GROUND WATER

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Definition :-

Ground Water hydrology is the science of occurrence, distribution and movement of water below the surface of the earth.

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Occurrence :-

* The main source of ground water is precipitation.
* A portion of rain falling on the earth's surface infiltrates into ground and travel through impervious layer and form ground water.
* Other sources of ground water include water from deep in earth is carried upward in intrusive rocks and water is trapped in Sedimentary rocks.
* Such type of water is highly mineralised and unsuited for use.
* The discharge from ground water occurs in two ways.
  1. Natural way
  2. Artificial way.

* The natural discharge occurs as flow in lakes, reservoirs, oceans and springs.

* The major artificial discharge constitute pumpage from wells.

Some Definitions:-

Aquifer:-

Aquifers are the permeable formations having structures which permit appreciable quantity of water to move through them under ordinary field conditions.

These are geological formations in which ground water occurs (i.e. sands and gravel)

Aquiclude:-

Aquiclude are impermeable formations which contain water but are not capable of transmitting and supplying a significant quantity (i.e. clays).

Aquifuge:-

Aquifuge is an impermeable formations which neither contains water nor transmits any water.

Aquifer Parameters:-

(i) porosity:- It is defined as the ratio of volume of voids (V_v) in the material to its total volume (V) and is expressed as percentage.

$$\therefore \quad n = \frac{V_v}{V} \times 100.$$

(ii) Specific Yield :- It is defined as the ratio expressed as a percentage of volume of water which after being saturated, can be drained by quality to its own volume.

$$\text{Specific yield} = \frac{\text{vol of water drained by gravity}}{\text{Total volume.}}$$

$$S_y = \frac{w_y}{V} \times 100$$

(iii) Specific retention (Sr) :- It is defined as the ratio of volume of water which will retain after saturation against the force of gravity to its own volume.

$$S_r = \frac{W_r}{V} \times 100$$

(iv) Transmissivity (or) co-efficient of transmissivity

It is defined as the rate of flow of water (in m^3/day) through the vertical strip of an aquifer of unit width (1m) and extending the full saturation height under unit hydraulic gradient at temp of $60°F$.

$$T = B \times K$$

Where K = co-efficient of permeability.

(or)

The co-efficient of transmissibility (T) equals to the field co-efficient of permeability (K) multiplyed by the aquifer thickness (B);

(v) permeability (or) co-efficient of permeability (K) :-

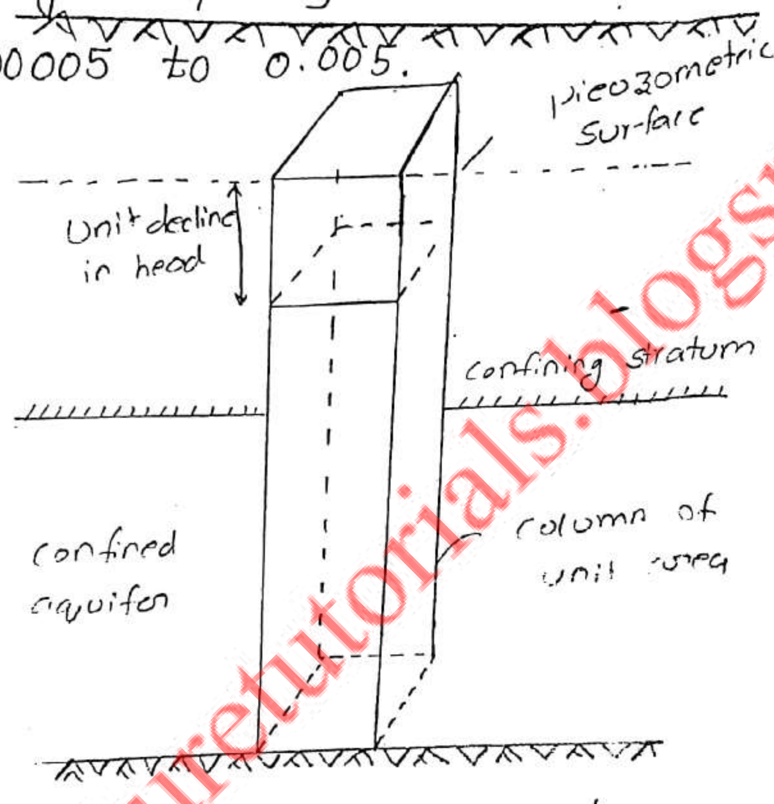
It is defined as the velocity of flow which will occur through the ~~water~~ total c/s area of the soil under a unit hydraulic gradient. The units is "cm/sec".

