecting groundwater flow:
  - Sorting - the degree of similarity of sedimentary particles in a sediment



Does groundwater flow and, if so, how?

- Factors affecting groundwater flow:
  - Permeability or hydraulic conductivity (k) - a measure of the ease with which fluids can pass through a body of soil or rock



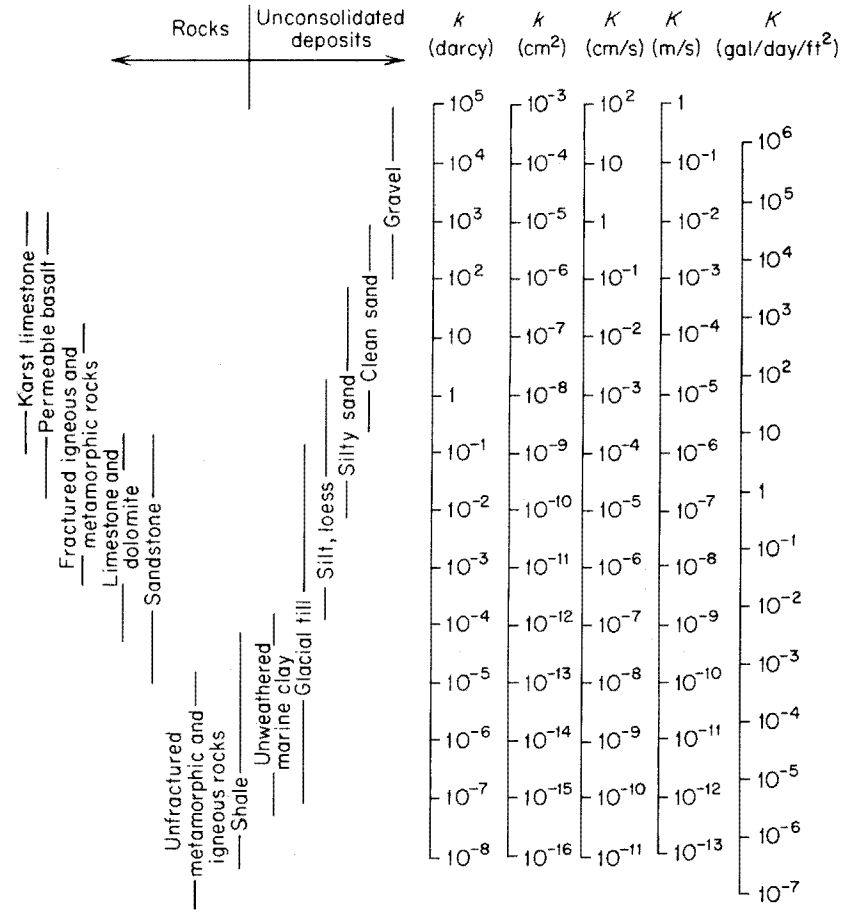
Permeability and Hydraulic Conductivity

High ⟷ **Low**

Does groundwater flow and, if so, how?

- Factors affecting groundwater flow:
  - Permeability ranges are known for various rock types

Table 2.2 Range of Values of Hydraulic Conductivity and Permeability



Does groundwater flow and, if so, how?

- Fundamental Flow Equation
  - Darcy's Law – named after Henry Darcy (1856). His equation describes fundamental groundwater flow.

$$Q = kiA$$

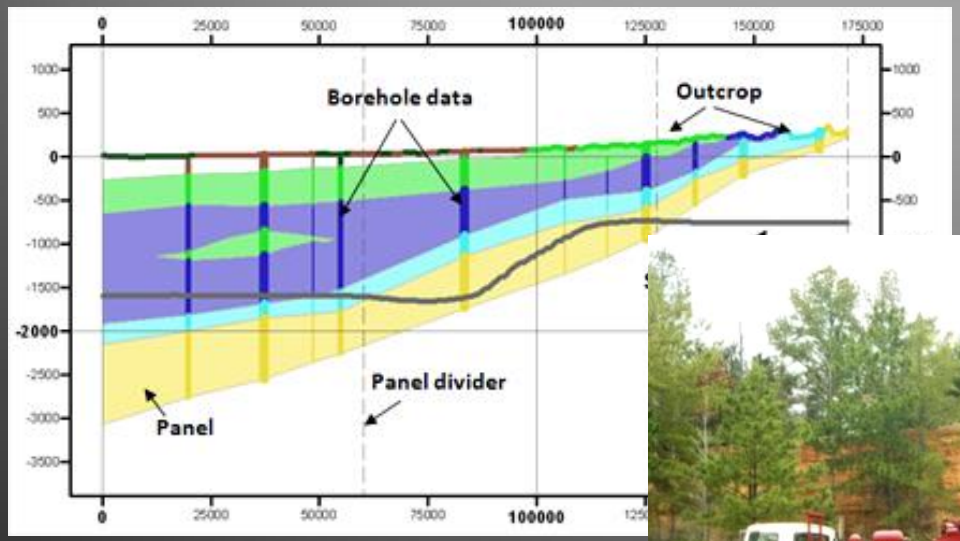
Q = Flow
k = Hydraulic conductivity
i = gradient
A = cross-sectional area perpendicular to flow

Does groundwater flow and, if so, how?

- Other Equations:
  - Theis – nonequilibrium radial flow equation
  - Thiem – equilibrium flow equation

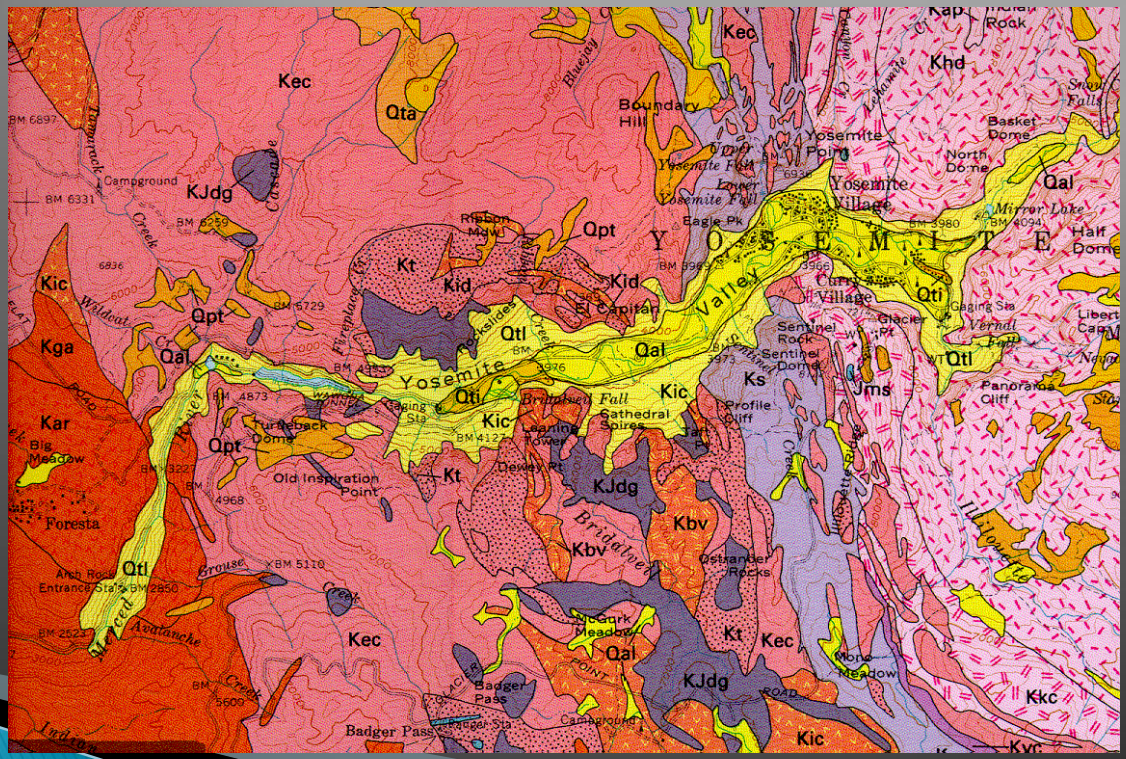
So what do we know about the subsurface?

- A lot surprisingly, but mostly inferred
  - Geotechnical Engineering – boreholes drilled to assess subsurface conditions and soil/rock properties



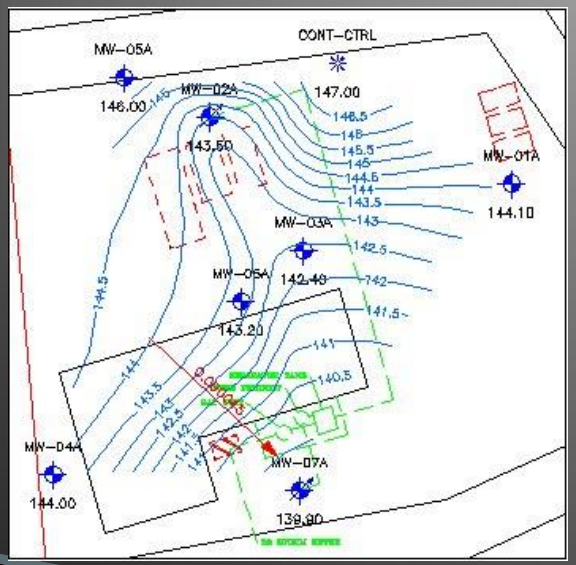
So what do we know about the subsurface?

