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Irrigation Engineering

Irrigation

Irrigation is the process of artificial application of water to soil for rising crops.

Need of Irrigation

- → Inadequate rainfall
- → Uneven distribution of rainfall.
- → Crop requirement
- → Non-uniform rainfall
- → Growing perennial crops.
- → Growing number of crops.

Objective of Irrigation

- → ensure enough moisture essential for plant growth.
- → provide crop insurance against short duration drought.
- → Cool the soil & atmosphere to provide to suitable surrounding.
- → Wash out harmful salt, chemicals of the soil.
- → for better crop production.

Function of Irrigation

- → Increasing the output & efficiency of crop production.
- → Growth of crops in absence of sufficient natural precipitation.

Advantages of Irrigation.

- → Increasing the food production.
- → Cultivation of each crops
- → Improvement of ground water storage.
- → Water supply.
- → Flood control.
- → Inland navigation

- → Protection from famine. (भोकमरी)
- → Elimination of mixed croping.
- → Generation of hydropower
- → Afforestation.

Disadvantages of Irrigation

- → Water logging.
- → Damp climate.
- → breeding of mosquitoes.
- → Water pollution.
- → no. of cross drainage structure are required.
- → increase cost of government.

History of Irrigation Development in Nepal

→ First Canal : Chandra canal → Location : Saptari

→ Construction start : 1979 BS

→ Distribution of water start : 1985 BS.

Juddha Canal → Location : Sarlahi → Construction : 1939 – 1942 AD.

Jagadishpur Dam → Location : Kapilbastu → Construction : 1939 – 1942 A

→ First irrigation policy of nepal : 2049 B.S.

→ Latest " " " " : 2070 B.S.

Important point used in irrigation

① Arid Region / Arid zone → The area in which no crops can growth without irrigation is called arid zone.

② semi – arid zone → The area in which some inferior low quality crops can growth without irrigation is called semi – arid zone.

③ saturation capacity → Maximum moisture holding capacity of soil → All air pores (Voids) are displaced with water.

④ Field Capacity → Water content after gravitational water has been removed is known as field capacity

$$\boxed{\text{Field capacity} = \text{Saturation Capacity} - \text{gravity water}}$$

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⑤ Permanent Wilting point → It is that water content at which the plant will die. (i.e, plant can no longer extra sufficient water for its growth)

⑥ optimum moisture content (OMC) → The water content in which crop production is maximum.

⑦ Paleo watering → The first watering before sowing the crops.

⑧ Kor watering → The first watering given to the crops when it has growth in few centimeters. → The first watering after sowing crops

Crops	Kor watering / Kor depth	Kor period	Base period
Rice	19 cm	2–4 Weaks	120 days
Wheat	13.5 cm	3–8 Weaks	120 days
Sugarcane	16.5 cm	—	330 days

⑨ Root zone depth → Maximum depth of soil strata in which crops spread its root system & derives water from soil.

Crops	Root zone depth (cm)
Rice	90
Maize	100
Wheat	100
Potato	60
Banana	90
Tobacco	80
Sugarcane	150
cotton	140

Note

p^H value of irrigation water = 6 to 8.5

p^H value of drinking water = 6 to 8.5

⑩ Available moisture

Available moisture content = field capacity – wilting point.

⑪ overlap allowance

→ Extend of water to be supplied for maturing a particular crops which extend from one seasons to other seasons is called overlap allowance.

Factor affecting crop water requirement

- → climate.
- → effective Rainfall.
- → Types of soil.
- → Base & crop period
- → canal condition.
- → Cultivation method.
- → Types of crops.
- → Method of irrigation

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Irrigation Water Requirement

① **Consumptive Use (C_u)** The amount of water utilized by the plant in transpiration & evaporation from adjacent soils of plant leaves is called Consumptive use. → This is also called evapotranspiration.

② **Effective Rainfall (Re)** Rainfall during the growing period of the crop that is available to meet water requirement of crop is effective rainfall.

③ **Land preparation & Leaching Water Requirement (LP, Le)** Before seeding (बिज डलें) & transplanting (रोपने) certain crops some additional water is required, this is called land preparation water requirement. Also some more water may be needed in certain soil to remove harmful salts, this amount of water required is called leaching.

→ $\boxed{IWR = CWR + Losses}$

④ **Irrigation Water Requirement** The amount of water that is to be supplied by irrigation for fulfilling the water requirements of crops is called irrigation water requirement.

→ **Crop Water Requirement** How much water is required to crops.

→ **Irrigation Water Requirement** How much water is supplied by irrigation

⑤ **Consumptive Irrigation Requirement** The amount of water to be supplied through irrigation to meet the consumptive use demand of crops is called CIR. ∴ $\boxed{CIR = C_u - Re}$

⑥ **Net Irrigation Requirement** The amount of water to be supplied at the root zone to meet water requirement of crops is called NIR. ∴ $\boxed{NIR = CIR - L.p \,\&\, Le}$

⑦ **Field Irrigation Requirement** The amount of water required to be supplied to the field to meet water requirements of the crop is called FIR. ∴ $\boxed{FIR = NIR + \text{Water application losses}}$

Also, $\boxed{FIR = \frac{NIR}{\eta_a}}$ Where; η_a = Water application efficiency

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⑧ Gross Irrigation Requirements The amount of water to be supplied from the Canal outlet to meet water requirements of crops is called GIR. ∴ $\boxed{GIR = FIR + \text{Conveyance loss}}$

Also, $\boxed{GIR = \frac{FIR}{\eta_c}}$ Where: η_c = Water Conveyance efficiency.

