Water in Subsurface Environment

Groundwater Engineering| CE60205

Lecture:04

Learning Objective(s)

- **To calculate the hydraulic head**
- **To differentiate between aquifer, aquitard, aquiclude**

Energy and Hydraulic Head

- Mechanical energy in water can take on three forms
  - Elastic potential energy: gained by compressing water
  - Gravitational potential energy: achieved by lifting water to higher elevation
  - Kinetic energy: stems from the velocity of water

$$E = pV + mgz + \frac{1}{2}mv^2$$

- The mechanical energy predicted by E can be thought of as the work required to compress, elevate, and accelerate a mass m of water to its current state from a reference state where $p = 0, z = 0, v = 0$.

- Hubbert's Fluid Potential (ϕ): energy per unit mass of water

$$\phi = \frac{E}{m} = \frac{p}{\rho_w} + gz + \frac{v^2}{2}$$

Energy and Hydraulic Head (Contd.)

- Hydraulic Head (h): energy per unit weight of water

$$h = \frac{E}{mg} = \frac{p}{\rho_w g} + z + \frac{v^2}{2g}$$

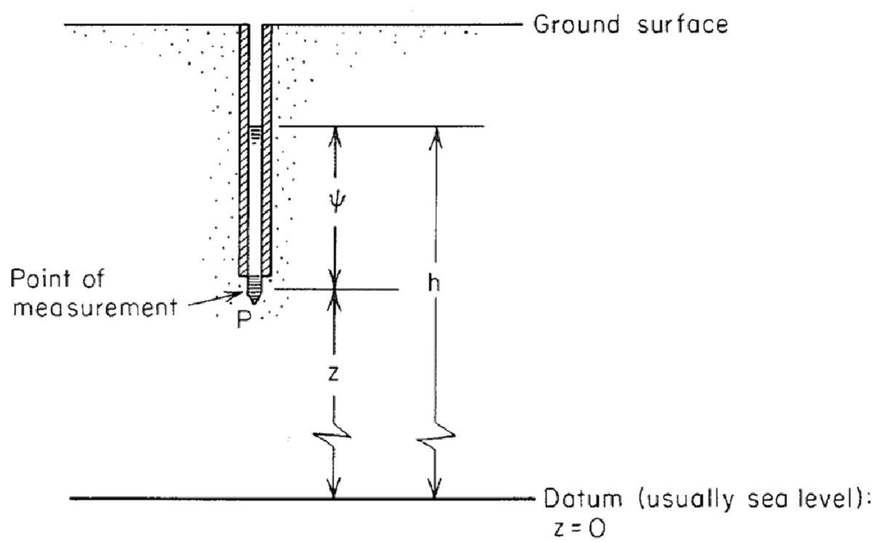
- The three terms on the right side are called the pressure head, elevation head, and velocity head, respectively.
- Hydraulic head has the simple unit of length
- Water always flows towards regions of lower hydraulic head
- Groundwater flows with very low velocity, usually less than a few meters per day ($\approx 20\ m/day$)
- Velocity head contributes an insignificant amount to the hydraulic head ($\approx 2.73 \times 10^{-9}\ m$)

Energy and Hydraulic Head (Contd.)

- Hydraulic head for groundwater flow

$$h = \frac{p}{\rho_w g} + z = \frac{p}{\gamma} + z = \psi + z$$

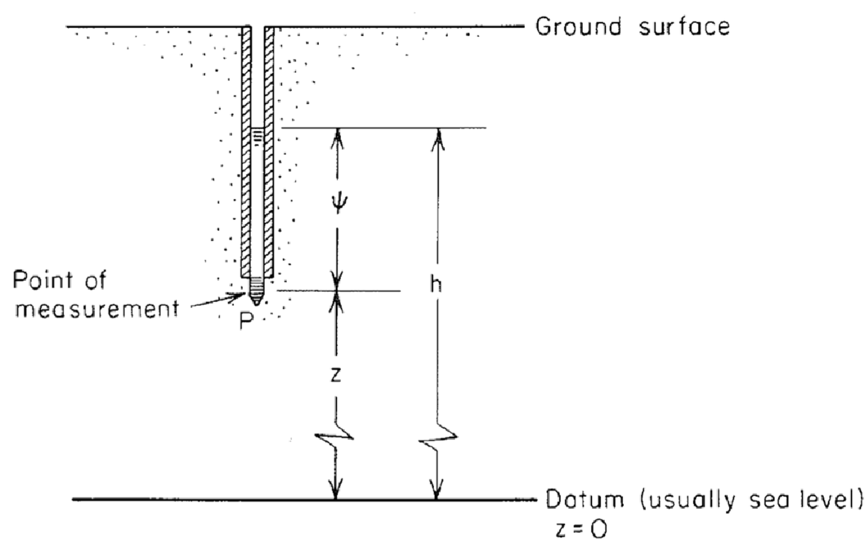
- All measurements of z are made relative to one elevation datum
- In case of small study areas, the elevation datum is often selected as some arbitrary horizontal surface.
- In case of large study areas, the elevation datum is selected as mean sea level (MSL)



