IRRIGATION ENGINEERING

Type of Irrigation — surface Irrigation / subsurface irrigation.

① **surface irrigation**: water applied/distributed over soil surface by either gravity or by pumping

- Flow Irrigation → water flow by gravity from high to low level
- lift irrigation → water lift up by mechanical equipment (like pump) then supply for irrigation.

Type of flow irrigation :-

ⓐ **Perrenial Irrigation**

- constant and continuous water-supply throughout the crop period
- Direct irrigation → direct divest river water to main canal by constructing weir / barrage.
- Storage irrigation → construct dam

ⓑ **flood Irrigation or uncontrolled irr. or Inundation Irr.**

Soil kept submerged & Throughly Flood with water so to cause throh saturation of Land.

② **Subsurface irrigation** :- water flows underground and nourish plant roots by cappilarity.

- natural subsurface irrigation
- Artificial subsurface irrigation

Method of Irrigation :

① **Free flooding (wild flooding)**

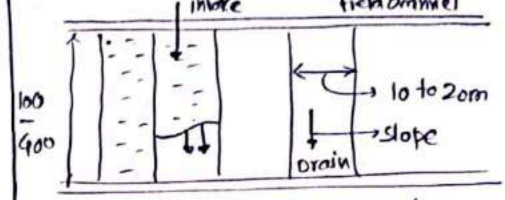
- After water leaves the ditches, no-attempt to made to controll the-flow by means of Levees → ∴ wild flooding

suit for close growing crops, pastures Particularly where land is steep

- method may be used on rolling land (topography irregular {where border's, check, furrows are not suitable}

(2) **Border method**

- Land divided into no. of strips, separated by low leaves called Borders.
- Strip Length = 100 to 400m width 10-20m.
- water is allowed to flow from the supply-ditch into each strip. The water flows-slowly towards the lower end and it infiltrates into the soil as it advances.



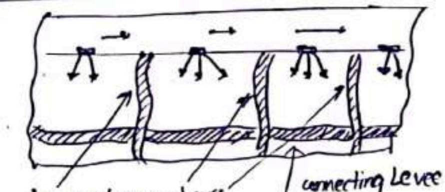
$$t = \frac{y}{I} \ln \frac{Q}{Q - IA}$$

y → depth over border strip; A → area of land strip; I → Infiltration rate

$$A_{max} = \frac{Q}{I}$$

Surface flow will stop after irrigation of this-area & deep percolation will start.

③ **check flooding**

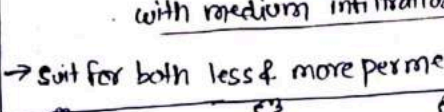


- similar to ordinary flooding except that the water is controlled by-surrounding the check area with low and flat levees.

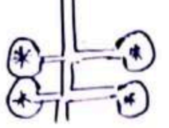
Best for → close growing crops (Jowar, paddy)
→ deep homogeneous loam or clay soil with medium infiltration rate are preferred

→ Suit for both less & more permeable soil

④ **furrow method**



- crops are usually grown on the ridges b/w the furrows
- Best for row crops { maize, cotton, potatoes, sugarcane, ground nut, tobacco

(5) Basin flooding	 • Best for orchard Tree • coarse sand not suitable because of more percolation loss
(6) Drip Irrigation method or Trickle Irrigation	• Popular in areas where scarcity of irrigation water and salt problem. • in This water & fertilizer is slowly and directly applied to the rootzone of Plants, to minimize the loss due to evaporation & percolation Best for row crops and orchards such as tomatoes, grapes, corn, citrus, meson etc.
(7) Sprinkler Irrigation method	• In this, irrigation water is applied to the land in form of spray. ~~through network of Pipe &~~ • Used for all crops except rice & jute. (∵ High water demand) • suit for all soils except for very heavy soil (soil with low infiltration rate) • Best suited for very light soil as deep percolation losses are avoided { Light soil → These soil drain quickly after rain & watering } • this method mainly by cultivators of Tea, coffee and vegetables. • This system is flexible to suit undulating Topography (hence levelling is not necessary) Best conditions for This method (I) Topography irregular (undulating) (II) land gradient steeper & soil easily erodable. (III) soil excessive permeable (IV) water table High (V) when water availability is difficult & scarce

Irrigation water Quality :-

(I) Proportion of sodium ion into cations → ESP, SAR

(i) Exchangable sodium percentage (ESP)

$$ESP = \frac{Na^+}{Na^+ + Mg^{+2} + K^+ + Ca^{+2}}$$

(ii) Sodium adsorption ratio (SAR)

$$SAR = \frac{Na^+}{\sqrt{\left(\frac{Ca^{+2} + Mg^{+2}}{2}\right)}}$$

→ epm (equivalent per million)

मतलब ⇒ $\frac{mg/lt}{(atomic\ wt/valency)}$

Category	SAR	Type of water	
S1	0-10	Low sodium water	for all soil & crops
S2	10-18	medium "	Coarse grain soil, organic soil with good Permeability
S3	18-26	High "	Drainage + Leaching (gypsum)
S4	>26	very high	not suitable

(II) total conc. of soluble salt → electrical conductivity (EC)

EC (mho/cm) @ 25°C	class	Salinity	Remarks
0 - 250	C1	Low	for all crops
250-750	C2	medium	all crop if Leaching done
750-2250	C3	High	for High salt tolerant plant with special measure to control salinity
>2250	C4	very high	not for irrigation

(III) Sediment concentration

(IV) conc. of potential toxic element (Boron, selenium) — if Boron > 0.3 PPm.

(V) Bicarbonate Conc.

(VI) Bacterial contamination

Reclamation → Process by which uncultivated land made fit for cultivation.

- Alkaline soil Reclamation → addition of zypsum to soil + Leaching
- Acidic soil reclamation → Use limestone as a soil-amendment

Leaching: in this land flooded with adequate depth of water, The Alkali-salts present in the soil, get disolved in this water which percolate down to join the water table or drained away by surface and subsurface drains, This Process known as Leaching.

- This process in repeated till the salts in the top layer of the land are reduced to such extent that some salt-resistant Crop can be grown.

Saline soil ——→ land affected by efflororscene

Alkali salt ——→ injurious → Na_2CO_3, NaCl, Na_2SO_4

Least harmful ——→ NaCl

most " ——→ Na_2CO_3

note:- when Na_2CO_3 is present (सतत Alkaline soil)

∴ add zypsum before Leaching

High salt resistant crop ——→ fodder, Berrem, Bajra

Alkaline soil: if efflororscence continue for long time ——→ Base reaction happens.

if soil clay then due to base rxn ——→ sodiumising clay making it impermeable, illaerated, highly unproductive

Land capability → US beauro of reclamation classification

Leaching requirement $= LR = \frac{D_i - C_u}{D_i}$

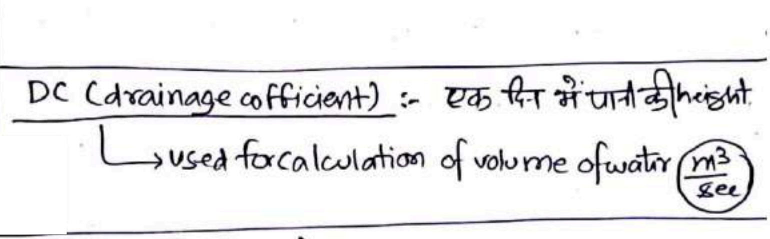
(C_u → Consumptive use + drain water out; D_i → total irrigation water applied.)

$$LR = \frac{D_d}{D_i} = \frac{D_i - C_u}{D_i} = \frac{(EC)_i}{(EC)_d} = \frac{C_i}{C_d}$$

DC (drainage cofficient) :- एक दिन में पानी की height

└→ used for calculation of volume of water $\left(\frac{m^3}{sec}\right)$

Depth & spacing of Tile drain :-



$$S = \frac{4k}{q}(b^2 - a^2)$$

(b → ज्यादा, a → कम)

P = 1% of Annual avg. rainfall

$$q = \left(\frac{P/100}{24 \times 3600}\right)[S \times l]$$ → length of tile drain

'or'

$$q = \left\{\text{drainage coff.} \times \text{spacing} \times \text{lgh of tile drain}\right\}$$

$\left\{0.116 \frac{m^3}{km^2}\right\}$ $(12 \times l)$ $S \times l$

Duty (D) :- area of land that can be irrigated by unit volume of irrigation water

'or'

area of land in hectares that can be irrigated if 1 cumec of water is supplied continuously to the land throughout the Base period.

$$D = \frac{8.64\, B(\text{days})}{\Delta(\text{metre})}$$

D ↕ hectare/cumec

note:- in tank irrigation Duty = ha/Mm³

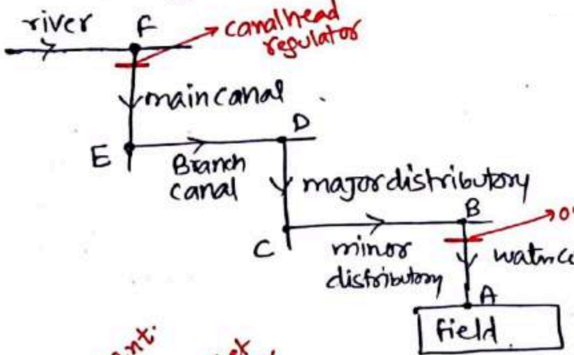
Base period (B) :- time b/w first watering to last watering.

- first watering ↓ to prepare land for sowing crop
- last watering ↓ before its harvesting

note:- crop period ⇒ sowing to harvesting time.

Delta (Δ) :- total Depth of water over the irrigated land req. by crop during its entire Base period.

note:- as one moves from head of canal to field → duty increases (मतलब downstream जाने पर duty बढ़ती जाती है)



∴ $D_A > D_B > D_C > D_D > D_E > D_F$

- D_A (Net qnt.) → duty on field
- D_A / D_B → outlet factor
- D_B → duty at outlet point of minor or duty at head of field channel/water course
- $D_C > D_D > D_E$ → Latiral duty or qnt.
- D_F (gross duty or gross qnt.) → duty at head of main canal

factors affecting duty :-

① type of crop	if qnt of water req. ↑ ∴ D↓
② climate condition	* Temperature : $T \propto \frac{1}{D}$ (loss due to ET↑) * Velocity (wind) $V \propto \frac{1}{D}$ * Humidity $H \propto D$ (loss due to ET↓) * Rainfall : $P \propto D$
③ System of irrigation	Perenial D > Inundation D
④ method of irrigation	furrow D > any other D surface method D < Sprinkler, drip D
⑤ Quality of irrigation water	Salt ↑ ⇒ D↓ ∵ अधिकतर पानी leaching में चला जायेगा
⑥ method of cultivation	Proper Plaugging ∴ D↑
⑦ Time of irrigation and frequency of irrigation	at initial stage more water required hence D↓ later D↑
⑧ Type of soil & subsoil of area through which canal passes	
⑨ Base period	B↑ ⇒ more water req. hence D↓
⑩ Canal conditions	earthen canal ⇒ D↓ lined canal ⇒ D↑

Season	time	फसल
रबी	oct – march	गेहूँ, मटर, चना, सरसों, आलू
खरीफ	Apr – sept	चावल, मूंगफली, कपास, ज्वार
Zaid period	march – June	

Perenial crop (सालभर) → Sugarcane.

Important Term's :-

(I) Commandarea → By a canal system How much area is irrigated.

(II) Gross Command area (GCA) :

CCA + Unculturable area

{Culturable Command area} , {Pond, Residence, road, forest}

(III) CCA (Culturable command area) = GCA − Unculturable

→ Culturable Cultivated area : Portion of CCA which is actually cultivated during crop season.

→ Culturable uncultivated area → (not cultivated)

(4) Intensity of irrigation :- % of CCA proposed to be irrigated annually.

Ex. if intensity of Irr. for Rabi = 50%.
 ——— Kharif = 65%.

∴ yearly intensity of irr = 50+65 = 115%

(5) Cropratio :- (Rabi-Kharif ratio) ⇒ Ratio of land irrigated during 2 main crop seasons rabi & kharif

$$CR = \frac{\text{CCA under Rabi}}{\text{CCA under Kharif}}$$

(6) paleo irrigation :- watering done prior to sowing of crop.

↳ This is done to prepare the land for sowing and to add sufficient moisture to the soil which would be required for the initial growth of the crop.