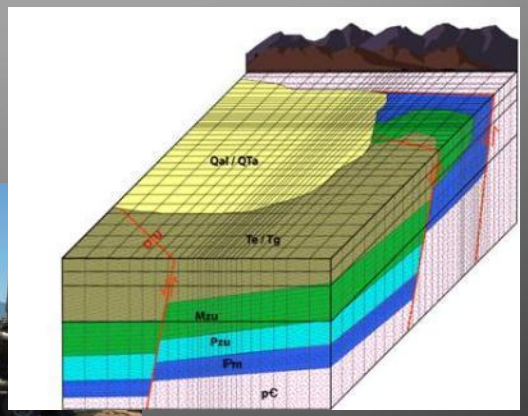
- A lot surprisingly, but mostly inferred
  - Geology – from published or field mapping and from exploration (water, oil, gas, mineral) wells



So what do we know about the subsurface?

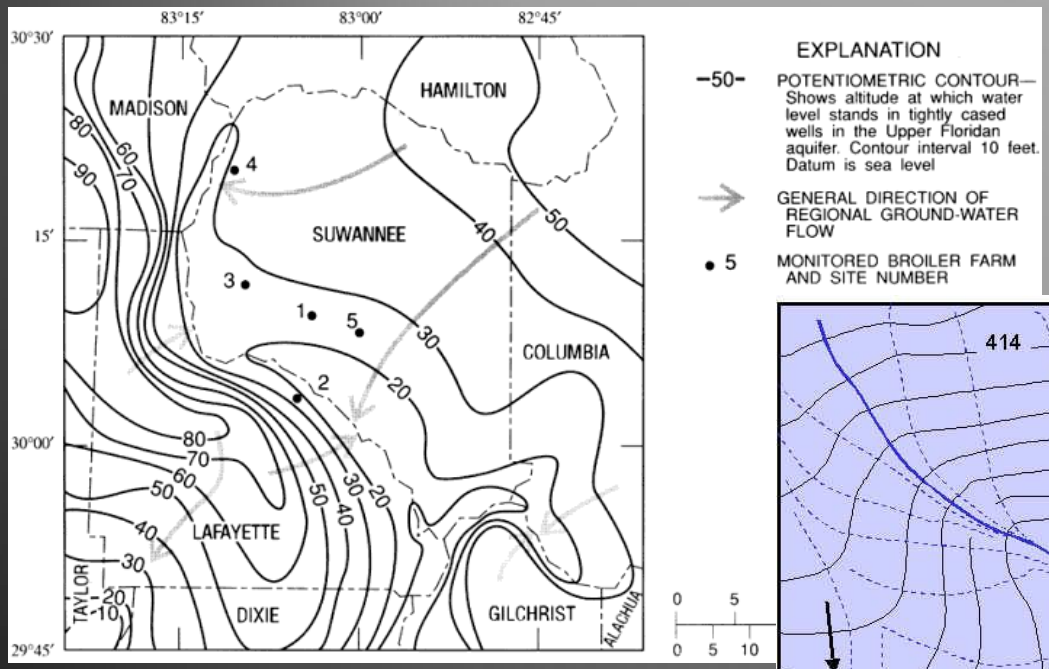
- A lot surprisingly, but mostly inferred
  - Hydrogeology – from published or field testing, local/regional water table observations, pumping tests, tracer tests, water quality analyses, and modeling

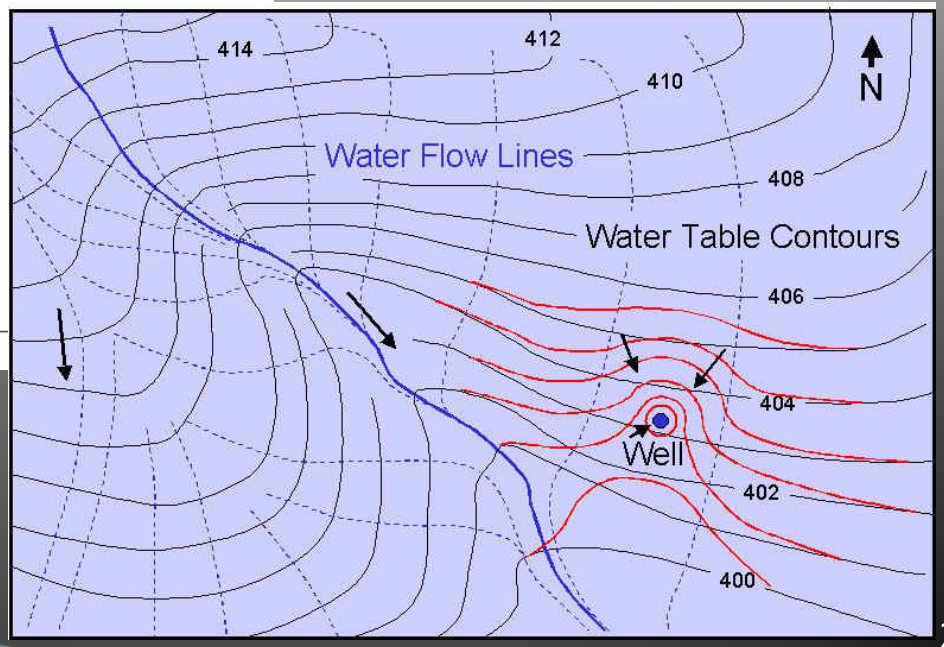




What can available subsurface information tell us?

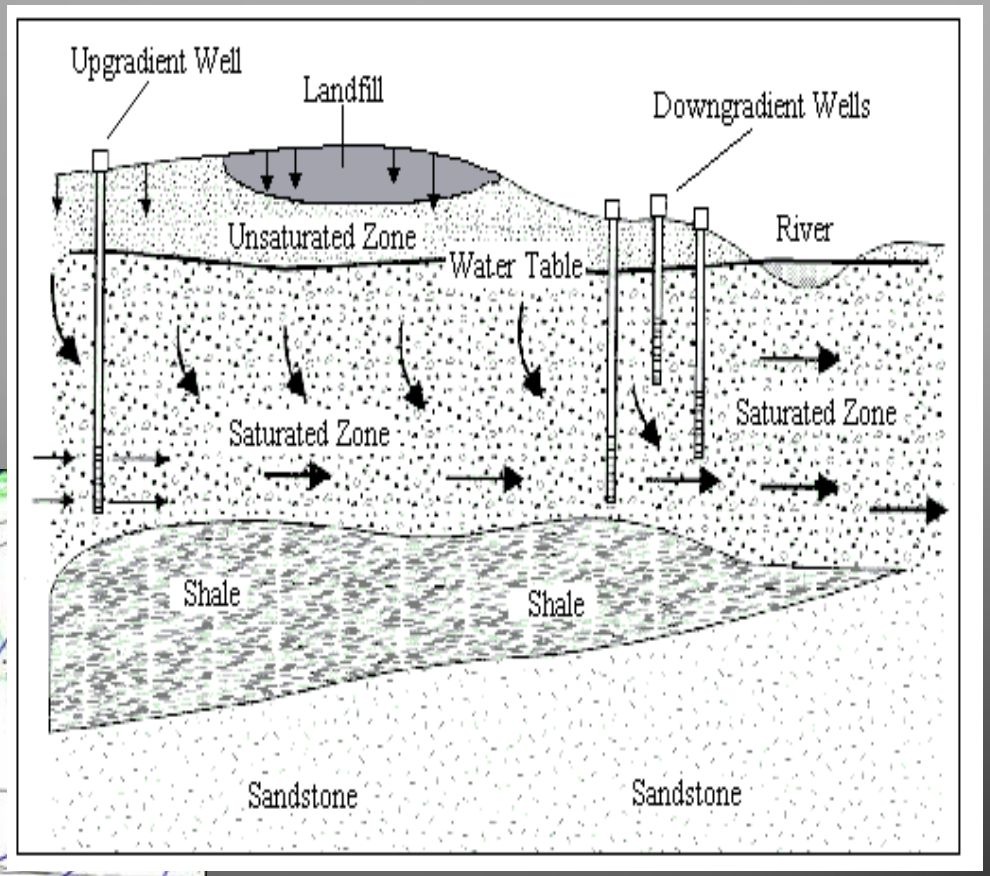
- Groundwater flow direction and travel time

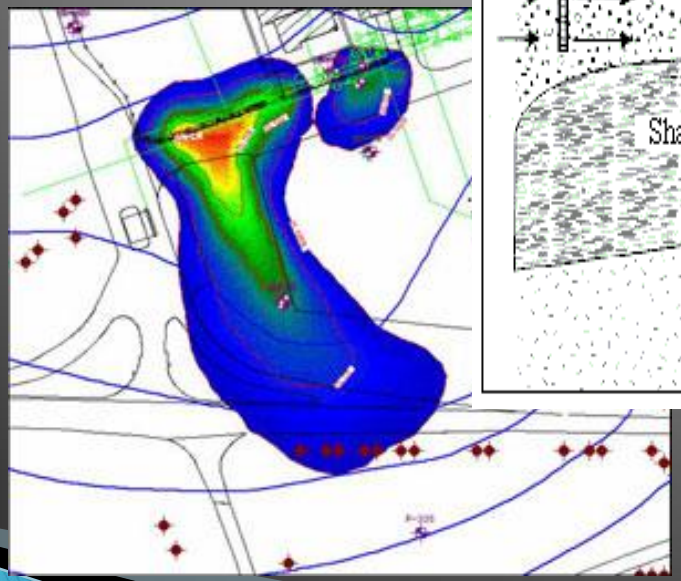




What can available subsurface information tell us?

