Groundwater and well :-

① The saturated portion over the impervious stratum is know as the zone of saturation. and is referred to as groundwater.

② water below the land surface may be divided in two zone.
① the zone of saturation ② zone of aeration.

Note ① zone of saturation :- the pores are completely filled or saturated with water. The upper surface of the zone of saturation is know the water-table.

② zone of aeration :- occurring above the zone of saturation consists of pores occupied partially by water and partially by air. zone divided into three from.

ⓐ soil water zone
ⓑ Intermediate zone
ⓒ capillary zone

(Moisture necessary for their growth).

→ (water in this zone is suspended by capillary force. (which cause water rise in a tube).

(this zone lies b/w the belt of soil water and the capillary fringe and connects both these zone.)
(water move pull of gravity).

6.2 Geologic formation for groundwater supply.
rocks are generally of two types
① consolidated type (granite, sandstone, lime stone materials etc).
② unconsolidated type (such as clay, sand, gravel).

Types of Aquifers :- ⓐ unconfined (watertable aquifers) ⓑ confined (artesian aquifer Aquifer) ⓒ semiconfined.

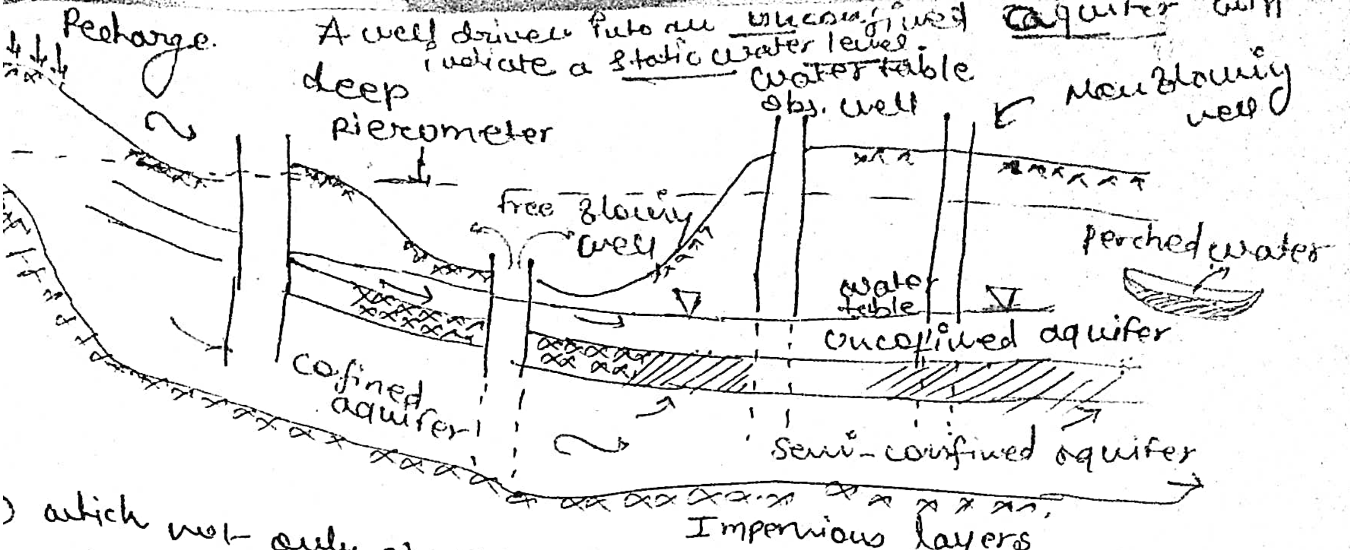
① unconfined :- which is not confined by an upper impermeable layer. (water in these (atmospheric pressure)

② confined :- which the water is confined by an overlying impermeable layer. (water in these aquifers under pressure above atm. pressure).

③ piezometric level :- The imaginary level to which water will rise in a well located in an artesian aquifer is know as the piezometric level.

④ The ~~cancer~~ Special type of an unconfined aquifer is the perched aquifer.

⑤ A semi-confined aquifer also know as a leaky aquifer is a completely saturated aquifer that is bounded above by a semi-pervious layer.



) which not only stores water but yields it in sufficient quantity
, aquifer transmits water relatively easily due to its high permeability

Aquitard :- which only seepage is possible and thus the yield is insignificant compared to an aquifer. It is partly permeable, example :- clay lenses.

aquiclude :- A geologic formation which can only store water but can not transmit significant amount is known as aqui-clude.

aqui-fuge :- A geologic formation with no interconnected pores and there for neither absorb nor transmit is aquifuge. Note :- An aquifer which is confined between impervious bed such as aquiclude and aquifuges.

Types of well :- ⓐ dug well or open well ② driven well ③ jetted wells ④ bored well ⑤ drilled wells or tube well.
→ discharge 400 to 45000 Litre/hr

into the driven well water enters the well through the cylinderical section also know as strainer. (well are suited for domestic supplies)

jetted well → only unconsolidated formation (loose material)

Types of Tube well :-

ⓐ cavity type well ⓑ Strainer type well ⓒ gravel packed well

Cavity type wells :- The cavity type of tubewell do not have a strainer and draw water from one strata only. (average discharge 45000 to 65000 L/hr)
(installed in confined aquifer)
Installed :- [aquifer with coarse sand and hard covering layer]

Strainer type well :- Strainers are located opposite these strata to allow the water to come into the tube well.

