

ENGINEERING GEOLOGY

CE1301

Lecture #9 Groundwater Geology

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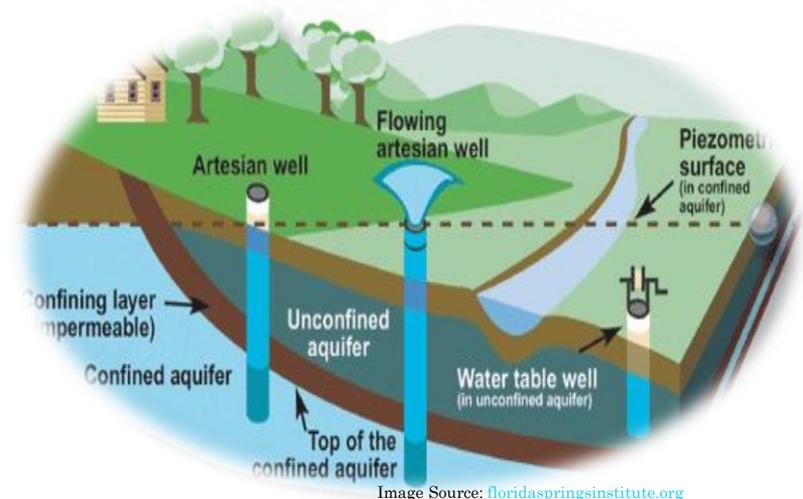


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GROUNDWATER

- ❖ **Groundwater** is the water located beneath Earth's surface in soil pore spaces and in the fractures of rock formations.

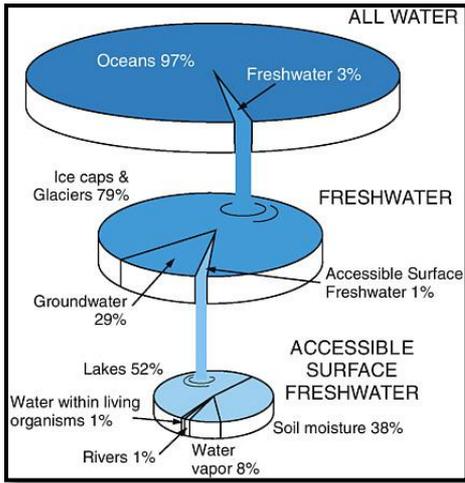


Image Source:
<https://blogs.ntu.edu.sg/hp331-2014-5/>

Aspects of groundwater in relation to civil engineering

- ❖ Water supply from wells: treatment of Groundwater typically involves only chlorination to kill bacteria.
- ❖ Engineering works: land drainage, irrigation, seepage, control of water drainage during soil and rock excavation, settlement of foundations and slope stability.

Advantages of the use of groundwater for water supply

- 1- It is commonly free of some harmful organisms and may not require a purification for domestic or industrial use.
- 2- The temperature is nearly constant, which is important for heat exchange purposes.

- 3- Color and turbidity effects are usually minimal.
- 4- Chemical composition for a single source is essentially constant.
- 5- Groundwater reservoirs are generally larger than those for surface water and therefore are not effected by drought of short duration.
- 6- Biological and radiological contamination of Groundwater is more difficult and less likely.
- 7- Can be found in areas that do not have significant surface supplies.

Drawbacks of the use of groundwater for water supply

- 1- Insufficient quantities or the formations have too low permeability.
- 2- High rates of dissolved solids.
- 3- The cost of developing wells, may likely be greater than that of impounding reservoirs on small streams.
- 4- Groundwater contamination has become prevalent in some urban areas.



Aquifers and aquicludes

- An **aquifer**: consists of a formation or a strata from which Groundwater can be obtained for beneficial use.
- Typical aquifers are gravel, sand, sandstone, limestone and fractured igneous and metamorphic rocks.
- An **aquiclude**: an impermeable body of rock or stratum of sediment that acts as a barrier to the flow of groundwater.
- Typical aquicludes are clay, mudstone, shale, evaporite and unfractured igneous and metamorphic rock.
- Karst aquifer may exist in regions with karst topography (see also Lecture#4).
- **soils** transmit water mostly through their pores whereas **rocks** transmit water mostly through fractures.
- Fractures normally transmit more water than pores as illustrated by the following values for the Chalk of S.E. England, a major aquifer:

