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Lecture (4)

3. Transmissivity (T)

Transmissivity (T) is the discharge rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Thus,

$T = Kb$ (confined aquifer)

$T = Kh$ (unconfined aquifer)

Where b is the saturated thickness of the aquifer. b is equal to the depth of a confined aquifer. h is equal to the average thickness of the saturated zone of an unconfined aquifer.

Transmissibility is usually expressed as m^2/s, or $m^3/day/m$ or l/day/m.

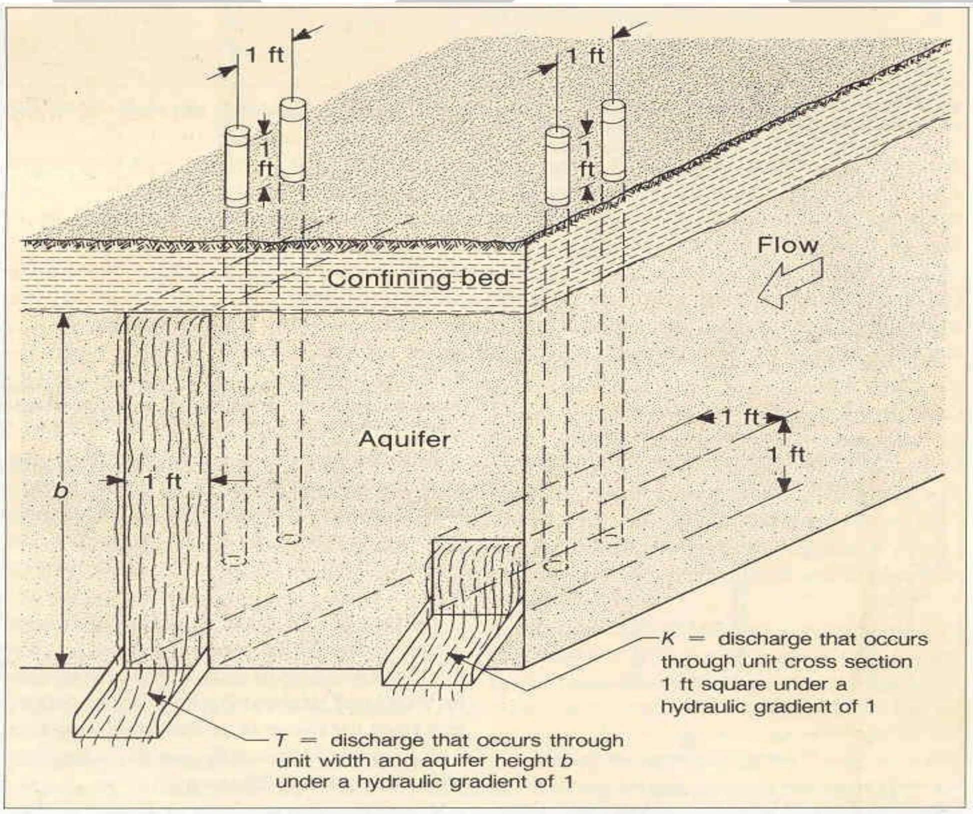

Figure --: Illustration the concepts of the Coefficients of hydraulic conductivity and transmissivity. Hydraulic conductivity multiplied by the aquifer thickness equals the coefficient of transmissivity.

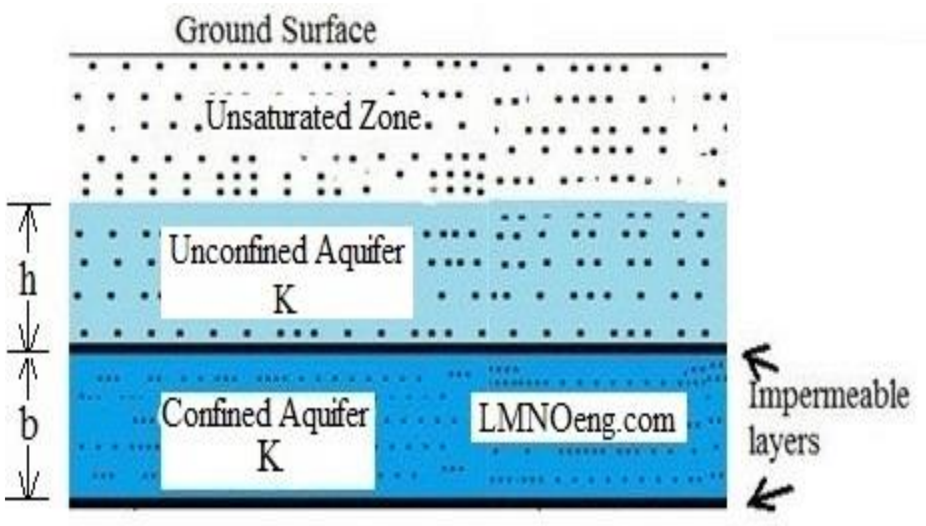

Table --: Classification of Transmissivity

Magnitude (m^2/day)	**Class**	**Designation**
> 1000	I	Very high
100-1000	II	High
10-100	III	Intermediate
1-10	IV	Low
0.1-1	V	Very low
<0.1	VI	Imperceptible