(vi) Storativity or storage co-efficient :-

* The water yielding capacity of a confined aquifer can be expressed in terms of storage co-efficient.

It is defined as the volume of water that an aquifer releases from or takes in to the storage per unit surface area of an aquifer per unit change in the component of head normal to that surface.

* The storage capacity of an aquifer ranges from 0.00005 to 0.005.



Storage coefficient

Types of Aquifer:-

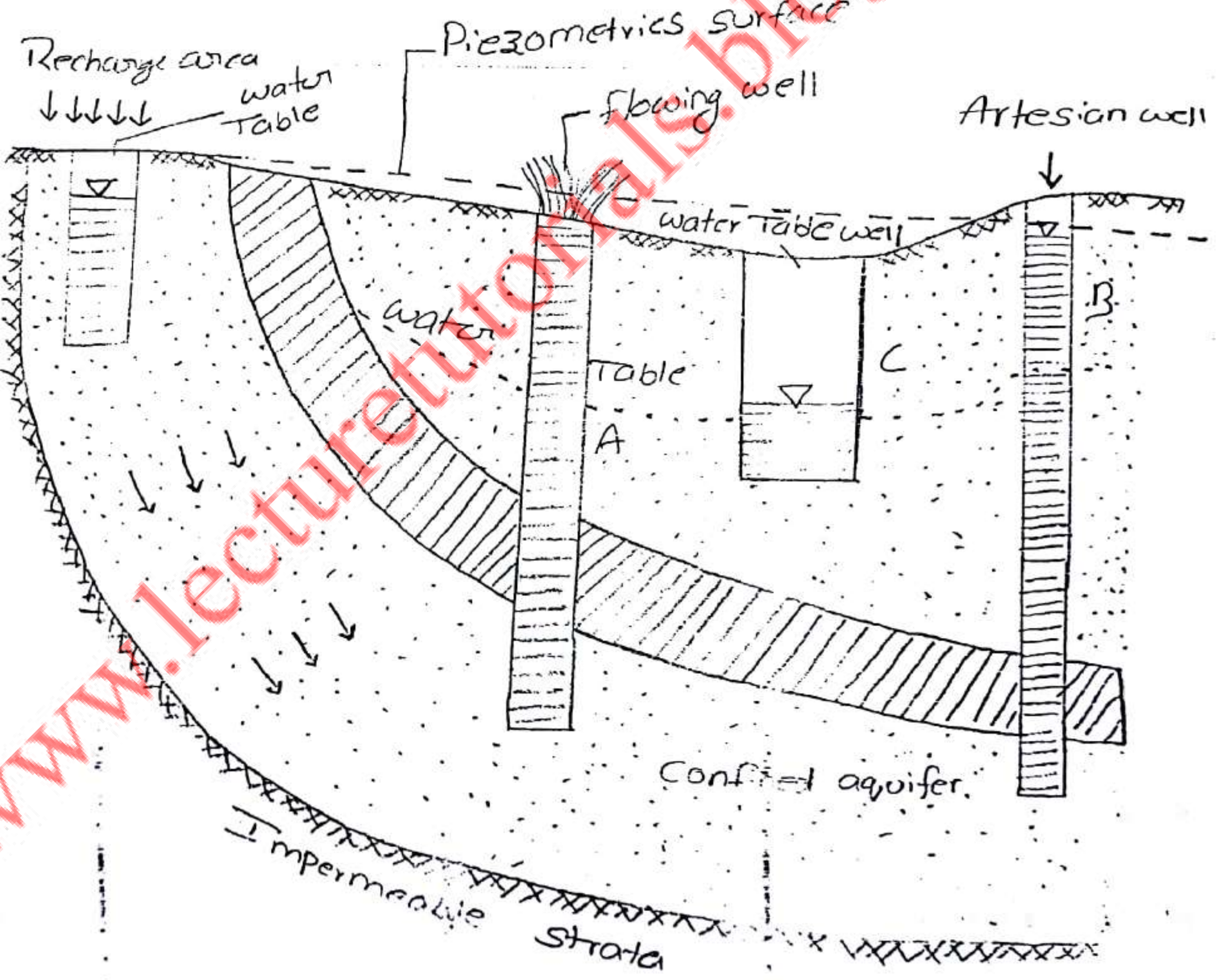
Mainly there are two types of aquifer.