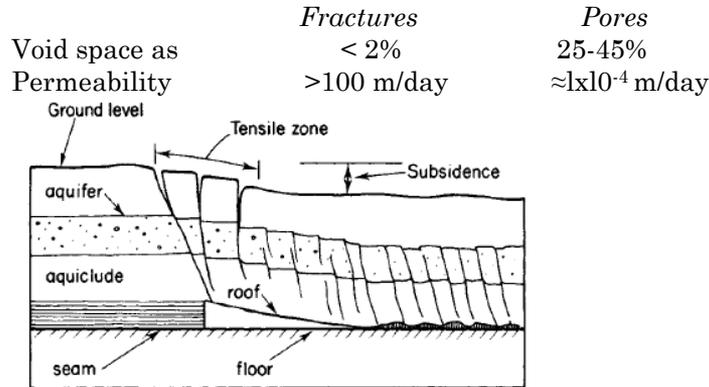


Fig. 13.13 Geological boundary moving above a mined area. Note that the increased fracturing greatly increases permeability.

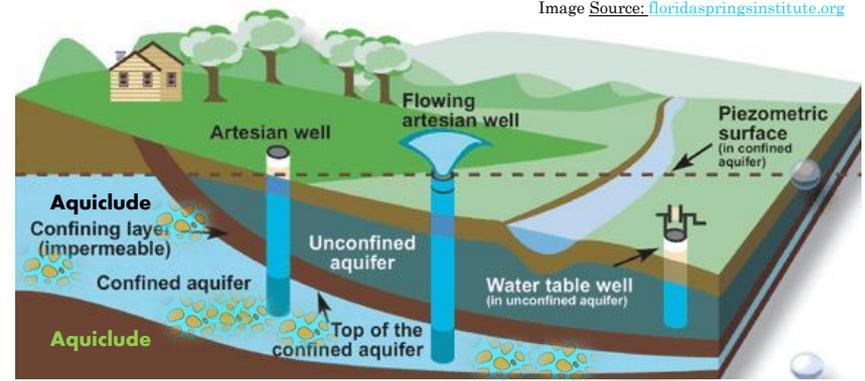


Image Source: floridaspringsinstitute.org

Karst aquifer



Image Source: groundwater.sdsu.edu

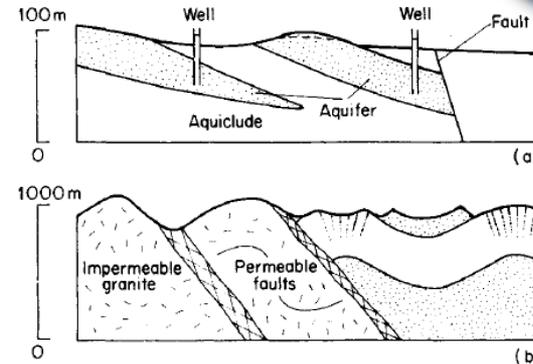


Fig. 13.10 Characteristic aquifers: (a) as strata, (b) as zones associated with faulting, and tensile fracturing on fold crests.

Groundwater flow

The movement of ground-water and its dissolved constituents may be considered the result of two mechanisms:

(1) the physical movement of molecules together with their associated solutes, called *advective flow*, and

(2) the chemical movement of solutes, called *diffusive flow*.

- ❖ When rates of advective flow are extremely slow, diffusion becomes the dominant form of mass transfer in response to chemical gradients in the ground.
- ❖ The potential of water to flow is defined by Bernoulli in terms of *elevation head* (H_e) and *pressure head* (H_p).
- ❖ ***Elevation head + pressure head = total head.***
- ❖ Flow is always from high to low total head.

