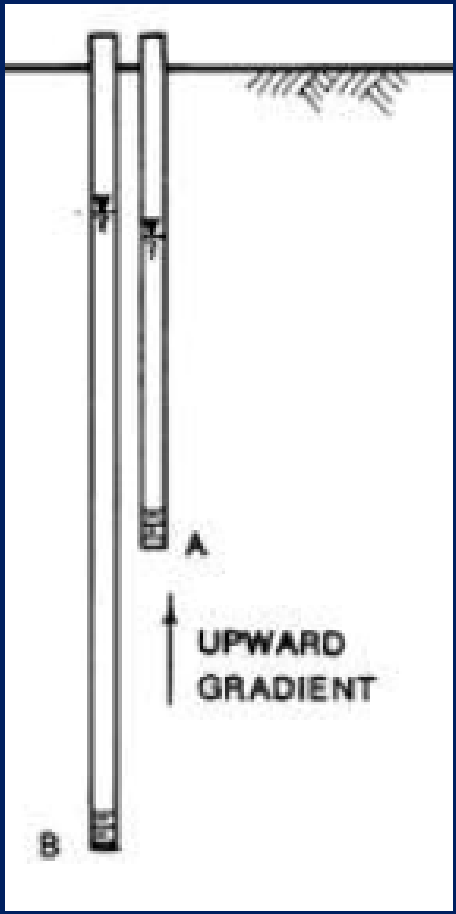
Vertical hydraulic gradient:

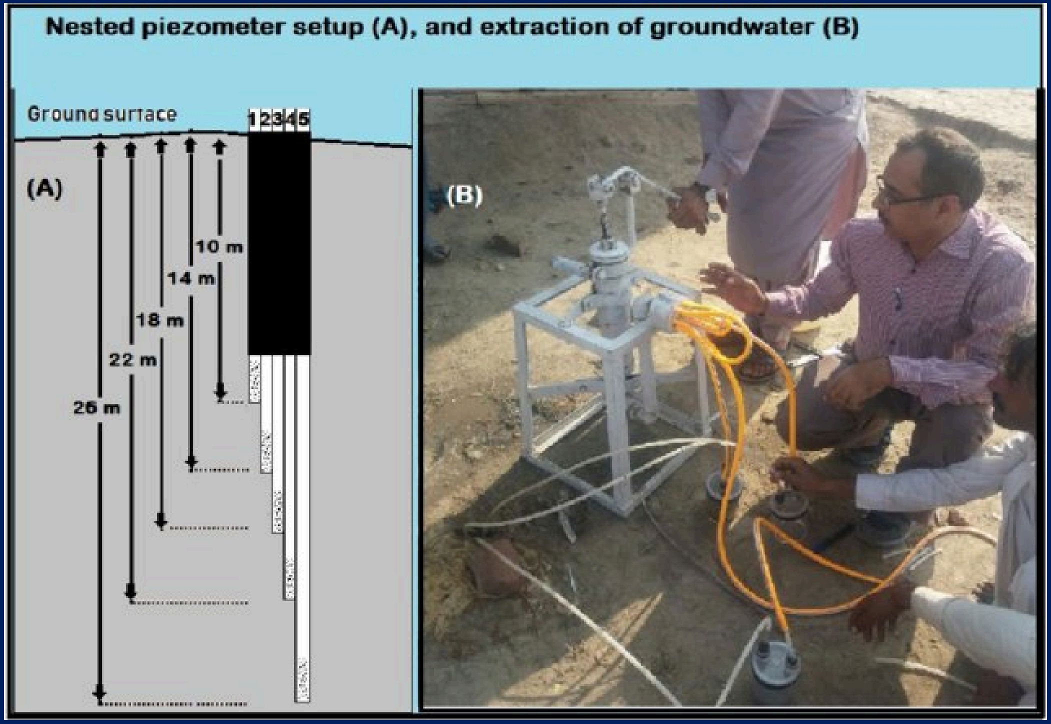
The magnitude of the vertical gradient is computed by comparing the absolute value of the head difference between the piezometers in the direction of flow, $\Delta h = | h_B - h_A |$, over the vertical distance separating their measurement locations, $\Delta L = | Z_B - Z_A |$. If piezometers or monitoring wells have screens open to the groundwater over an interval, the measuring point is designated as the midsection of the screened interval. The direction of the gradient is determined by comparing the head in the shallow piezometer, A, with that of the deeper piezometer, B. In Figure 26, the head at B is less than the head at A, so flow is downward. If the head in B was higher than A then the gradient would be upward.