1. Unconfined aquifer
2. Cartesian aquifer) Confined Aquifer.

1. Unconfined Aquifer:-

It is the type of aquifer in this a water table serves as the upper surface of the zone of saturation.

* It is also known as free, phreatic (or) non artesian aquifer.
* In this aquifer the water table varies in undulating form and in slope.
* Rises and falls in water table corresponding to changes in the volume of water in storage will occur in this type of aquifer.



Confined and unconfined aquifers.

Confined Aquifer:-

In this type of aquifer the ground water is confined under pressure greater than atmospheric pressure by over-lying, relatively impermeable strata.

* It is also known as Artesian Aquifer.
* This type of aquifer usually have relatively small recharge areas as compared with unconfined aquifer.
* It has storativity value less than 0.01.
* It has water table above their upper boundary.

Definitions of Flowing Well and Artesian Well.

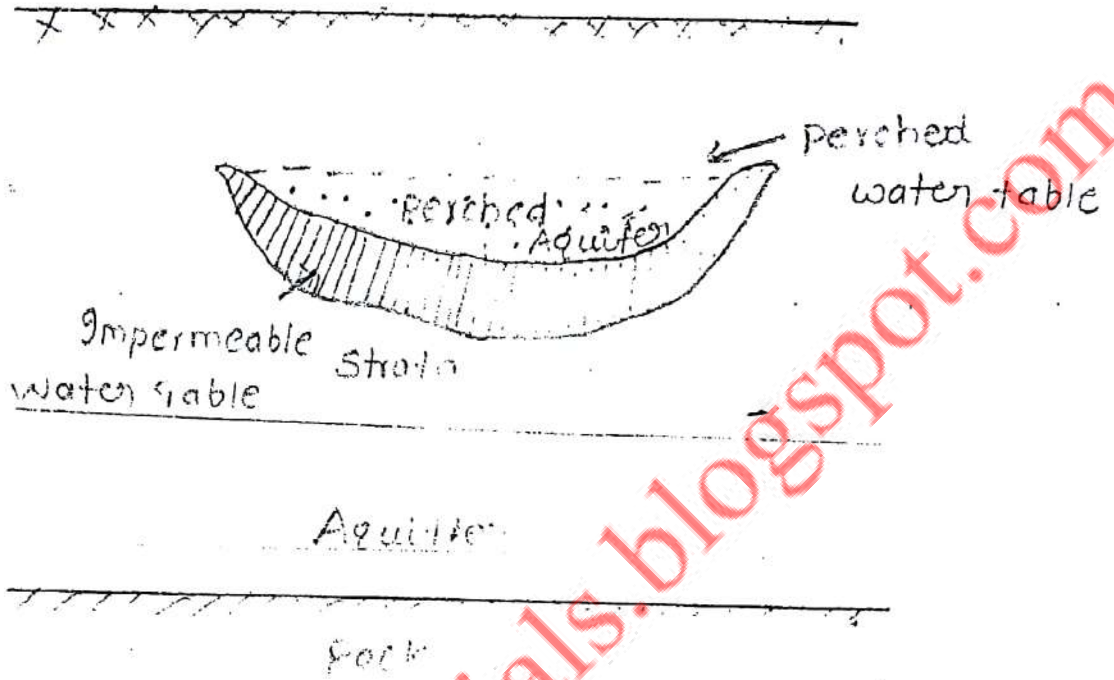
When a well penetrates a confined aquifer, if artesian pressure is sufficient to raise the water above the ground level, the "flowing well" occurs.

If the water level in a well is below ground level but above the local water table it is known as "Artesian well".

Perched Aquifer:-

It is a special type of unconfined aquifer and occurs where a ground water body

Separated from the main ground water by a relatively impermeable stratum of small arial extent and by the zone of aeration above the main body of ground water.



Darcy's Law:-

Perched Aquifers.

According to this law the rate of flow of water or discharge per unit time is directly proportional to the hydraulic gradient

$$Q \propto i$$

$$Q = kiA$$

$$v = \frac{Q}{A} = ki$$

Where

Q = Discharge

i = hydraulic gradient

$= \frac{-dh}{dt}$

K = Darcy's co-efficient of permeability

A = Total cross-sectional Area

V = Velocity of flow.

