HYDRAULIC HEAD AN FLUID POTENTIAL

Groundwater flows from states of higher energy levels to states of lower energy. The energy state at any point within an aquifer can be presented by the hydraulic head, h, which is a function of the pressure and potential energy per unit weight of the fluid.

The kinetic energy of the water in the aquifer is neglected because of the small magnitude of groundwater velocities.

Definitions:

Force= Mass x Acceleration (Newton's second law of motion)
Unit is Newton ($N=kg.m/s^2$)
Weight of a body is the gravitational force exerted on it by the earth.
$W=m.g$ unit: Newton
Density, ρ, of fluid is its mass per unit volume. $\rho= m/V$ [g/cm^3; kg/m^3)
Specific weight or unit weight of a fluid is its weight per unit volume.
$\gamma= W/V$ [N/m^3]
Specific weight depends on g. $\gamma= =mg/V= \rho g$

Energy: capacity to do work, implying that some resistance to change in motion must be overcome.
Work is done when a force is applied to a fluid while the fluid is in motion.

WORK= FORCE x DISTANCE

Fluid potential (ϕ) is the mechanical energy per unit mass of the fluid [L^2/T^2]
Hydraulic head is the mechanical energy per unit weight of the fluid [L]

There are three types of energy to consider:

1) Kinetic Energy: A moving fluid tends to remain in motion due to its kinetic energy.

$$E_k = \frac{1}{2}mv^2 \quad kg\frac{m^2}{s^2} = N * m = Joule$$

2) Potential Energy: Work is done in moving a mass (m) of fluid from some reference datum vertically upward to a distance z:

$$E_g = mgz$$

3) Fluid- Pressure Energy: A fluid mass has a source of potential energy due to the pressure of the surrounding fluid acting upon it.

$$P = \frac{F}{A} \qquad P = \frac{N}{m^2} = Pascal = \frac{N*m}{m^3} = \frac{Joule}{m^3}$$

Pressure may be thought as potential energy per unit volume of the fluid.

For a unit volume V=1, m= ρ

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Total energy of the unit volume of fluid:

$$E_{tv} = E_k + E_g + P$$

$$E_{tv} = \frac{1}{2}\rho.v^2 + \rho.g.z + P$$

Fluid potential (ϕ) is the mechanical energy per unit mass of the fluid [L^2/T^2]

Divide by ρ: Total energy per unit mass [L^2/T^2], Bernoulli Equation

$$\varphi = E_{tm} = \frac{v^2}{2} + g.z + \frac{P}{\rho}$$

Total energy per unit mass [L^2/T^2], Bernoulli Equation

$$\phi = E_{tm} = \frac{v^2}{2} + g.z + \frac{P}{\rho}$$

Hydraulic head is the mechanical energy per unit weight of the fluid [L]

Divide by g: Total energy per unit weight [L], [Joules/N]= N.m/m= m

$$E_{tw} = \frac{v^2}{2g} + z + \frac{P}{\rho g}$$

Total energy per unit weight is known as total head is expressed in terms of length units.