Crop seasons & principal crops.

① Kharif Crops	② Rabi Crops
→ Crops which are sown at the beginning of shouth west mansoon/ summer seasons.	→ Crops which are sown at the winter/non-mansoon seasons.
→ Start from 1st april to 30th september.	→ Start from 1st october to 31st march.
→ Example; Rice, maize, groundnut (मक्का), Cotton, bajra, jowar	→ Example; Wheat, potato, mustard. barley (जौ), tobacoo,
→ Also Called Summer crops.	→ Also called winter Crops
→ Consume more Water.	→ Consume less Water

③ perennial Crops → Base period lies in both Kharif & rabi seasons.

→ Example; Sugercane & Garden Crops. ④ Eight month Crop Cotton

Crop period Time period betn the Sower & harvesting of crops.

Base period Time period betn the first watering of Crop at the time of Sower to last watering before harvesting.

Note; ① Generally; Crop period > Base period

② practically; both are taken as same thing.

③ Both are expressed in days.

$$\text{Crop Ratio} = \frac{\text{Area irrigated in rabi season}}{\text{Area irrigated in Kharif season}}$$

Duty

→ Duty of water is defined as the area of land in hectares that can be irrigated by constant supplying $1 m^3/sec$ of water throughout the base period.

→ Mathematically; $\boxed{\text{Duty } (D) = \frac{A}{Q}} = \frac{ha}{m^3/s} = \frac{ha}{\text{cumecs}}$

Note : 1 hector = $10{,}000 m^2 = 1 \times 10^4 m^2$.

Factor Affecting of duty

① Climate → Tempr → wind velocity → Humidity → Atm. pressu

② Types of soil

③ Types of crop

④ Topography

⑤ Method of irrigation

⑥ Canal Condition.

⑦ Base period of crop.

Note : Duty is maximum on the field.

→ The duty at outlet point (i.e at head of water course canal) is called as outlet duty or outlet factor.

Delta

→ The total depth of water required by a crop throughout its base period to attain full maturity is called delta.

→ It is generally measured in cm & m. → Symbol : Δ

Crops	Delta on field
① sugarcane	120 cm
② Rice	120 cm
③ Tobacco	75 cm
④ Garden fruits	60 cm
⑤ Cotton	50 cm
⑥ Mustard	45 cm
⑦ Wheat	40 cm
⑧ maize	25 cm

Crops	Delta on field
⑨ Vegetables	4-5 cm
⑩ Barley	30 cm
⑪ fooder	22.5 cm
⑫ peas	15 cm

Relationship Between Duty, Delta & Base period.

Let $1\ m^3/sec$ water can irrigate D hectares land throughout the base period B. & Water requirement of crop is Δ meters.

Now, D = Duty in ha/m³/sec

B = Base period in days

Δ = Total depth of water supplied in meter

$$\text{Discharge } (Q) = \frac{\text{Volume}}{\text{time}} = \frac{m^3}{sec}$$

$$A = \text{Area} = 1 \text{ hector} = 10{,}000\ m^2 = 1\times10^4 \times D m^2$$

∴ Volume of water applied to the Crop for base period B day

$$\text{Volume } (V) = \text{Discharge} \times \text{Time}$$

$$= 1\ m^3/sec \times 1 \text{ days}$$

$$= 1 \cdot \frac{m^3}{\cancel{sec}} \times 24\times60\times60\ \cancel{sec}$$

$$= 86400\ m^3 \#$$

$$\therefore\ V = 86400 \times B \text{ ——— } ①$$

$$\text{Depth of water applied in B days} = \frac{\text{Volume}(V)}{\text{Area }(A)} = \frac{86400B}{1\times10^4}$$

$$\therefore\ \boxed{\Delta = \frac{8.64B}{\Delta}}\quad \Delta \text{ in m.}$$

In Conclusion :- $\boxed{\Delta = \frac{864B}{\Delta}}$ Δ in cm.

Note : if base period increase, duty increase.
if delta increase, duty decrease.

Methods of Irrigation

① **Surface Irrigation** : Irrigation water applied & distributed over the soil surface either by gravity or by pumping.

② Sub-surface Irrigation

③ Sprinkler Irrigation

④ Lift Irrigation

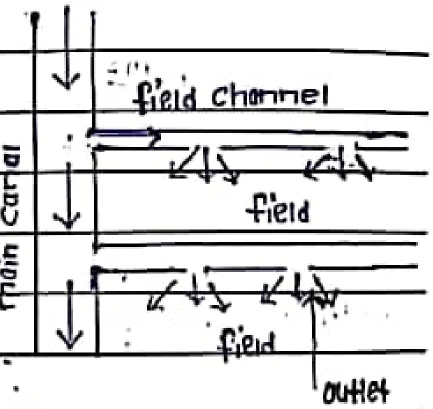
① Surface Irrigation

↓ Flooding Method ↓ Furrow method ↓ Contour Farming

Flooding Method ↓ Wild flooding ↓ Control flooding

Control flooding ↓ Free flooding ↓ Border strip flooding ↓ Check flooding ↓ Basin flooding

ⓐ free flooding



→ Land is divided into several plots.