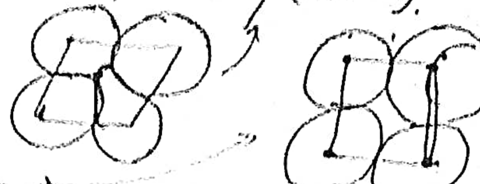
gravel packed wells or Shrouded wells :- These well are an improvement over the strainer type of wells. In shrouded well slotted pipes are used as strainers and as such these well are also refered to as slotted tubewell

... of wells :- Darcy law is used for studying groundwater flows in alluvial formations. Darcy's law however is not
Note
valid for studying the movement of groundwater in case of aquifers in hard rock area.

Porosity :- The ratio of the volume of the interstices to the total volume (V) (interstice > 2.2%) $\left[n = \frac{V_v}{V} \right]$

(a) The rhombohedral arrangement → lowest porosity (26%).

(b) Cubical arrangement → highest porosity (48%)



Permeability :- The permeability of a material is a measure of its ability to transmit fluid such as water under a hydraulic gradient. expressed (LT^{-1}) m/day, cm/day

Note: Darcy's law is a particular case of general "viscous fluid flow"

Transmissivity :- which water is transmitted through a unit width the aquifer under a unit hydraulic gradient. It is equal to kb, expressed as $[L^2T^{-1}]$ m^2/day. $[T = kb]$

Specific yield :- The ratio of the volume of water a material will yield when drained by gravity (V_d) to the total volume.

$$\left[S_y = \frac{V_d}{V} \times 100 \right]$$

Specific Retention :- The volume of water a material retain after drainage by gravity to the total volume

$$\left[S_r = \frac{V_r}{V} \times 100 \right]$$

[Note :- Specific Retention indicates the water held against the forces of gravity by capillary forces and molecular attraction]

[Specific yield + specific retention = porosity.]

$e = \frac{n}{1-n}$

these term are used only Unconfined aquifer]

Storage cofficient :- The volume of water an aquifer release from or takes into storages per unit surface area of the aquifer per unit change in head.

$$\text{storage cofficient} = \frac{V}{A \times dh} \quad [\text{dimensionless}]$$

(a) confined aquifer ranges ⇒ 10^{-5} to 10^{-3}

(b) Uncofined aquifer range ⇒ 0.1 to 0.3

Storativity :- ~~cofined~~ (a) Confined aquifers :- the amount of water released from storage through a vertical column of the aquifer having a unit cross-sectional area under a unit decline in hydraulic head.

Unconfined aquifers :- Storativity equals the effective porosity (Specific yield) and represents the drainable pore volume.

⇒ Note (1) The distance from the ~~well~~ centre of the well to the outer limit of the cone of depression is know as the radius of influence.

(2) The boundary line representing the water table is also a streamline.

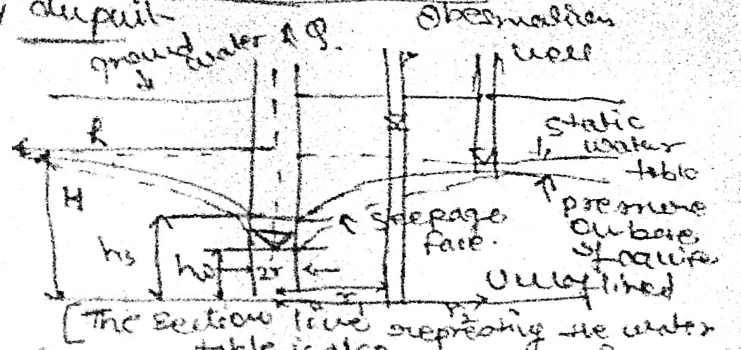
Imp

Radial flow Towards A well in an (Unconfined aquifer):-

This analysis was proposed by dupuit

$\Rightarrow Q = \frac{2\pi K H s_w}{\ln(R/r_w)} = \frac{2\pi T s_w}{\ln R/r_1}$ draw down term.

Normal formula, $Q = \frac{\pi k(H^2 - h_w^2)}{\ln(R/r_w)}$ $(h_w = H - s)$



[The section line representing the water table is also a streamline.

Note :- Dupuit-forchheimer assumption only for unconfined aquifers.

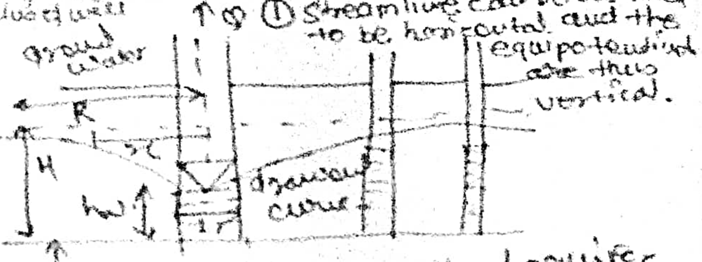
R = radius of influence
r_w = radius of well

confined aquifer :-

$$Q = \frac{2\pi k b(H - h_w)}{\ln(R/r_w)}$$

$(H = h_w + s)$

$$Q = \frac{2\pi T s}{\ln(R/r_w)}$$ confined aquifer



① streamline can be assumed to be horizontal and the equipotential are thus vertical.

b = thickness ← confined aquifer

assumption ① aquifer is homogeneous and isotropic → permeability same.

dupuit assumption. ② the flow is laminar and Darcy's law is applicable.