4. Storage Coefficient (S)

Storage coefficient (S) is the volume of water released from storage, per unit of aquifer storage area and per unit change in head.

* The storage coefficient is also called **Storativity**, as it is the ratio of the volume of water released from the original unit volume.

* In unconfined aquifers, Storativity is the same as the specific yield of the aquifer.

* In a confined aquifer, Storativity is the result of compression of the aquifer and expansion of the confined water when the head (pressure) is reduced during pumping.

* The storage coefficient is dimensionless and is always greater than 0. Its approximate values in confined aquifers range from about (5×10^{-5} to 5×10^{-3}) (i.e. fall in the range $0.00005 < S < 0.005$). Storage coefficients can best be determined from pumping tests of wells (required observation well) or groundwater fluctuation in response to atmospheric pressure or ocean tide variation. While in unconfined aquifers range from about (5×10^{-2} to 3×10^{-1}) (i.e. fall in the range $0.05 < S < 0.3$).

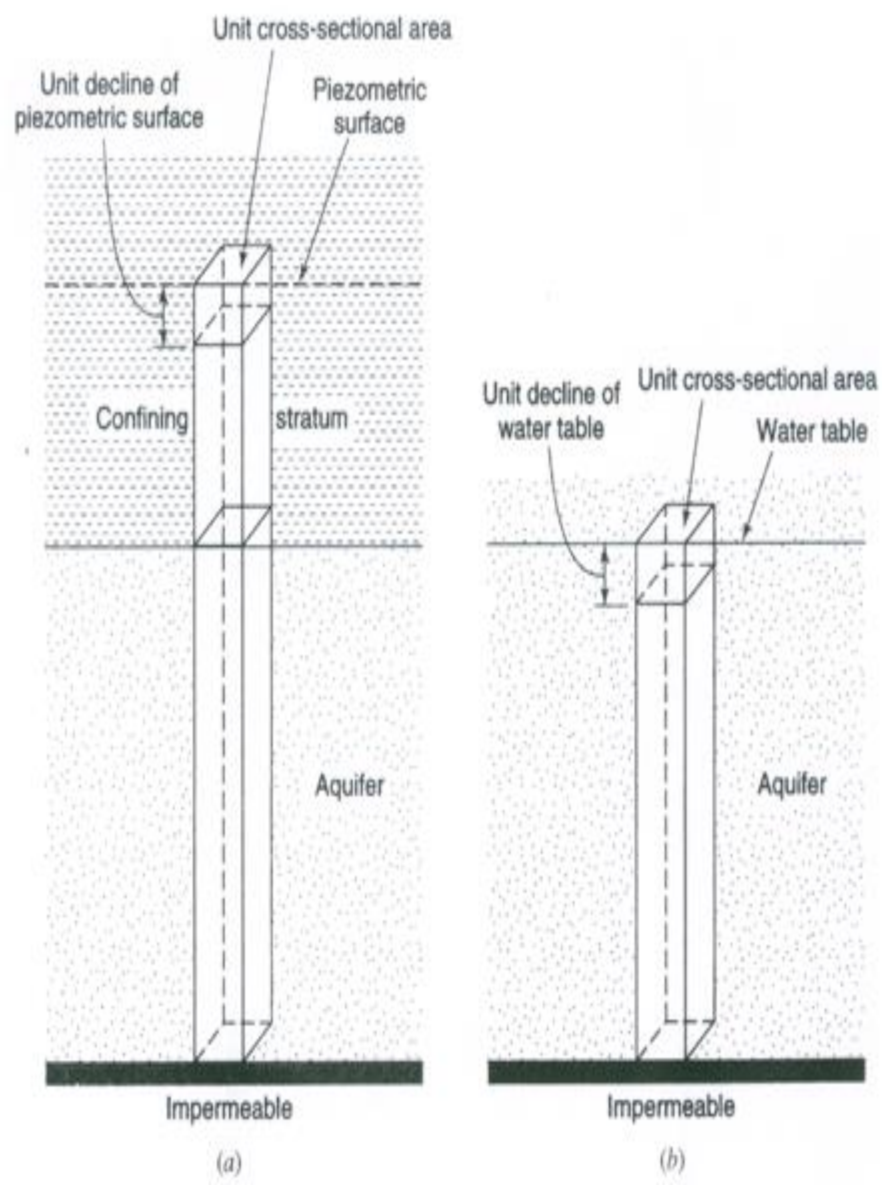

Figure --: Illustrative sketches for defining storage coefficient of (a) confined and (b) unconfined aquifers