This darcy's law is valid as long as the Reynold's number (Re) is equal to (or) less than unity

$$Re = \frac{\rho V d}{\mu} \le 1$$

where ρ = mass density

μ = dynamic viscosity

d = diameter of particle size

V = velocity of flow.

* This law may not be applicable to unconsolidated aquifers with steep hydraulic gradients or in those containing large diameter openings.

*Steady radial flow to a well : Depuits Theory

* When the water from the well is pumped, water is removed from the aquifer and the water table depending upon the type of aquifer, results in a circular depression in the water table. This depression is known as "Cone of depression" or "drawdown curve"

* At any point, away from the well, the drawdown is the vertical distance by which the water table is lowered.

* The Analysis of such radial flow towards a well was originally proposed by Dupuit (1863). This analysis is two types

A) Well in unconfined aquifer

B) Well fully penetrating a confined aquifer.

* Assumptions and Limitations of Dupuit's theory :-

Dupuit's theory of flow for unconfined aquifer is based on following assumptions.

1. The velocity of flow is proportional to the tangent of the hydraulic gradient instead of sine.

2. The flow is horizontal and uniform every where in vertical s/c.

3. Aquifer is homogeneous, isotropic and of infinite aerial extent.

4. The well penetrates and receives water from the entire thickness of the aquifer.

5. The co-efficient of transmissibility is constant at all places and at all times.

6. Natural ground water regime affecting an aquifer remains constant with time.

4. flow is laminar and Darcy's law is applicable.

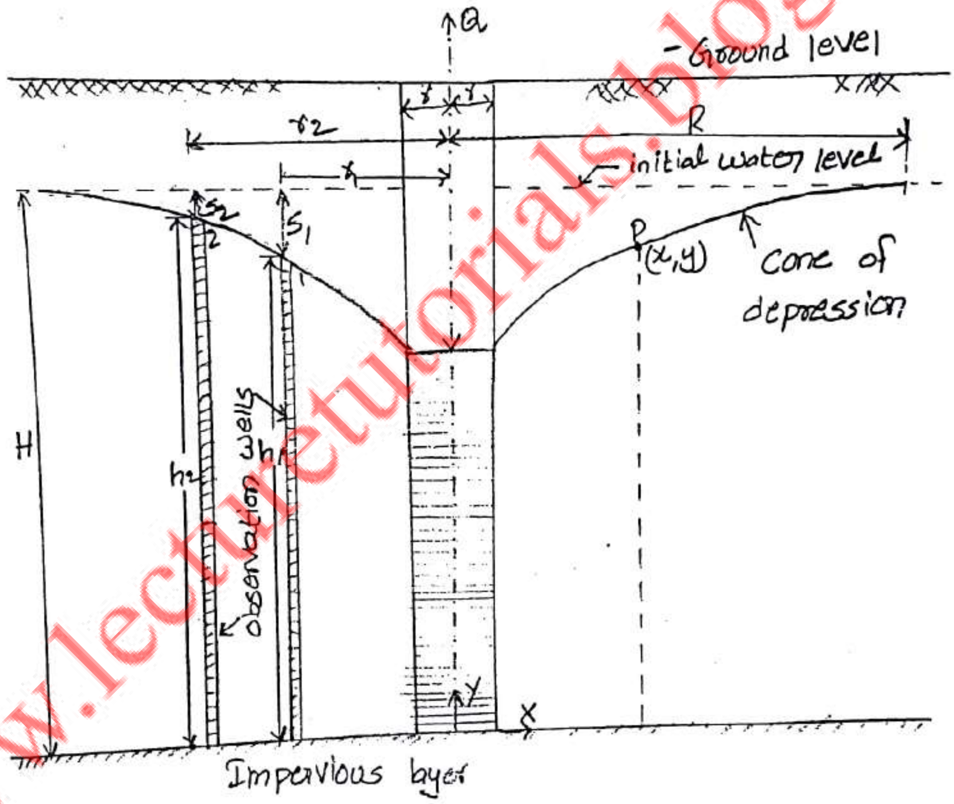
Well in unconfined aquifer:-

Let r = Radius of the Well

H = Thickness of aquifer

s = drawdown at well

h = Depth of water in well.



considering the origin of co-ordinates at a point 'o' at the centre of the well and at its bottom, let the co-ordinates of any point 'p' on the drawdown curve be (x,y).