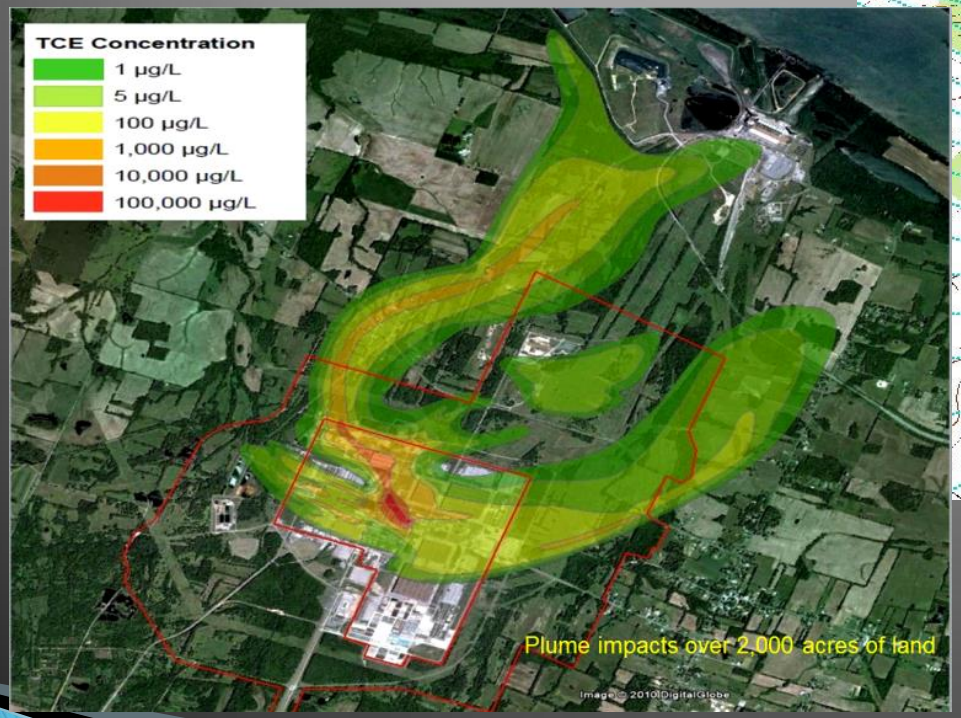
- Inferred upgradient influence and downgradient impacts

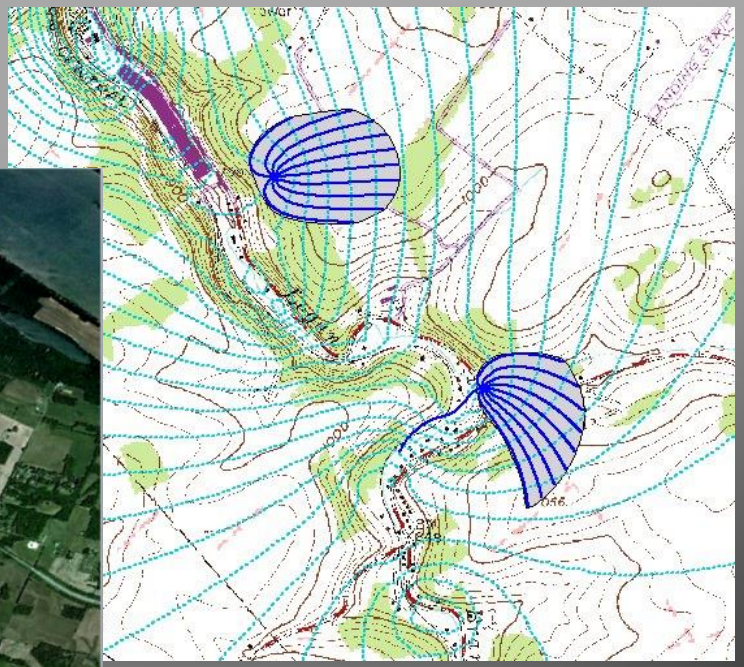




What can available subsurface information tell us?

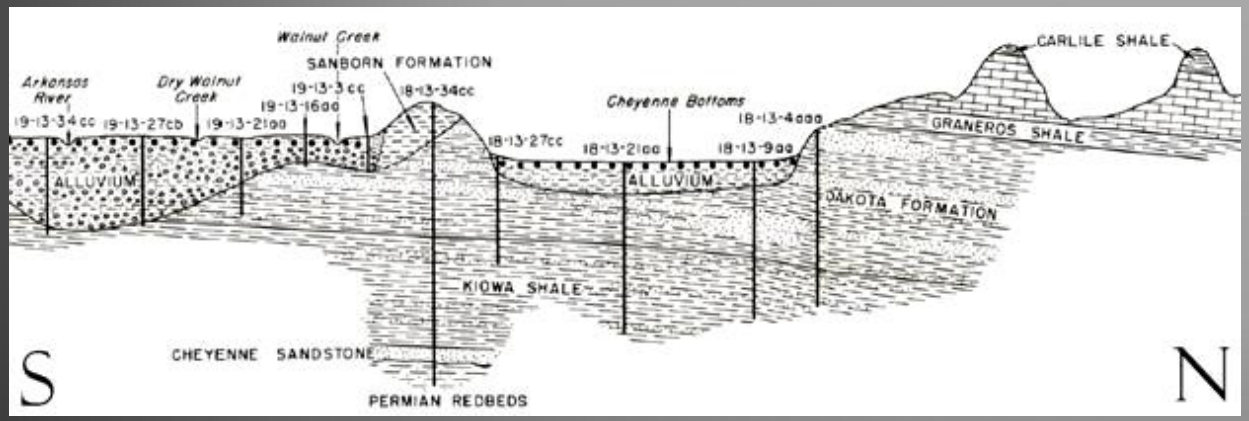
- Extent of contaminant plume or well influence area

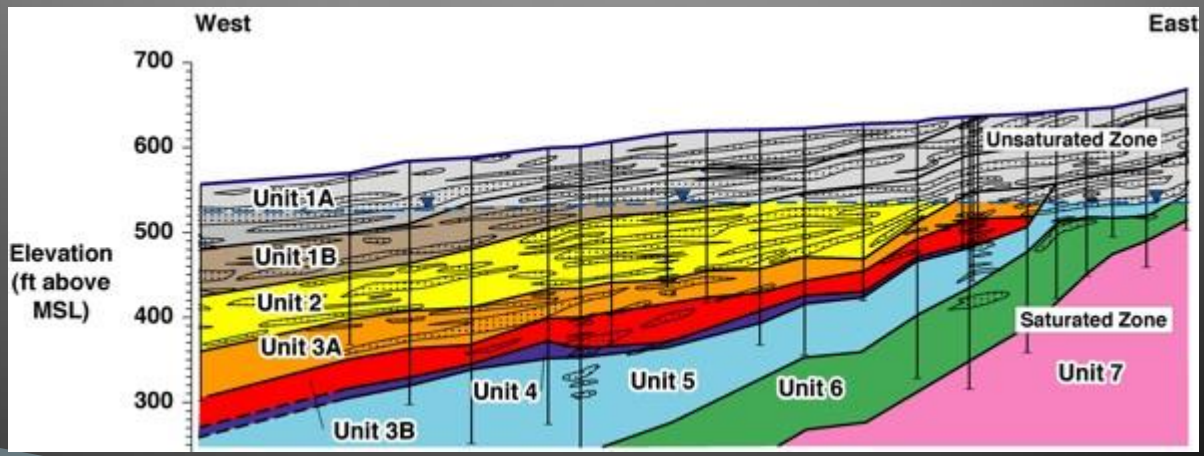




What can available subsurface information tell us?

- Water supply well locations





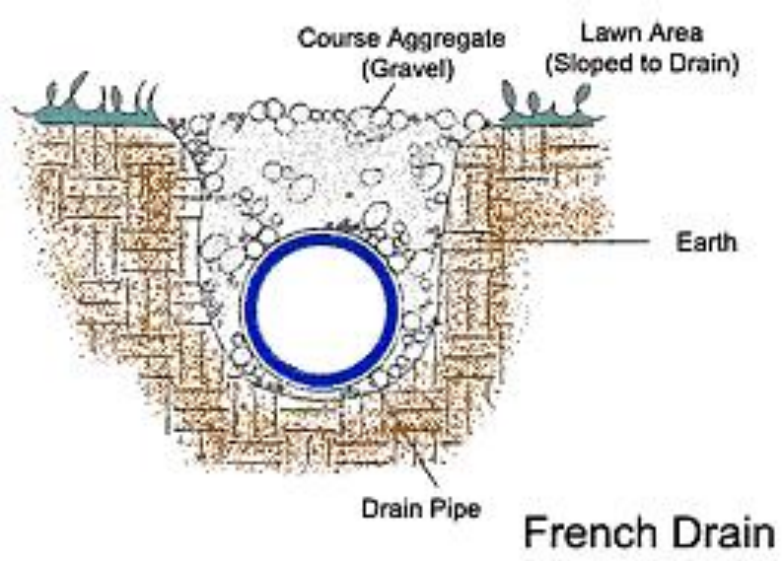
Is the subsurface or inferred information fool-proof?