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

Vertical hydraulic gradient:

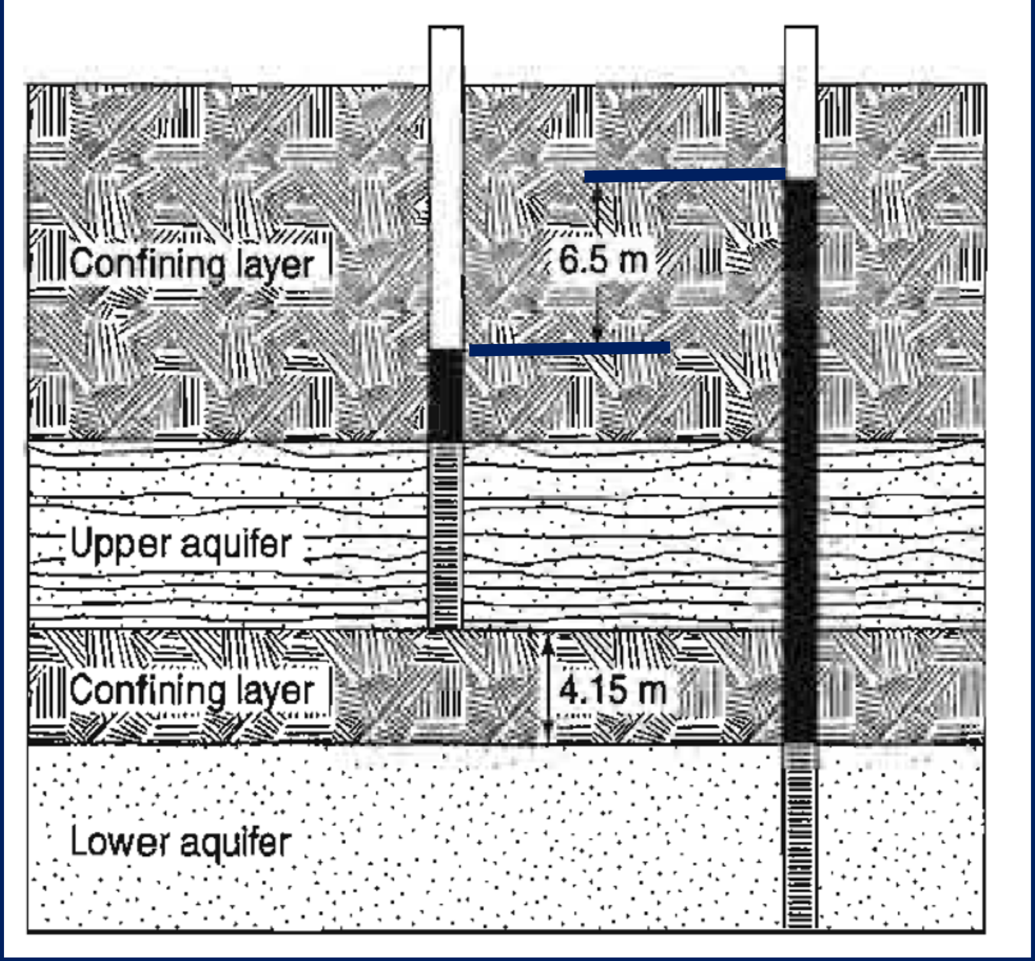
1) Install several nested piezometers to different depths.
2) Measure the hydraulic head at each piezometer.
3) Groundwater flows in the direction of decreasing hydraulic head.



https://www.researchgate.net/publication/339892540_Spatio-temporal_investigation_of_groundwater_quality_variation_employing_nested_piezometers_downstream_of_Kotri_Barrage_toward_the_Indus_Delta/figures?lo=1

Two confined aquifers are separated by an aquitard. The hydraulic head difference between the upper and lower aquifers are 6.5 m.