→ [③ The flow is horizontal and uniform everywhere in the vertical section

④ The hydraulic gradient is given by its slope of the drawdown curve.

⑤ The curvature of the free surface is very small so that the streamline can be assumed to be horizontal at all.

which show that yield of a well is directly proportional to the depth

$$\frac{Q_1}{Q_2} = \frac{b_1}{b_2}$$ → drawdown $\frac{Q_2}{Q_1} = \frac{s_2}{s_1}$

determination of aquifer constant:-

ⓐ Theis's Method :- $\log r^2 = [\log \frac{4Tt}{S}] + \log u(t)$ → $r^2 = \frac{4Ttu(t)}{S}$ S = storage coefficient

How new formula $K = \frac{aL}{A\,\Delta t}\ln\frac{h_1}{h_2}$ → time; a = standpipe cross area section; A = area

ⓑ JACOB's Method :- $s_2 - s_1 = \frac{2.3Q}{4\pi T}\log t_2/t_1$ $\Delta s = \frac{2.3Q}{4\pi T}$ drawdown

ⓒ chow's Method :

$\Rightarrow f(u) = \frac{w(u)\,e^u}{2.3}$ $f(u) = \frac{s}{\Delta s}$ $T = \frac{2.3Q}{4\pi\Delta s}$ $\Delta s = \frac{2.3Q}{4\pi T}\log\frac{t_2}{t_1}$

pumping and Recuperation Tests:-

means determining the maximum rate of discharge which an open well can yield.

Recuperation Test :- The water level in the well is lowered by pumping to the maximum extent possible and the pumping is stopped. Both test are used designing open well in the same area. specific capacity

$K = \frac{1}{t}\ln\frac{H_1}{H_2}$ recuperation rate

A = ... H_2 ...

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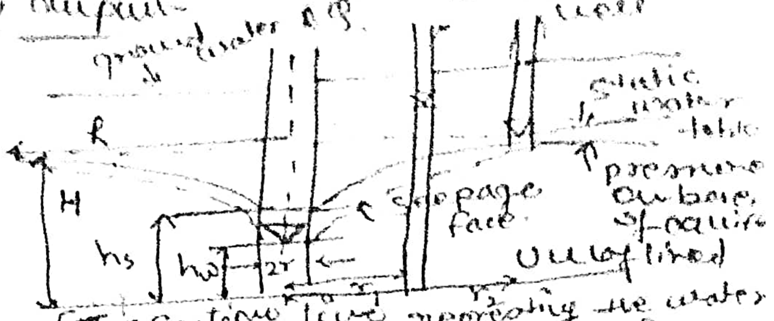

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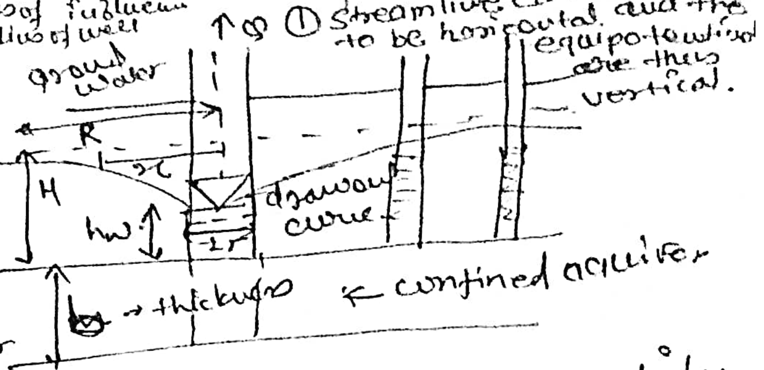
$$Q = \frac{2\pi T S}{\ln(R/r_w)}$$ → confined aquifer



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means determining the maximum rate of discharge which an open well can give.

Recuperation Test :- The water level in the well is lowered by pumping to the maximum extent possible and the pumping is stopped. Both test are used designing open well in the same area.

$\boxed{\frac{K_0}{A} = \frac{1}{T_2}\ln\frac{H_1}{H_2}}$ recuperation time; ratio specific capacity per unit area

$\boxed{k_0 = \text{specific capacity}}$

Various method that are available for drilling tubewell.

1. Percussion drilling (also know as cable tool method).
   - (a) hand boring by rope or rod.
   - (b) Mechanical Boring with power rigs.
2. Rotary drilling
   - (a) direct circulation hydraulic rotary. (special chemical like "Aquagel" or bentonite are used)
   - (b) reverse circulation hydraulic rotary. (heavy gravel or for drilling large sized bores).
   - (c) rotary - air percussion drilling.
3. Other Method
   - (a) auger Method → domestic use
   - (b) core drilling.
   - (c) water jet method.