(7) $$\text{Time factor (T.F)} = \frac{\text{no. of days canal run}}{\text{Irrigation Period}}$$ $\frac{140}{180}$

$$Q_{design} = \frac{Q}{T.F}$$

(8) $$\text{Capacity factor (CF)} = \frac{\text{MSQ of canal}}{\text{FSQ}}$$

Ex. in kharif if discharge required = 0.95 Q_{max}
 hence CF = 0.95

(9) cash crops :- encashed in marketting for processing.
{Can not directly consumed by cultivator}
Ex. {जूट, चाय, [redacted], कॉफी, तम्बाकू}

(10) cropcalender :- tool provides information about planting, sowing, harvesting of locally adopted crop in an area.

concept : KOR :-

(I) Kor watering :- 1st watering after plants have grown a few centimeters high.

(II) Kor Depth :- Depth of water Applied during this watering (Kore watering)

(III) Kor period :- Kor watering must be done in a limited period which is known as kor period

		Day kore period	Kor depth (cm)
Rember :-	Rice	14 day	19 cm
Imp.	wheat	28 day	14 cm

Irrigation efficiency:

(I) water-conveyance efficiency	$\eta_c = \frac{\text{field water}}{\text{diverted from river into canal}}$ • It accounts for the water losses which occure in conveyance from the point of diversion into the canal system to the field
(II) Application efficiency	$\eta_a = \frac{\text{water stored in root zone}}{\text{field water}}$ • It accounts for the water losses which occures during the application of irrigation water (Ex. surface runoff & deep percolation)
(III) water use efficiency	$\eta_u = \frac{\text{water used beneficially including the water req. for Leaching}}{\text{field water}}$
(IV) storage efficiency	$\eta_s = \frac{\text{amt of water stored in root zone}}{\text{water needed to bring the m.c of soil to field capacity.}}$
(V) water distribution efficiency	$\eta_d = \left[1 - \frac{y}{d}\right] \times 100$ $d \rightarrow$ avg. depth of water $\Rightarrow \frac{d_1 + d_2 - - d_n}{n}$ $y \rightarrow$ Avg. numerical Deviation in depth of water $\frac{\lvert d_1 - d\rvert + \lvert d_2 - d\rvert - - \lvert d_n - d\rvert}{n}$
(VI) Consumptive efficiency.	$\eta_{ce} = \frac{\text{water Use consumptively}}{\text{net amt of water depleted from root zone}}$

irrigation Requirement of crop :-

GIR > FIR > NIR > CIR

- GIR: Gross ⇓ $\frac{FIR}{\eta_c}$
- FIR: field ⇓ $\frac{NIR}{\eta_a}$
- NIR: Net ⇓ CIR + Leaching requirement (LR) + PSR (Presowing requirement) + NWR (nursery water req.)
- CIR: Consumptive ⇓ $C_u - R_e$

IR :- amt of irrigation water that is req. to meet the evapotranspiration need of a crop during its full growth.

Soil moisture relationship

① **Gravitational water** :- → not for plant use

- not held by soil, but drain out freely by gravity action hence not available for plant use.

② **Capillary water** :- → available water

→ held by surface Tension

③ **Hygroscopic water** :- → not for plant use

→ not removed easily

→ Below PWP soil has hygroscopic water

④ **Saturation capacity** :- max. water holding capacity of soil, when all pores filled with water

- Soil moisture tension = 0

⑤ **FC (Field capacity)** Soil moisture tension ⇒ $\frac{1}{3} - \frac{1}{10}$ atm

→ upper limit of capillary water

→ after gravity water drain off, max. amount of water which can be held up by soil against gravity.

Depth of water stored in root zone (in filling the soil up to FC)

$d_w = d \frac{\gamma_d}{\gamma_w}(fc) = nd$

$\therefore n = \gamma_d/\gamma_w * fc$

⑥ **PWP** Soil moisture tension ⇒ 7 - 32 atm.

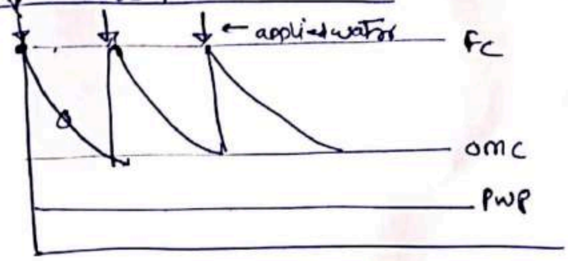
FC

capillary water or available water | RAM (Readily available moisture)

OMC

PWP

non available water or Hygroscopic water } → can not extracted



Type-1 :- FC = 28% PWP = 15%

RAM = 80% of AM

Soln :-

FC = 28%

RAM = 80 × 13/100 = 10.4%

omc 17.6%

PWP = 15%

AM = 28 - 15 = 13%

∴ omc = 28 - 10.4 = 17.6%

$\therefore d_w = d \frac{\gamma_d}{\gamma_w} [28 - 17.6]$ or (10.4%) → RAM

Type-2 :- FC = 40% PWP = 18%

MC falls to 40% of Available water

'or' MC falls by 60% of Available water

Soln :- $RAM = \frac{60}{100} \times (40 - 18) = 13.2$

FC = 40

13.2 = RAM

omc = 26.8

PWP = 18

$d \frac{\gamma_d}{\gamma_w} (40 - 26.8) = d$ (13.2)

Type-3 :- Allowable depletion = 40% of AW

40% of AW

FC

omc

PWP

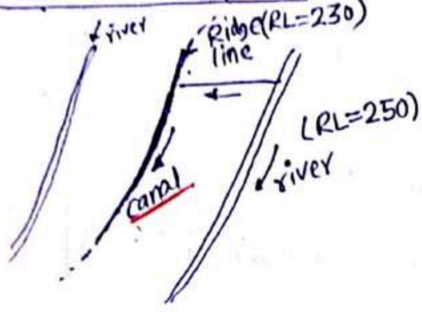
note :- $\frac{1}{3}$rd atm. moisture point ⇒ % of moisture retain in soil sample when placed on porous plate & subjected to pressure = atm pressure/3

Irrigation canal can be aligned in any of the 3 ways

1) Watershed or Ridge canal

Watershed/Ridge :- The divide line b/w catchment area

- Canal which is aligned along any natural watershed / ridge.



- aligning the canal on ridge ensure gravity irrigation on both side of canal.

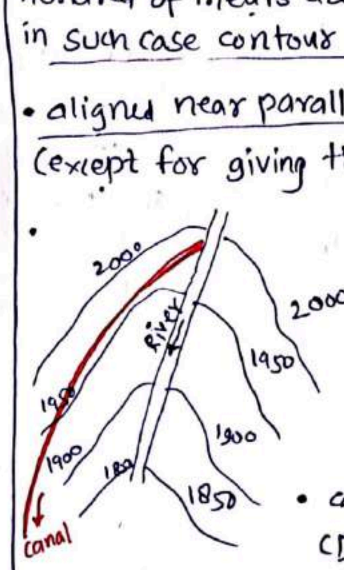
{ hence large area can be irrigated ⇒ large command area }

Imp.
- cross drainage works (CD works) ⇒ not required or minimum { ∵ drainage flow away from ridge }
- Preferred in plain areas where land slopes are relatively flat & uniform.

2) Contour Canal

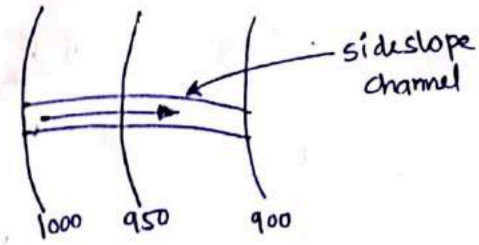
note :- In hilly areas as it is impossible to take the canal on the top of higher ridge as ridge line may be hundred of meters above river. in such case contour canal constructed

- aligned near parallel to countour (except for giving the req. longitudinal slope)



- It irrigates on one side (because the areas on the other side is higher)
- construction of CD work is must as the drainage flows is always right angle to the ground contour.

3) Side slope canal



- aligned at right angle to contour.
- in such canal, flow runs parallel to natural drainage
- Usually flow in such canals does not intercept the drainage thus avoid construction of CD work.
- this canal neither on watershed nor in valley (in b/w)

Other types of canal :-

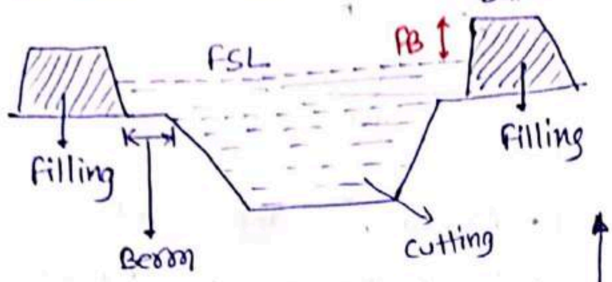
1) Feeder canal

- constructed to feed another canal.
- no direct irrigation is carried out from feeder canal.
- Ex. Indiragandhi feeder canal

2) Inundation canal

- This canal gets its supply only when the water level in the river from which it takes off rising during flood.
- these are nonperinial canal ∵ depend on periodical rise of water level in the river.
- These obtain their supplies through open cuts in bank of river which are called heads.

Cross section of irrigation canal :-



① freeboard (FB)

- lined canal (FSL to top of lining)
- unlined canal (FSL to top of Bank)

note:- IS 7112:1973 :-

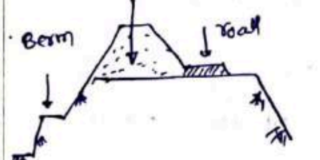
m^3/s	Min FB
Q < 10	0.50 (meter)
Q > 10	0.75 (meter)

FB → ensures that water does not overtop bank.

② Berms :- horizontal distance left at ground level b/w toe of Bank to the top edge of cutting.

- Berms are provided in canals, if these are partly in excavation & partly in embankment.
- provide a scope for future widening of canal.

③ Dowlas :- → as a measure of safety in driving provided along the bank, also helps in preventing slope erosion due to rains.



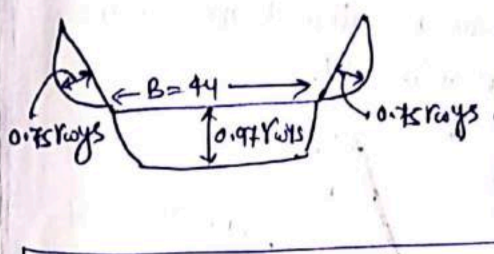
④ Steep slope in cutting than filling.

⑤ Bank aim → to retain water

⑥ Service roads → on canals for inspection purpose

(unlined canal)
Shield method → (design of nonscouring-stable channel having protected side slope)

$\{Re > 400,\ d_{min} > 6\ mm\}$



Average
- Bottom: $\tau_0 = \gamma_w RS$
- Side: $\tau_0' = 0.75\gamma_w RS$

at channel bottom :-

$$\tau_c = 0.056\gamma_w d(S-1)$$

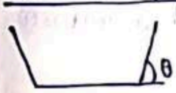
S → SG of sediment = 2.65; d → dia > 6 mm

for design $\tau_0 \le \tau_c$, where $\tau_0 = \gamma_w RS$

$\therefore d \geq 10.8 RS \simeq 11 RS$

↓ min size of Bed material that will remain in rest.

at side slope of channel :-



$$\tau_c' = \tau_c\sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}$$

φ → angle of repose of soil

$\therefore \tau_0' \le \tau_c'$, where $\tau_0' = 0.75\gamma_w RS$

$$n = \frac{d^{1/6}\ (\text{meter})}{24}\ \{\text{for rigid Boundary channel}\}$$

$$V = 4.05\, d^{1/2} S^{-1/6}\ (d \to \text{meter}) \quad \text{or} \quad 4.85\,\frac{d_{cm}^{1/2} S^{-1/6}}{\sqrt{100}}$$

Design of stable channel in India — Kenedy / Lacey Theory

Kenedy Theory :-

1. conducted experiment at upper bari Doab canal system.

$$V_0(m/s) = 0.55\, m y^{0.64}$$

m → critical velocity ratio: 1–1.2 coarse sediment; 0.7–1 fine

2. Silt is in suspension due to eddy formed from bottom of channel.
3. only for regime channel {no silting, no scouring} avg.
4. Trial & error procedure
5. mean velocity by Kutter formula, hence Kutter limitation exist.
6. B/D significance not considered.
7. no eqn of Bedslope given
8. Silt charge or Silt concentration $\left\{\frac{\text{weight of silt}}{\text{volume of water}}\right\}$,

   silt grade → not considered.
9. m (CVR) → no logic given, no method to get 'm'