5. Specific capacity (Sc)

Specific capacity is the value of discharge available (Q) for a unit drawdown (Sw), i.e. it is the ratio of pumping rate to the drawdown. Expressed in square meters per day (m^2/day). It is measured of a well productivity, it is a measure of the productivity of both the aquifer and the well; clearly the higher specific capacity (Sc) better the well efficiency (Todd, 2007). The specific capacity (Sc) is also a function of well characteristics, such as degree of penetration, well radius, and well loss.

Sc = Q / Sw

Where; Sc: Specific Capacity (m^2/day). Q: Pumping rate measured (m^3/day). Sw: Drawdown (m).

6. Specific Yield (S_y)

Specific yield (S_y) is the ratio of the volume of water that drains from a saturated rock owing to the attraction of gravity (or by pumping from wells) to the total volume of the saturated aquifer. It is defined mathematically by the equation:

$$S_y = \frac{V_w}{V} X\ 100\%$$

Where, V_w is the volume of water in a unit volume of earth materials (L^3, cm^3, or m^3). V is the unit volume of earth material, including both voids and solids (L^3, $cm^{3,}$ or m^3).

All the water stored in a water-bearing stratum cannot be drained out by gravity or by pumping, because a portion of the water is rigidly held in the voids of the aquifer by molecular and surface tension forces (see Table --).

Table --: Specific Yield in Percent (after Freeze & Cherry, 1979)

Formation	S_y (range)	S_y (average)
Clay	0 - 5	2
Sandy clay	3 - 12	7
Silt	3 - 19	18
Fine sand	10 - 28	21
Medium sand	15 - 32	26
Coarse sand	20 - 35	27
Gravelly sand	20 - 35	25
Fine gravel	21 - 35	25
Medium gravel	13 - 26	23
Coarse gravel	12 - 26	22
Limestone		14

7. Specific Retention (S_r)

Specific retention (S_r) is the ratio of the volume of water that cannot be drained out to the total volume of the saturated aquifer. Since the specific yield represents the volume of water that a rock will yield by gravity drainage, hence the specific retention is the remainder. The sum of the two equals porosity.

$$n = S_r + S_y$$

The specific yield and specific retention depend upon the shape and size of the particle, distribution of pores (voids), and compaction of the formation.

* The specific retention increases with decreasing grain size.

* It should be noted that it is not necessary that soil with high porosity will have high specific yield because that soil may have low permeability and the water may not easily drain out. For example, clay has a high porosity but low specific yield and its permeability is low. Therefore, the best groundwater reservoirs are in sandy formation, where specific yield is high and specific retention is low.