Hydrostatics

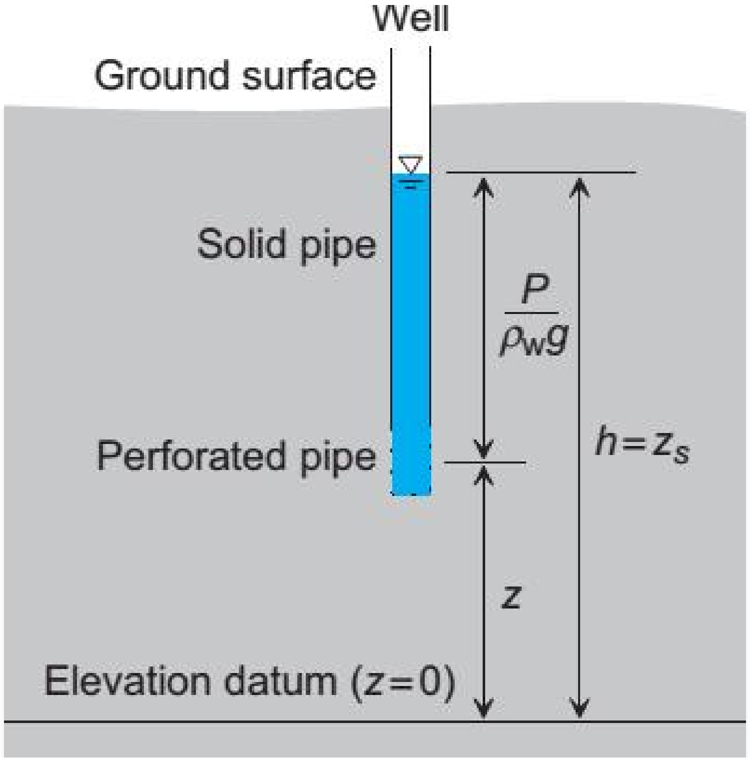
- Constant hydraulic head => no flow ($v = 0$) => hydrostatic condition
- Going down from the surface, h remains constant, while p increases at the same rate z decreases
- Under uniform fluid density condition, pressure can be calculated as

$$p = \rho_w g(h - z)$$



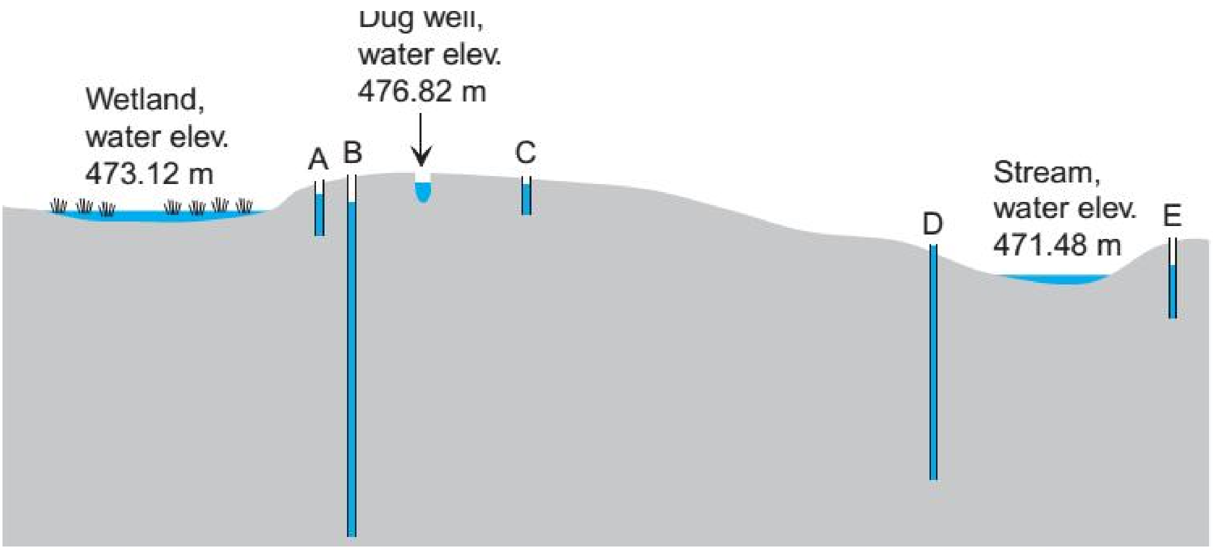
Measuring Hydraulic Head with Wells and Piezometers