Steps :-

(I) $V_0 = 0.55 m y^{0.64}$

(II) $A = Q/V_0 = By + y^2 z$ {z = 0.5}

$B = ?$

(III) $R = \frac{A}{P}$, $P \rightarrow B + 2y\sqrt{1+z^2}$

(IV) $V = C\sqrt{RS}$

Kutter: $C = \dfrac{\frac{1}{n} + \left(23 + \frac{0.00155}{S}\right)}{1 + \left(23 + \frac{0.00155}{S}\right)\frac{n}{\sqrt{R}}}$

if $V = V_0$ then ok otherwise repeat

Lacey theory :-

→ for True & final regime (not for initial regime)

Regime	Side slope	Bed Slope
Initial	Constant	Change 2
True	Constant	Constant
Final	Change 5	Change 6

Trick 256 → चेंज करा

Artificial channel (fixed section, fixed slope) will be in regime condition as per Lacey if

(I) Q = constant

(II) flow = uniform

(III) silt charge, silt grade = constant

[wt of silt / volume of water] {type & amount of silt}

Lacy's 3 basic eqn :-

$$V = 10.8 R^{2/3} S^{1/3}$$ ($V \propto S^{1/3}$)

$$Af^2 = 140 V^5$$

$$R = \frac{5}{2}\frac{V^2}{f} \quad \text{or} \quad V = \sqrt{\frac{2}{5} fR}$$

Solve then

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

(II) $f = 1.76\sqrt{d_{mm}}$ silt factor

(III) $R = \frac{5}{2}\frac{V^2}{f}$

(IV) $P = 4.75\sqrt{Q}$

(V) $S = \frac{f^{5/3}}{3340\, Q^{1/6}}$

(1) Lacey normal regime scour depth $= 0.472\left(\frac{Q}{f}\right)^{1/3}$

Condition → when river width follows $P = 4.75\sqrt{Q}$ or river width = regime width

Otherwise :-

Lacey normal scour depth (R) $= 1.35\left(q^2/f\right)^{1/3}$

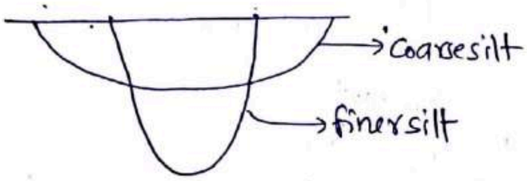
(below d/s water level)

(1.5–2R)

Lacy
note:-

Da channel in which all variables (discharge, silt grade, silt charge, width, Bed slope, depth) are equally free to vary has a tendency to assume a semi-elliptical section.

(II) Coarser the silt ⟶ flatter the semiellipse
finer the silt ⟶ more nearly the section attain the semicircle.



note:-

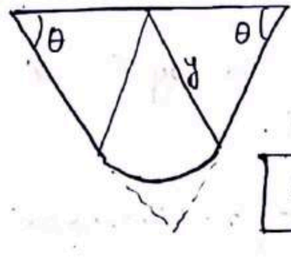
(I) Kenedy → trapezoidal section
Lacy → semielliptical section,

(II) Kenedy ⟶ no slope eqn, Lacy → slope eqn given

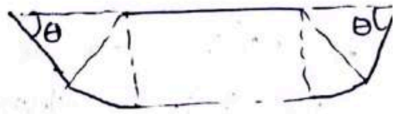
(III) Kenedy ⟶ Alluvial channel
Lacy ⟶ Alluvial channel + River

Design of lined canal

- for small discharge $Q \le 150 \, m^3/s$ ⇓ Triangular channel-section with circular-bottom
- for Large discharge $Q > 150 \, m^3/sec$ ⇓ Trapezoidal-channel section with rounded section



$\cot\theta = Z$



$A = y^2(\theta + \cot\theta)$

$P = 2y(\theta + \cot\theta)$

$R = A/P = y/2$

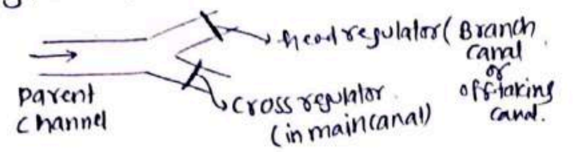
$A = By + y^2(\theta + \cot\theta)$

$P = B + 2y(\theta + \cot\theta)$

$R = A/P$

Canal regulation works

① canal regulator (Best Alignment → 0°)
- Cross regulator (controll flow depth)
- Head regulator



② canal falls or canal drop (controll of grade)

③ Canal Escape (controll of FSL) → safety value of irrigation channel system

④ metering flumes

⑤ Canal outlets & modulus (controll of discharge)

Cross Regulator :- ① in main canal / channel

imp (II) controll of flow depth ⇒ (Level @ U/S ↑)

मतलब to provide sufficient depth for offtaking canal.

(III) combined with road, bridge, falls.

(IV) absorb fluctuation in canal system (effective regulation of entire canal system)

Head regulator :- ① in offtaking canal / [redacted] channel

(II) sill controll in offtaking channel

(III) regulate / controll supply to offtaking channel.

(IV) serve as meter

Canal falls / drop :- (N more of small size)

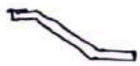
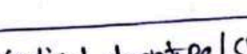
① provide when natural ground slope > design Bed slope

(II) dissipate energy otherwise there will be errosion

(III) canal directly irrigate the field
locate if [drop cost < filling cost]

(IV) canal not directly irrigate the field
locate FSL & CBL cross eachother.

Types of canal falls :-

① ogee falls	• smooth transition {combination of convex & concave curve) KE not dissipate ∴ erosion of d/s Bed & Banks
(II) Rapid falls	• when slope even & long • long glacis (gradient) assured formation of hydraulic jump. 
(III) Trapezoidal notch fall	• energy dissipated by Turbulent Diffusion • depth discharge relationship of channel remains unaffected.
(IV) stepped fall	• modifier form of rapid falls. long glacis —replace by→ floors in steps 
(V) well type fall or cylinder fall or syphon well drops	• for large drop of small discharge → useful • commonly used as tail escape for small canals • energy dissipated in cell in Turbulence
(VI) simple vertical drop type or sharda type fall	• raised crest fall with a vertical Impact • no Hydraulic Jump • energy dissipate by Turbulent diffusion
(VII) straight glacis fall	• Hydraulic Jump ⟶ energy dissipation ($Q = 60 m^3/sec$ $h = 1.5 m$ drop)
(VIII) montague type falls	replace straight glacis by Parabolic glacis. Parabolic glacis known as montague profile
(ix) Inglish fall or Baffle fall	(QAll & h > 1.5m) • Horizontal Impact for energy dissipation 
(X) metring & nonmetring fall	• vertical drop type / sharda type ⟶ not for metering purpose • Glacis type fall → used for measuring discharge Ex { flumed glacis fall / flumed Baffle fall }

cistern / cistern element :-

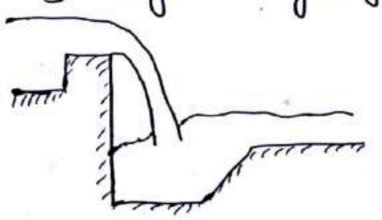
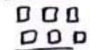
• element of fall on d/s of crestwall to dissipation energy

objective :- (I) intensity of impact of Jet ↓

(II) to Provide water cushion to dissipate energy of falling jet.

(III) to produce reverse flow by Providing a suitable end wall to ensure an impact in the cistern.

elements :-

(I) cistern	• A tank for storing water • Water cushion provided by - depress the floor below d/s Bed of channel to protect the floor from impact of stream of water falling freely under gravity.  • vertical Impact cistern → most effective • Inclined ——— → least "
(II) Roughening Device	• in cistern to dissipate energy • depend on turbulence & Boundry friction. → staggered friction block  → Arrow 
(III) dentated Sill	• Breaks up the stream jet into smaller jet Causes reverse rollers.
(IV) Deflector or Baffle wall 	• Short wall • Provided if high velocity flow continues upto the end of cistern which helps in dissipating residual energy.
(V) Biff wall 	• vertical wall with a horizontal Projection ending in cistern. • end wall of cistern • at d/s edge of cistern to produce reverse rollers.
(VI) Ribbed Pitching	• To dissipate excess energy. • The bricks projecting into flow Cross-section increases the Boundry friction

Canal escape → (controll of FSL)

↳ safety value of irrigation channel system.

Types:-

(I) Surplus-water escape	• provided at regular interval along banks • capacity → 0.33 – 0.50 × {capacity of channel at site of escape} • usually There should be a cross-regulator across the channel on d/s side of location of escape.
(II) Canal-scouring escape (regulatory-type escape)	• Usually provided only in head reaches of main canal. • Provide in Bank channel • to remove excessive silt deposited in head reaches from time to time. (replaced by silt ejector)
(III) Tail escape (weir type escape)	• to maintain FSL at tail end of channel. • across the channel at tail end Provided • In case of irrigation channel which end in natural drain.

Metering flume :-

(I) works on principle of venturimeter.

(II) More gradual the convergence & divergence then less will be the head loss.

Types :-

(1) Drowned venturiflume or non modular venturiflume or venturiflume	• Gradually contracting channel leading to throat & gradually expanding channel leading away from it. Stilling well :- for measuring head at entrance & Throat.
(2) Free flow venturiflume or modular venturi flume or Standing wave-flume	• Hydraulic Jump (Standing wave) forms thus more head loss (h_L) {if $h_L = 0$ ⇒ then act as venturi flume note:- Better than venturiflume ∵ Q depend only u/s head over crest of Throat. and also for same u/s head, discharging capacity more than that of venturiflume

Canal outlet :- → controll of discharge

↳ structure built at head of water course

So to connect it with minor/major distributory.

Canal outlet types :-

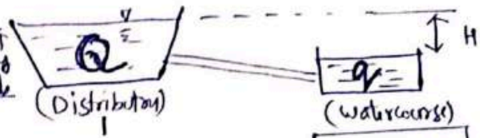
(I) nonmodular Ex. (i) open sluice 2) Drowned or submerged pipe outlet (Generally embedded in concrete & fix horizontly at right angle to direction of flow.	• Q depend on difference of head b/w distributory and water course. • fluctuation both side. ↳ • discharge varies with either change in water level of distributory or that of water course.
(II) semimodular (Flexible outlet) Ex. (i) pipe outlet (ii) venturiflume outlet or kenedy gauge outlet (iii) open flume outlet (iv) Adjustable orifice semi-module. (v) crumps adjustable proportional module	• discharge will increase with rise in distributory level (vice versa) • here discharge = f^n (distributory level) as long as min. working head available.
(III) modular outlet (Rigid outlet)	• discharge is constant and fixed within limits, no affect of fluctuations on any side.

Ex.

(I) Gibbs rigid module.

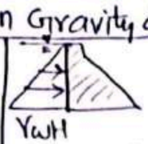
(II) masonary alm orifice.

Criteria for judging performance of module :-

(1) flexibility (F) $f = 0$ ⇒ rigid or modular outlet $f \neq 0$ flexible/ Semimodular outlet $f > 1$ hyperproportional outlet $f < 1$ subproportional outlet.	$F = \frac{dq/q}{dQ/Q} = \frac{my}{Hn}$ माई / इन्नी  Discharge through outlet $q = KH^m$ → outlet index distributory $Q = Cy^n$ → channel index
(2) Proportionality	when $F = 1$ * $\frac{my}{Hn} = 1 \Rightarrow \frac{m}{n} = \frac{H}{y}$ (m → outlet index, n → channel index)
(3) setting	Setting $= \frac{m}{n} = \frac{H}{Y}$ (H → difference of level, Y → distributory depth) wide Trapezoidal channel :- $Q \propto y^{5/3}$ $n = 5/3$ orifice type outlet $(m) = 1/2$ weir type outlet $m = 3/2$ triangular — $m = 5/2$
(IV) sensitivity	$S = nF$ { for rigid/modular $f = 0$ ∴ $S = 0$ $S = \frac{dq/q}{dy/y}$

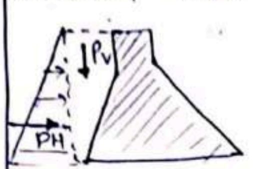
Forces on Gravity dam :- (apart from self wt)

1) Water Pressure (P)



$P = \frac{1}{2}\gamma_w H^2$ @ $H/3$ from Base

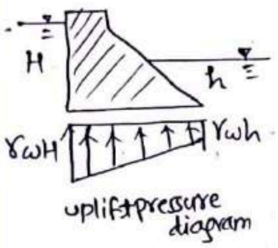
note:- if u/s face partly vertical & partly inclined then P_H, P_V

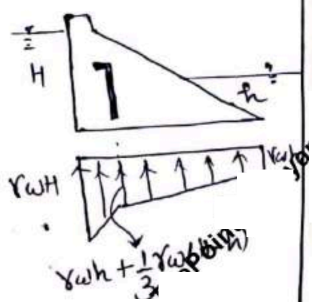


2) Uplift Pressure (U)

- due to pores/cracks & fissures of foundation material.
- It reduces wt. of Body (W) & destablize the dam against stability.

no drainage gallery | gallery





3) Silt pressure

- silt gets deposited against the u/s face of dam. if u/s face inclined then vertical weight of silt supported on slope also acts as vertical force.
- given by Rankine formula.