→ hydrochloric acid is commonly used. → in Incrustation (inhibited acid).

→ Polyphosphates are chemicals used to disperse the iron and manganese

Water Lifting devices :- (Mechanical operating devices)

Pump

- Positive displacement pump.
  - reciprocating pump
  - rotary pump
- centrifugal pump
- turbine pump
- submersible pump
- propeller pump.

discharge calculations :-

volume swept per stroke, or displacement $= \frac{\pi}{4} \times D^2 \times 2R$

The average rate of discharge

$$Q = \frac{\pi}{4} \times D^2 \times \frac{2RN}{60}$$

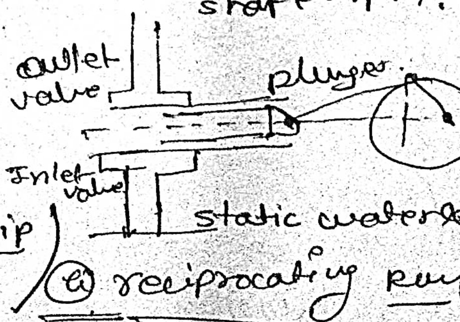
D = dia. of plunger.
R = crank radius.
N = speed of crank-shaft - rpm.

the actual discharge Q_a is less than Q.

Volumetric efficiency $(\eta_{vol}) = \frac{Q_a}{Q}$

percentage slip $= \frac{Q - Q_a}{Q} \times 100$

actual discharge $(Q_a) = \frac{\pi}{4} \times D^2 \frac{2RN}{60} \left(\frac{100 - slip}{100}\right)$



(a) reciprocating pump.

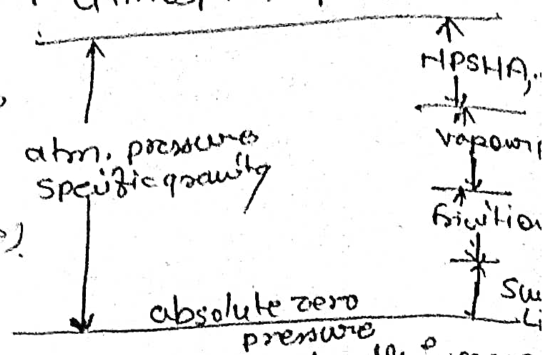
Centrifugal pump :-

→ two type → horizontal pump and vertical pump

(a) horizontal pump are used in Irrigation. (less costly than other pump.),
(b) vertical pump → Maintenance More difficults.
(2) impeller are classified open, semiopen, and enclosed.
The open and semiopen impellers are suitable for pumping suspended material or trash in water. (Enclosed impeller have higher capacity)

Net positive suction Head:- Installed above the water level, such amount of energy is required to move the water into the eye of the ... The source of energy available for this purpose is the atmospheric pressure. The maximum suction lift of centrifugal pump depends upon atmospheric pressure.

Note:
NPSHA = (barometric pressure at water surface) − (static suction lift, m) (friction loss / vapour pressure)



① condition ①

Note NPSHA > NPSHR ⇒
(The pump may have to be lowered towards the water surface or the suction pipe could be changed to reduced the friction loss).

NPSHR gradually increase as the pump discharge increase.

② condition ②
NPSHA < NPSHR ⇒
(not sufficient to required air and water will be pumped together which will damage the pump).

- Total power required at the pump shaft-

$$P = \rho g Q H$$

P = power required (W)
ρ = mass density kg/m³
g = acceleration
Q = pump discharge m³/s
H = Head.

ⓐ **Water horsepower:-**

$$WHP = \frac{Q(L/s) \times H(m)}{75}$$

ⓑ **shaft horse power:-**

$$SHP = \frac{\text{water horsepower}}{\text{Pump efficiency}} = \frac{Q \times H}{\eta \times 75}$$