→ Water is supplied at higher level & cut off at lower end.

→ Water is applied to field without any control structure (border or levees आदि).

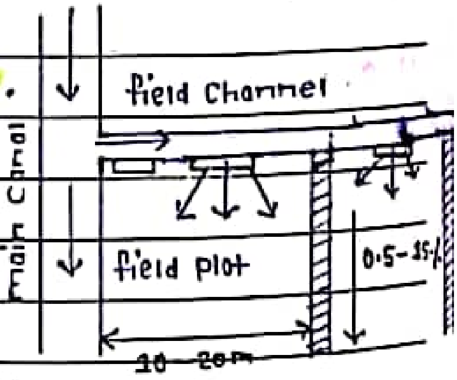
→ Also called wild flooding.

→ Suitable, if irrigation water is inexpensive.

→ In this method, quantity of water is high. → on rolling land

→ The application efficiency is low. → suitable for flat leveled land.

ⓑ Border strip flooding



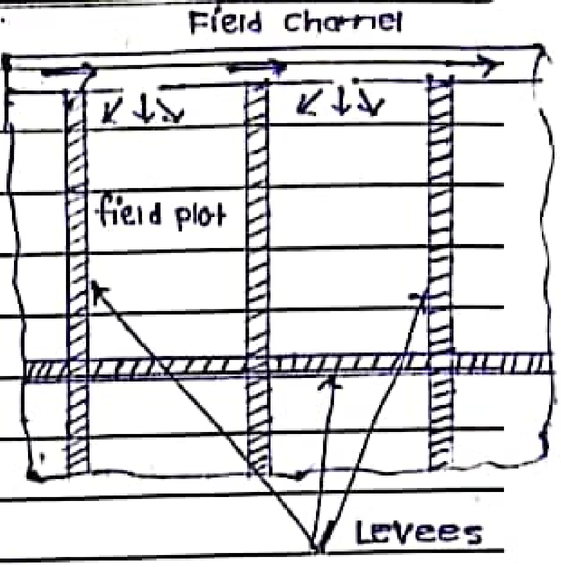
→ Land divided into a number of strips. by the low levees called borders.

→ Length = 100 - 400m.

→ width = 10 - 20m.

→ slope = 0.5 - 15 %.

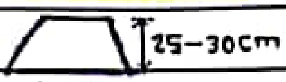
→ Discharge = $0.015\ m^3/sec$ to $0.3\ m^3/sec$.



© Check Flooding.

→ Similar to border strip flooding but water controlled by surrounding levees.

→ All levees are connected with cross levees.



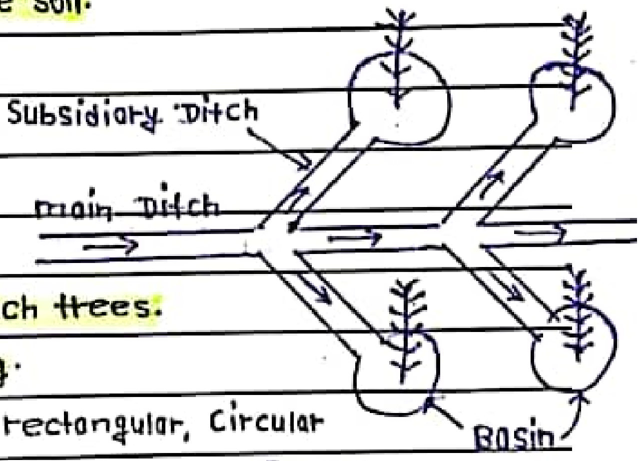
→ Levees, ~~(Check)~~ wide = 2 to 3 m

height = 25 – 30 cm

→ Applied in level ground.

→ most suitable for permeable soil.

ⓓ Basin Flooding



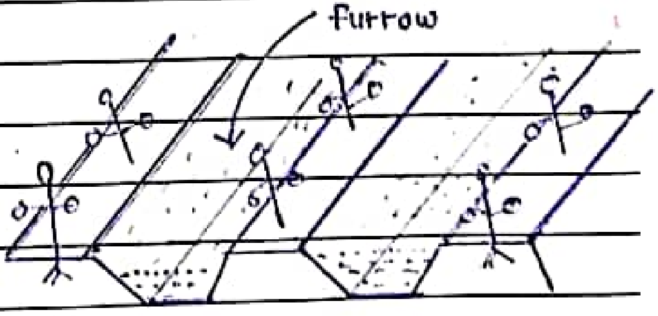
→ Irrigation water is applied for orchard (बगीचा) trees/garden Parks etc.

→ Water basin are formed for each trees.

→ special type of check flooding.

→ shape of basin can be, square, rectangular, circular or may be irregular.

Furrow Method



→ Furrows are series of long narrow channel in betⁿ rows of plants to be irrigated.

→ Water is applied only in furrow not in entire surface area.

→ water reaches the roots of plants by percolation methods.

→ suitable for crops may get injured due to contact with water.

→ For example; cauliflower, potato etc.