$P_{silt} = \left(\frac{1}{2}\gamma_{sub}H^2\right) * K_a$ @ $H/3$ from Base

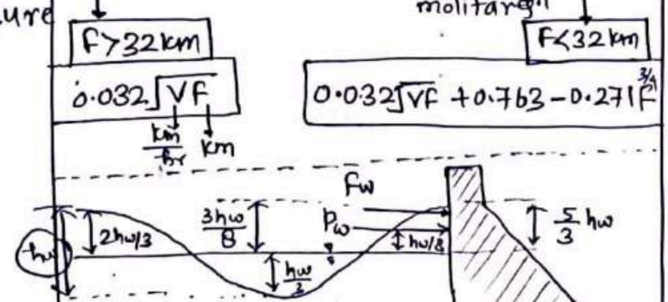
4) Wave Pressure

- towards d/s side, depend on wave height (h_w)

Molitor eqn

$F > 32$ km	$F < 32$ km
$0.032\sqrt{VF}$	$0.032\sqrt{VF} + 0.763 - 0.271F^{3/4}$

V in km/hr, F in km



(i) resultant wave pressure $P_w = 2.4\gamma_w h_w$ {@ $\frac{h_w}{8}$ from still water}

(ii) total wave force $F_w = 2\gamma_w h_w^2$ kN/m @ $\frac{3h_w}{8}$ {from still water surface}

$\frac{1}{2} \times P_w \times \frac{5}{3}h_w$

5) Earthquake force.

$\alpha_h = 0.1g$ to $0.2g$

$\alpha_v = 0.75\alpha_h$

$\alpha = \beta I \gamma_0$ → (Basic seismic coefficient); I → Importance; β → Soil foundation system factor; Seismic coefficient

	Zone	Z
low	2	0.10
moderate	3	0.16
Severe	4	0.24
very severe	5	0.36

(1) effect of vertical acceleration $\alpha_v = k_v g$

[critical → $\alpha_v\downarrow$]

(A) when vertical acceleration acts in upward direction → ($\alpha_v\uparrow$) ⇒ F↓ ⇒ ∴ effective weight of dam increases ∴ stress developed ↑

(B) when vertical acceleration acts in downward ($\alpha_v\downarrow$) ⇒ F↑ ⇒ effective weight ↓ thus worst case of design.

Thus net weight of dam $= W - \frac{W}{g}\alpha_v$

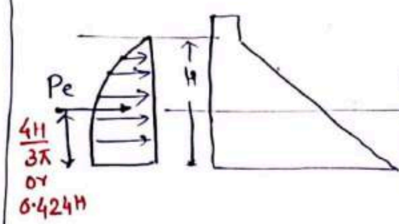
$= W\left(1 - \frac{K_v g}{g}\right)$

$= W(1 - K_v)$

note:- vertical acceleration(↓) reduces the unit weight of dam material and that of water to $(1-K_v)$ times their original weight.

(2) effect of horizontal acceleration (critical – α_H ←)

- It causes
  - Hydrodynamic Pressure.
  - Horizontal inertia force. $F = \left(\frac{W}{g}\right)\alpha_H$



moment of this force about Base $= P_e\left(\frac{4H}{3\pi}\right)$

As per Von Karman Hydrodynamic force

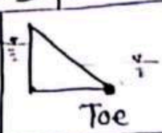
$P_e = 0.555\,\alpha_H \gamma_w H^2$ @ $\frac{4H}{3\pi}$ from Base

note:- α_H acting towards reservoir (α_H←) increase in water pressure (as foundation and dam accelerates towards reservoir) & water resists the movement owing to its inertia. Thus extra pressure exerted by this process.

Modes of failure and criteria for str. stability of gravity dam. (imp)

FOS	1	1.5	3
	sliding	over-turn	SFF

(I) overturn by Toe



$$FOS = \frac{M_R}{M_o}$$

(II) Sliding

$$FOS = \frac{\mu \Sigma F_V}{\Sigma F_H} \quad \left\{ \text{sliding factor} = \frac{\Sigma F_H}{\Sigma F_V} \right\}$$

if shear strength is taken then shear friction factor (SFF)

$$SFF = \frac{\mu \Sigma F_V + q(B \times 1)}{\Sigma F_H}$$

(III) Crushing or Compression

$e = \frac{B}{2} - \bar{x}$ (from mid of Base)

$\bar{x} = \frac{M_R - M_o}{\Sigma F_V}$ (from toe)

$$\frac{\sigma_{max}}{\sigma_{min}} = \frac{\Sigma F_V}{B}\left(1 \pm \frac{6e}{B}\right)$$

note:- if $e < B/6 \Rightarrow$ no Tension anywhere [basically middle 1/3rd rule]

for no failure $\boxed{\sigma_{max} \le \sigma_c}$ {crushing strength}

case-1 :- when shear stress acts also on a horizontal plane.

(I) Principle stress :- (imp)

toe $\boxed{\sigma_1 = P_V \sec^2\alpha - P\tan^2\alpha}$ — P: due to tail water Principle stress decrease.

P_V → at toe stress $\sigma_{max} = \frac{\Sigma F_V}{B}\left[1 + \frac{6e}{B}\right]$

(II) Shear stress :-

toe $\boxed{\tau = (P_V - P)\tan\alpha}$ → P due to tail water

case-2 when earthquake considered.

$$\sigma_1 = P_V \sec^2\alpha - (P - P_e)\tan^2\alpha$$

$$\tau = [P_V - (P - P_e)]\tan\alpha$$

- Hydrodynamic Pressure P_e exerted by tail water moving towards reservoir (← → P_e) Because effect of earthquake reduces tail-water Pressure.

(IV) failure due to Tension

$\sigma_{min} \ge 0$ ✓

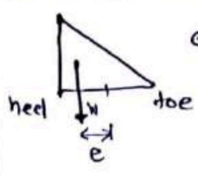
for no tension at All → $e \le B/6$

Elementary profile of dam :- → weight of dam (W), → water pressure (P), → uplift pressure (U)

(no earthquake force considered) (no tailwater)

- shape triangle same as shape of hydrostatic pressure distribution

(A) when reservoir empty ($P = 0$, $U = 0$)



$e = B/6$

$\therefore \sigma_{heel} = \frac{\Sigma F_V}{B}\left(1 + \frac{6e}{B}\right)$ ($\Sigma F_V \to W$, $e \to B/6$)

$\therefore \sigma_{heel} = \sigma_{max} = \frac{2W}{B}$

& $\sigma_{toe} = \sigma_{min} = 0$

(B) when reservoir full condition :-

(I) for no overturning

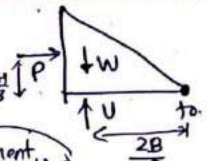
$P = \frac{1}{2}\gamma_w H^2$

$U = \frac{1}{2}(C\gamma_w H)B$

$W = \frac{1}{2}(G\gamma_w)BH$

$\Sigma M_R \ge \Sigma M_o$

$(W - U)(2B/3) \ge \frac{PH}{3}$ (moment about the toe)



$\therefore B \ge \frac{H}{\sqrt{2(G - C)}}$

or $\boxed{B \ge \frac{H}{\sqrt{2(S - C)}}}$ (imp)

(II) for no tension

$e \le B/6$ $\quad B/2 - \bar{x} \le B/6$, $\bar{x} \to \frac{M_R - M_o}{\Sigma F_V}$

or, $(W - U)B/3 \ge PH/3$

no tension at heel, resultant should pass through outermost middle 3rd point hence directly take moment about that point (through which resultant pass)

$\boxed{B \ge \frac{H}{\sqrt{S - C}}}$ (imp)

(III) for no sliding $\mu \Sigma F_V \ge \Sigma F_H \quad \therefore \quad \boxed{B \ge \frac{H}{\mu(S - C)}}$

(IV) for no crushing

$\boxed{\sigma_1 \le f}$ → (σ_y / FOS)

$\sigma_V \sec^2\alpha - P\tan^2\alpha$ (no tailwater ($P = 0$))

$\boxed{\tau_{toe} = H\gamma_w\sqrt{S - C}}$

for safe in all above 3 case $B \ge \frac{H}{\sqrt{S - C}}$

$\sigma_1 = \therefore \boxed{\sigma_{toe} = H\gamma_w(S - C + 1)}$ (imp)

$\therefore \boxed{H_{critical}\ (H_c) = \frac{\sigma_1 \text{ or } f}{\gamma_w(S - C + 1)}}$

- $H > H_c$ (High dam)
- $H < H_c$ (Low dam)

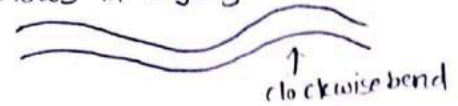
note:- drawning ratio = (d/s / u/s) → ratio of depth of water over crest

Rivers classification in Alluvial plain :-

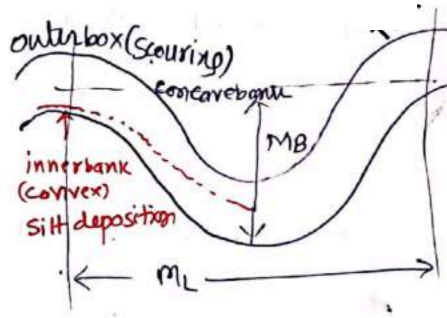
① meandering Type river

only in this river training work required.

- flows in zigzag fashion..



- They meander freely from one-bank to another & carry-Sediment which is similar to bed material.
- (Imp) material gets eroded constantly from outer edge of the band and get deposited either on the inner edge of the succesive bend or b/w 2 Succesive bends to form a bar.
- when once a straight moving River slightly deviates from its axis, The unbalance created goes on multiplying with constant erosion from outer edge, if unchecked, this process continues & resulting in the formation of Large meanders.



$$\text{meander ratio (M.R)} = \frac{MB}{ML}$$

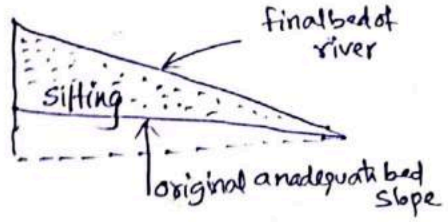
$$M_L \propto \sqrt{Q} \quad \{ 65.8\sqrt{Q_{dominant}} \}$$

$$\text{tortuosity} = \frac{\text{Curve length}}{\text{Straight lgth}} = \frac{\smile}{\text{—}}$$

Different Theory of meandering :-

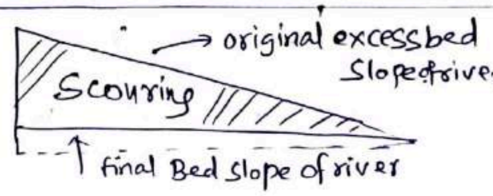
(I) Disturbance Theory By frelkin & werner
(II) helicoidal flow theory
(III) Excess energy Theory
(IV) Instability Theory.

② Aggrading type river or Silting river



- aggrading type of river is in Process of building up its bed to a certain slope.
- silting is due to heavy sediment load, construction of dam or weir, sudden-intrusion of sediments from a tributary, extension of delta at the river mouth.
- This type of river usually has Straight & wide reaches with Shoals in the middle.