1) Show the direction of flow
2) Do you need a horizontal or a vertical K value?



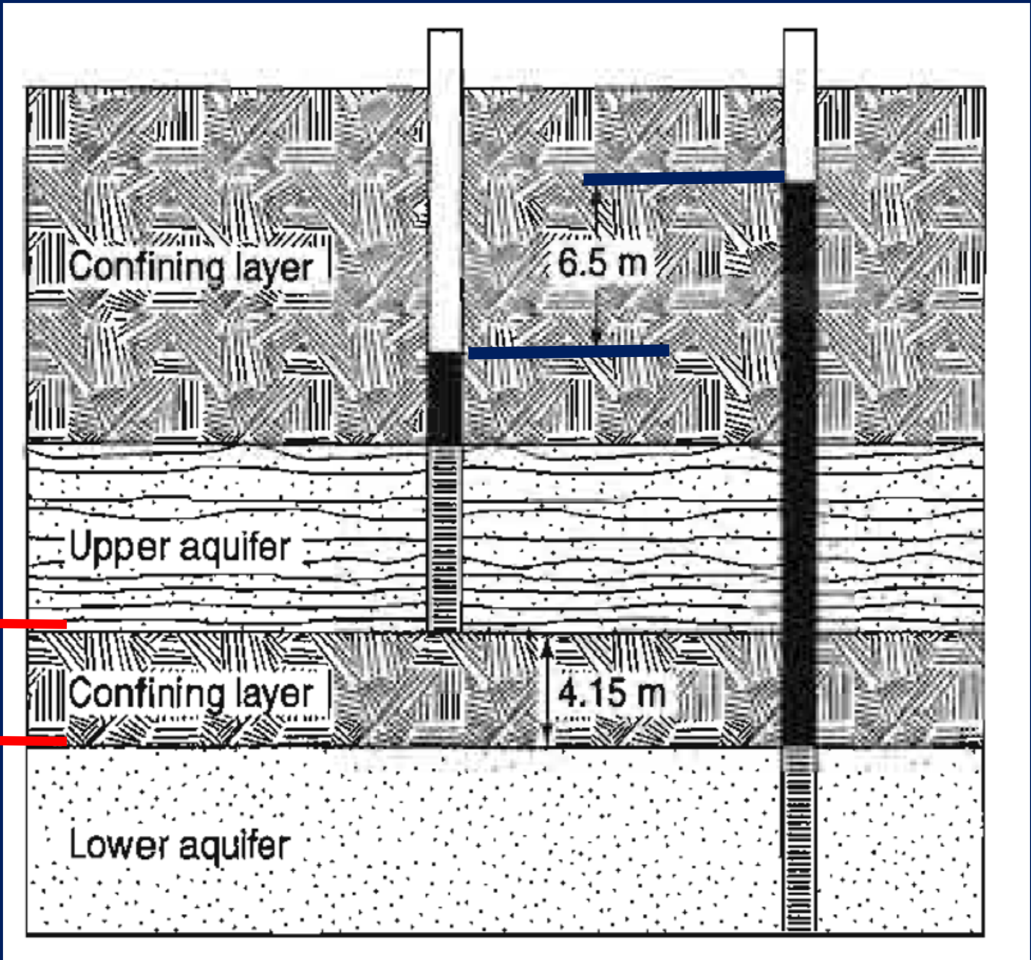
Two confined aquifers are separated by an aquitard. The hydraulic head difference between the upper and lower aquifers are 6.5 m. The vertical hydraulic conductivity of the aquitard is 0.046 m/day. What would be the leakage amount and the direction of the leakage inside the aquitard in an area of 0.5 km^2. Calculate the travel time of a water molecule inside the aquitard (aquitard thickness: 4.15 m)?