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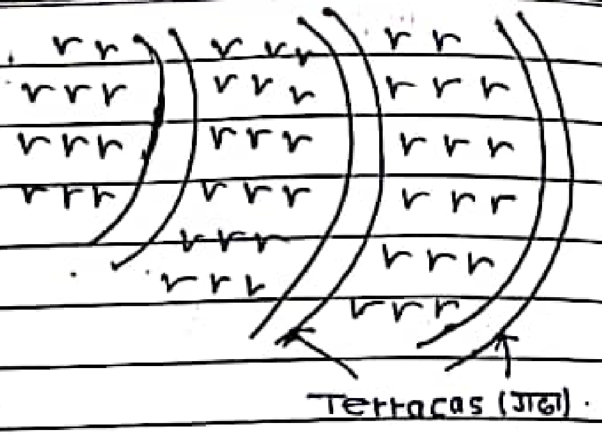
Contour Forming



② sub- surface Irrigation

① Natural sub-surface irrigation
→ Leakage from Pond, lake, river etc.

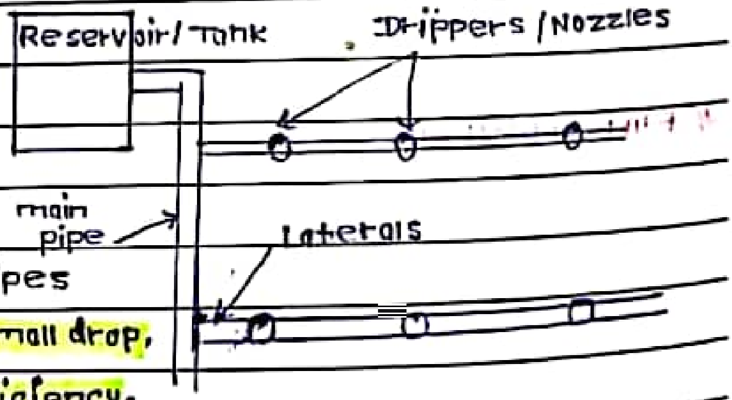
② Artificial sub-surface irrigation
→ Water is supplied beneath the land surface through pipe networking.

③ Drip/ Trickle irrigation

Sub-surface Irrigation : In sub-surface irrigation water is applied to the crops directly at the root zone of the crops. Water is not applied from surface & it is applied below ground surface. this method costly & difficult.

Drip Irrigation

→ Irrigation water is directly applied to the root zone of crops with the help of Network of pipes & nozzles, form of small drop,



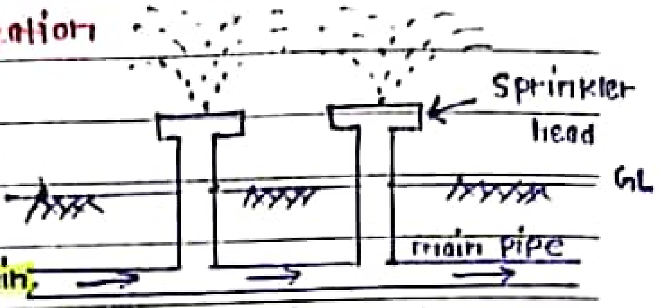
→ High application efficiency.

→ less evapo-transpiration losses, Percolation losses.

→ High cost of installation, operation & maintenance.

Note: minimum height of soil above the network pipes for artificial sub-surface irrigation. = 40 cm

③ Sprinkler Irrigation



→ Application of pumps.

→ Water is applied to the land in the form of spray.

→ It is also known as artificial rain.

→ upper most part of the sprinkler irrigation is rotating head.

→ Applied where topography is undulating, irregular. → Shallow roots

→ Applied where quantity of water is not sufficient to carry. surfac irrigation. → Applied where land gradient is steeper. → h [illegible]

Note : General pressure in rotating head = 1·4 — 2·1 kg/cm².

Advantages & Disadvantages of Irrigation Methods

Surface Irrigation

Advantages	Disadvantages
→ No Control over Water.	→ No Control over water.
→ Initial cost is less.	→ Wastage of water.
→ Not required skill manpower.	→ Chances of water logging.
→ Not required high technology.	→ Crop suffer from water.
→ Very easy to supervise.	→ chance of erosion of soil.

Sub-surface Irrigation

→ No wastage of water.	→ Initial cost is more.
→ Control over water.	→ Required skilled manpower.
→ chance of erosion of soil is less	→ Required high technology.
→ chance of destruction is less	→ Very difficult to supervise.
→ Fertilizer mixed with water.	→ Chance of Clogging nozzles.

Sprinkler Irrigation

→ Eliminated the seepage losses.	→ High initial cost.
→ Land levelling is not required.	→ Effect of wind.
→ Saving water & labor.	→ Require electrical power.
→ Efficient use of land.	→ Abrasion & Clogging of nozzles.
→ Frost & climatic control.	→ Frequent supervision required.

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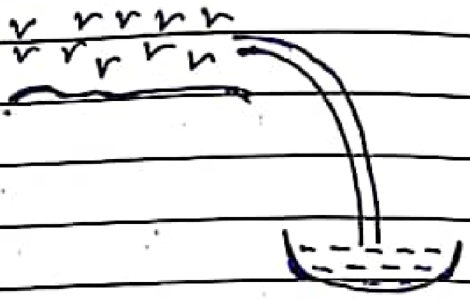
④ Lift Irrigation

→ The method of irrigation the field with lifting water from the available source at low level.