③ Degrading type river



- if the river bed is constantly getting scoured to reduce & dissipate available excess land slope then-the river is known as degrading river.
- degrading results deficit of sediment

type of River trainings

① High-water training	discharge	* use:- flood controll. {provide sufficient cross-section to pass max. flood)
② Low water Training	depth	* use:- navigation purpose during low water period, close other channels
③ mean water Training	Sediment	* use:- efficient disposal of suspended load, Bed load {:Preserve channel in good shape}

→ forms basis on which former two are planned.

methods of river training :-

① Marginal embankment or Levees	• earthem embankment to protect area from flooding use:- किसीगांवसे नदी गुजरती हो तो नदी के किनारे ये बनाते हैं parallel में
(II) GuideBank or GuideBund	• confine the River flow • Prevent river from changing its course
(III) Pitching of Bank & Provision of Launching-apron.	direct method → work done on bank indirect method → use groynes to deflect current
(IV) Pitched Island	artificial Island in river bed and protected by stone pitching on all sides.
(V) miscellaneous methods	(i) Sills (submerged dyke) (ii) Closing dyke (iii) Bandalling

(vi) Groyne's or spur :- structure constructed transverse to river flow extending from bank into river.

function :- ① train river along course by attracting, deflecting, repelling flow in river

(II) protect river bank by keeping the flow away from it.

(III) Contract wide river channel, usually for improvement of depth.

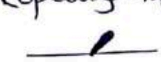
↓ types :-

① As per material of construction :-

- Permeable Groyne's
  - → Tree groynes
  - → Pile Groynes
- Impermeable Groynes

(II) As per height of groynes :-
- non submerged groynes
- Submerged groynes

(III) Based on function served :-

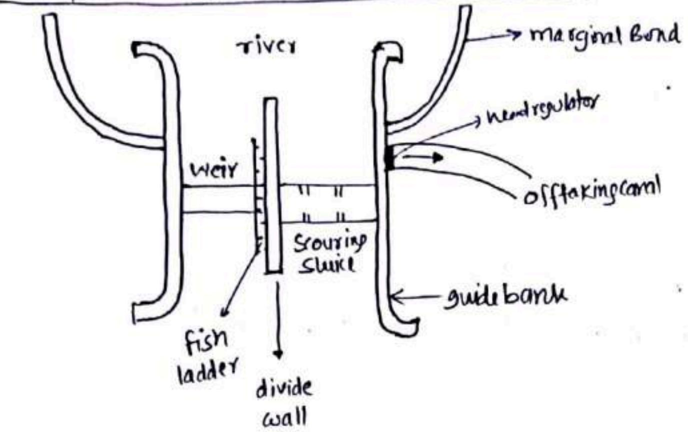
① Attracting Groynes 	• Tend to attract river flow towards bank • not useful for bank protection.
② Repelling Groynes 	• repell • head of groynes need strong protection directly subjected to current.
③ Deflecting Groynes (Gives only local protection)	• 90° deflects flow without repelling • relatively short Length
④ Sediment Groynes (Ex. permeable groynes)	• Best for river carrying sediment • Causes deposition of sediment carried by river without repelling / Deflecting.

To the point
dhyani
28/4/20

Headwork :- in order to divert water from river into canal, structure constructed across river & at head of offtaking canal.

1- storage headwork :- dam constructed across river to store water during excess flow in river.
2- diversion headwork : raises the water level in river then divert the required quantity into canal.

Component of Diversion headwork :-



① Weir	• construct across river to raise water level and divert water into offtaking canal. major ponding by raised crest. weir types :- (i) Gravity weir :- weight of weir = uplift pressure caused by head of water seeping below weir. (ii) non gravity weir :- weight of concrete slab plus weight of divide peirs keeps the structure safe against uplift. note :- Barrage : crest is kept at low level & ponding is done by means of gates.
② Scouring Sluice	• helps in removing silt near head regulator. • opening provided in weir wall with crest at low level. (gate operated) • located on same side of offtaking canal . less turbulent pocket of water near head regulator.
③ Divide wall or divide groyne	- masonary / concrete wall 90° to the axis of weir to seperate weir from undersluice. • can be designed as cantilever retaining wall subjected to silt pressure & water pressure from undersluice side. • provides quiet pocket in front of canal head regulator resulting in deposition of silt in pocket & entry of clear water into canal
④ Fish Ladder ↓ located adjacent to divide wall near undersluice	• Flow energy dissipated in such a manner so as to provide smooth flow at sufficiently low velocity (3-3.5 m/s) • anadromous fish moves from u/s to d/s in beginning of winter in search of warm water & return to u/s before monsoon for clearer water. • To check velocity flow in fish ladder, Baffles or staggering devices are provided.
⑤ Canal head regulator	• at head of offtaking canal • regulate supply to canal • controll entry of silt into canal. • completely exclude High flood from entering into canal. • Head regulator consist of no. of spans separated by peir which supports the gates provided for regulation of flow into canal.
⑥ Silt controlling device ⇓ controll entry of silt into canal	Ⓐ silt excluder :- {canal में enter करने से पहले} • on river bed, infront of head regulator • exclude silt from entering the canal Ⓑ silt extractor :- (बाद में) or silt ejector → remove silt which already enters into canal → provided in canal little distance from head regulator.

Cross Drainage Works" (C D works)

{ contour canal → max. CD
watershed/ridge canal → min. CD }

CBL → Canal Bed level
DBL → drain Bed level
canal → FSL (Full supply level)
drain → HFL (High flood level)

Case-1 :- **Canal ऊपर**

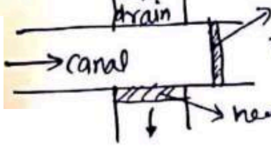
- aqueduct {High flood discharge for long time} (HFQ↑ T↑)
  (CBL > HFL)
- Syphon aqueduct
  (HFL > CBL)
  ⇓
  imp: most severe condition of uplift on floor occures when canal dry and drain is at HFL

Case-2 :- **drain ऊपर**

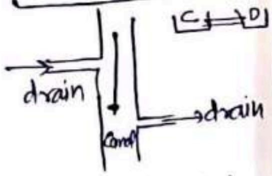
- superpassage {High flood discharge for long time} HFQ↑ T↑
  (DBL > FSL)
- syphon
  (DBL < FSL)

Cross drainworks admitting the drain into canal :-

- (HFQ↑↑ T↓↓) **Level crossing**
  - when Both canal & drain meets at same level.



  - Same arrangement as in canal headworks
- (HFQ↓) **Inlet & outlet**



  - inferior than Aqueduct, superpassage But cheaper
  - provided where silt load of drainage is small
  - inlet → provided in canal bank to pass drain water into canal.
  - inlet → non regulating structure
  - not necessary inlet & outlet are same.

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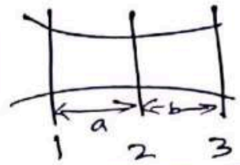
methods To design Channel Transition :-

- **Mitra's method** — water Depth → constant
- **Chaturvedi's method** — (water Depth → constant)



$$\frac{V_1 - V_2}{a} = \frac{V_2 - V_3}{b}$$

note:-
Hind's method — water Depth constant or vary.

To the point
dlyr
29/4/2020

Failure of weir on permeable foundation :-

(i) piping / undermining
(ii) uplift pressure
(iii) By scour on u/s & d/s of weir
(iv) By suction ((-) pressure) due to hydraulic jump (standing wave)

{ ∵ acts in direction of uplift pressure, suction happens due to conversion of high pressure before jump to low pressure after jump.

Bligh's creep theory (for permeable foundation) :-

- Theory of subsurface flow, This theory assumed that water follows outline of the base of structure which is in the contact with the subsoil.
- Bligh creep cofficient (C) = reciprocal of hydraulic gradient

$$C = \frac{1}{i} \quad (i = H/L)$$

case-1 :- Safety against piping $L_{req} \geq CH$ — c = 5 to 15 depend on soil type

case-2 :- Safety against uplift pressure

h → above top of floor

h' → HGL ordinate {above bottom of floor}

$t = h'/G$, $Gt = h'$. $Gt - t = (h' - t)$ h , $t = \frac{h}{G-1}$

limitation :- (i) no distinction b/w horizontal & vertical creep. (weightage factor = 1 for both)

(ii) valid or good if horizontal distance b/w cutoff > 2 × depth of cutoff.

(iii) did not tell about exit gradient

(iv) headloss ∝ creep length (but it is not correct)

(v) did not specify the absolute neccesity of providing cutoff at d/s end of floor

{ यह कि undermining prevent करने के लिये सबसे जरूरी है)

Lane's creep Theory :- improvement over Bligh Theory.

But practically Bligh's theory used (Lane's theory nowhere used)

{ weightage factor :- $\frac{1}{3}$ → horizontal creep, 1 → vertical creep }

Question Based on Bligh Theory :-

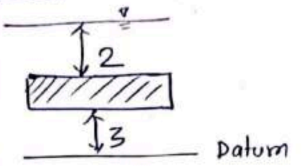
(i) while Designing structure, The piezometric head at bottom of floor = 10 meter

datum is 3m below floor Bottom.

Standing water Depth above floor = 2m

Find floor Thickness? (G concrete = 2.5)

Sol^n :-



Piezometric head = 10

$P/\rho g + Z = 10$ (pressure head + datum head)

Datum head = 3

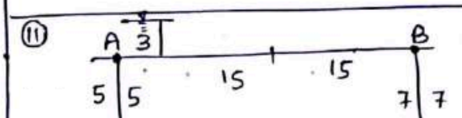
∴ Pressure head = 7

∴ wt of floor + wt of water above it ⇒ counteracted by this upward pressure head

$(G\gamma_w)t + 2\gamma_w = 7\gamma_w$ (G = 2.5)

(t = 2m)

(ii)



G = 2.5

$i = 3/54$

Sol^n :-

(i) total creep length As per Bligh = 5+5+15+15+7+7 = 54

(ii) uplift pressure head at A = $3 - \left[\frac{3}{54}\right] \times 10 = 2.44$

B = $3 - \left(\frac{3}{54}\right) \times 40 = 0.78$

take avg. 2.44 — 0.78 ⇒ $\frac{2.44 + 0.78}{2} = 1.61$ ⇒ uplift pressure head

wt of floor = counteracted by this upward pressure head

$(2.5\gamma_w \times 30 \times 1 \times t) = 1.61\gamma_w \times 30 \times 1$, t = 0.645m

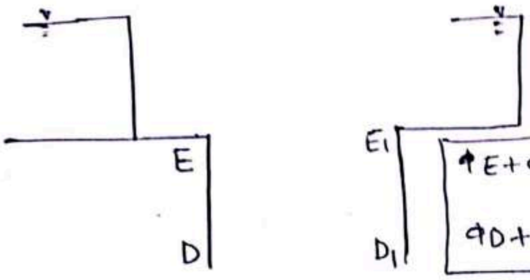
Khosla Theory :- (for design of weir on Permeable foundation)

→ method of independent variable

Case-1 :- Straight horizontal floor of negligible thickness, sheet pile at either end / intermediate point.

Case-2 :- Straight horizontal floor depressed below the bed but without any vertical cutoff

Keypoints :-	Corrections
(i) actual junction point of pile & bottom of floor	(i) for Thickness of floor
(ii) Bottom point of pile	(ii) for slope of floor
(iii) Bottom corner of depressed floor.	(iii) for mutual Interference of piles



$\phi_E + \phi_{E_1} = 100$

$\phi_D + \phi_{D_1} = 100$

Khosla's Exit gradient :- $G_E = \frac{H}{d\pi\sqrt{\lambda}}$

$\lambda = \frac{1+\sqrt{1+\alpha^2}}{2}$

$\alpha = b/d$

b → Length of Horizontal floor

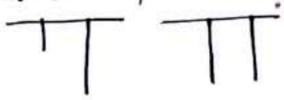
d → length of downstream pile

I- correction for mutual Inference of pile :-

$$C = 19\sqrt{\frac{D}{b'}}\left(\frac{D+d}{b}\right)$$

Trick: (19) $\frac{D+d}{b}$

not valid :- (i) if intermediate pile ≤ outer pile



(ii) if dist. b/w them < 2× outer pile length

C → correction to be applied as percentage of head

b' → distance b/w piles

b → total floor length

D → due to which Interference is created.