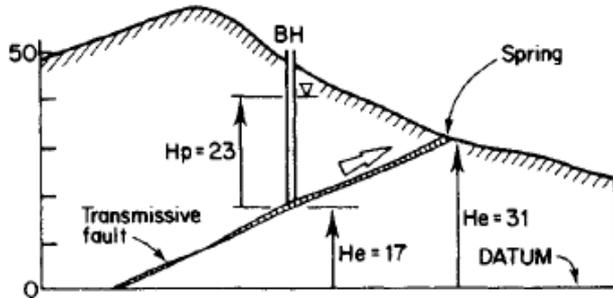
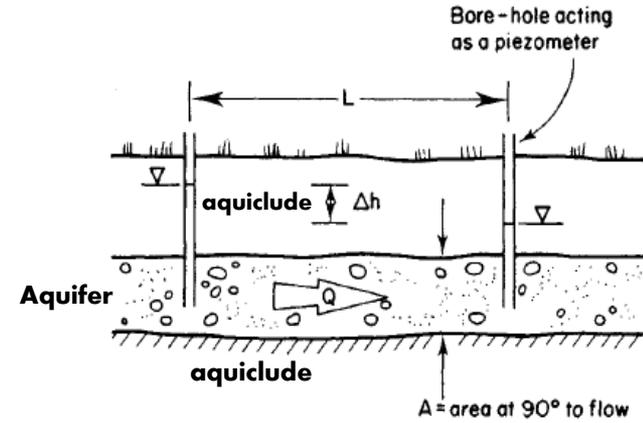


Fig. 13.16 Total head at bore-hole (BH) = $17 + 23 = 40$. Total head at spring = $31 + 0 = 31$. Flow of ground-water is from high to low total head (or water level). H_e = elevation head, H_p = pressure head: all measurements are in metres.

The discharge

The discharge of ground-water Q (L^3/T) through an aquifer is:



$$Q = k \frac{\Delta h}{L} A$$

where $\Delta h/L$ is the loss in total head per unit length of flow, A is the cross-section area (dimensions L^2), (i.e. the hydraulic gradient: dimensionless L/L) and k is the *coefficient of permeability* (L/T).

- Permeability is rarely the same in all directions. k in the direction of ground-water flow is usually used.
 - In sediments and sedimentary rocks, the greatest k value is usually in the direction of bedding.
- If our aquifer has two different types of permeable materials, how do we deal with k ? **Think!**

Origin of subsurface water

- Most of the water in the subsurface has been supplied via the atmosphere by the way of **hydrologic cycle**.

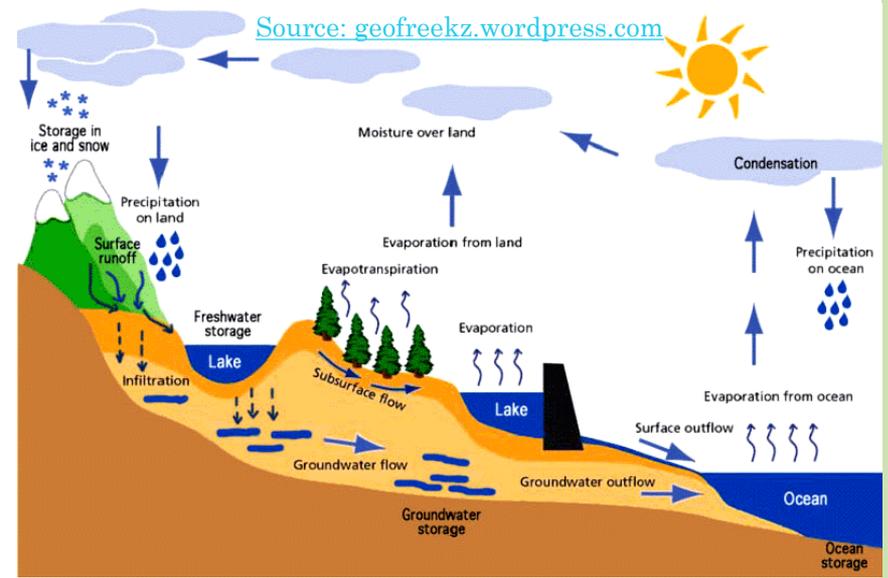
1- Ocean water

2- Connate water (pore water)

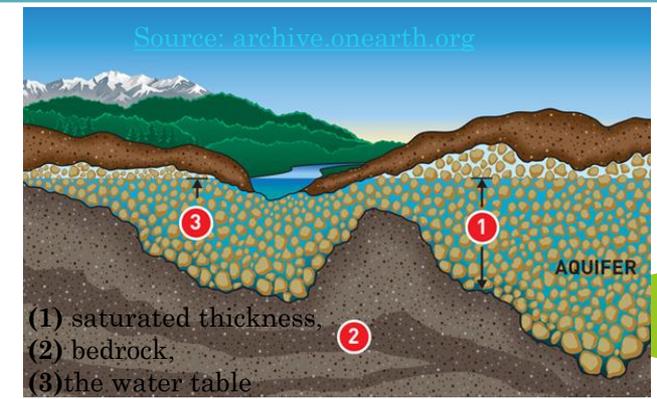
- Connate water are liquids that were trapped in the pores of sedimentary rocks as they were deposited.
- For marine sediments, the most common, connate water originates as seawater.
- If the pore fluid is salt-rich, it will be unsuitable for most uses as water supply.