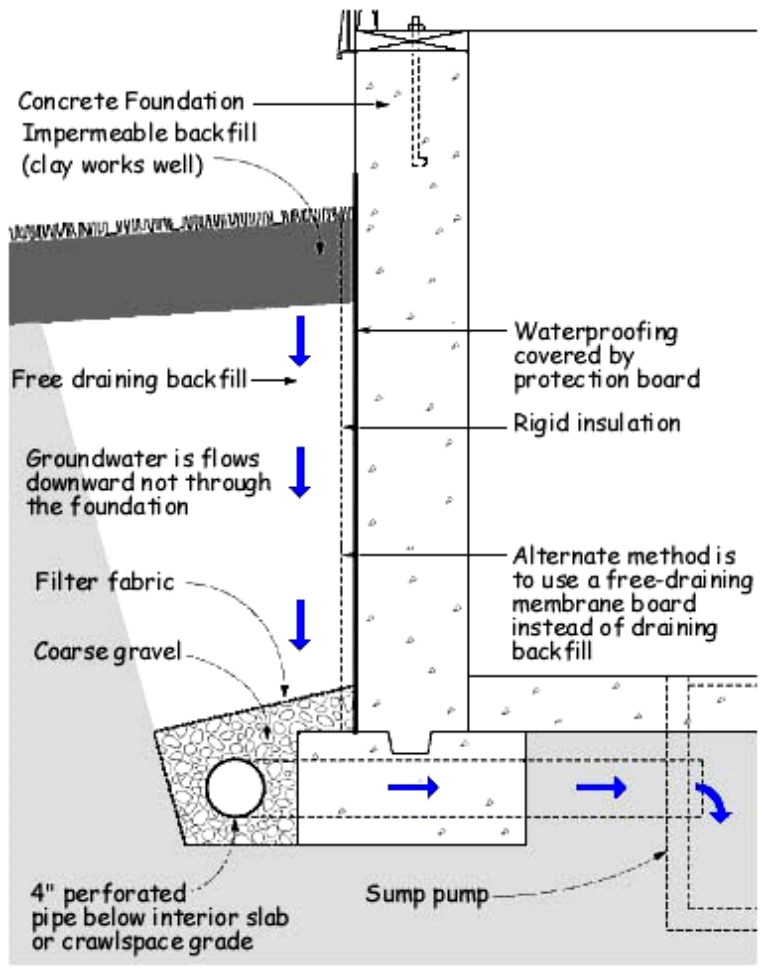
How do we use and manage the groundwater resource?

- Water Supply Wells
  - Permitting
  - Design and Construction
  - Testing

How do we use and manage the groundwater resource?

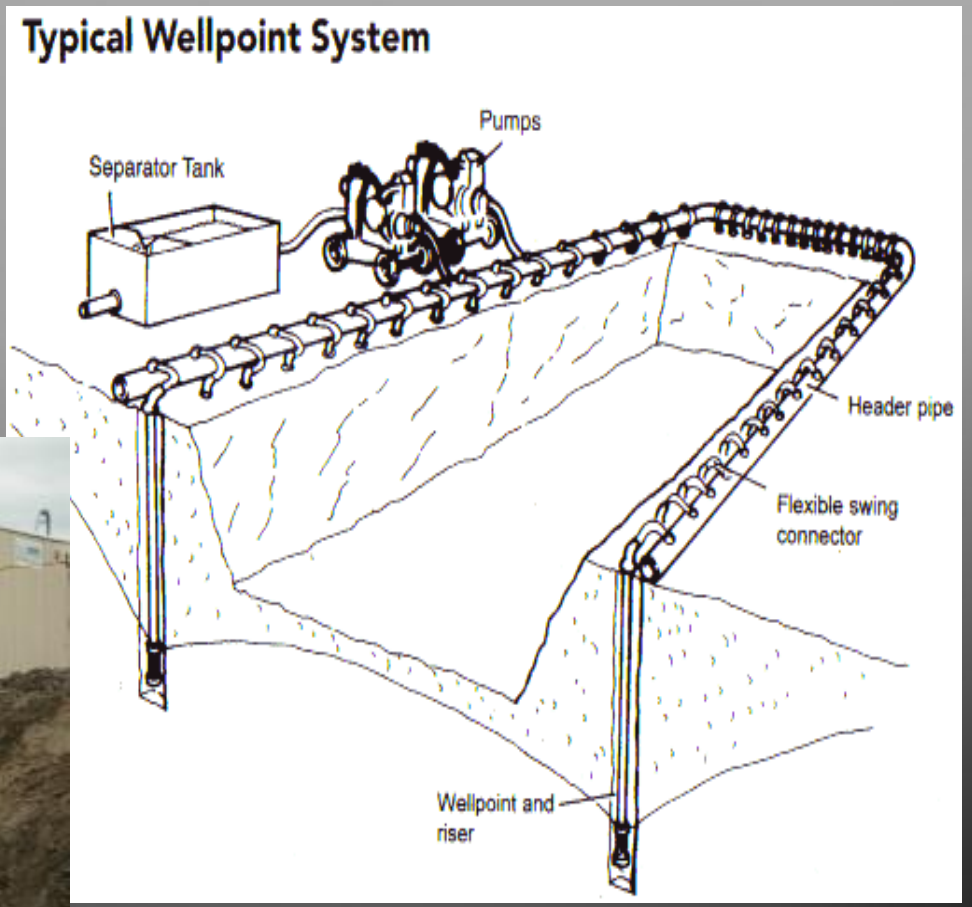
- Property or Foundation Protection
  - Underdrains and Sumps





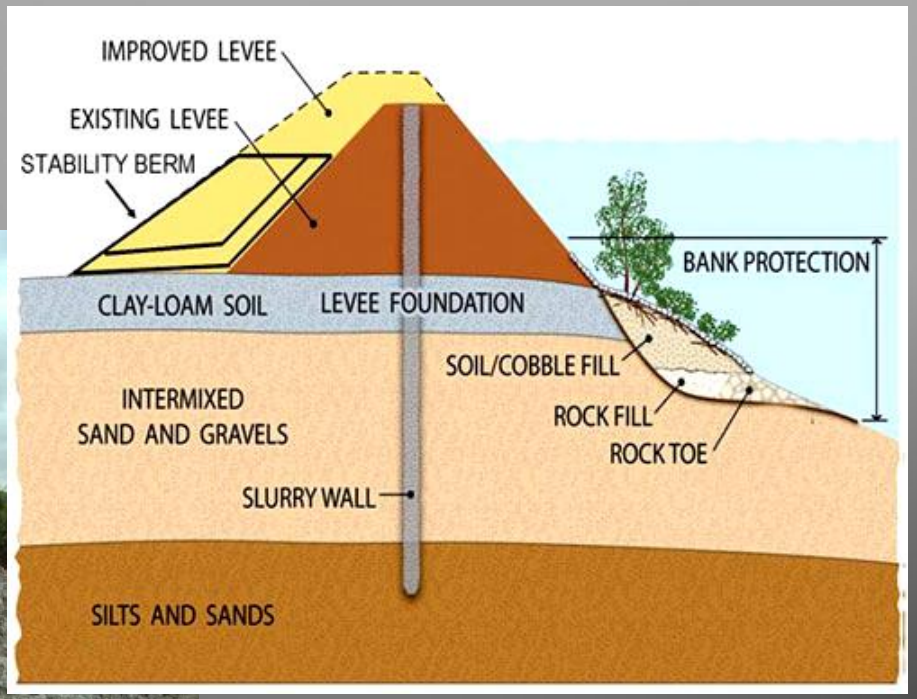
How do we use and manage the groundwater resource?

- Construction Dewatering Systems
  - Well Points



How do we use and manage the groundwater resource?

- Containment Devises
  - Slurry Walls



Is there a connection between groundwater and surface water?

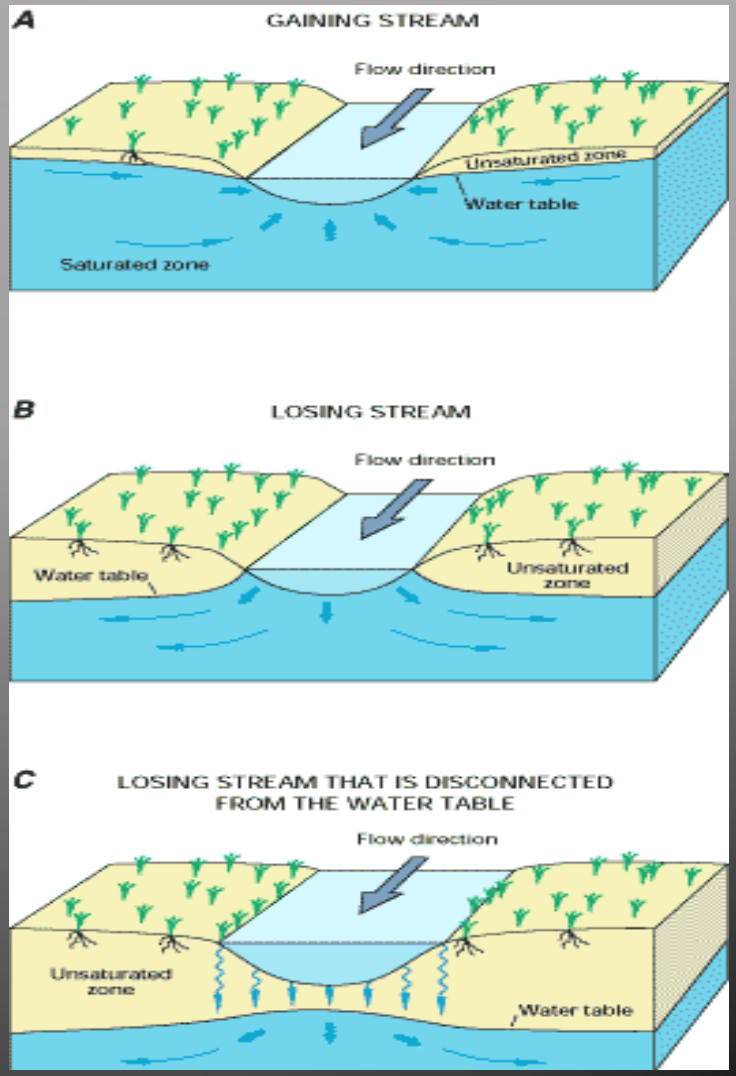
- YES, without question. However, the connection may…
  - Not be obvious
  - Be seasonal or episodic
  - Change over longer periods of time

How is groundwater and surface water connected?