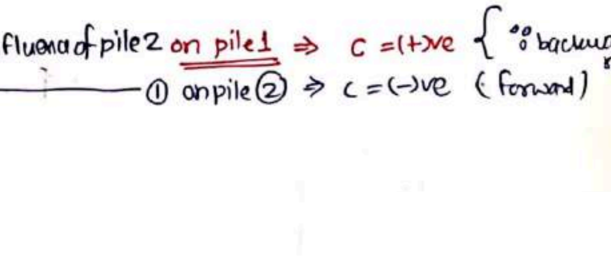
d → depth of pile on which effect of interference is considered

(Trick on) $\phi = \frac{\text{Residual seepage head or uplift pressure head}}{\text{total seepage head}} \times 100$ (in %)

C = (+)ve ⇒ for backward / rear points (←)

C = (−)ve ⇒ for points forward in direction of flow.

Ex.



Influence of pile 2 on pile 1 ⇒ C = (+)ve { ∵ backward / rear point }

——— ① on pile ② ⇒ C = (−)ve (forward)

② correction for slope of floor :-

C = (+)ve → for downward slope in direction of flow.

C = (−)ve → —— upward slope ——.

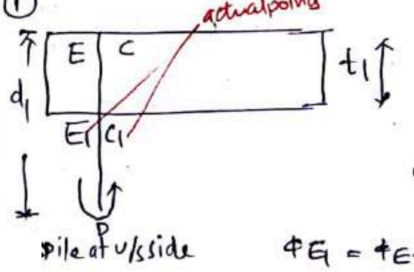
- apply only to key points of pile line fixed at start or end of slopes.

- ज्यादा slope → ज्यादा correction → (% of pressure)

Ex.	
1 in 1	11.2
1 in 8	2

③ correction for Thickness of floor :-

①



$\phi_{C_1} > \phi_C$

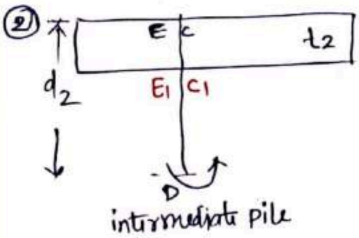
$\phi_{C_1} = \phi_C + ct$

$ct = (\phi_D - \phi_C) \times \frac{t_1}{d_1}$

$\phi_{E_1} = \phi_E - ct$ { $\phi_E > \phi_{E_1}$ }

↳ $(\phi_E - \phi_D) \times \frac{t_1}{d_1}$

②



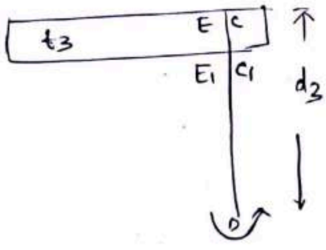
$\phi_{E_1} = \phi_E - ct$

$(\phi_E - \phi_D)\frac{t_2}{d_2}$

$\phi_{C_1} = \phi_C + ct$

↳ $(\phi_D - \phi_C)\frac{t_2}{d_2}$

③



$\phi_{E_1} = \phi_E - ct$

↓

$(\phi_E - \phi_D) \times \frac{t_3}{d_3}$

$\phi_{C_1} = \phi_C + ct$

$(\phi_D - \phi_C)\frac{t_3}{d_3}$

Testing point
dly
30/4/2020

Spillway :

1- provide in dam
2- safety valve of dam
3- waterway to dispose off surplus floodwater from reservoir after it fillup with max-capacity
4- some device for dessipation of energy on d/s side of spillway is required.

Spillway capacity → find by flood routing, need following data

1- Inflow Hydrograph (Inflow rate Vs time)
2- discharge curve (discharge through spillway Vs reservoir surface elevation)
3- Reservoir capacity curve (Plot of reservoir storage Vs reservoir surface elevation)

Type of spillways :-

① free fall Spillway (Straight drop Spillway)

for Low earth dam (earthen bund)

- For which controll str. is a low height narrow crested weir having its d/s face vertical/nearly vertical.
- provided where hydraulic drop from headpool to tailwater ≯ 6m.

② Ogee spillway — improvement over free fall spillway

- widely used with concrete, masonry, arch, buttress dam
- Least suitable for an earth dam
- The profile of this spillway is made in accordance with the shape of lower nappe of a free falling jet over a ventilated sharp crested weir
- ogee spillway can be easily used on valley where width of river is sufficient to provide the required crest length.

note:- for spillway having vertical U/s face The d/s crest is given by eqn

$$x_d^{1.85} = -2y\, H_d^{0.85}$$

③ Chute Spillway (wasteweir)

- A spillway whose discharge is conveyed from reservoir to d/s level through an open channel placed either along a dam abutment or through a saddle may be called as Chute spillway.
- It is lighter and adoptable to any type of foundation and hence provided easily on earth & rock fill dams.

note:- The minimum slope of chute is governed by the condition that supercritical flow must be maintained.

④ Side channel spillway

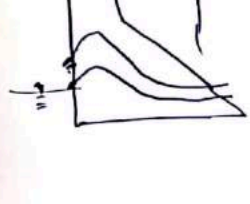
Provided in "narrow valley"

- in which control weir is placed along the side off and approximately parallel to the upper portion of spillway discharge channel.
- The slope of side channel should be sufficient to overcome friction losses as well as to provide acceleration in the direction of flow against the mass of incoming water.

⑤ Shaft spillway (Morning Glory)

in which water enters from the reservoir into a vertical shaft which conveys This water and water is discharged into a d/s river channel.

⑥ Siphon spillway



- U shape
- maintain reservoir storage level.

Tothepoint
Myd

Energy Dissipators :-

1- water flow over spillway, at the toe of spillway potential energy converted into KE so arrangement made to dissipate this energy hence These arrangements are known as energy dissipators.

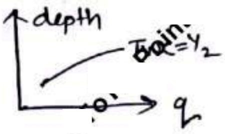
2- Generally KE (kinetic energy) of supercritical flow can be dissipated into 2 ways ⟶

ⓐ convert supercritical flow into subcritical flow by Hydraulic jump

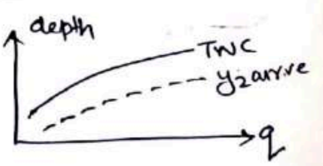
ⓑ or during the flow into air and then making it fall away from toe of structure

case-1 :- Tailwater curve (TWC) coincide with y_2 for all discharge

- Ideal case
- HJ forms at toe of spillway for all discharge.

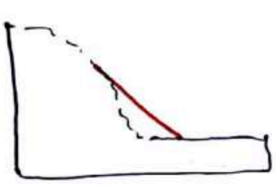


case-2 :- TWC > y_2

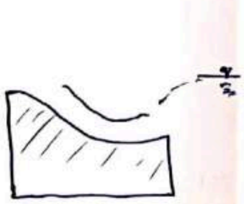


sol^n

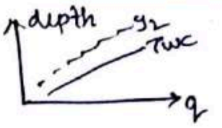
① sloping apron above river bed level



(ii) roller bucket



case-3 :- TWC < y_2 curve



sol^n :-

- Skijump bucket
  - Inf. required Sound & rocky bed
  - energy dissipation mainly by Impact.
  - Some by diffusion, aeration.
- Sloping apron below river bed
- construction of subsidiary dam below main dam

Case-4 :- TWC lying above y_2 at smaller q, below y_2 at higher q

sol^n :- sloping apron partly above & partly below the river bed

Case-5 :- TWC lying below y_2 at smaller q, above y_2 at higher q.

sol^n :- Sloping apron partly above & partly below the river bed

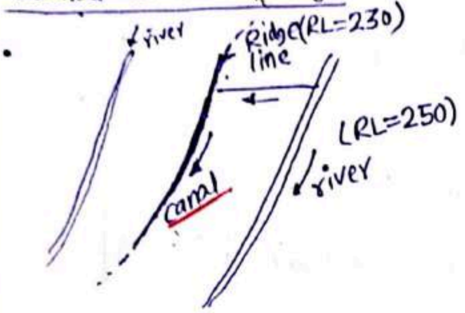
To the point
3/4/2020

Irrigation canal can be aligned in any of the 3 ways

1) Watershed or Ridge canal

watershed/Ridge :- The divide line b/w catchment area

- Canal which is aligned along any natural watershed/ridge.



- aligning the canal on ridge ensure gravity irrigation on both side of canal.

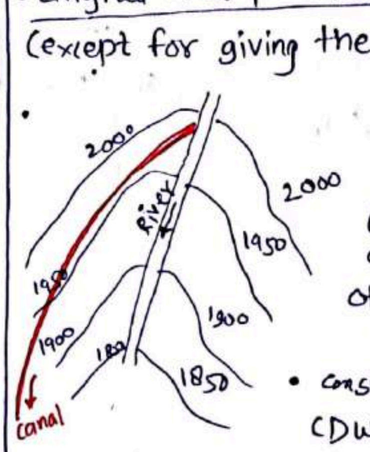
{hence large area can be irrigated ⇒ large command area}

Imp.
- cross drainage works (CD works) ⇒ not required or minimum {∵ drainage flow away from ridge}
- Preferred in plain areas where land-slopes are relatively flat & uniform.

2) Contour canal

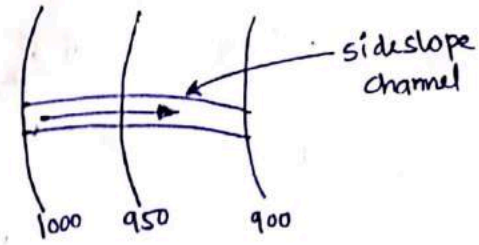
note:- In hilly areas as it is impossible to take the canal on the top of higher ridge as ridge line may be hundred of meters above river.
in such case contour canal constructed

- aligned near parallel to contour (except for giving the req. longitudinal slope)



- It irrigates on one side (because the areas on the other side is higher)
- construction of CD work is must as the drainage flows is always right angle to the ground contour.

3) Side slope canal

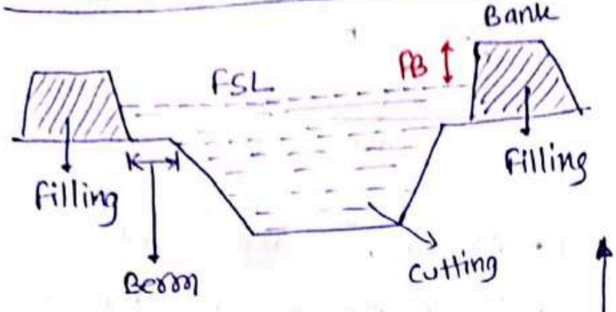


- aligned at right angle to contour.
- in such canal, flow runs parallel to natural drainage
- Usually flow in such canals doesnot intercept the drainage thus avoid construction of CD work.
- this canal neither on watershed nor in valley (in b/w)

other types of canal :-

① Feeder canal	• constructed to feed another canal. • no direct irrigation is carried out from feeder canal. • Ex. Indiragandhi feeder canal
② Inundation canal	• This canal gets its supply only when the water level in the river from which it takes off rising during flood. • these are nonperinial canal ∵ depend on periodical rise of water Level in the river. • These obtain their supplies through open cuts in bank of river which are called heads.

Cross section of irrigation canal :-



① freeboard (FB)

- lined canal (FSL to top of lining)
- unlined canal (FSL to top of Bank)

note:- IS7112:1973 :-

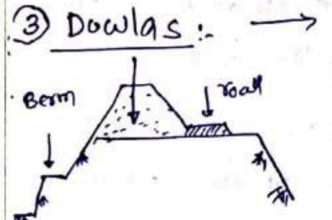
m^3/s	Min FB
Q < 10	0.50 (meter)
Q > 10	0.75 (meter)

FB → ensures that water does not overtop bank.

② Berms :- horizontal distance left at ground level b/w toe of Bank to the top edge of cutting.

- Berms are provided in canals, if these are partly in excavation & partly in embankment.
- provide a scope for future widening of canal.

③ Dowlas :- → as a measure of safety in driving provided along the bank, also helps in preventing slope erosion due to rains.



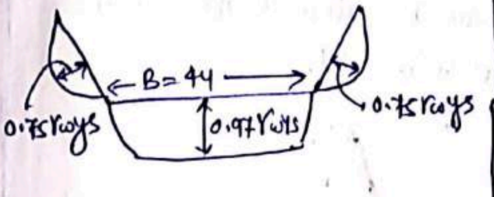
④ steep slope in cutting than filling.