3- Magmatic water or Juvenile water

- Magmatic water: is that water absorbed by magma then released in a form of steam when extrusive rocks flow onto the surface.



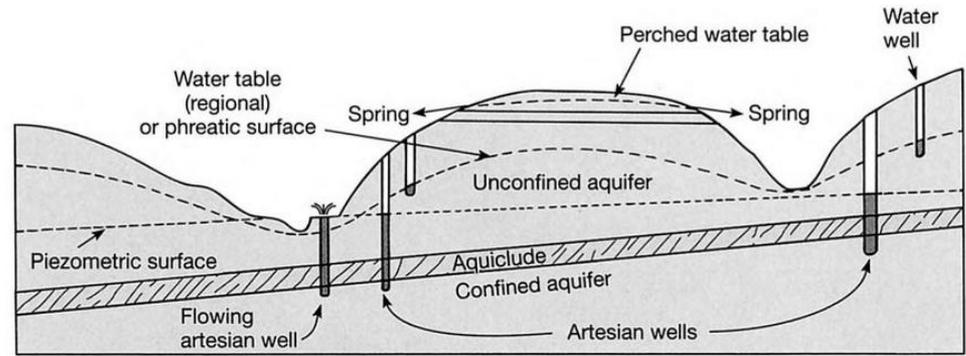
$$\text{Rainfall} = \text{Evaporation} + \text{Transpiration} + \text{Infiltration} + \text{Runoff}$$



- (1) saturated thickness,
- (2) bedrock,
- (3) the water table

Water table (WT)

- The water table is the surface in an unconfined aquifer along which the hydrostatic pressure of the water is equal to the atmospheric pressure (i.e. gauge pressure = 0).
- Can be obtained by drilling wells that penetrate the saturated zone.
- Perched aquifer: is an aquifer that occurs above the regional water table, in the vadose zone. The aquifer occurs between the surface and an impermeable layer of rock or sedimentary soil (aquiclude).

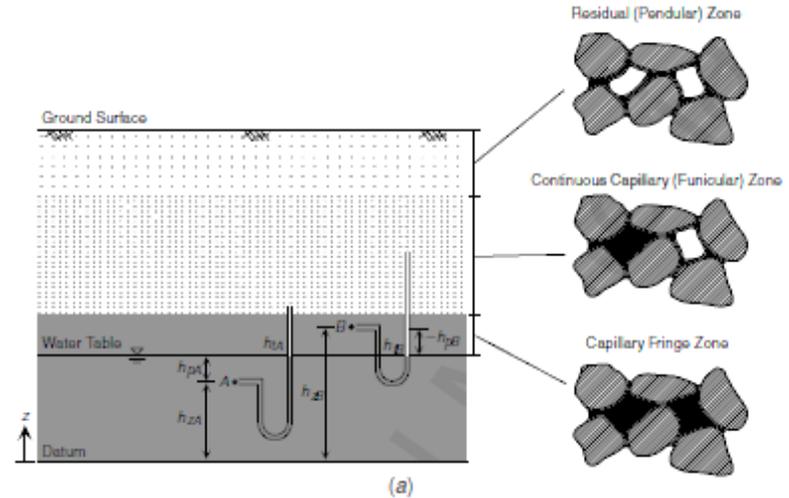


Vadose zone

- Unsaturated zone between the land surface and the water table.

Can be subdivided into three zones:

- (1) **capillary fringe zone** : soil remains saturated under negative pore water pressure;
- (2) **continuous capillary zone**: soil is unsaturated and water pressure is negative;
- (3) **residual zone**: water phase is discontinuous. The pores is largely filled with air.