from Darcy's law

$$Q = k A_x i_x$$

where

$$A_x = (2\pi x)\, y$$

i_x = hydraulic gradient

$$i_x = \frac{dy}{dx}$$

$$\boxed{Q = k \cdot \frac{dy}{dx} \cdot 2\pi x y}$$

$$Q \cdot \frac{dx}{x} = 2\pi y k \cdot dy$$

By integrating the above eqn b/w the limits (R, r) for 'x' and (H, h) for 'y' we get.

$$Q \cdot \int_r^R \frac{dx}{x} = 2\pi k \int_h^H y \cdot dy$$

$$\Rightarrow \quad Q \left[\log_e x\right]_r^R = 2\pi k \left[\frac{y^2}{2}\right]_h^H \cdot dy$$

$$\Rightarrow \quad Q = \frac{\pi k (H^2 - h^2)}{\log_e (R/r)}$$

$$Q = \frac{1.36\, k\, (H^2 - h^2)}{\log_{10} (R/r)} \quad \text{———} (2)$$

If there are two observations in a well at a radial distance r_1 & r_2 $(r_2 > r_1)$ and if the depth of water in them are h_1 & h_2

then

$$Q = \frac{\pi k (h_2^2 - h_1^2)}{\log_e (r_2/r_1)}$$

If the draw down is measured at the well face then

$$S = H - h$$

$$H = S + h \text{ (or) } H + h = S + 2h$$

$\therefore$ From eq^n — (2)

$$Q = \frac{\pi k (H-h)(H+h)}{\log_e (R/r)}$$

$$Q = \frac{\pi k s (S + 2h)}{\log_e (R/r)} \quad \text{——— (3)}$$

$$Q = \frac{\pi k s (S + 2L)}{\log_e (R/r)}$$

where $h = L$ = length of strainer

$$Q = \frac{2\pi k s [L + (S/2)]}{\log_e (R/r)}$$

$\therefore$ The discharge from the well in on unconfined aquifer is given by

$$\boxed{Q = \frac{2.72\ ks\ (L + S/2)}{\log_{10} (R/r)}}$$

B) Well in fully penetrating Confined Aquifer

Let x, y be the co-ordinates of any point 'p' measured w.r.t. origin 'O'.

From darcy's law

$$Q = K \cdot i_x \cdot A_x \quad \text{——— (1)}$$

where $A_x = 2\pi x b$

b = thickness of confined aquifer

$$i_x = \frac{dy}{dx}$$

$$Q = K \cdot \frac{dy}{dx} \cdot 2\pi x b$$

$$Q \cdot \frac{dx}{x} = 2\pi K b \cdot dy$$

By integrating the above eqn (R, r) for x
(H, h) for y.

$$\Rightarrow Q \int_r^R \frac{dx}{x} = 2\pi k b \int_h^H dy$$

$$\Rightarrow Q (\log_e)_r^R = 2\pi K b (H-h)$$

$$Q = \frac{2\pi K b (H-h)}{\log_e (R/r)}$$

$S = H-h$

$H = S+h$

$$Q = \frac{2\pi K b (S)}{\log_e (R/r)}$$

$$Q = \frac{2.72\, bks}{\log_{10}(R/r)}$$

[For diagram refer pg-no-11]

$$Q = \frac{2.72\, T.S.}{\log_{10}(R/r)}$$

where T = co-efficient of transmissivity
= bk.

If h_1, h_2 are depth of water in a well and r_1, r_2 are radial distance from the observation of two wells. then

$$Q = \frac{2.72\, bk(h_2 - h_1)}{\log_{10}(r_2/r_1)} = \frac{2.72\, T(h_2 - h_1)}{\log_{10}(r_2/r_1)}$$

If 'h_x' is the depth at any radial dist 'x' then discharge

$$Q = \frac{2\pi bk\,(h_x - h)}{\log_e (r_x/r)}$$

$$\Rightarrow h_x - h = H - h \;\frac{\log_e (r_x/r)}{\log_e (R/r)}$$

The above eqn shows that the head varies linearly with the logarithm of dist regardless of rate of discharge.

Types of Wells:-

The types of wells are

1. open well or Dug well
2. Tube well or Bored or drilled wells.

1. open well:-

A open well is of large diameter and it is suitable for discharge of water upto 0.005 cumecs.

* The c/s area of a flow is less and water can be withdrawn safely only at critical and velocity of soil.

* These are of two types

i) shallow open wells

ii) Deep open wells.