- Using hydrostatic principles, hydraulic head in the pore water of the saturated zone can be measured directly.
- Upper end of the pipe must be open to the atmosphere
- At or near the bottom of the pipe, holes or slots allow water to move into the pipe from the surrounding saturated rock or soil
- Small diameter pipes are called piezometers
- Larger diameter ones are called wells



Example

- Calculate the hydraulic head at piezometers A and B, and the water pressure at the bottom of these two piezometers. Does groundwater flow in the vicinity of these two piezometers have an upward or a downward component?



Well	Elevation, TOC (m)	Elevation, BOC (m)	Depth to Water (m)
A	476.93	470.92	2.18
B	477.67	455.16	3.44
C	477.04	472.74	0.35
D	472.22	458.03	0.05
E	472.41	466.84	0.71

TOC: top of piezometer casing.
BOC: bottom of piezometer casing, open to subsurface.
Depth to water measured down from TOC.

$$h_A = \text{TOC} - \text{Depth to water}$$
$$= 476.93 - 2.18$$
$$= 474.75 \text{ m}$$

$$h_B = 474.23 \text{ m}$$

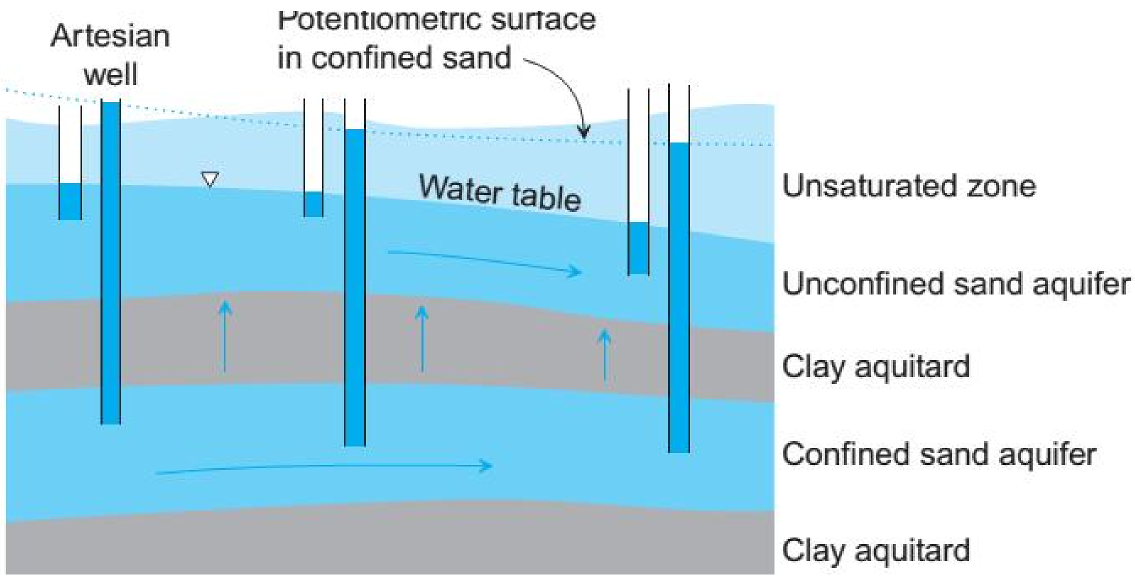
$$P_A = (h_A - z_A)\rho_w g$$
$$= 37,572\,\text{N/m}^2$$