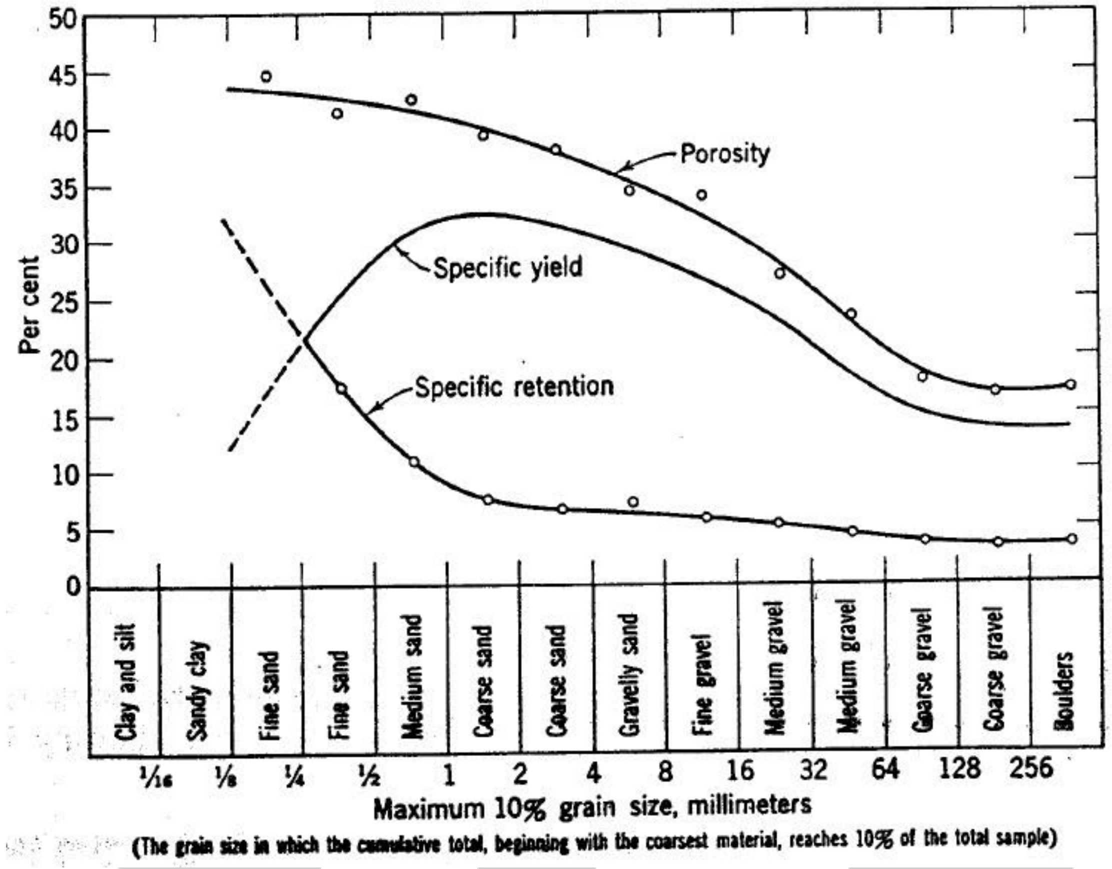

Fig.-- Porosity, Specific yield, and Specific retention variations with grain size, South Coastal Basin, Calif. (after Eckis[13]).

Isotropy and Homogeneity

The terms isotropy, anisotropy, homogeneity, and heterogeneity are used to describe the spatial variation and directional trends in aquifer property values.

If the hydraulic conductivity, K, is independent of position within a geological formation, the formation is *homogeneous*. If the hydraulic conductivity varies from place to place, then the formation is *heterogeneous*. The type of *heterogeneity* will depend on the geological environment that gave rise to the deposit or rock type. As shown in Fig.--.

An *isotropic* geological formation is one where the hydraulic conductivity is independent of the direction of measurement at a point in the formation. If the hydraulic conductivity varies with the direction of measurement at a point, the formation is *anisotropic* at that point.