Artesian conditions

- Artesian aquifer is a confined aquifer with a positive pore water pressure which causes the water level in a well to rise to a point where the hydrostatic equilibrium has been achieved.
- The well drilled into such aquifer is called artesian well.

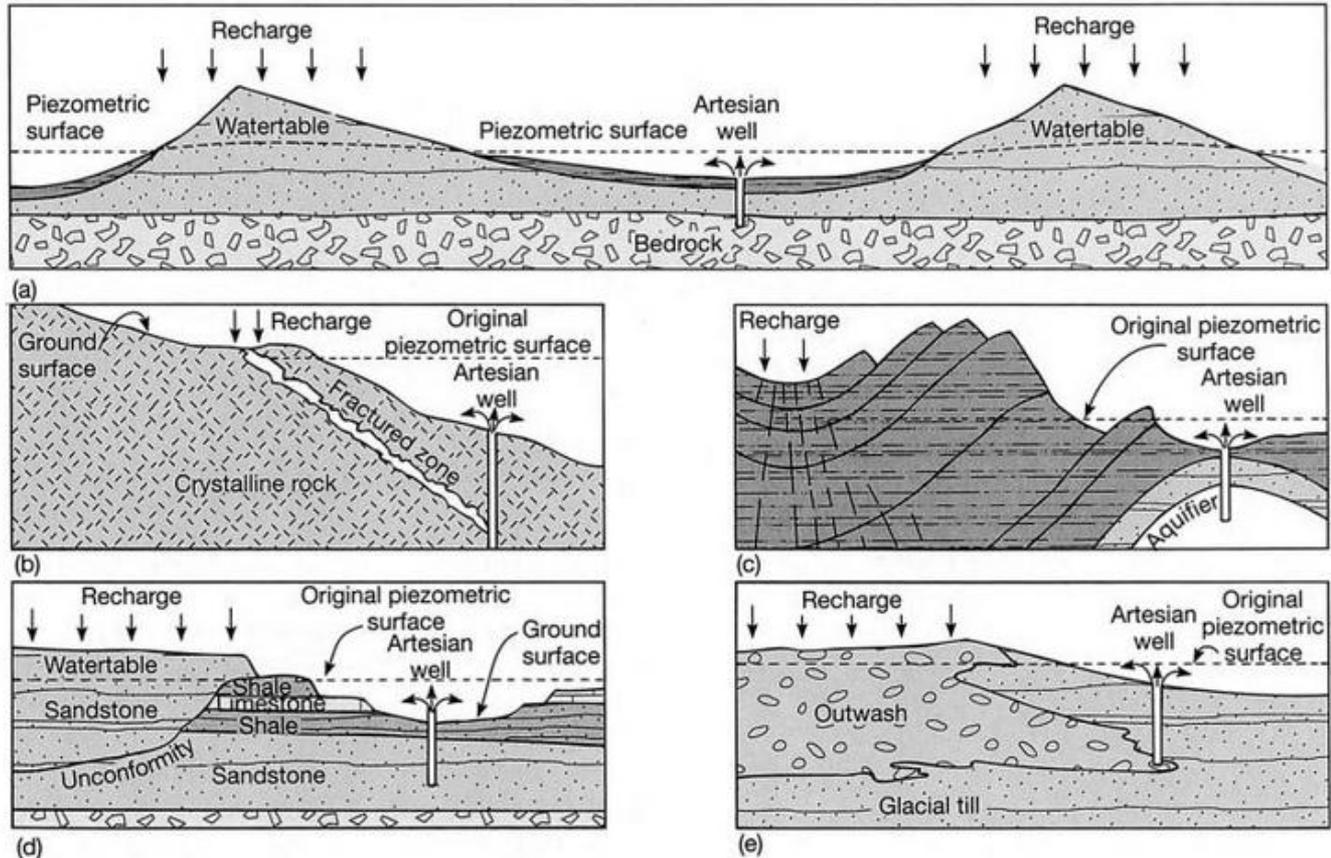


FIGURE 15.4 Geologic settings yielding artesian conditions. (a) Stabilized sand dunes, (b) crystalline rock, (c) complexly folded and fractured sedimentary rocks, (d) horizontal sedimentary rocks, and (e) glacial deposits.

Hydrogeological investigations

For what?

- ❖ Engineering works
- ❖ Potential sources for water supply.