Total head= Velocity head + Elevation head + Pressure head

Groundwater velocities– small! Neglect velocity head…

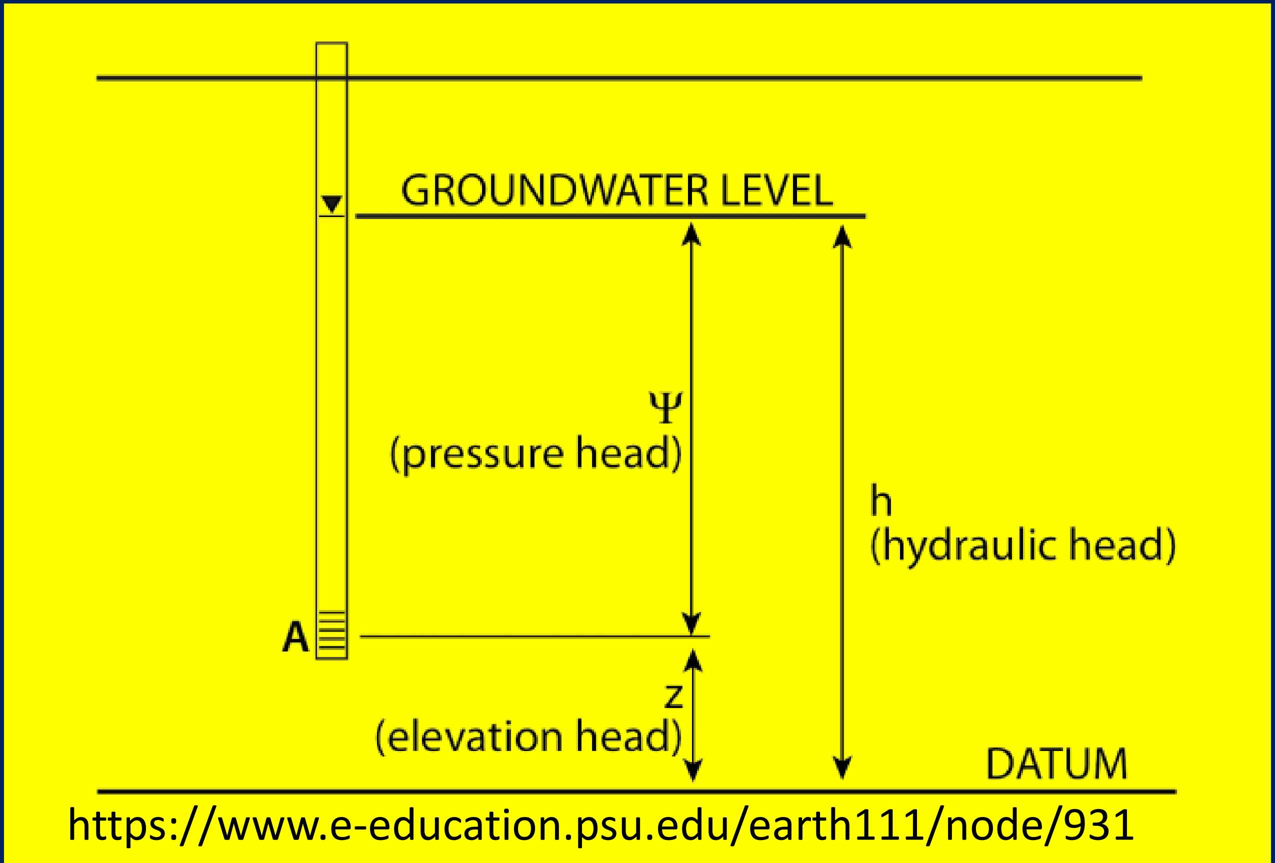
Total head= Elevation head + Pressure head

$$E_{tw} = z + \frac{P}{\rho g}$$

Hydraulic head: Total energy per unit weight of the fluid. Groundwater flow always takes place from higher towards lower hydraulic head values.

The fluid pressure, P, at a point is equal to the weight of the overlying water per unit x-sectional area.

P= ρgΨ



h= z+ψ

Fluid potential (φ) is the mechanical energy per unit mass of the fluid [L^2/T^2]

$$\phi = E_{tm} = g.z + \frac{P}{\rho} = g.z + \frac{\rho.g.\psi}{\rho} = g\,(z + \psi) = \mathrm{g.h}$$

Darcy's law can be expressed in terms of fluid potential:

$$Q = -\mathrm{K.A.}\frac{dh}{dl} = -\frac{KA}{g}\frac{d\phi}{dl}$$

https://books.gw-project.org/hydrogeologic-properties-of-earth-materials-and-principles-of-groundwater-flow/chapter/hydraulic-gradient/