$$P_B = 187,077 \text{ N/m}^2$$

$$h_A > h_B$$

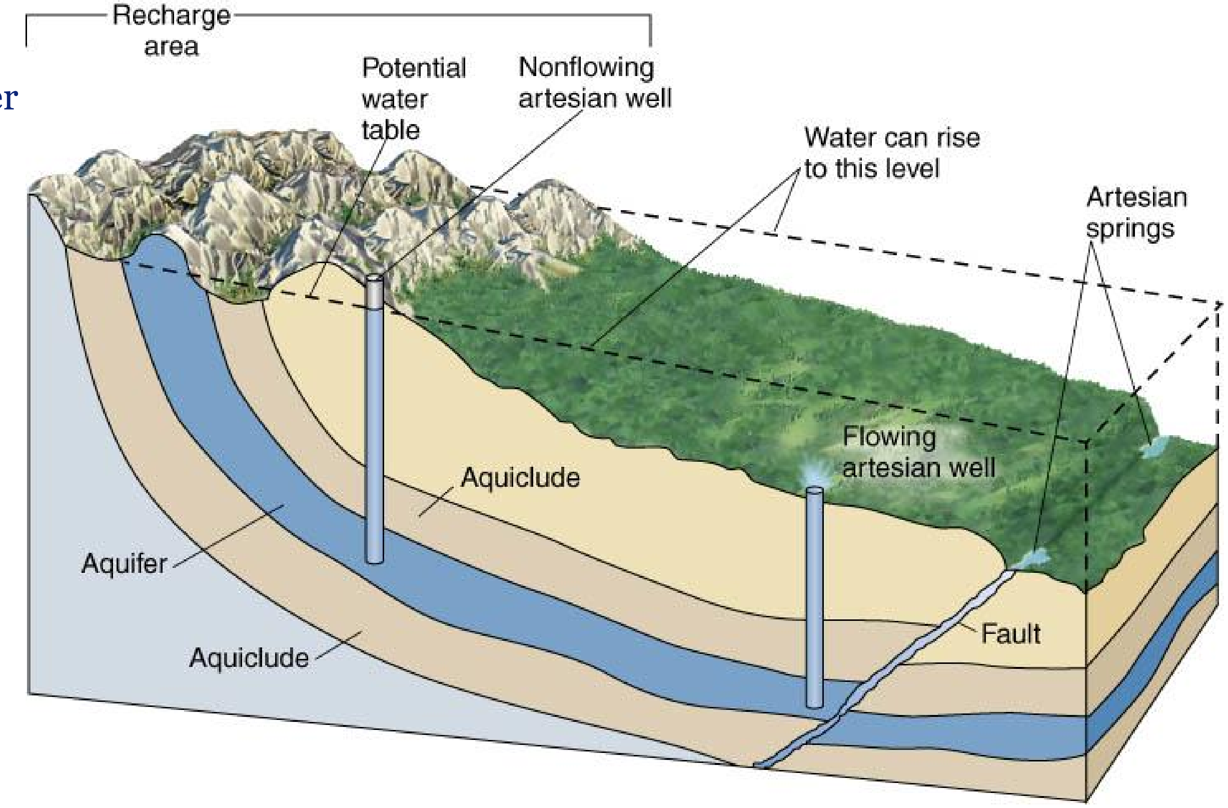
Aquifers and Confining Layers

- The terms aquifer and confining layer are relative descriptors of water-bearing zones or layers in the subsurface.
- Aquifers are the layers that are typically tapped by water supply wells, and aquifers transmit most of the flow in a given location.
- Confining layers (also called aquitards) retard flow and typically transmit relatively little water.
- The term aquiclude is no longer used much, and it means an extremely low K confining layer that virtually "precludes" flow.



Aquifers and Confining Layers (Contd.)

- **Aquifer**
  - Store & transmit enough water
- **Aquitard**
  - Transmit, cannot store water
- **Aquiclude**
  - Store, cannot transmit water



Aquifers and Confining Layers (Contd.)