Canal & Canal Design

Canal Canal is the artificial open conduit either lined or unlined which is used to convey water.

Types of Canal

[A] Based on the nature of source.

① Permanent Canal / Perennial Canal

→ Runs throughout the year.

→ Consists of permanent diversion structures.

② Inundation Canal / Non-perennial Canal

→ Runs only in monsoon seasons.

→ Does not consists of permanent diversion structures.

→ Water is available only during the flood periods.

[B] Based on the Financial output

① Protective Canal

→ protection from famine. → Make the government.
(अनिकाल)

② Productive Canal

→ Generate revenue. → Make private Company.

[C] Based on the type of soil

① Alluvial Canal → Canal passes through alluvial soil.

② Non-alluvial Canal → Canal passes through rocky plains.

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[D] Based on Function

① Irrigation canal: Constructed to supply water for irrigation.

② power canal: Constructed for hydropower generation.

③ Feeder canal: Constructed to feed two or more other Canals.

④ Navigation Canal: Constructed for water transportation.

⑤ Drainage Canal: Excavated to drain water of water logged area.

[E] Based on lining.

① Unlined canal

② Lined Canal

[F] Based on Discharge

① Main Canal

→ Takes off water directly from river or reservoir, or headwork.

→ It carries water in large amount to feed the branch & distributary canals.

→ Very high discharge > 30 m^3/sec (30 Cumes)

→ usually no direct irrigation.

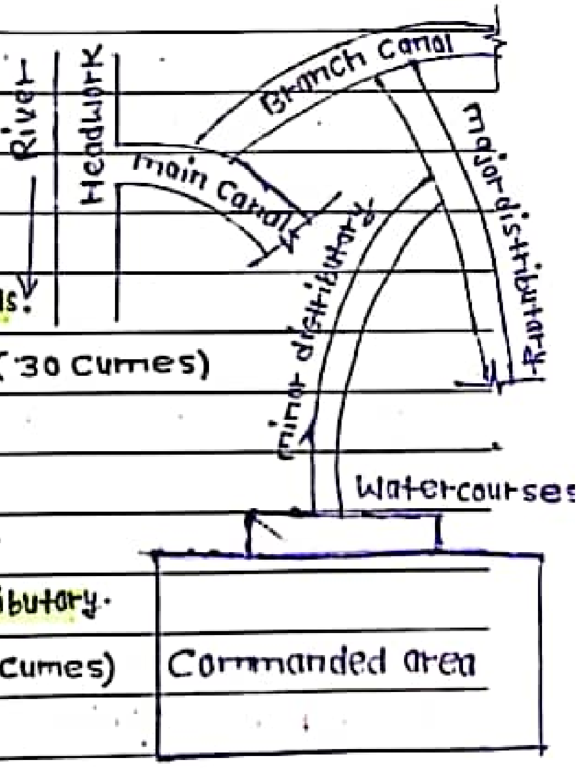
② Branch Canal

→ Takes off water from main Canal.

→ Supply water to major & minor distributory.

→ Discharge > 5 m^3/sec. (5 – 30 Cumes)

→ no direct irrigation.



③ Major Distributary.

→ Takes off water from branch Canal & Sometime also from main Cana

→ Supply water to minor distribuatry, Watercourses & field Channel.

→ Discharge : 0.25 – 5 m^3/sec. → Generally, used for direct irrigation

④ Minor Distributory

→ Takes of water from major distributary & Sometime also from branch Canal

→ Supply water to field channels | Watercourses.

→ Discharge < 0.25 m^3/s.

⑤ Water-courses / Field Channels

→ Small channels excavated by cultivators in irrigation field.

→ These channels fed by distributary & branch canal.

→ Irrigated to field.

⑥ Based on Canal alignment

Canal Alignment The center line of canal is known as canal alignment. → Canal alignment should be shortest as possible. → Cross drainage structure & religious areas should be avoided from canal alignment.

Types of Canal Alignment

① Contour Canal

→ Canal is aligned roughly parallel to contour line of area.

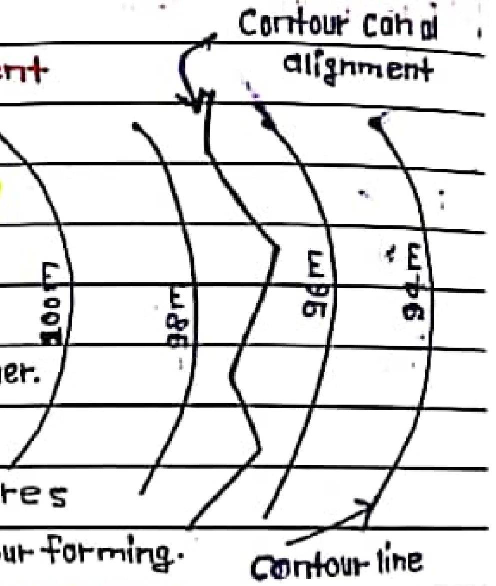
→ Irrigation is done only one side of canal. because other side higher.

→ Mostly used in hilly area.

→ Various cross-drainage structures are required. → Suitable for contour forming.

→ sometime it is called single bank canal.

→ They are aligned generally when canals take off from river.