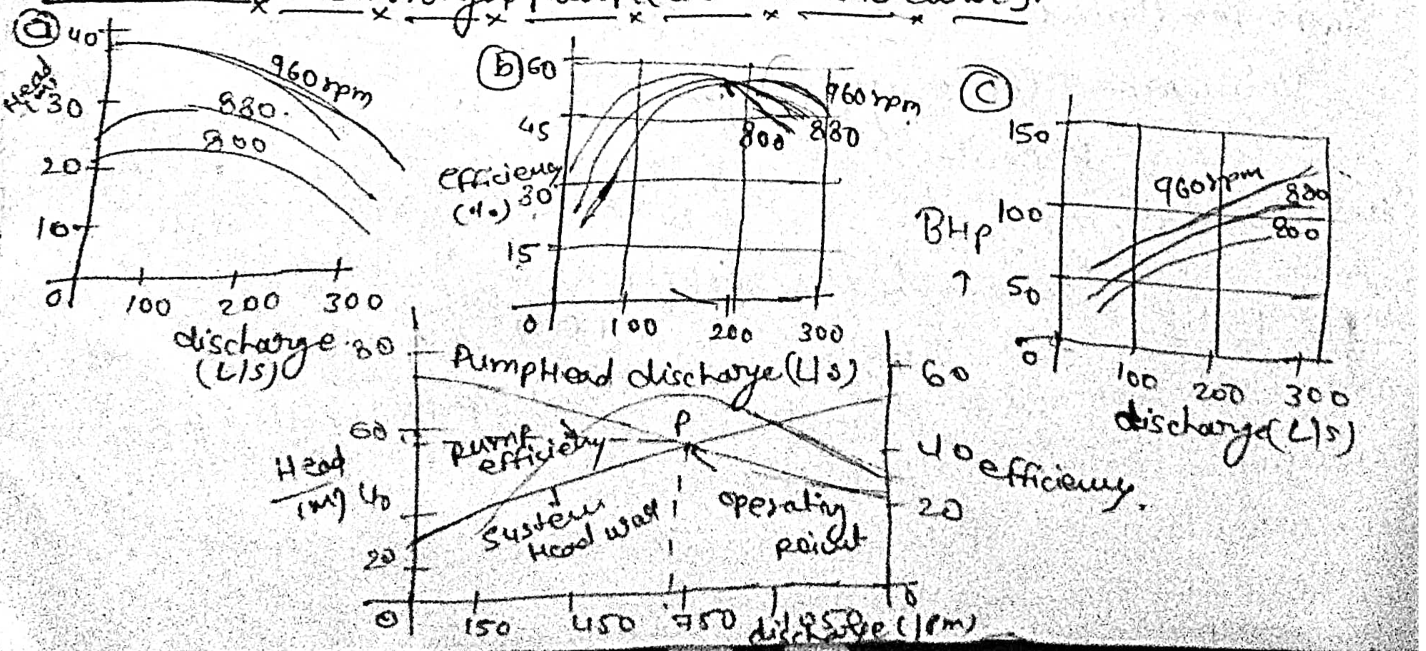
In case of belt or other indirect drive,

$$BHP = \frac{WHP}{\text{pump eff.} \times \text{drive Eff.}}$$

(Input horse power) IHP

$$IHP = \frac{BHP}{\text{Motor effeciency}}$$

Selection of centrifugal pump. (characteristic curve).



Imp **Specific speed of centrifugal pumps** :-

specific speed $(N_s) = \dfrac{N \times \sqrt{Q}}{H^{3/4}}$

Turbine specific speed

$N_s = \dfrac{N\sqrt{P}}{H^{5/4}}$

$Q = m^3/s$
N = speed rpm
P = Power kW
H = head m

N = speed of centrifugal pump. rpm.
Q = discharge m^3/s L/s
H = Head (m).
N_s = specific speed

N_s = specific speed rpm

affinity law :-

discharge

$$\frac{Q}{Q_0} = \frac{N}{N_0} = \left(\frac{D}{D_0}\right)^3 = \frac{w}{w_0}$$

head

$$\frac{H}{H_0} = \left(\frac{N}{N_0}\right)^2 = \left(\frac{D}{D_0}\right)^2 = \left(\frac{w}{w_0}\right)^2$$

w = width
N = rpm.

power

$$\frac{P}{P_0} = \left(\frac{N}{N_0}\right)^3 = \left(\frac{D}{D_0}\right)^5 = \left(\frac{w}{w_0}\right)^3$$

priming :- it is necessary to fill the suction pipe and pump case with water to expel the air. The operation of filling the suction and pump case is called "priming"

expel → निकाल देना / छोड़ना

drainage engineering

drainage :- the removal and disposal of excess water from agricultural land. / removing the salts form root zone.

excess water in the root zone is detrimental to crop production.

① it restricts, Soil aeration,
② affect soil temp.
③ hinders.
④ tillage operation.

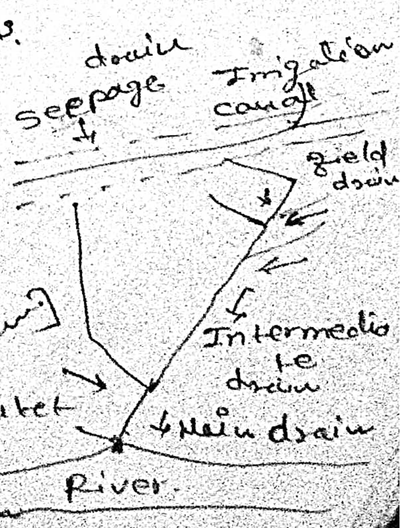
waterlogging :- when the watertable comes near the surface such that crop growth is affected.

Causes of waterlogging :-

Imp **Surface drainage** :- both → ⓐ rainfed areas. ⓑ irrigated areas.

↳ three functional parts.