- **Aquifer: "a geologic unit that can store enough water and transmit it at a rate fast enough to be hydrologically significant."**

- **Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy**

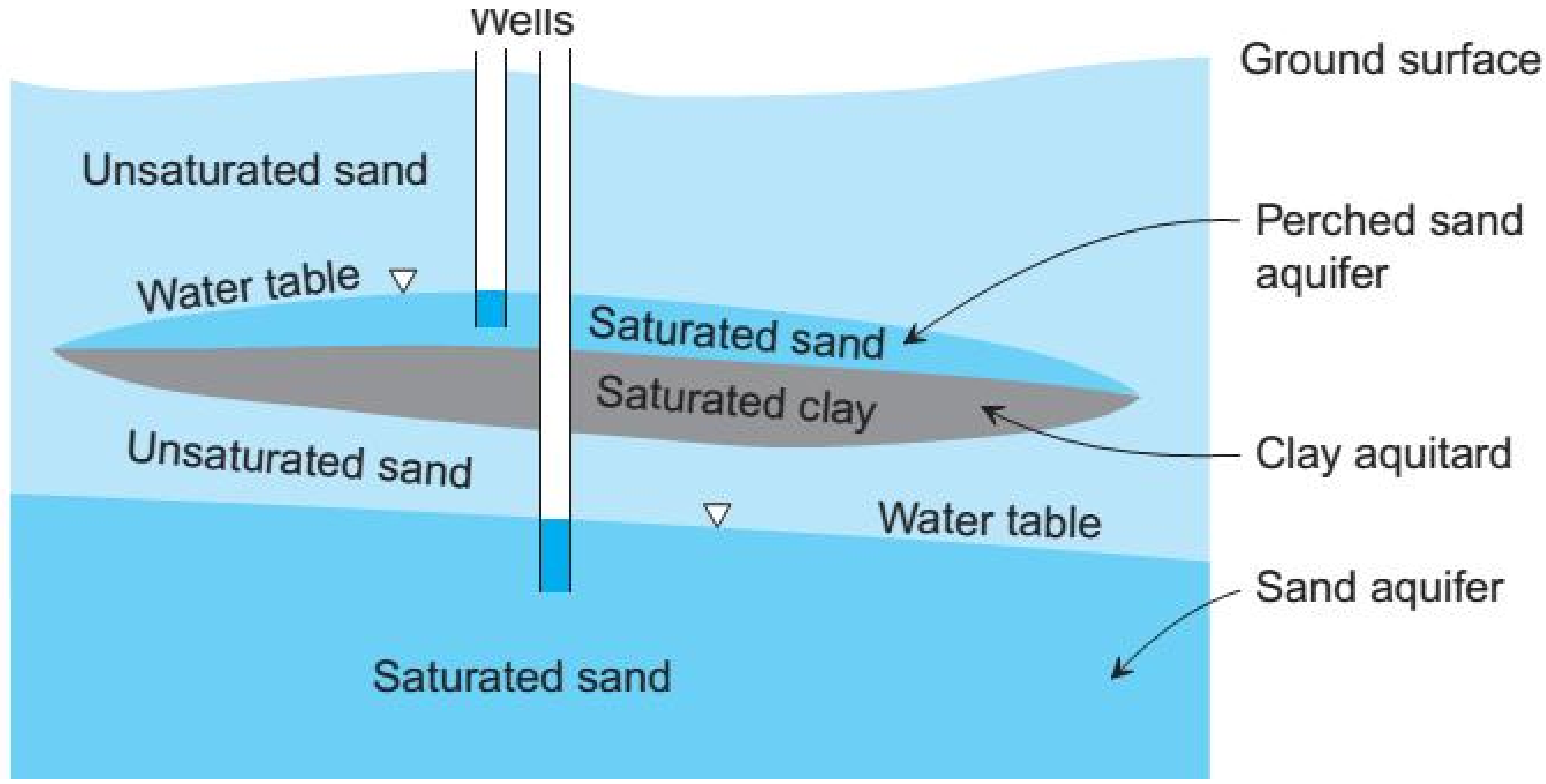
- Article 7

Waters used for the abstraction of drinking water

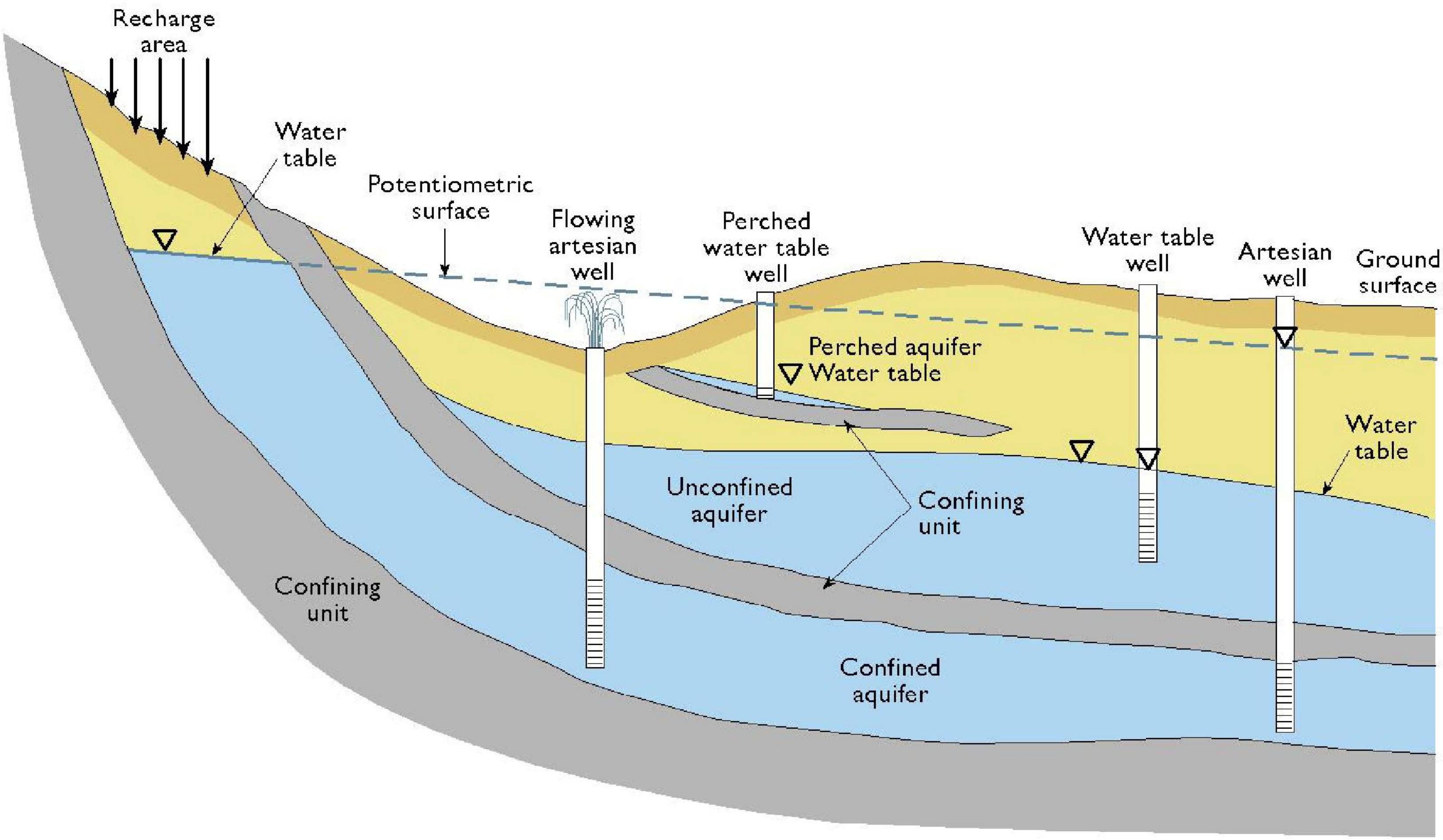
1. Member States shall identify, within each river basin district:

   - all bodies of water used for the abstraction of water intended for human consumption providing more than 10 m^3 a day as an average or serving more than 50 persons, and
   - those bodies of water intended for such future use.

Aquifers and Confining Layers (Contd.)



Aquifers and Confining Layers (Contd.)