⑤ Bank aim → to retain water

⑥ service roads → on canals for inspection purpose

Shield method (unlined canal) → (design of non scouring-stable channel having protected side slope)

$\left\{ \begin{array}{l} Re > 400 \\ d_{min} > 6\ mm \end{array} \right\}$



Average

Bottom	$\tau_0 = \gamma_w RS$
Side	$\tau_0' = 0.75\gamma_w RS$

at channel bottom :-

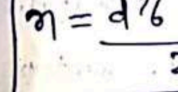
$$\tau_c = 0.056\gamma_w d(S-1)$$

S → SG of sediment = 2.65; d → dia > 6 mm

for design $\tau_0 \le \tau_c$, where $\tau_0 = \gamma_w RS$

$\therefore\ d \geq 10.8RS \simeq 11RS$ → min size of Bed material that will remain in rest.

at side slope of channel :-



$$\tau_c' = \tau_c\sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}$$

φ → angle of repose of soil

$\therefore\ \tau_0' \le \tau_c'$, where $\tau_0' = 0.75\gamma_w RS$

$$n = \frac{d^{1/6}\ (\text{meter})}{24}\ \{\text{for rigid Boundary channel}\}$$

$$V = 4.05\, d^{1/2} S^{-1/6}\ (d \text{ in meter}) \quad \text{or} \quad 4.85\frac{d_{cm}^{1/2} S^{-1/6}}{\sqrt{100}}$$

Design of stable channel in India < Kenedy. / Lacey Theory

Kenedy Theory :-

1. • conducted experiment at upper bari Doab canal system.

$$V_0 (m/s) = 0.55\, m y^{0.64}$$

$m \rightarrow$ critical velocity ratio < 1–1.2 coarse sediment; 0.7–1 fine

2. • Silt is in suspension due to eddy formed from bottom of channel.
3. • only for regime channel {no silting, no scouring avg.}
4. Trial & error procedure
5. mean velocity by kutter formula, hence kutter limitation exist.
6. B/D significance not considered.
7. no eqn of Bedslope given
8. Silt charge or Silt concentration {weight of silt / volume of water},

   silt grade ⟶ not considered.
9. m (CVR) ⟶ no logic given, no method to get 'm'

Steps :-
(I) $V_0 = 0.55\, m y^{0.64}$

(II) $A = Q/V_0 = By + y^2 z$ $\{z = 0.5\}$

$B = ?$

(III) $R = \frac{A}{P}$, $P \rightarrow B + 2y\sqrt{1+z^2}$

(IV) $V = C\sqrt{RS}$

kutter $C = \dfrac{\frac{1}{n} + \left(23 + \frac{0.00155}{S}\right)}{1 + \left(23 + \frac{0.00155}{S}\right)\frac{n}{\sqrt{R}}}$

if $V = V_0$ then ok otherwise repeat

Lacey theory :-

⟶ for True & final regime (not for initial regime)

Regime	Side slope	Bed slope
Initial	Constant	Change 2
True	Constant	Constant
Final	Change 5	Change 6

Trick 256 → Change करो

Artificial channel < fixed section, fixed slope

will be in regime condition as per Lacey if

(I) Q = constant

(II) flow = uniform

(III) silt charge, silt grade = constant

[wt of silt / volume of water] {type & amount of silt}

Lacey's 3 basic eqn :-

$V = 10.8 R^{2/3} S^{1/3}$ $(V \propto S^{1/3})$

$Af^2 = 140 V^5$

$R = \frac{5}{2}\frac{V^2}{f}$ or $V = \sqrt{\frac{2}{5} fR}$

⟵ Solve than

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

(II) $f = 1.76\sqrt{d_{mm}}$ silt factor

(III) $R = \frac{5}{2}\frac{V^2}{f}$

(IV) $P = 4.75\sqrt{Q}$

(V) $S = \dfrac{f^{5/3}}{3340\, Q^{1/6}}$

(I) Lacey normal regime scour depth $= 0.473\left(\frac{Q}{f}\right)^{1/3}$

Condition → when river width follows $P = 4.75\sqrt{Q}$ or river width = regime width

Otherwise :-

Lacey normal scour depth (R) $= 1.35\left(\frac{q^2}{f}\right)^{1/3}$

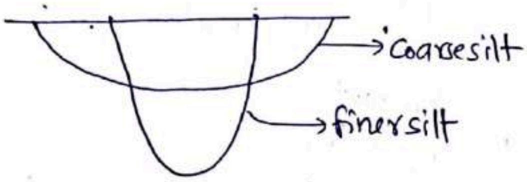
(below d/s water level)

(1.5–2R)

Lacy
note:-

Ⓘ a channel in which all variables (discharge, silt grade, silt charge, width, Bed slope, depth) are equally free to vary has a tendency to assume a semi-elliptical section.

(II) Coarser the silt ⟶ flatter the semiellipse
finer the silt ⟶ more nearly the section attain the semicircle.



note:-

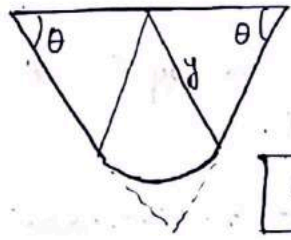
Ⓘ Kenedy → trapezoidal section
Lacy → semielliptical section,

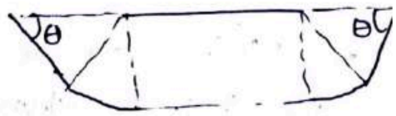
(II) Kenedy ⟶ no slope eqn, Lacy → slope eqn given

(III) Kenedy ⟶ Alluvial channel
Lacy ⟶ Alluvial channel + River

Design of lined canal

- for small discharge $Q \le 150 \, m^3/s$ ⇓ Triangular channel-section with circular-bottom
- for Large discharge $Q > 150 \, m^3/sec$ ⇓ Trapezoidal-channel section with rounded section





$\cot\theta = Z$

Triangular section:

$A = y^2(\theta + \cot\theta)$

$P = 2y(\theta + \cot\theta)$

$R = A/P = y/2$

Trapezoidal section:

$A = By + y^2(\theta + \cot\theta)$

$P = B + 2y(\theta + \cot\theta)$

$R = A/P$

Soil moisture relationship

① **Gravitational water** :- → not for plant use

- not held by soil, but drain out freely by gravity action hence not available for plant use.

② **Capillary water** :- → available water
  - ↳ held by surface tension

③ **Hygroscopic water** :- → not for plant use
  - ↳ not removed easily
  - ↳ Below PWP soil has hygroscopic water

④ **Saturation capacity** :- max. water holding capacity of soil, when all pores filled with water

- Soil moisture tension = 0

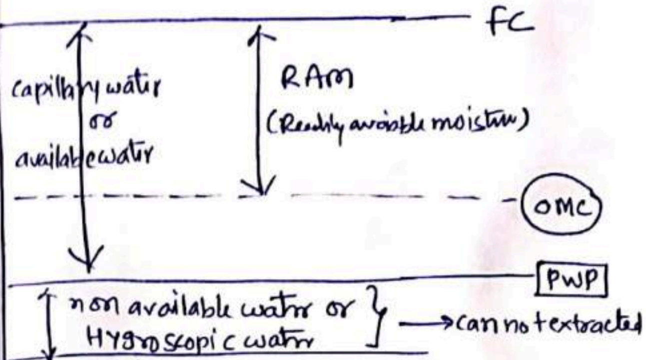
⑤ **FC (field capacity)** Soil moisture tension ⇒ $\frac{1}{3} - \frac{1}{10}$ atm

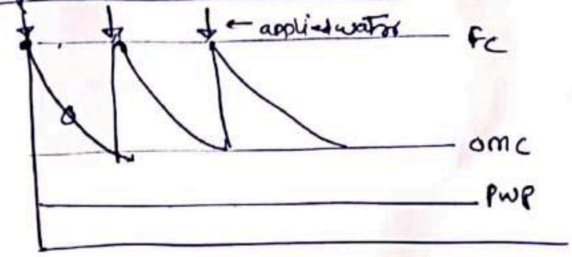
- ↳ upper limit of capillary water
- ↳ after gravity water drain off, max. amount of water which can be held up by soil against gravity.

Depth of water stored in root zone (in filling the soil up to FC)

$d_w = d \frac{\gamma_d}{\gamma_w}(FC) = nd$ $\therefore n = \gamma_d/\gamma_w * FC$

⑥ PWP Soil moisture tension ⇒ 7–32 atm.





Type-1 :- FC = 28%, PWP = 15%

RAM = 80% of AM

Soln :-

—— FC = 28%

RAM = 80 × 13/100 = 10.4%

—— OMC 17.6%

—— PWP = 15%

AM = 28 − 15 = 13%

∴ OMC = 28 − 10.4 = 17.6%

$\therefore d_w = d \frac{\gamma_d}{\gamma_w}[28 - 17.6]$ or (10.4%) → RAM

Type-2 :- FC = 40%, PWP = 18%

MC falls to 40% of Available water

'or' MC falls by 60% of Available water

Soln :- RAM = $\frac{60}{100} \times (40 - 18) = 13.2$

—— FC = 40

13.2 = RAM

—— OMC = 26.8

—— PWP = 18

$\frac{d \gamma_d}{\gamma_w}(40 - 26.8) = d$ (13.2)

Type-3 :- Allowable depletion = 40% of AW

40% of AW

—— FC

—— OMC

—— PWP

Note :- $\frac{1}{3}$rd atm. moisture point ⇒ % of moisture retain in soil sample when placed on porous plate & subjected to pressure = atm pressure/3

Type of Irrigation — Surface Irrigation / Subsurface irrigation.

① Surface irrigation : water applied/distributed over soil surface by either gravity or by pumping

- Flow Irrigation → water flow by gravity from high to low level
- lift irrigation → water lift up by mechanical equipment (like pump) then supply for irrigation.

Type of flow irrigation :-

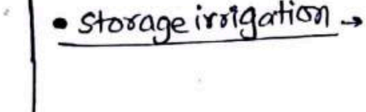
ⓐ Perrenial Irrigation	• constant and continuous water-supply throughout the crop period • Direct irrigation → direct divest river water to main canal by constructing weir/barrage. • Storage irrigation → construct dam
ⓑ Flood Irrigation or Uncontrolled irr. or Inundation Irr.	soil kept submerged & Throughly Flood with water so to cause thorh saturation of Land.

② Subsurface irrigation :- water flows underground and nourish plant roots by cappilarity.

- natural subsurface irrigation
- Artificial subsurface irrigation

Method of Irrigation :

① Free flooding (wild flooding)



• After water leaves the ditches, no-attempt to made to controll the-flow by means of Levees → ∴ wild flooding

suit for close growing crops, pastures Particularly where land is steep

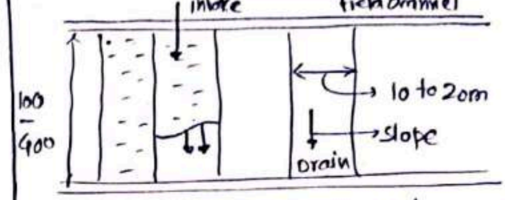
• method may be used on rolling land (topography irregular {where border's, check, furrows are not suitable}

(2) Border method

• Land divided into no. of strips, separated by low leaves called ~~strip~~ Borders.

• Strip Length = 100 to 400m width 10-20m.

• water is allowed to flow from the supply-ditch into each strip. The water flows-slowly towards the lower end and it infiltrates into the soil as it advances.



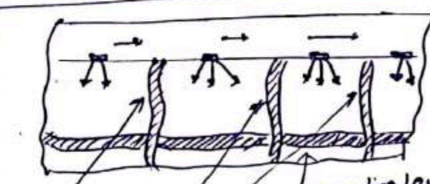
$$t = \frac{y}{I} \ln \frac{Q}{Q - IA}$$

y → depth over border strip; A → area of land strip; I → Infiltration rate

$$A_{max} = \frac{Q}{I}$$

Surface flow will stop after irrigation of this-area & deep percolation will start.

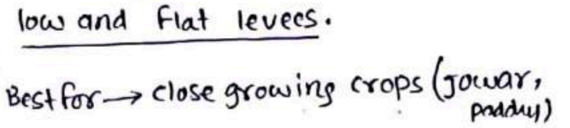
③ Check flooding



• similar to ordinary flooding except that the water is controlled by-surrounding the check area with low and Flat levees.