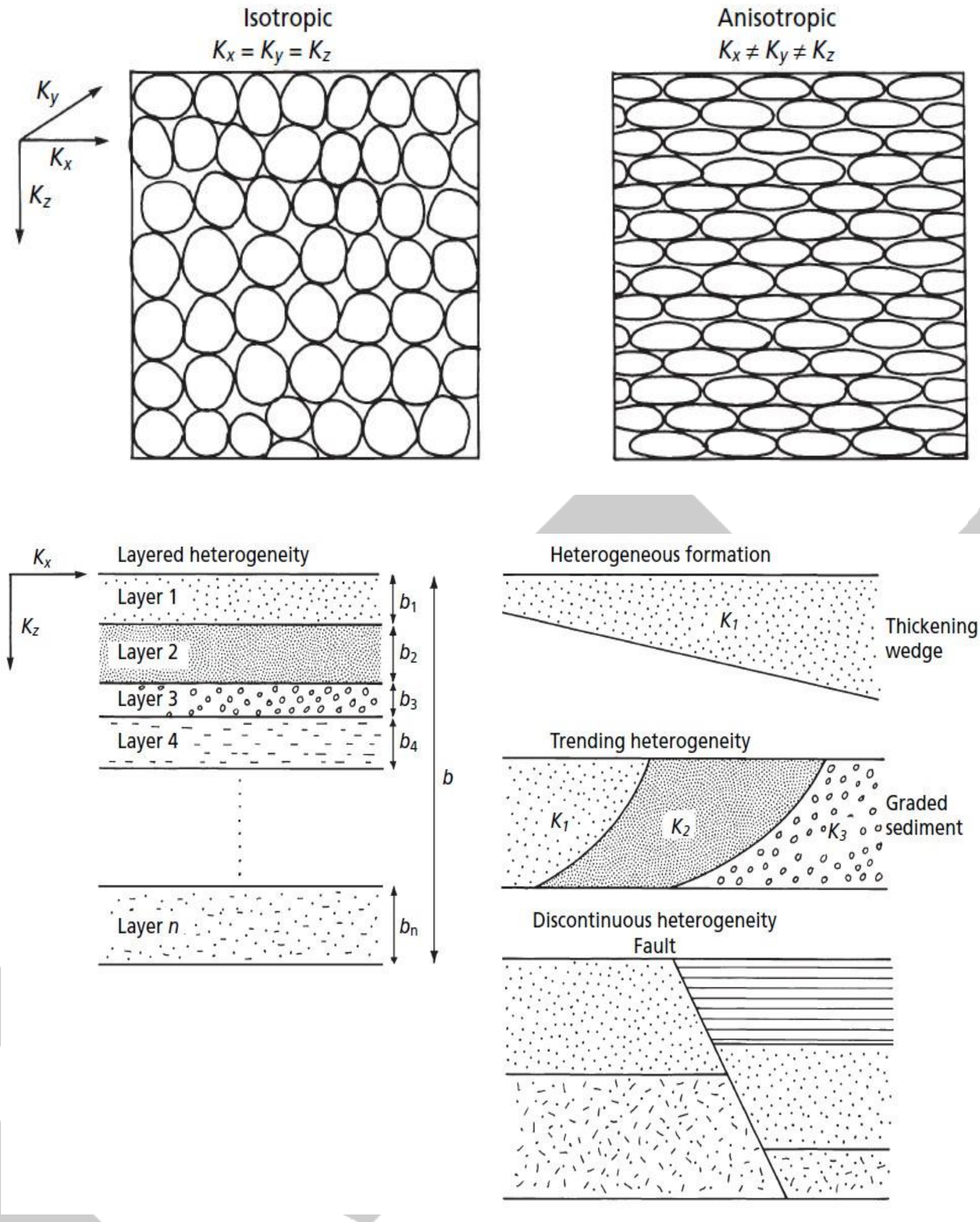

Fig. --: Examples of isotropy, anisotropy, and heterogeneity showing the influence of grain shape and orientation, sedimentary environment, and geological structure on hydraulic conductivity. (Data from Fetter 2001.)

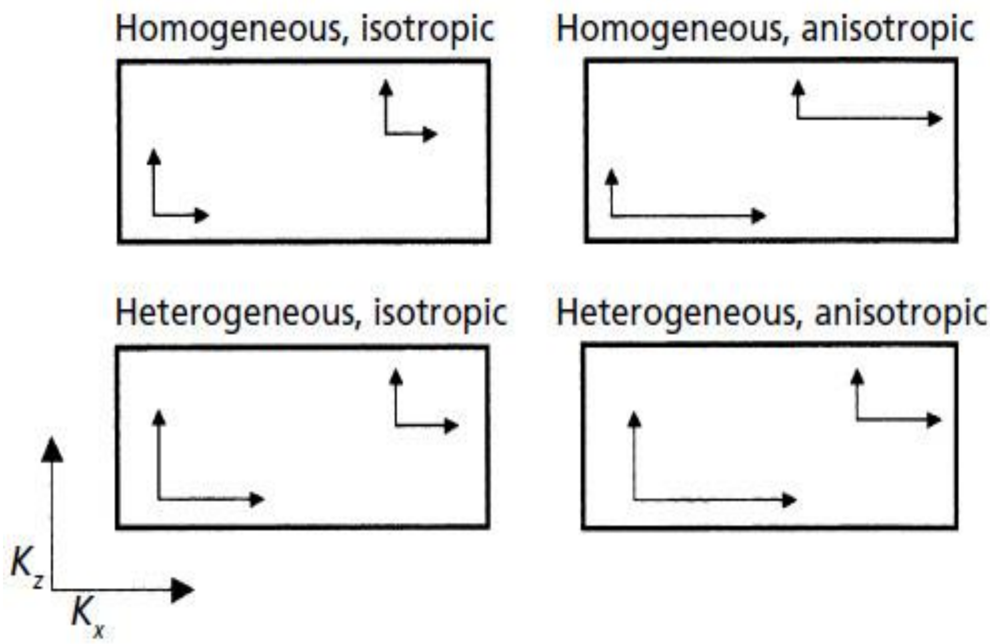

Fig. --: Four possible combinations of heterogeneity and anisotropy describing the hydraulic conductivity of a porous material. (Adapted from Freeze and Cherry 1979. Reproduced with permission of Pearson Education, Inc.)

References:

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- **Analysis and Evaluation of Pumping Test Data**, Kruseman, G. P., and de Ridder, N. A. 1994.
- **Hydrogeology Principles and Practice**, Second Edition, Kevin M. Hiscock and Victor F. Bense.
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