Modified after Harlan and others, 1989

- **Confined Aquifer**
  - Under pressure
  - Bounded by impervious layers
- **Unconfined Aquifer**
  - Phreatic or water table
  - Bounded by a water table

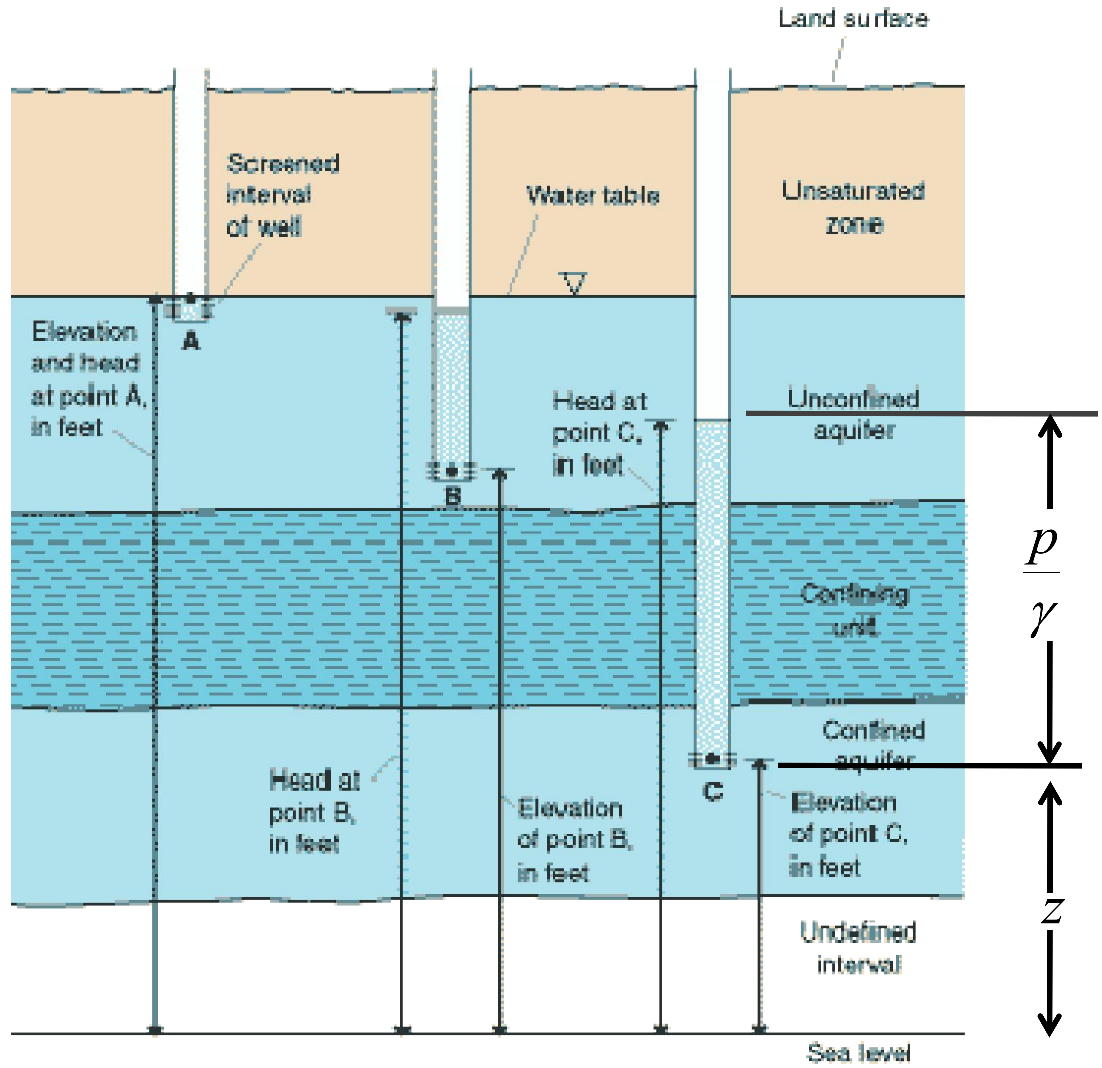
Aquifers and Confining Layers (Contd.)

- **Unconfined aquifer**
  - piezometric head = elevation

$$h = \cancel{\frac{p}{\gamma}} + z$$

$$p = 0$$

$$h = z$$



Home Lab

- Foldable Aquifer Project -http://aquifer.geology.buffalo.edu/
- Paper aquifer model
  - Example Aquifer – The basics

Learning Strategy

Chapter 2: Physical Properties

Section 2.5, 2.6

Thank you