② Watershed Canal / Ridge Canal

→ Canal is aligned along ridge line.

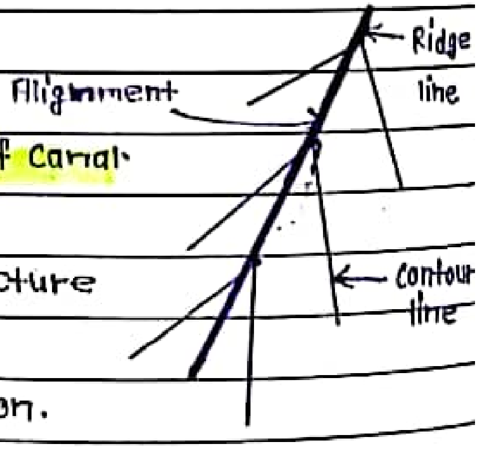
→ Irrigation is done on both side of canal.

→ It is suitable for plain area.

→ minimum cross drainage structure are required.

→ It is mostely used in irrigation.

→ Best canal alignment.



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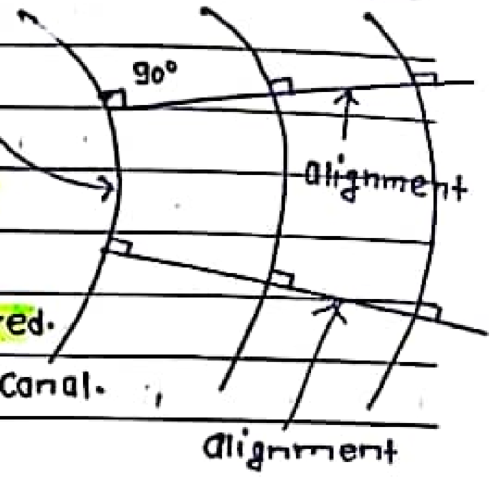
③ side slope canal



- → canal is aligned at right angle to the contour line.
- → The canal runs roughly parallel to the natural drainage.
- → cross-drainage work are not required.
- → Irrigation is done on both side of canal.
- → Double bank canal.

Components of Canal Networks

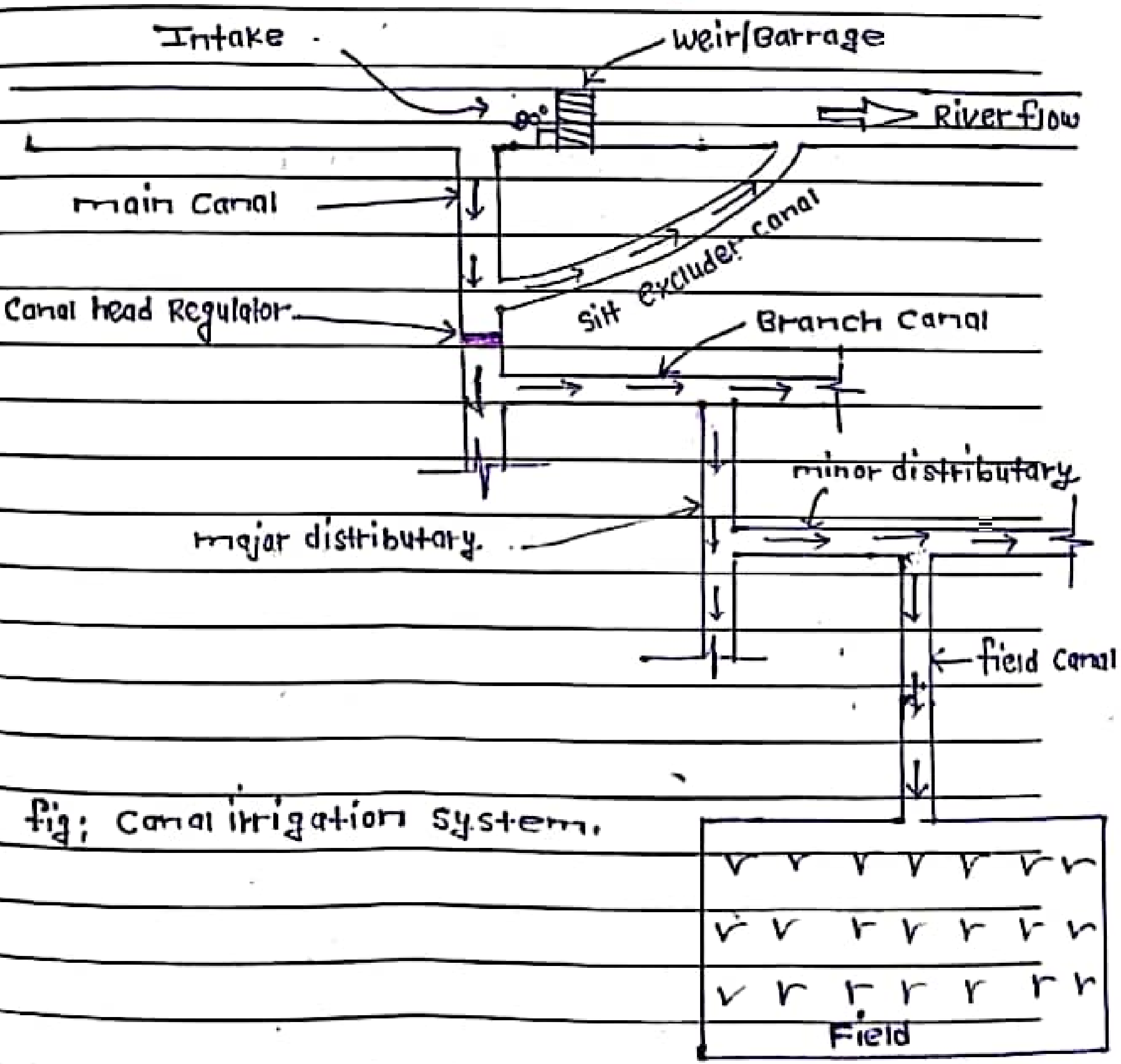


fig: Canal irrigation system.