ⓐ collection system ⓑ Conveyance. & disposal systems
ⓒ outlet,



① salinity :- soluble salts mostly chloride, sulphate in Na, Ca, Mg, inversely effect. ↑ EC > 4 PH → below 8.5

② alkali → :- Salts dominated by bicarbonated and carbonated of Na. EC < 4 [surface drainage system]

Salinity and alkali :- PH → usually [8.5 to 10]

Electrical conductivity and sodium adsorption ratio

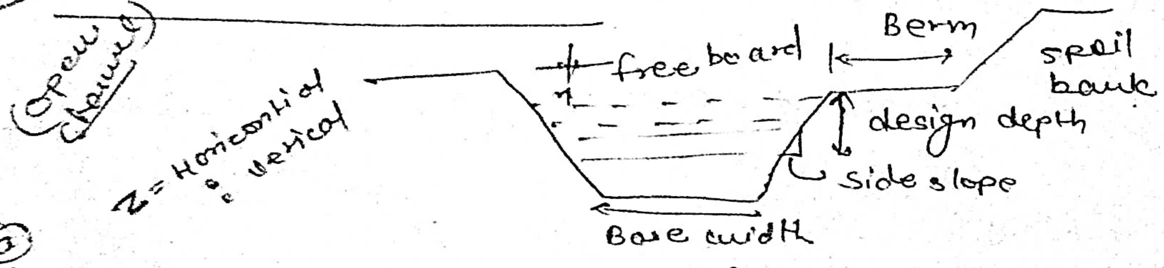
there are 4 types of drainage system
used in flat area (< 2 % slope)

1. random drain system, (where small scattered depressions to be drained ... over the area.)
2. parallel field drain system.
3. parallel open ditch system
   - (a) is applicable in soils that require both surface and subsurface drainage.
   - (b) ditch spacing = 60 to 200 m
4. bedding system.
   essentially a land forming process.
   (slope exceeding 2%)

Note:- (1) surface drainage Method adopted are same as those adopted for erosion control.

Drainage cofficient:- (1) The depth of water in cm to be removed in 24 hour period form the entire drainage area. It is also expressed flow rate per unit-area.
(2) The intensity of rain and its duration are inversely proportional to the time allowed for removal of water.

channel cross section :- (trapezoidal channel) (Open channel)



(a) **Area of cross-section :-**

$$A = \frac{1}{2}(b+t)\,y$$

$$A = bd + zd^2$$

(b) **wetted perimeter :-**

$$P = b + 2l$$

l = length of side

$$\sqrt{(zd)^2 + d^2}$$

$$P = b + 2d\sqrt{z^2+1}$$

(c) **Hydraulic Radius**

$$R = A/P$$

(d) **Hydraulic slope :-**

$$S_f = h/x$$

drop of Head b/w two channel sectors located at a distance x.

(e) **freeboard :-**

(f) **Top width of channel**

$$T = b + 2zd$$

(1) discharge through open channel.

$$Q = A \cdot V$$

(2) **chezy formula**

$$V = C\sqrt{RS_f}$$

c = chezy's roughness cofficient
S_f = frictional slope
R = Hydraulic radius

③ Manning's formula:-

$$V = \frac{1}{n} R^{2/3} \times S_f^{1/2} \rightarrow \boxed{S_f = \frac{\Delta h_f}{\Delta L}}$$

critical depth:-

$$\frac{Q^2}{g} = \frac{(bY_c + zY_c^2)^3}{b + 2zY_c}$$

④ Lacey's theory:-

ⓐ $P = 4.75\, Q^{1/2}$

P = wetted perimeter, m

ⓑ $S = \frac{f^{5/3}}{3340\, Q^{1/6}}$ S = Bed slope of the channel.

f = constant, Lacey's No.

ⓒ $A = 2.27 \times \left(\frac{Q}{f^{2/5}}\right)^{5/6}$

ⓓ $R = 0.4725 \left(\frac{Q}{f}\right)^{1/3}$

ⓔ Mean velocity

$V_m = \left(\frac{Qf^2}{140}\right)^{1/6}$

Subsurface Drainage :-

Subsurface drainage refers to the removal of excess water present below the ground surface.

⇒ high water = Subsurface drainage is not provided, crop growth is adversely affected.

Hydraulic Conductivity :-

Hydraulic Conductivity is the cofficient k in the Darcy's law $\boxed{V = ki}$

① Single auger Hole Method :- This Method is used when the watertable is present near the ground surface.

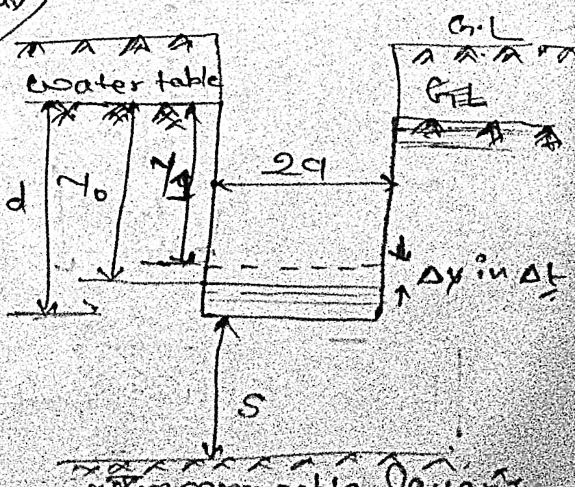
$$K = \frac{aS}{(2d+S)\,\Delta t} \ln (Y_0/Y_1)$$

② Hooghoudt's equation:

(assumptions)