- Hydraulic Connectivity:
  - Water moves in relation to elevation differences (i.e., downhill)
  - Surface water and groundwater want to move deeper, unless hydraulically prevented
  - Water will follow the path of least resistance
  - Sometimes the path of least resistance is lateral

How is groundwater and surface water connected?

- Stream or Ditch Systems:
  - Gaining
    - Humid regions
    - Wet season
  - Losing
    - Arid regions
    - Dry season
  - Disconnected

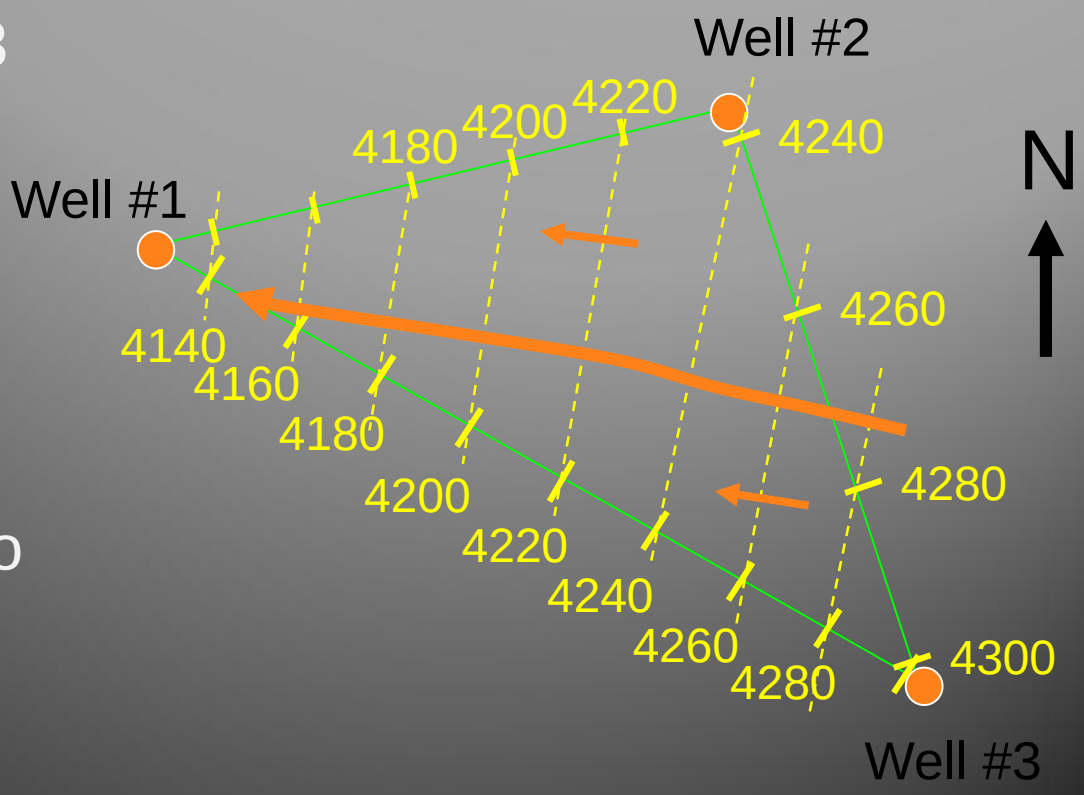


How does this knowledge assist a municipal planning board?

- There is a basic set of information that can be obtained for all properties relative to understanding the groundwater resource.
- There are some logical underlying physical principles and properties which govern groundwater movement.
- There are cause-and-effect relationships (in both directions) between proposed development and groundwater.

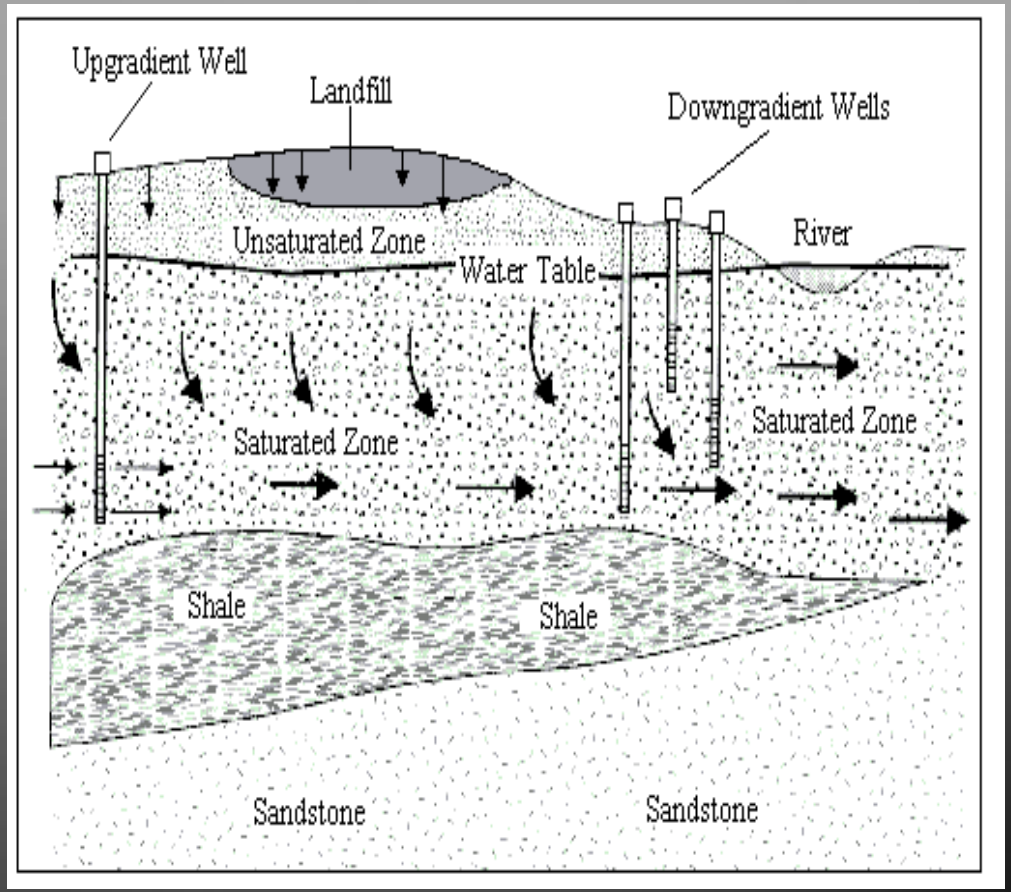
How does this knowledge assist a municipal planning board?

- Basic set of information
  - A minimum of 3 monitoring wells for flow direction and gradient
  - Full year of observations (to see seasonal variability



How does this knowledge assist a municipal planning board?

- Logical principles and properties
  - Upgradient (background)
  - Downgradient (effects)
  - Subsurface Materials
  - Barriers and conduits

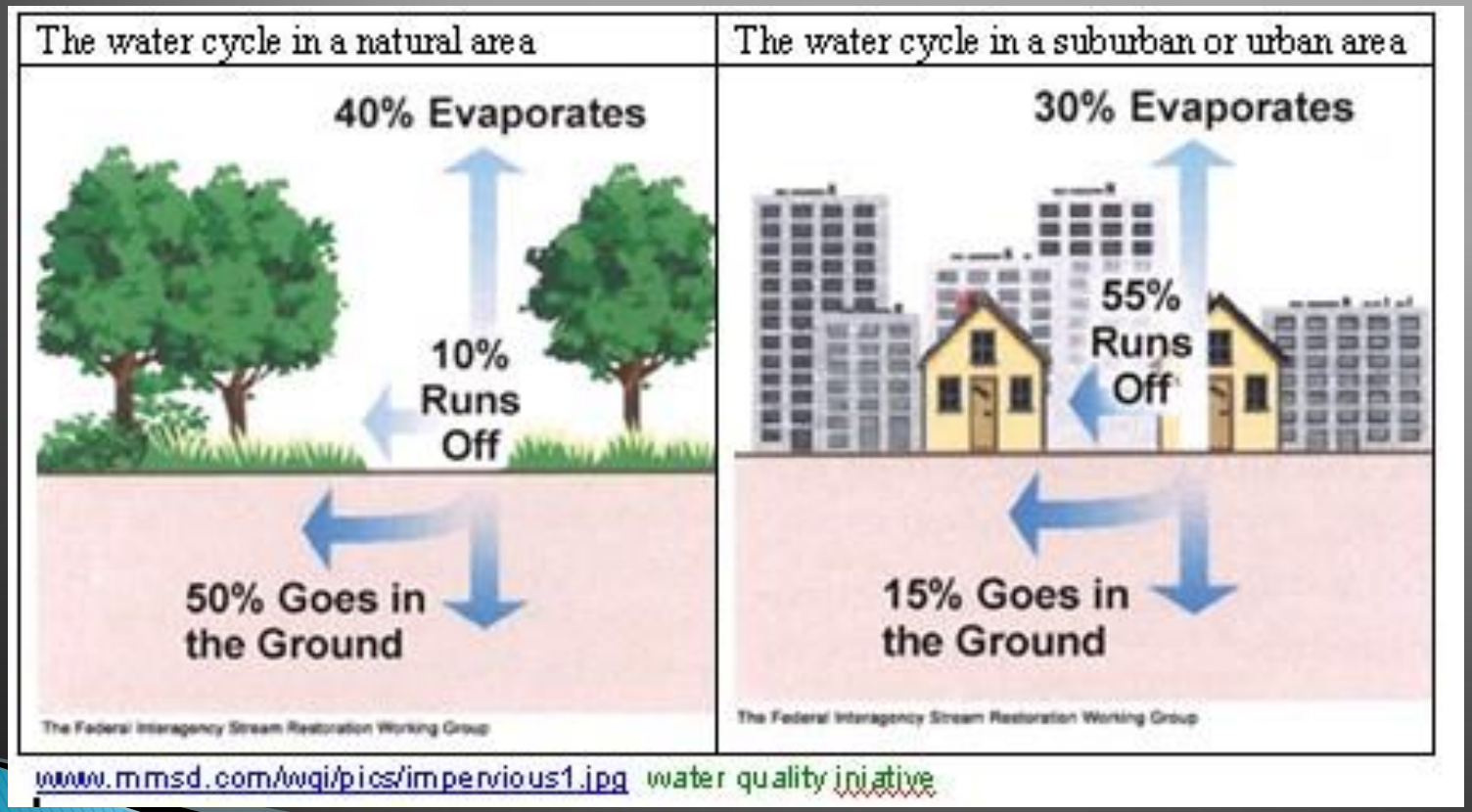


How does this knowledge assist a municipal planning board?