Head Works

The hydraulic structures constructed at the head of canal to divert required amount of silt free water to store & divert water are called headworks.

Types of Head Works

① Diversion Headworks

→ It serves to divert the required supply into the canal from river.

② Storage Headworks

→ It stores water during the period of excess supply in the river & released it when demand overtakes the supply

Function of Diversion Headworks

→ To divert the river water into canal.

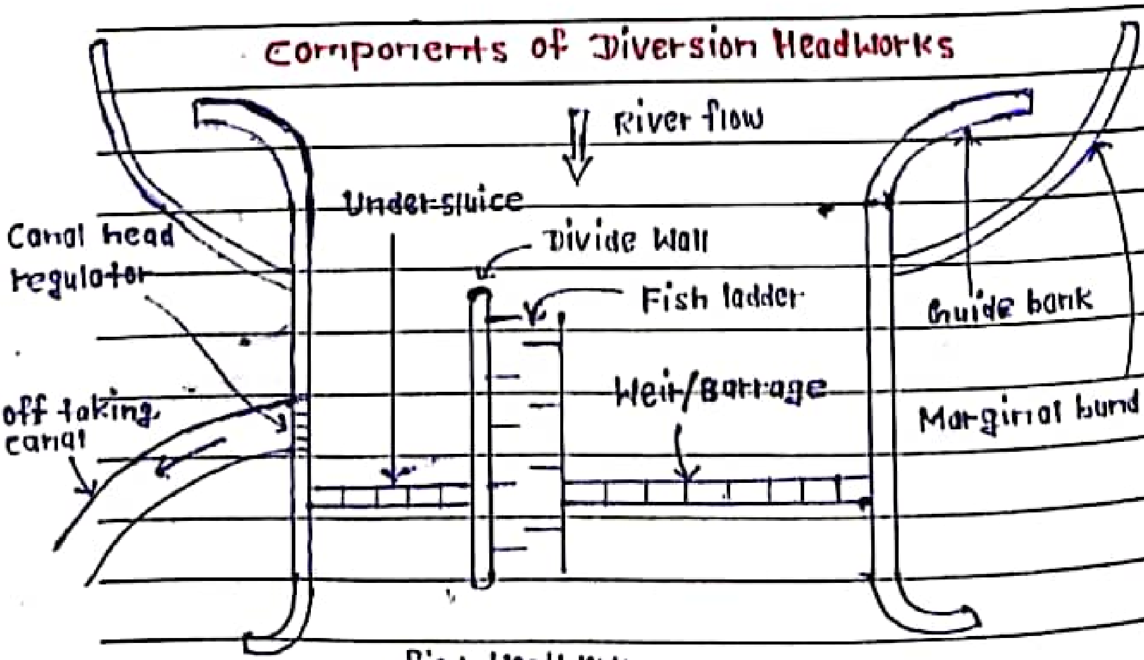
→ To rise the water level.

→ To withdraw required amount of water from river.

→ To control the silt entry into the canal.

→ To pass the flood.

Components of Diversion Headworks

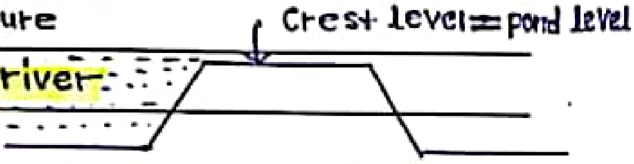


fig; HeadWork

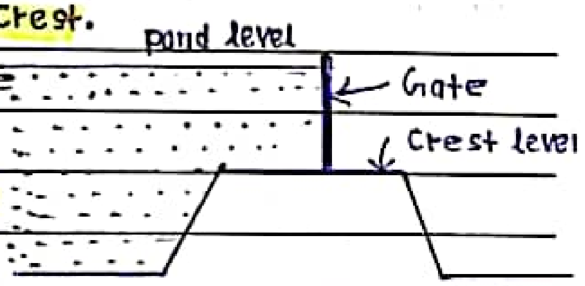
① Weir & Barrage.

Weir	Barrage
→ Higher crest level.	→ Lower crest level.
→ Not consists of gates.	→ Consists of gates.
→ The primary purpose is not control flood.	→ The primary purpose is Control flood.
→ They are used where sediments are relatively smaller in size.	→ They are used where sediments are relatively larger in size.
→ Cost of construction is low.	→ Cost of construction is high.
→ Silting in upstream is high.	→ Silting in upstream is low.
→ It can't connected with the roadway.	→ It can be connected with the roadway (Koshi barrage)

Weir : It is a solid barrier structure constructed transverse to the river flow in which the ponding of water achieved mainly by the raised crest.