1. Now calculating the Hydraulic conductivity.

$$\boxed{K = 5{,}23{,}000\, a^2 \frac{\log \frac{Y_0}{Y_1}}{\Delta t}}$$



② The Pipe cavity Method:-

-formula:

$$\boxed{K = \frac{\pi r^2 \ln (Y_0/Y_1)}{S(t_2 - t_1)}}$$

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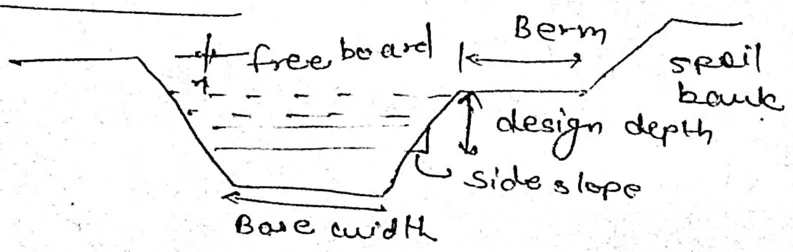

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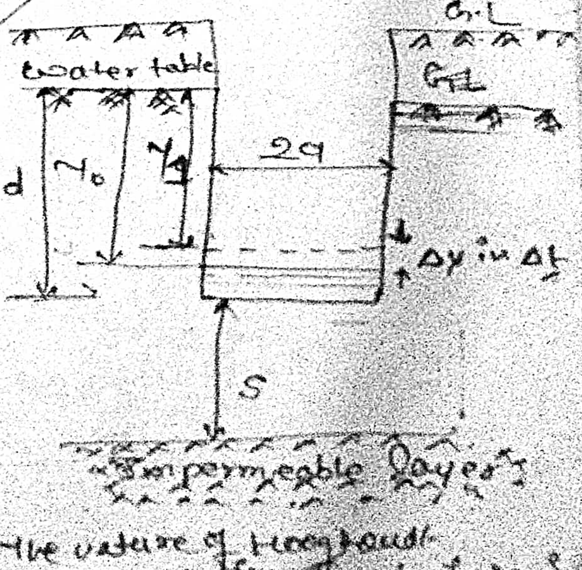
$$K = \frac{aS}{(2d+S)\,\Delta t} \ln (Y_0/Y_1)$$

1. Now calculating the Hydraulic conductivity.

$$\boxed{K = \frac{5{,}23{,}000\, a^2 \log \frac{Y_0}{Y_1}}{\Delta t}}$$



The nature of Hooghoudt equation for drainspacing → Elliptic

③ The Pipe cavity Method:-

formula:

$$\boxed{K = \frac{\pi r^2 \ln (Y_0/Y_1)}{S(t_2 - t_1)}}$$

④ Cylinder permeameter Method:

⑤ Pond-infiltration test: cm/s

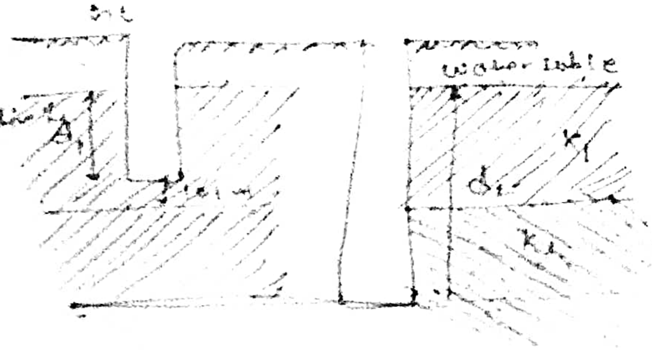
$$I = k_T \frac{\phi + z + h}{z}$$

I = infiltration rate cm/s
k_T = hydraulic conductivity cm/s
ϕ = suction at the bottom of the transmission zone (cm)
z = depth of transmission zone (cm)
h = height of water in the cylinder (cm)

⑥ Hydraulic Conductivity of layered soils :-

two layer determining hydraulic conductivity

$$k_1 d_1 + k_2(d_2 - d_1) = k d_2$$



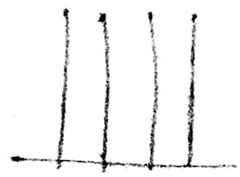
Drain Systems layout:-

① random system

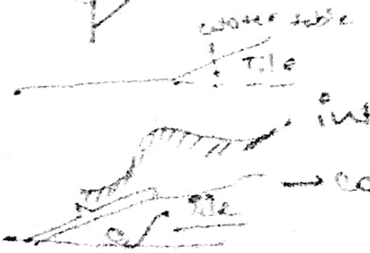
②

Herringbone

⑤ Grid iron: - (the laterals enter the mainline only from one side).



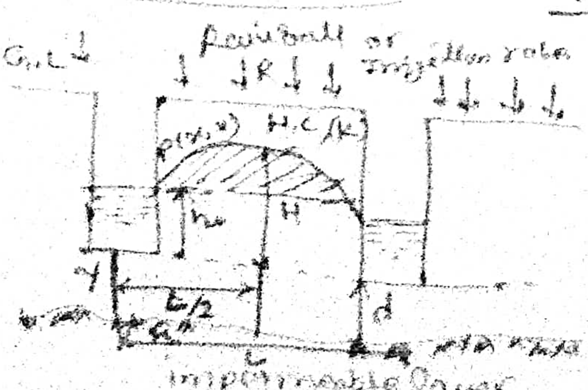
③



interceptiy drain → considerable land area.