Q=KAi

V=K.i

$$V = 0.046 * \frac{6.5}{4.15}$$

V=x*t



Homogeneity and Isotropy

A homogeneous unit is one that has the same properties at all locations. For a sandstone, this would indicate that the grain-size distribution, porosity, degree of cementation and thickness are variable only within small limits. The values of transmissivity and storativity of the unit would be the same wherever present.

In heterogeneous formations, hydraulic properties change spatially (for example: change in thickness)

In a porous medium made of spheres of the same diameter packed uniformly, the geometry of the voids is the same in all directions. Thus, the intrinsic permeability of the unit is the same in all direction, and the unit is said to be isotropic.

If the geometry of the voids is not uniform, there may be a direction in which the intrinsic permeability is greater, in which case the medium is anisotropic.

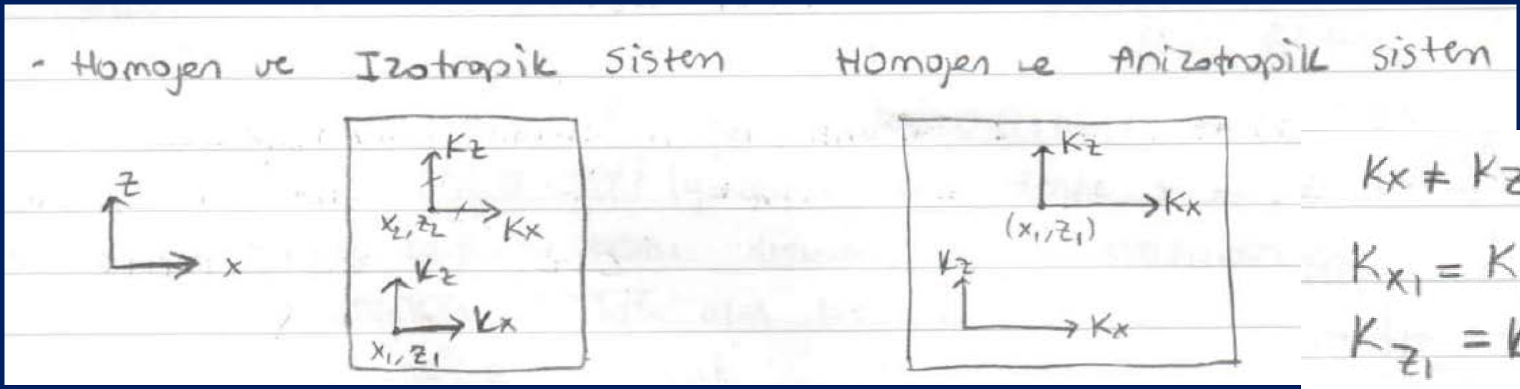
K(x,y,z)= For all x, y, z hydraulic conductivity is the same, no spatial change--- homogeneous medium

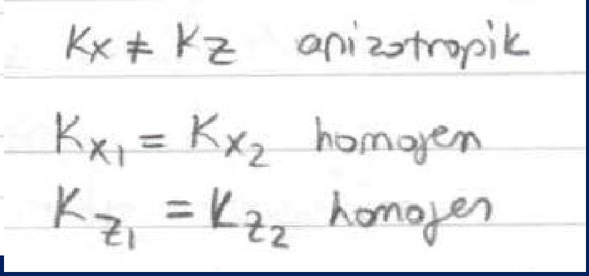
K(x,y,z) ≠ constant, porous medium is heterogeneous