Best for → close growing crops (Jowar, paddy)
→ deep homogeneous loam or clay soil with medium infiltration rate are Prefered
→ Suit for both less & more permeable soil

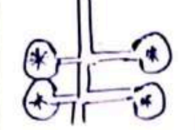
④ Furrow method



• crops are usually grown on the ridges b/w the furrows

• Best for row crops { maize, cotton, potatoes, sugarcane, ground nut, tobacco

(5) Basin flooding



- Best for orchard Tree
- coarse sand not suitable because of more percolation loss

(6) Drip Irrigation method or Trickle Irrigation

- Popular in areas where scarcity of irrigation water and salt problem.
- in This water & fertilizer is slowly and directly applied to the root zone of Plants, to minimize the loss due to evaporation & percolation

Best for row crops and orchards such as tomatoes, grapes, corn, citrus, meson etc.

(7) Sprinkler Irrigation method

- In this, irrigation water is applied to the land in form of spray. ~~through~~ ~~Network of Pipe &~~.
- Used for all crops except rice & Jute. (∵ High water demand)
- suit for all soils except for very heavy soil (soil with low infiltration rate)
- Best suited for very light soil as deep percolation losses are avoided
  { Light soil → These soil drain quickly after rain & watering }
- this method mainly by cultivators of Tea, coffee and vegetables.
- This system is flexible to suit undulating Topography (hence levelling is not necessary)

Best conditions for This method

(I) Topography irregular (undulating)
(II) land gradient steeper & soil easily erodable.
(III) soil excessive permeable
(IV) water table High
(V) when water availability is difficult & scarce

Irrigation water Quality :-

(I) Proportion of sodium ion into cations → ESP, SAR

(i) Exchangable sodium percentage (ESP)

$$ESP = \frac{Na^+}{Na^+ + Mg^{+2} + K^+ + Ca^{+2}}$$

(ii) Sodium adsorption ratio (SAR)

$$SAR = \frac{Na^+}{\sqrt{\left(\frac{Ca^{+2} + Mg^{+2}}{2}\right)}}$$

→ epm (equivalent per million)
मतलब ⇒ mg/lt / (atomic wt/valency)

Category	SAR	Type of water	
S1	0-10	Low sodium water	for all soil & crops
S2	10-18	medium "	Coarse grain soil, organic soil with good Permeability
S3	18-26	High "	Drainage + Leaching (Gypsum)
S4	> 26	very high	not suitable

(II) total conc. of soluble salt → electrical conductivity (EC)

EC (mho/cm) @ 25°C	class	Salinity	Remarks
0 - 250	C1	Low	for all crops
250-750	C2	medium	all crop if Leaching done
750-2250	C3	High	for High salt tolerant plant with special measure to control salinity
> 2250	C4	very high	not for irrigation

(III) Sediment concentration

(IV) conc. of potential toxic element (Boron, selenium) — Boron > 0.3 PPm. if

(V) Bicarbonate Conc.

(VI) Bacterial contamination

Reclamation → Process by which uncultivated land made fit for cultivation.

- Alkaline soil Reclamation → addition of zypsum to soil + Leaching
- Acidic soil reclamation → Use limestone as a soil-amendment

Leaching: in this land flooded with adequate depth of water, The Alkali-salts present in the soil, get disolved in this water which percolate down to join the water table or drained away by surface and subsurface drains, This process known as Leaching.

• This process in repeated till the salts in the top layer of the land are reduced to such extent that some salt-resistant crop can be grown.

Saline soil → land affected by efflorosceme

Alkali salt → injurious → Na_2CO_3, NaCl, Na_2SO_4

Least harmful → NaCl

most " → Na_2CO_3

note:- when Na_2CO_3 is present (सतत Alkaline soil)

∴ add zypsum before Leaching

High salt resistant crop → { fodder, Berrem, Bajra }

Alkaline soil: if efflorosceme continue for long time → Base reaction happens.

if soil clay then due to base rxn → sodiumising clay making it impermeable, illaerated, highly unproductive

Land capability → US beauro of reclamation classification

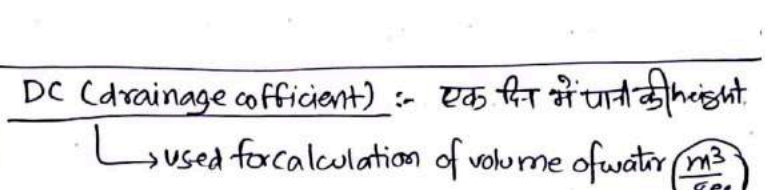
Leaching requirement = $LR = \frac{D_i - C_u}{D_i}$ (C_u → Consumptive use + drain water out; D_i → total irrigation water applied.)

$$LR = \frac{D_d}{D_i} = \frac{D_i - C_u}{D_i} = \frac{(EC)_i}{(EC)_d} = \frac{C_i}{C_d}$$

DC (drainage cofficient) :- एक दिन में पानी की height

└→ used for calculation of volume of water (m^3/sec)

Depth & spacing of Tile drain :-



$$S = \frac{4k}{q}(b^2 - a^2)$$

(b → ज्यादा, a → कम)

(P = 1% of Annual avg. rainfall)

$$q = \left(\frac{P/100}{24 \times 3600}\right)[S \times l]$$ → length of tile drain

'or'

$$q = \{\text{drainage coff.} \times \text{spacing} \times \text{lgh of tile drain}\}$$

$\{0.116\ \frac{m^3}{km^2}\}$ $(12 \times l)$ $S \times l$

Duty (D) :- area of land that can be irrigated by unit volume of irrigation water

'or'

area of land in hectares that can be irrigated if 1 cumec of water is supplied continuously to the land throghout the Base period.

$$D = \frac{8.64\ B(\text{days})}{\Delta(\text{meter})}$$

D ↓ hectare/cumec

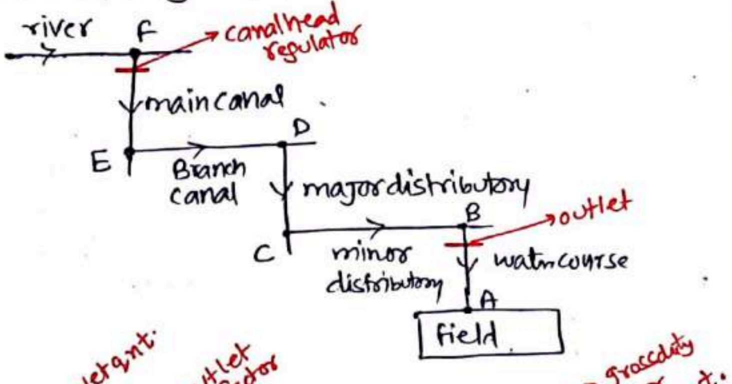
note:- in tank irrigation Duty = ha/M m³

Baseperiod (B) :- time b/w firstwatering to Last watering.
- firstwatering ↓ toprepare land for sowingcrop
- Last watering ↓ beforeits harvesting

note:- cropperiod ⇒ sowing to harvestingtime.

Delta(Δ) :- total Depth of water over the irrigated land req. by crop duringits entire Base period.

note:- as one moves from head of canal to field ⟶ duty increases (मतलब downstream जाने पर duty बढ़ती जाती है)



∴ $D_A > D_B > D_C > D_D > D_E > D_F$
- D_A (Net qnt.) ↓ dutyonfield
- D_B (outlet factor) ↓ dutyat outletpoint of minor or duty at head of fieldchannel/watercourse
- $D_C > D_D > D_E$: Latiral duty or qnt.
- D_F (grossduty or grossqnt.) ↓ duty at head of main canal

factors's affecting duty :-

① type of crop	if qnt of water req. ↑ ∴ D↓
② climate condition	* Temperature : $T \propto \frac{1}{D}$ (loss due to ET↑) * Velocity (wind) $V \propto \frac{1}{D}$ * Humidity $H \propto D$ (loss due to ET↓) * Rainfall : $P \propto D$
③ System of irrigation	Perenial D > Inundation D
④ method of irrigation	furrow D > any other D surfacemethod D < Sprinkler, drip D
⑤ Quality of irrigation water	Salt ↑ ⇒ D↓ ∵ अधिकतर पानी leaching में चला जायेगा
⑥ method of cultivation	Proper Plaugging ∴ D↑
⑦ Time of irrigation and frequency of irrigation	at initial stage more water required hence D↓ later D↑
⑧ Type of soil & subsoil of area throgh which canal passes	
⑨ Base period	B↑ ⇒ more water req. hence D↓
⑩ canal conditions	earthen canal ⇒ D↓ lined canal ⇒ D↑

Season	time	फसल
रबी	oct – march	गेहूं, मटर, चना, सरसों, आलू
खरीफ	Apr – sept	चावल, मूंगफली, कपास, ज्वार
Zaid period	march – June	

Perenial crop (बारहमासी) ⟶ Sugarcane.

Important Term's :-

(I) Commandarea → By a canal system How much area is irrigated.

(II) Gross Command area (GCA) :

CCA + Unculturable area

{Culturable Command area} {Pond, Residence, road, forest}

(III) CCA (Culturable command area) = GCA − Unculturable

→ Culturable cultivated area: Portion of CCA which is actually cultivated during crop season.

→ Culturable uncultivated area → (not cultivated)

(4) Intensity of irrigation :- % of CCA proposed to be irrigated annually.

Ex. if intensity of Irr. for Rabi = 50%.
Kharif = 65%.

∴ yearly Intensity of irr = 50+65 = 115%

(5) Cropratio :- (Rabi-Kharif ratio) ⇒ Ratio of land irrigated during 2 main crop seasons rabi & kharif

$$CR = \frac{\text{CCA under Rabi}}{\text{CCA under Kharif}}$$

(6) paleo irrigation :- watering done prior to sowing of crop.

↳ This is done to prepare the land for sowing and to add sufficient moisture to the soil which would be required for the initial growth of the crop.

(7) $$\text{Time factor (T.F)} = \frac{\text{no. of days canal run}}{\text{Irrigation Period}}$$ $\frac{140}{180}$

$$Q_{design} = \frac{Q}{T.F}$$

(8) $$\text{Capacity factor (CF)} = \frac{\text{MSQ of canal}}{\text{FSQ}}$$

Ex. in kharif if discharge required $= 0.95\,Q_{max}$
hence $CF = 0.95$

(9) cash crops :- encashed in marketting for processing.
{Can not directly consumed by cultivator}
Ex. {जूट, चाय, [redacted], काफी, तम्बाकू}

(10) cropcalender :- tool provides information about planting, sowing, harvesting of locally-adopted crop in an area.

concept : KOR :-

(I) Kor watering :- 1st watering after plants have grown a few centimetres high.

(II) Kor Depth :- Depth of water Applied during This watering (kore watering)

(III) Kor period :- Kor watering must be done in a limited period which is known as kor Period

		Day kore period	Kor depth (cm)
Rember :-	Rice	14 day	19 cm
Imp.	wheat	28 day	14 cm

Irrigation efficiency:

(I) water-conveyance efficiency	$\eta_c = \frac{\text{field water}}{\text{diverted from river into canal}}$ • It accounts for the water losses which occure in conveyance from the point of diversion into the canal system to the field
(II) Application efficiency	$\eta_a = \frac{\text{water stored in root zone}}{\text{field water}}$ • It accounts for the water losses which occures during the application of irrigation water (Ex. surface runoff & deep percolation)
(III) water use efficiency	$\eta_u = \frac{\text{water used benificially including the water req. for Leaching}}{\text{field water}}$
(IV) storage efficiency	$\eta_s = \frac{\text{qnt of water stored in root zone}}{\text{water needed to bring the m.c of soil to field capacity}}$
(V) water distribution efficiency	$\eta_d = \left[1 - \frac{y}{d}\right] \times 100$ $d \rightarrow$ avg. depth of water $\Rightarrow \frac{d_1 + d_2 -- d_n}{n}$ $y \rightarrow$ Avg. numerical Deviation in depth of water $\frac{\lvert d_1 - d\rvert + \lvert d_2 - d\rvert -- \lvert d_n - d\rvert}{n}$
(VI) Consumptive efficiency	$\eta_{ce} = \frac{\text{water use consumptively}}{\text{net amt of water depleted from root zone}}$

irrigation Requirement of crop :-

GIR > FIR > NIR > CIR

- GIR — Gross $\Rightarrow \frac{FIR}{\eta_c}$
- FIR — field $\Rightarrow \frac{NIR}{\eta_a}$
- NIR — Net $\Rightarrow$ CIR + Leaching requirement (LR) + PSR (Presowing requirement) + NWR (nursery water req.)
- CIR — Consumptive $\Rightarrow$ Cu − Re

IR :- amt of irrigation water that is req. to meet the evapotranspiration need of a crop during its full growth.