Hooghoudt's equation :-

relationship the spacing of drains and the height of the watertable.



assumptions :-

① The soil is homogeneous.
② Darcy's law is valid for the flow
③ the hydraulic gradient at any point is equal to the slope of the watertable above that point ($\frac{dy}{dx}$) and the water flow horizontally.

Note

$$L^2 = \frac{4K(H^2 - h^2 + 2dH - 2dh)}{R}$$

this equation $h = 0$

$$L^2 = \frac{4KH(2d + H)}{R}$$ [equation ellipse]

R → drain discharge.

discharge through drain

$$q = R = \frac{4K(H^2 - h^2 + 2dH - 2dh)}{L^2}$$

The ditch Conduit formula:

Calculating the load on pipe in Narrow trenches.

$$W_c = C_d \times w \times B_d^2$$

W_c = load on the pipe

C_d = Load Coefficient

w = unit weight of fill Material.

B_d = width of trench at the top of the pipe.

Accessories for tile drain system;-

① For uniform soils = $\frac{D_{50} \text{ of envelope}}{D_{50} \text{ of soil}}$ = 5 to 10

② for graded soils = $\frac{D_{50} \text{ of envelope}}{D_{50} \text{ of soil}}$ = 12 to 58

MOLE DRAINAGE!-

is a semi-permanent Method of subsurface drainage

⇒ Note ① temporary Method of drainage for heavy clay soil
It is also know as pipeless drain

Open drains:- used → interceptor:
→ relief drain: removes of excess water and gives relief to the land.
(this drain used in gridiron or herring bone system)

interceptor drain (length required) < relief drain

Note

Capacity of the interception drain (used Darcy's law)

$$q = KiA$$

In case:-

$A = d_e L$ → L = length of the drain (L)
d_e = effective depth of the drain

$$q = \frac{K i \times d_e \times L}{24 \times 60 \times 60}$$

Note:- Mole drain is most suitable drainage system for heavy clay soil. (fine texture soil)

well:-

① Specific capacity:- $\frac{\text{discharge (well)}}{\text{Unit drawdown (S)}}$ = $q = PoH$ → dispression
Specific Head capacity

② permeability:- with the relationship

(Falling Head permeater)

$$K = \frac{ah}{At} \ln\left(\frac{h_0}{h_1}\right)$$

a = area of stand pipe.
A = cross section of sample area
h = height of sample.

h_1 = head drop. h_0 = initial head

Daily evaporation — average depth of water applied in irrigation [illegible]

Total

maximum allowable surface flow rate

$q_m = \frac{0.6}{S}$

Note (1) orifice discharge (large orifice) rectangular

$$Q = \frac{2}{3} \times b C_d \sqrt{2g} \, H^{3/2}$$

(free flow)

Small orifice discharge

$$Q = C_d \times a \sqrt{2gH}$$

→ submerged orifice

$$Q = C_d \times b (H_2 - H_1) \sqrt{2gH}$$

Note (2)

→ weir (Trapezoidal weir) :-

$$Q = 0.0186 \, L H^{3/2}$$

Note (3)

→ V-notch weir :-

$$Q = 0.0138 \, H^{5/2}$$

(discharge through the triangular notch)

$$Q = \frac{8}{15} C_d \tan\frac{\theta}{2} \times \sqrt{2g} \, H^{5/2}$$

(1) Types of current meters

→ Anemometer and

→ propeller velocity meter

(Irrigation and watershed measurement)

In tile drainage

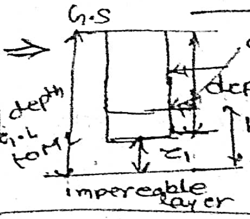
→ perimeter $= \pi d$

→ area $= \frac{\pi}{4} \times d^2$

Now

→ Drainage coefficient :- expressed depth of water removed in 24 hours (cm/day) (cm/day)

→ "Drainable porosity" :- "the volume of water drained by gravity per unit volume of the saturated soil" it also called "effective porosity" or "specific yield"



→ depth of G.L from ground surface

depth of piezometer

hydraulic head

Hydraulic gradient $= \frac{\Delta H_2 - \Delta H_1}{z_2 - z_1}$

Specific Capacity (Q_s) :- is the yield per unit drawdown.

(1) The porosity of sand soil usually range from 35 to 50 %

(2) The porosity of clayey soil usually range from 40 to 60 %

(3) The density of soil organic matter is usually about 1.3 to 1.5 g/cc

Note drop inlet spillway :- discharge

$$Q = \frac{a\sqrt{2gh}}{\sqrt{1 + K_e + K_c L}}$$

(h → total head; L → length of channel; K_c → friction head coefficient; K_e → entrance friction)

Normal slope $= K_c \frac{v^2}{2g}$

$S_n = \frac{\Delta H}{L}$

Note The difference in the water-table elevation and the water level inside of well known as depression head

$Q = K_0 H$

(K_0 → constant but represent discharge per unit drawdown is called specific capacity)