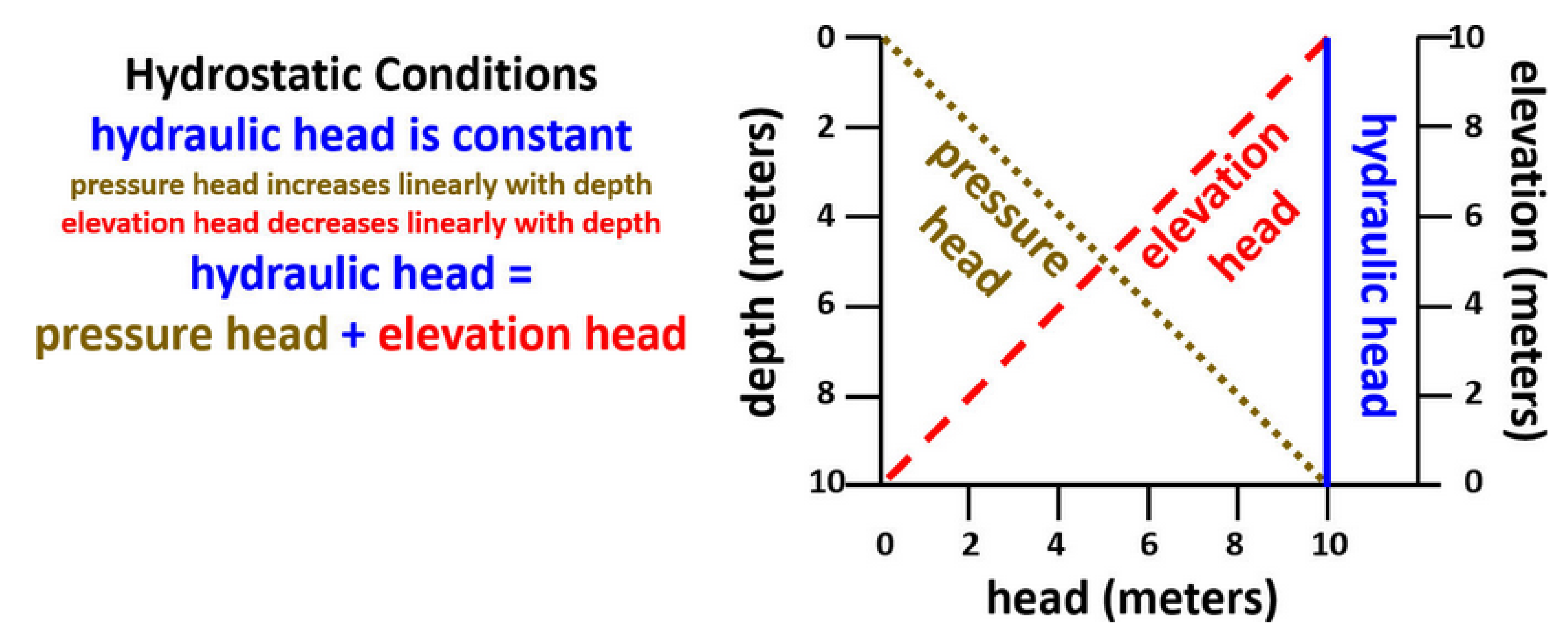
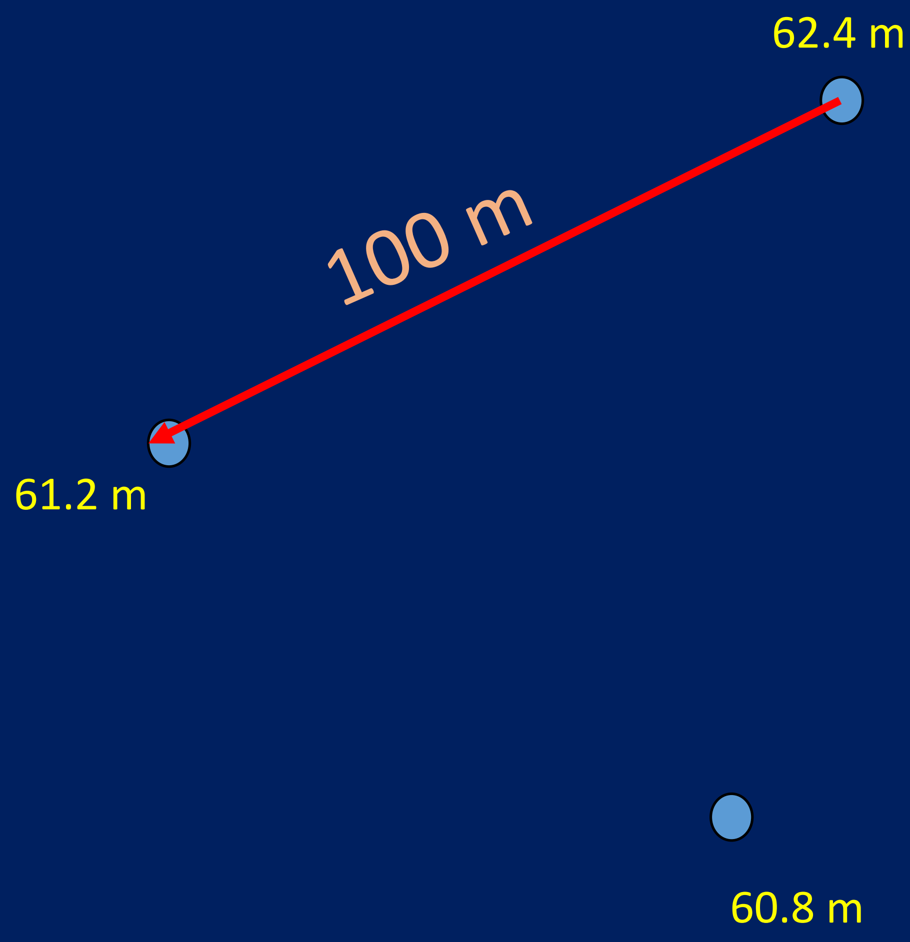


Figure 24 – Under hydrostatic conditions in this example, hydraulic head is 10 m at all depths. Hydraulic head is the sum of the pressure head and elevation head. Pressure increases linearly with depth and elevation decreases linearly with depth.

Horizontal hydraulic gradient:



Horizontal hydraulic gradient:

1) Install at least three piezometers to the same level in the ground.
2) Measure the hydraulic head at each piezometer.
3) Contour the head values.
4) Gradient is in the direction perpendicular to the hydraulic head.