- Provides a basic understanding regarding potential cause-and-effect relationships (two-way) between a proposed development and groundwater
  - Pervious vs. Impervious Areas
  - Stormwater Designs
  - Utility Trenches
  - Dewatering Systems
  - Underground Parking Structures

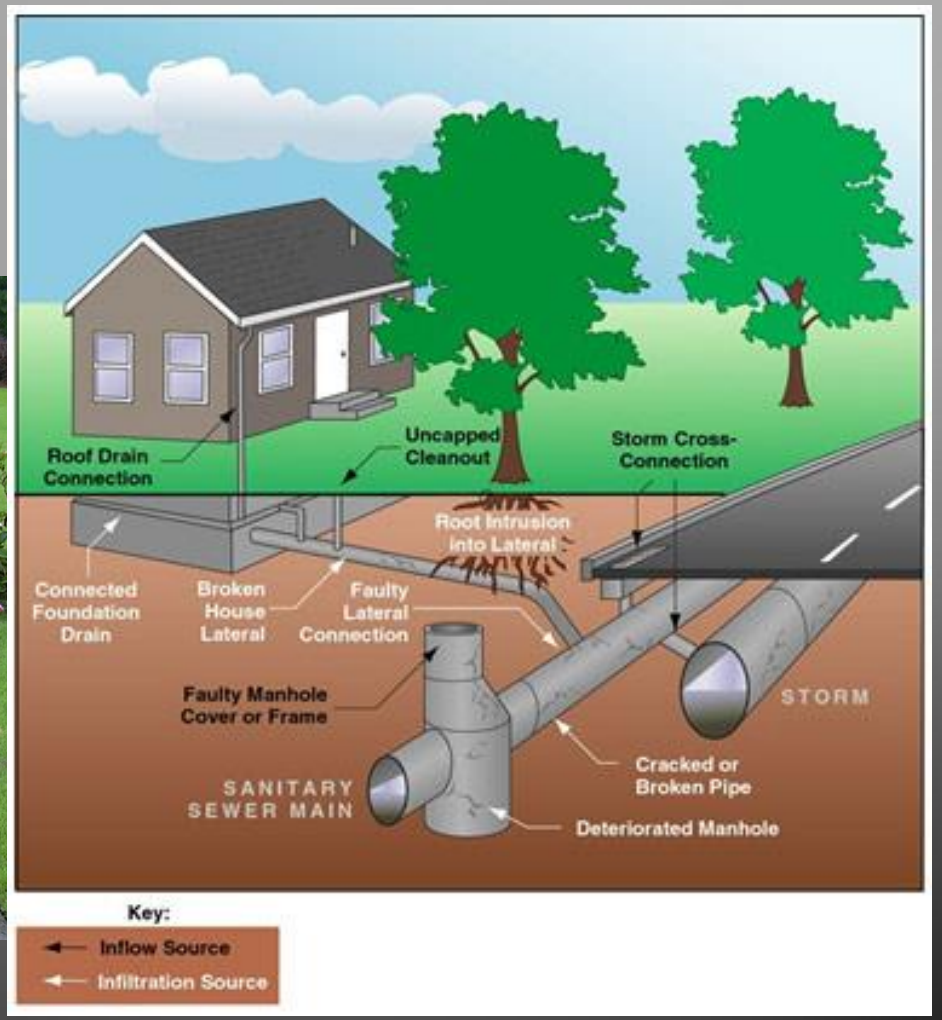
How does this knowledge assist a municipal planning board?

- Pervious vs. Impervious Areas



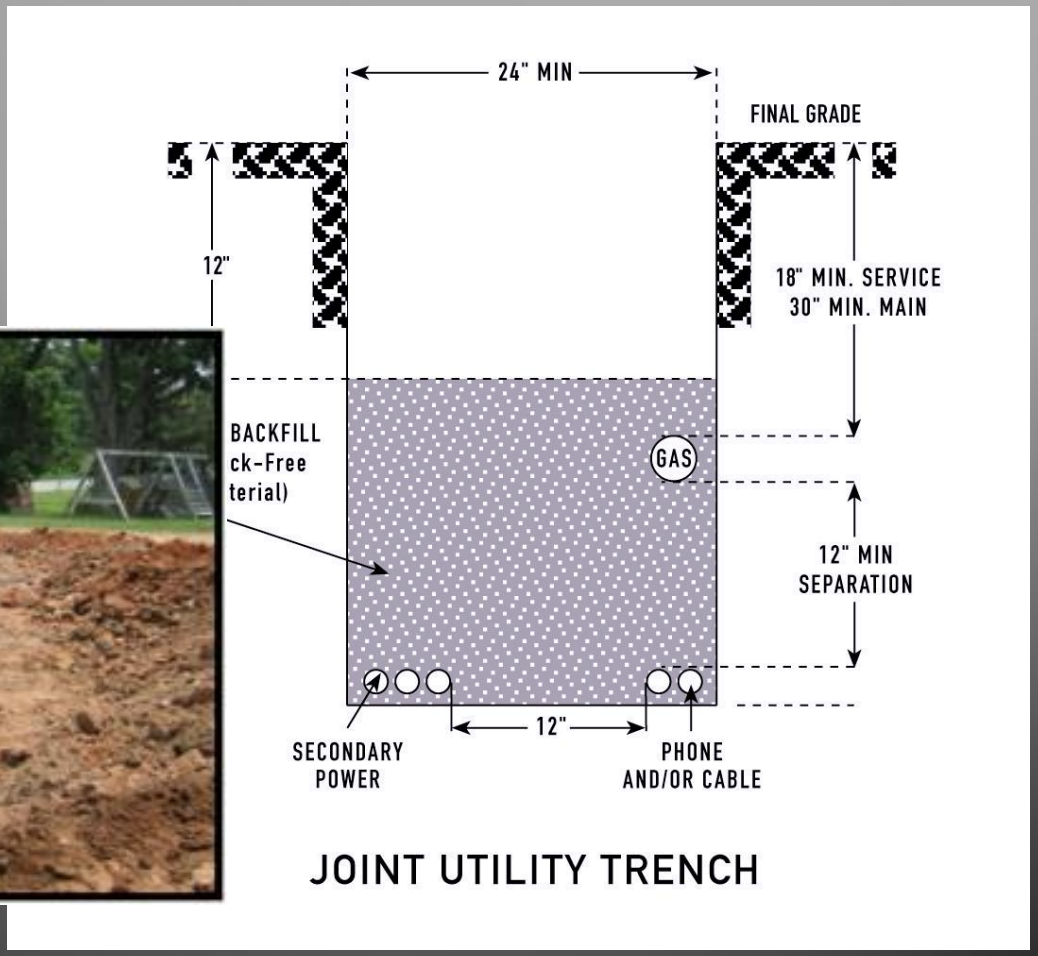
How does this knowledge assist a municipal planning board?

- Stormwater Systems



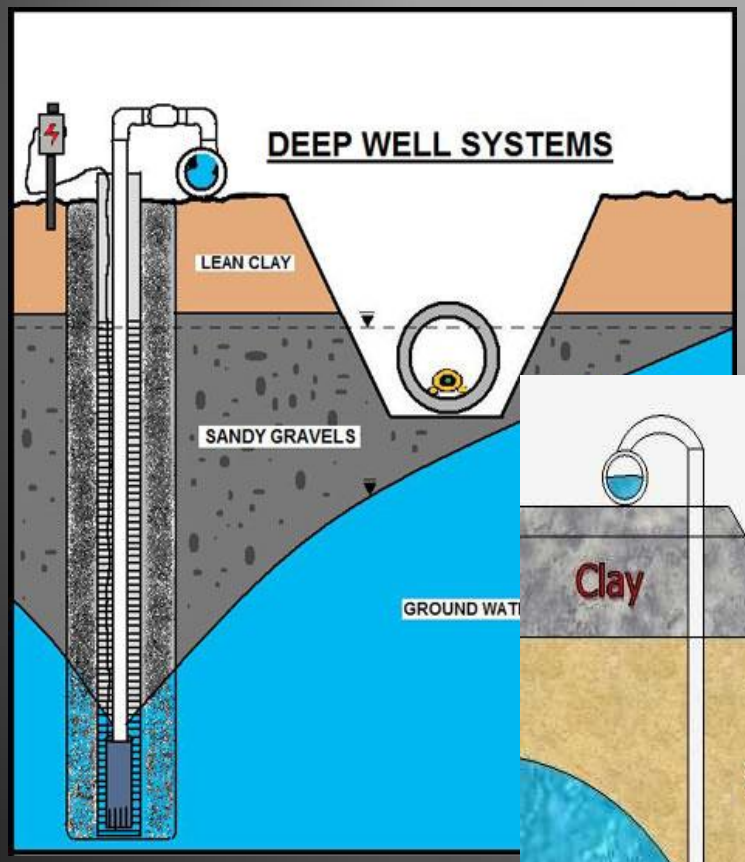
How does this knowledge assist a municipal planning board?