A- Surface investigations (at the ground level)

Main objectives:

- (1) To make a hydrogeological map of the area showing the distribution of:
 - aquifers
 - geological boundaries, such as those created by stratigraphy and faulting.
 - hydrological boundaries such as rivers, lakes and spring lines.

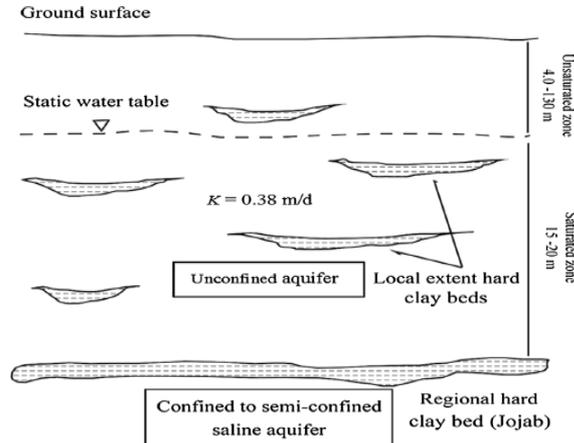
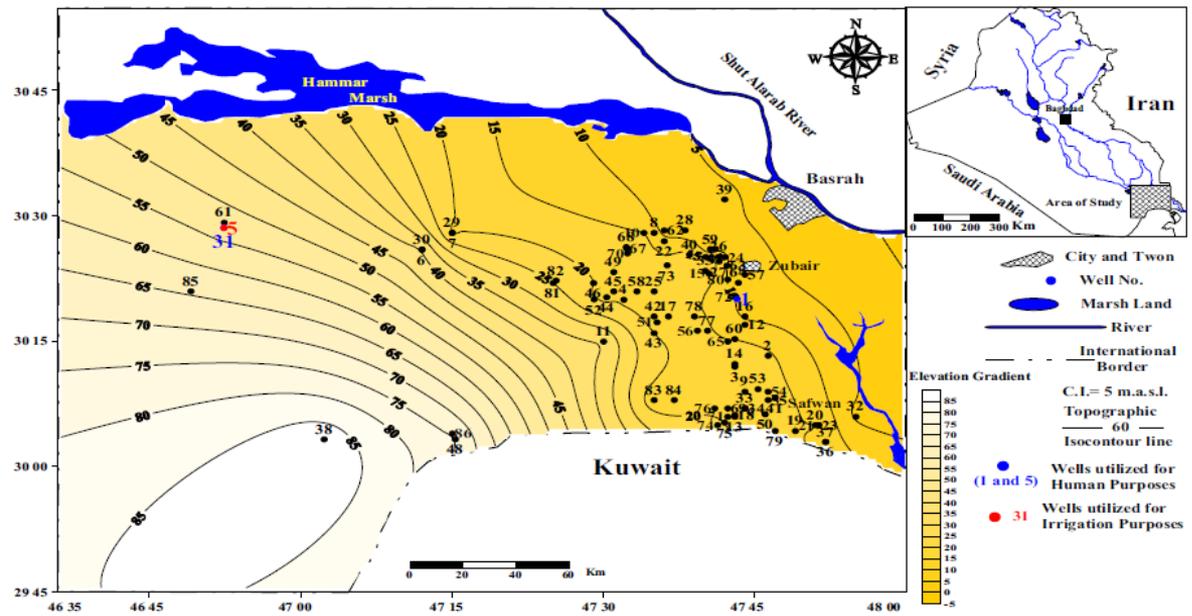
- (2) To draw one or more vertical cross-sections showing:

- geological structure.
- thickness and confinement of aquifers.
- the dip of hydrogeological boundaries.

B- Sub-surface investigations

To confirm:

- (1) the level of water in the ground;
- (2) the location, depth, thickness and lateral extent of aquifers and aquicludes;
- (3) the permeability of these zones and the storage of aquifers;
- (4) the chemistry of the aquifers and their contained water, and their temperature, if required.



Images Source: Al-Sudani, H. I. Z. (2019). *Groundwater system of Dibdibba sandstone aquifer in south of Iraq. Applied Water Science*, 9(4). doi:10.1007/s13201-019-0952-6.

Groundwater pollution

This topic is left for your investigation