Anisotropic aquifer $K_x \neq K_y \neq K_z$

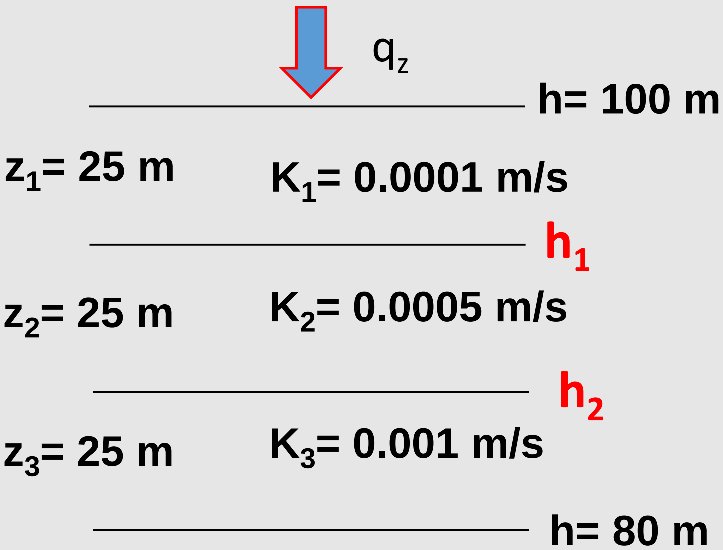
İsotropic aquifer $K_x = K_y = K_z$

PLEASE REFER TO YOUR NOTEBOOKS FOR DETAILS!!!!!!

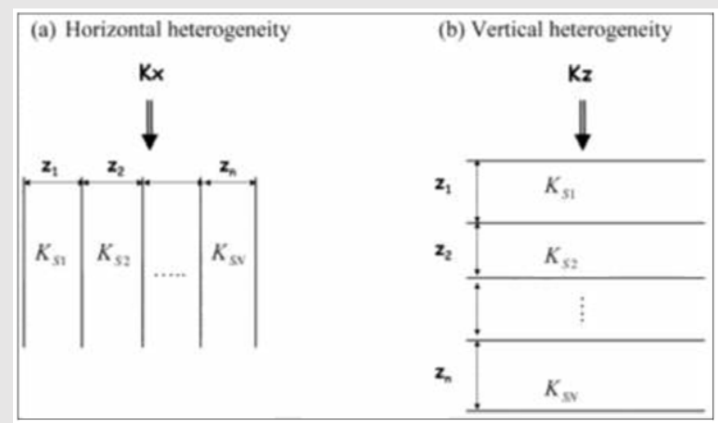




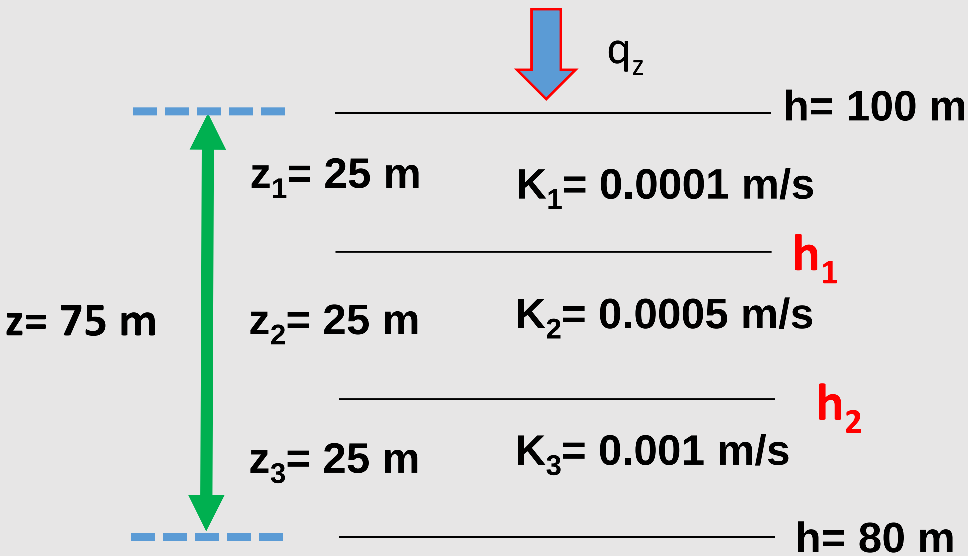
Three formations, each 25 m thick, overlie one another.If a constant-velocity flow field is set up across the set of formations with h=100 m at the top and h= 80 m at the bottom, calculate h at the two internal boundaries. The hydraulic conductivity of the top formation is 0.0001 m/s, the middle formation is 0.0005 m/s, and the bottom formation is 0.001 m/s.