2. Tube wells : (Bored or Drilled)

* It is a long pipe sunk in to the ground with a strainer which allows the water to pass through but prevent the sand coming from it.

* Because of the strainer high velocity of flow can be permitted without the danger of soil particles carried with water.

The dia of a tube well is very less when compared with open well.

* There are 3 types of tube wells.
  a) Strainer wells
  b) Cavity wells
  c) Slotted wells.

Yield of a open well - recuperation test:-

The yield from an open-well can be found out by two tests

1. constant level pumping test
2. Recuperation test.

2. Recuperation test:-

* In this test the water level is depressed to any level below the normal and pumping is stopped.
* The time taken for the water to recuperate to the normal level is noted
* From the data discharge can be calculated as below.

Let a a : static water level in the well before pumping started.

bb = water level in the well when pumping is stopped.

cc = water level in a well at a time 't' after pumping is stopped.

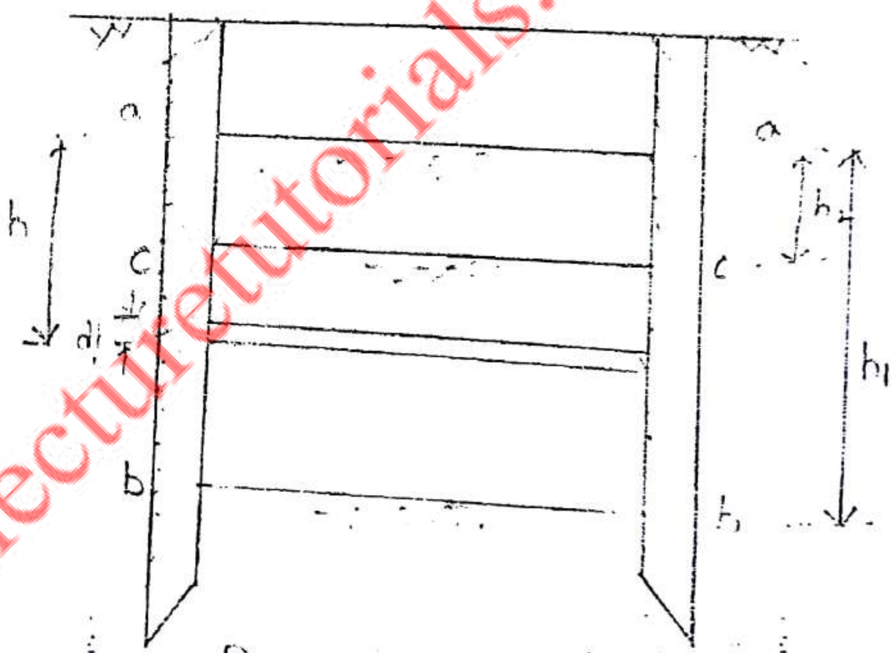
h = Depression head in a well at a time 't'.

h_1 = Depression head in a well when the pumping is stopped

h_2 = Depression head in a well at a time 'T'

dh = decrease in depression head in a time 'dt'.

t x T = time in hours.



Recuperation test

The volume of water entering the well when the head recuperates by dh then

$$dv = A \cdot dh \quad \text{———} \quad (1)$$

where A = c/s area of well at its bottom.

If Q is rate of discharge in well at a time the volume of water entering into the well by

$$dv = Q \cdot dt$$

$$Q \alpha h$$

$$Q = K \cdot h \quad \text{——} \quad (2)$$

$$dv = K \cdot h \cdot dt \quad \text{——} \quad (3)$$

where

K - a constant

$\therefore$ By equating (1) & (3), we get

$$K \cdot h \cdot dt = -A \cdot dh \quad \text{——} \quad (4)$$

where (-ve) sign indicates that 'h' decreases as time 't' increases.

Integrating b/w the limits $t=0$ and $h=h_1$
$t=T$ and $h=h_2$

we get

$$\frac{K}{A} \int_0^T dt = -\int_{h_1}^{h_2} \frac{dh}{h}$$

$$K/A \int_0^T dt = +\int_{h_2}^{h_1} \frac{dh}{h}$$

$$\frac{K}{A} \cdot T = \left(\log_e h\right)_{h_2}^{h_1}$$

$$\boxed{\frac{K}{A} = \frac{2.303}{T} \log_{10} (h_1/h_2)}$$

Thus by knowing the values of h_1, h_2 and T from the recuperation test K/A can be calculated:

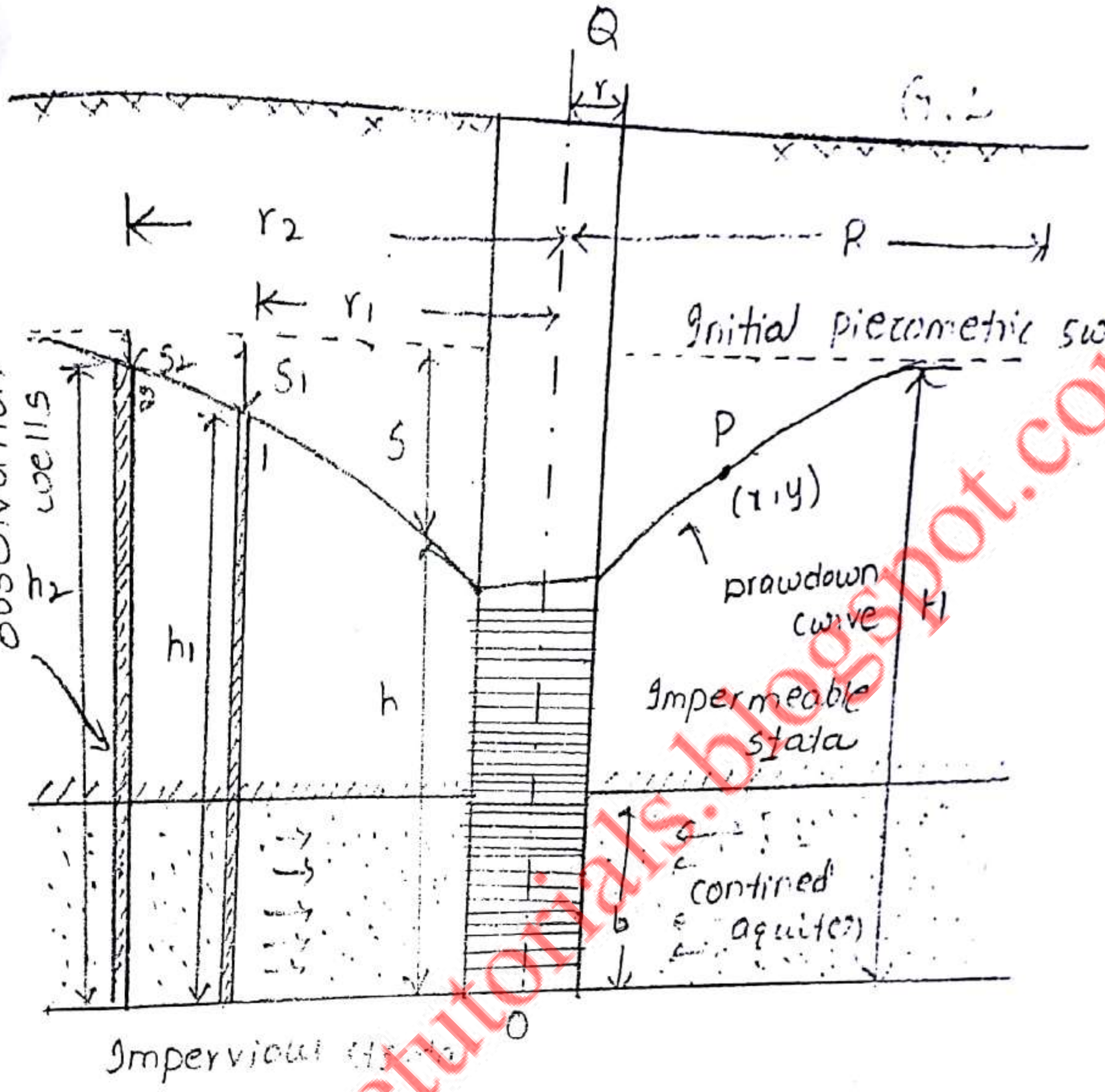
where $\frac{K}{A}$ = specific yield (or) specific capacity of an open well in $m^3/h^r/m^2$

By knowing the value of K/A by the observation the discharge from a well under a constant depression head H, is calculated as

$$Q = K \cdot H$$

$$Q = \left(\frac{K}{A}\right) \cdot A \cdot H$$

$$Q = \frac{2.303}{T} \log_{10}(h_1/h_2) \cdot A \cdot H. \quad m^3/h.$$



Confined Aquifer