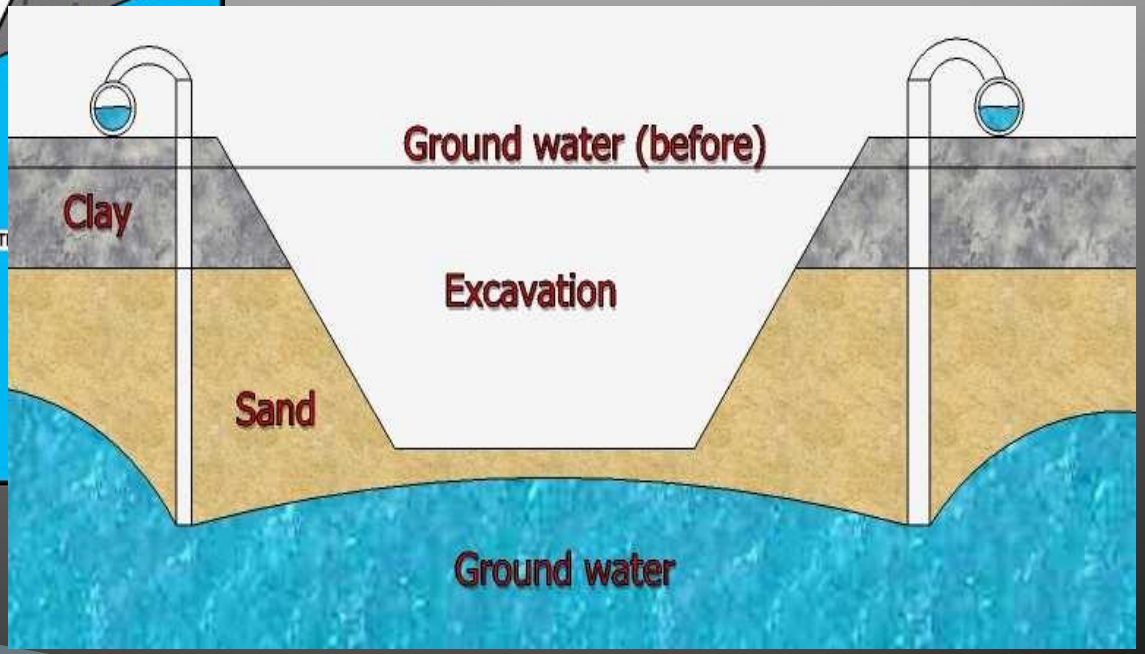
- Utility Trenches



How does this knowledge assist a municipal planning board?

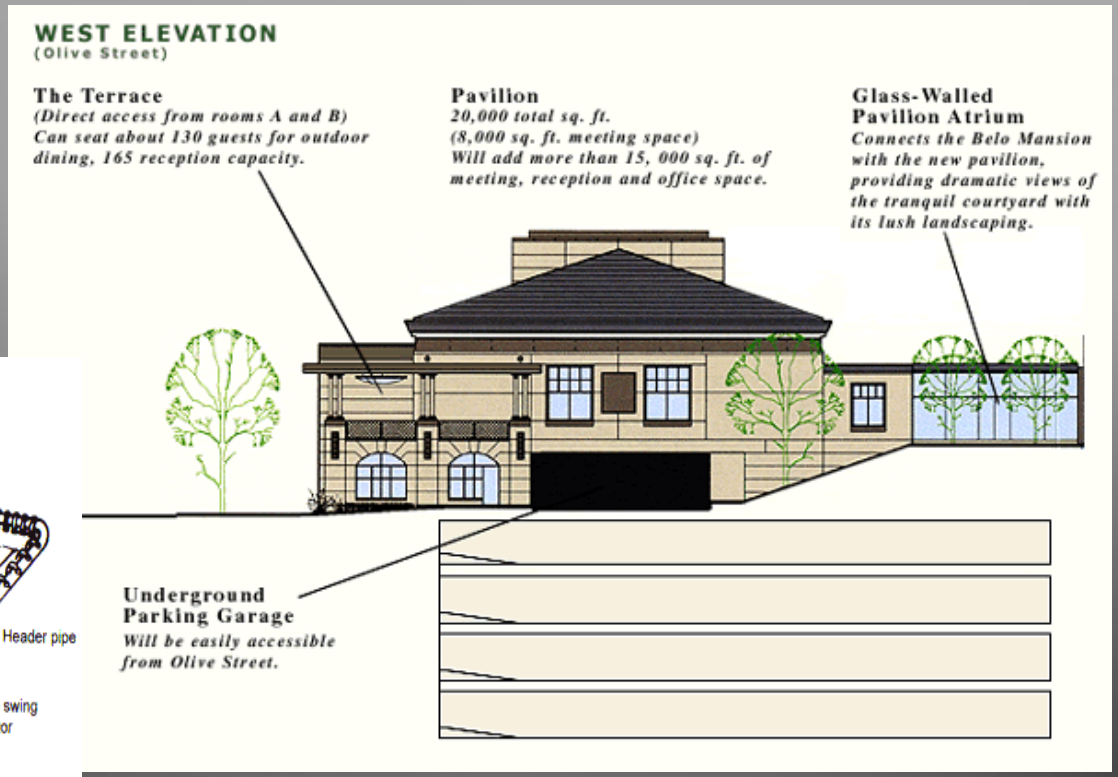
- Dewatering Systems

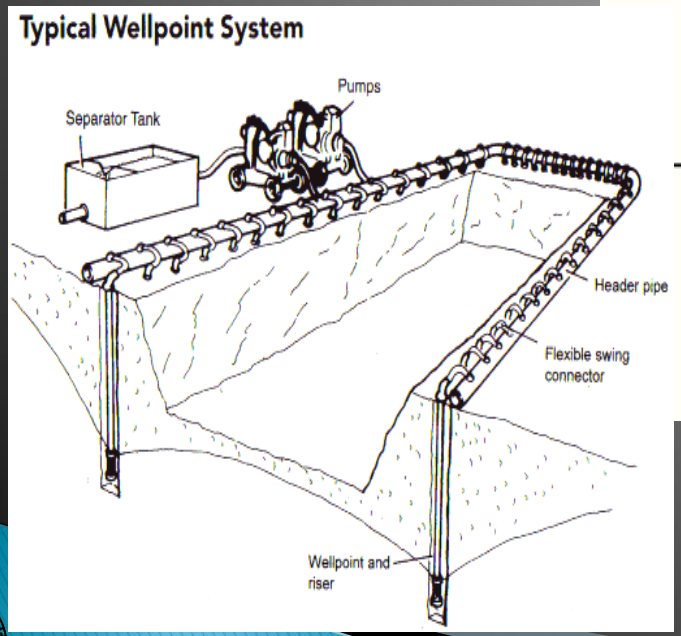




How does this knowledge assist a municipal planning board?

- Underground Parking Structures



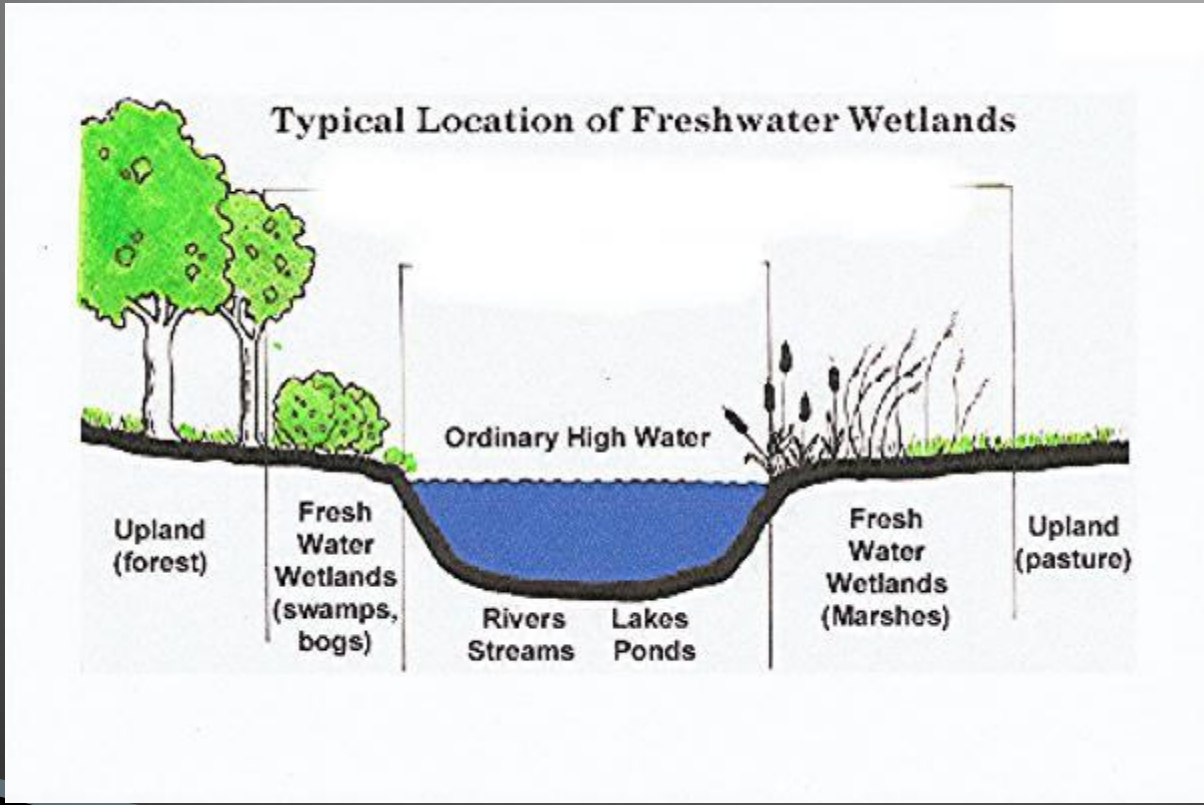


How does this knowledge assist a municipal planning board?