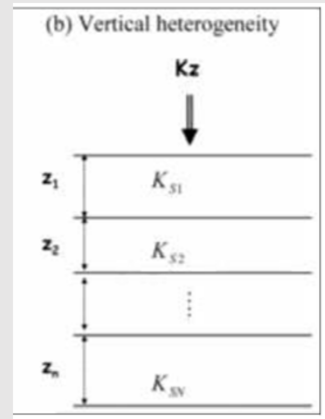


$$K_x = \sum_{i=1}^{n} \frac{K_i z_i}{z_i}, \qquad K_z = \frac{\sum_{i=1}^{n} z_i}{\sum_{i=1}^{n} \frac{z_i}{K_i}}$$



Three formations, each 25 m thick, overlie one another.If a constant-velocity flow field is set up across the set of formations with h=100 m at the top and h= 80 m at the bottom, calculate h at the two internal boundaries. The hydraulic conductivity of the top formation is 0.0001 m/s, the middle formation is 0.0005 m/s, and the bottom formation is 0.001 m/s.





$$K_z = \frac{\sum_{i=1}^{n} z_i}{\sum_{i=1}^{n} \frac{z_i}{K_i}}$$

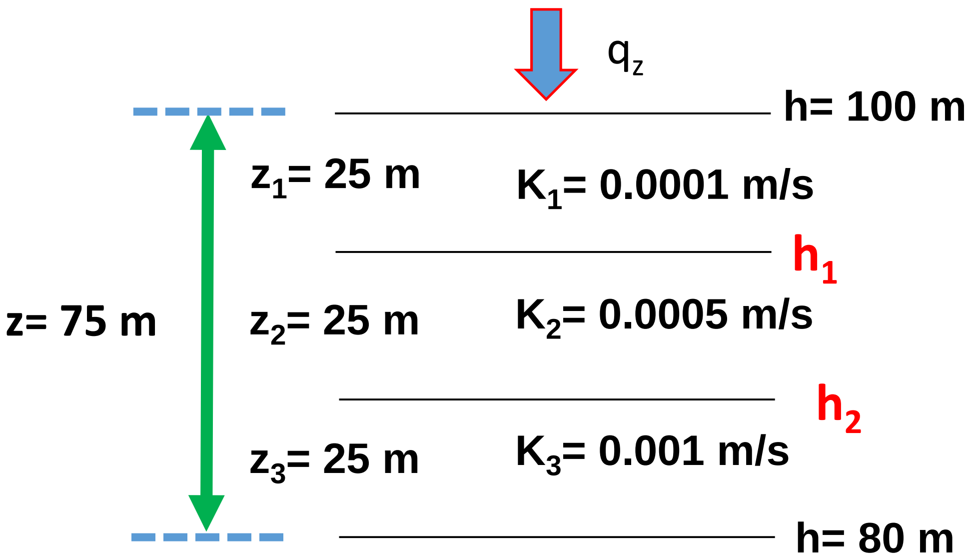
$$K_z = \frac{75}{\frac{25}{0.0001} + \frac{25}{0.0005} + \frac{25}{0.001}} = 2.31 * 10^{-4}\, m/s$$

Average hydraulic conductivity of the system

$$q_z = K_z \frac{dh_{total}}{z} = 0.000231 \frac{100-80}{75} = 6.16 * 10^{-5}\, m/s$$

q_z is the same in all layers!

Three formations, each 25 m thick, overlie one another.If a constant-velocity flow field is set up across the set of formations with h=100 m at the top and h= 80 m at the bottom, calculate h at the two internal boundaries. The hydraulic conductivity of the top formation is 0.0001 m/s, the middle formation is 0.0005 m/s, and the bottom formation is 0.001 m/s.



q_z is the same in all layers!

$$q_z = K_z \frac{dh_{total}}{z} = 0.000231 \frac{100 - 80}{75} = 6.16 * 10^{-5}\, m/s$$

$$q_z = K_1 \frac{dh_1}{z_1} = 0.0001 \frac{100 - h_1}{25} = 6.16 * 10^{-5}\, m/s$$