- Potential upgradient and downgradient effects on:
  - Wetlands
  - Native Vegetation (trees)
  - Streams
  - Ditches
  - Wells
  - Water Quality

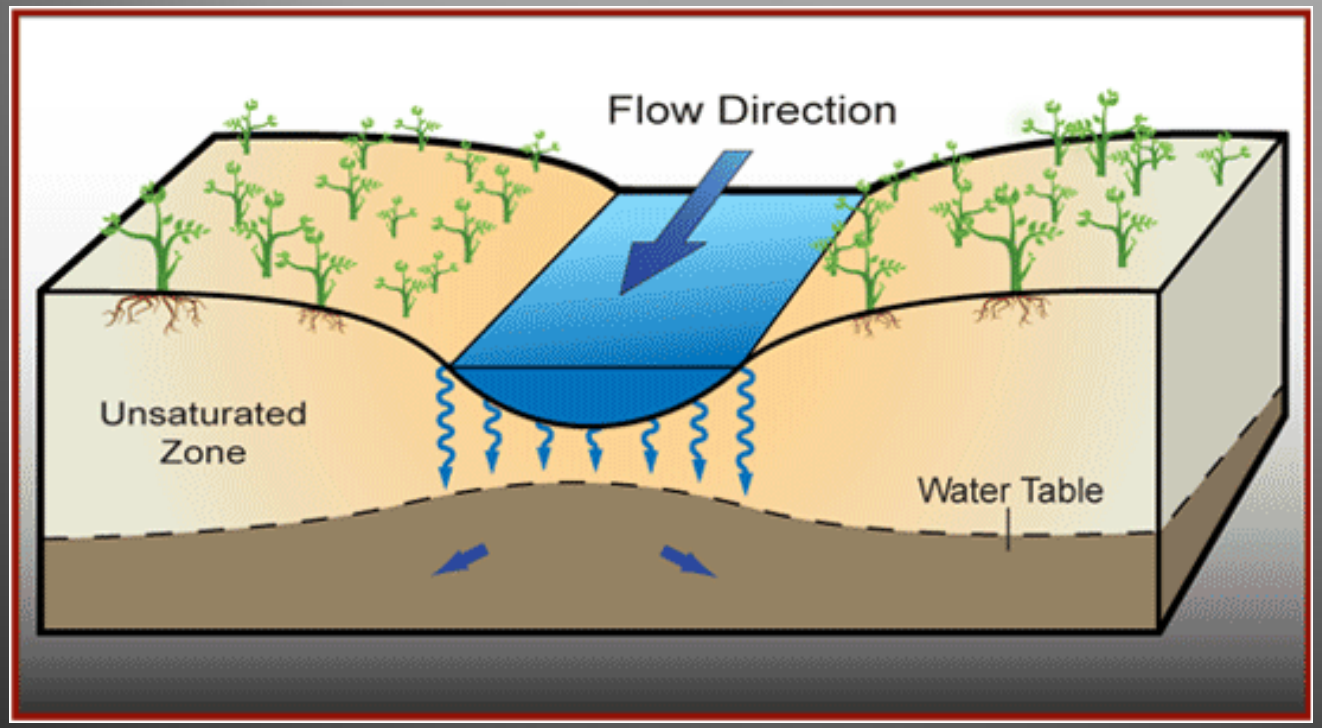
How does this knowledge assist a municipal planning board?

- Wetlands and Native Vegetation



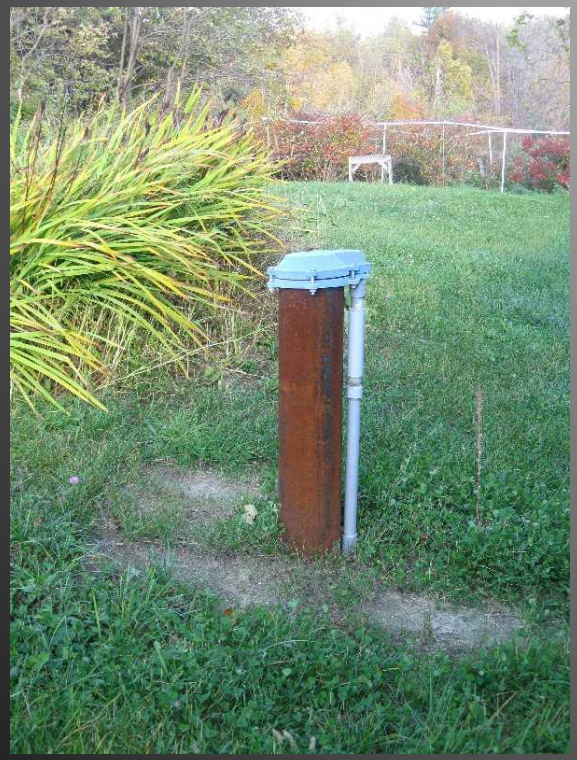
How does this knowledge assist a municipal planning board?

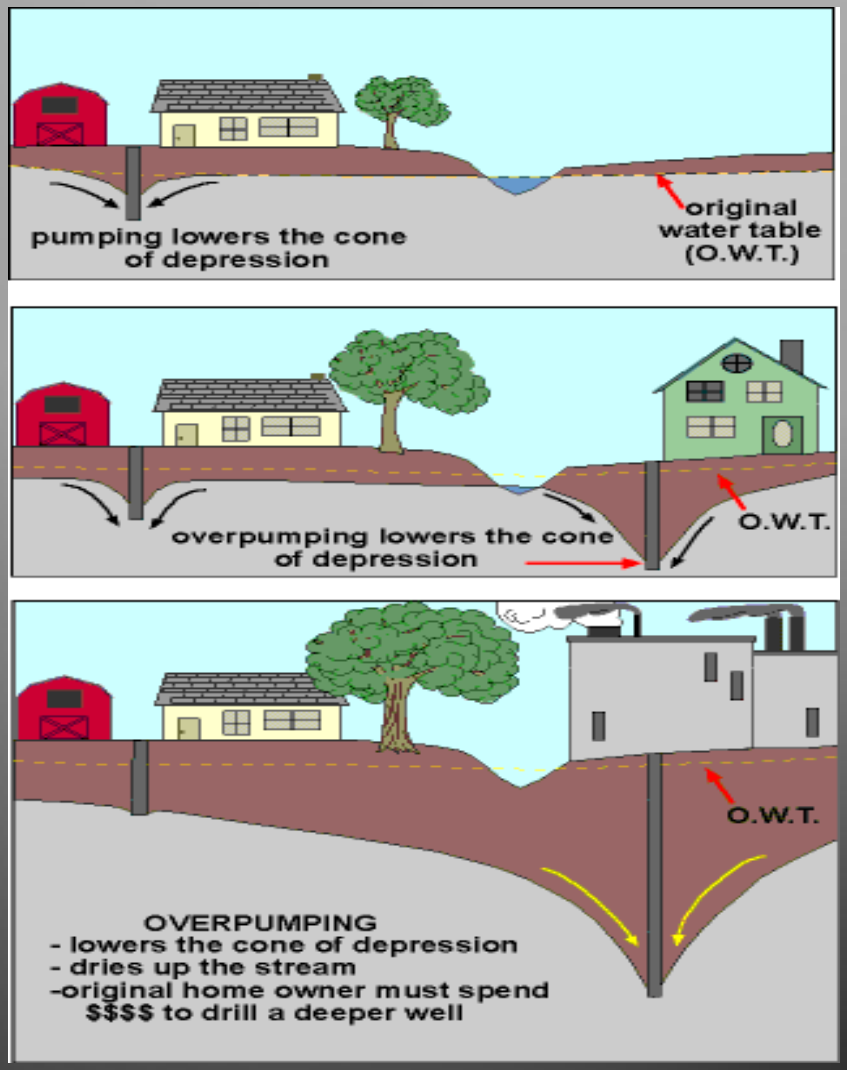
- Streams and Ditches



How does this knowledge assist a municipal planning board?

- Wells





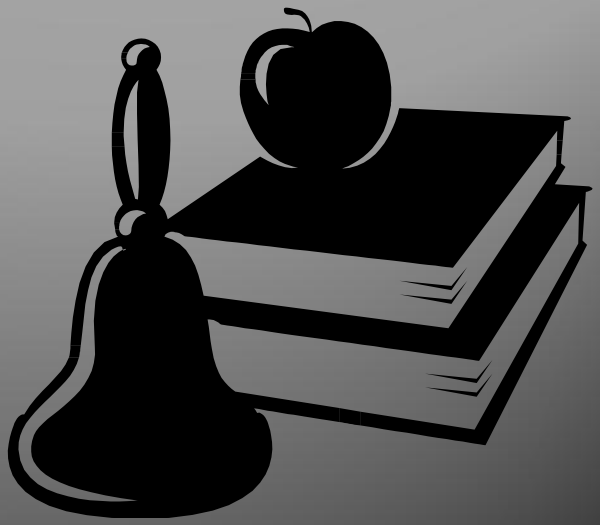
How does this knowledge assist a municipal planning board?

- Water Quality

Example of an urban watershed

1. Downspout
2. Untreated runoff
3. Storm drain
4. Sewer system
5. Untreated stormwater discharge
6. Urban stream

Questions



Answers