Barrage : It is a hydraulic structure constructed transverse to the river flow in which the ponding of water achieved mainly by the gates.



Note : An ideal case, Angle betn intake & barrage = 90°

→ But, best favourable, " " " " " = 110° (practically used)

② Canal head regulator –

→ A structure which is constructed at the head of the canal to regulate the flow of water into the canal is known as canal regulator.

→ Consists of gates

→ To maintains flow & water level in canal.

Functions of canal head regulator.

→ It regulates the supply of water entering the canal.
→ It controls the entry of silt into the canal.
→ It prevents the river-floods from entering the canal.

③ Divide Wall

The divide wall is the concrete or masonry wall which is constructed perpendicular to the weir axis & which separates weir portion & undersluice portion.

Functions of Divide Wall.

→ Separates the undersluices from weir proper.
→ Create a still pocket near the canal head regulator.
→ To control cross current in front of canal head.
→ Increase the effectiveness of the undersluice portion.

④ Undersluice

Undersluice is the part of the diversion structure which is mainly constructed to flush the sediment deposited near the head regulator.

⑤ Fish ladder

Fish ladder is constructed to allow the movement of fish along the river or U/s or d/s around the weirs.
→ Fish move U/s to D/s in winter & D/s to U/s in summer.
→ Main principle of ladder is to reduce velocity.

Note : Fish can not travel in opposite direction if the velocity of water is greater then 0.3 m/sec.

⑥ Silt control Devices : Control the silt entry in canal.

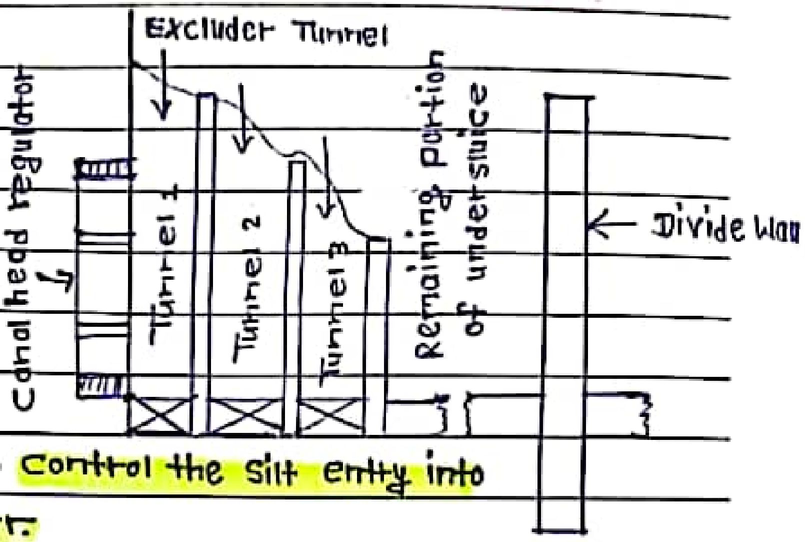
Two types

ⓐ Silt excluder

→ It is the structures provided in the river bed & upstream of head regulator.

→ The main purpose of silt excluder is to control the silt entry into the canal from river.

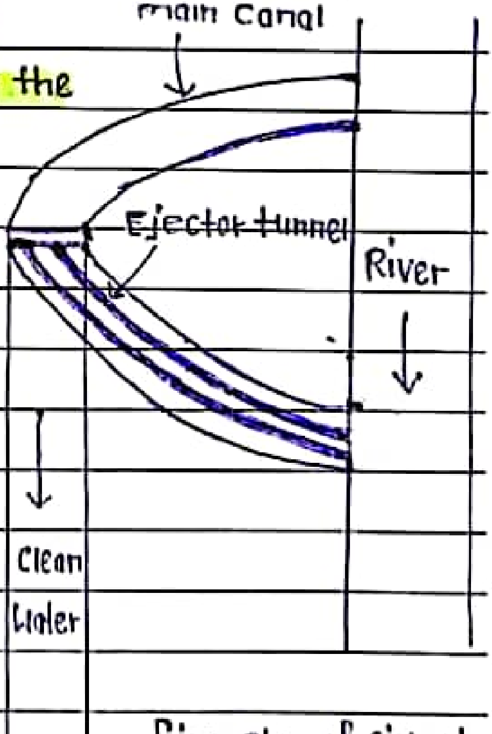
→ parallel tunnel along the river length.



fig; plan of silt excluder Tunnels

ⓑ Silt ejector or Silt extractors

→ It is the structure provided in the canal bed & downstream of head regulator.



fig; plan of silt ejector

⑦ River training structures

River training structure are required at the headwork side to avoid the change in path of river, to make river water flow in specific path, to save river banks from cutting & many other purpose.

ⓐ Marginal bunds/Embankments

→ Embankment constructed along the river.

→ It is constructed roughly parallel to the river.

→ It is also called dyke or levees.

ⓑ Guide bank

→ It is also known as bell's bund.

→ It is provided to guide the river water flow in a specified path.

ⓒ Spurs / Groynes

→ Spurs are provided to avoid cutting of the river bank due to flood.

Canal Standards (Cross section of an irrigation canal)

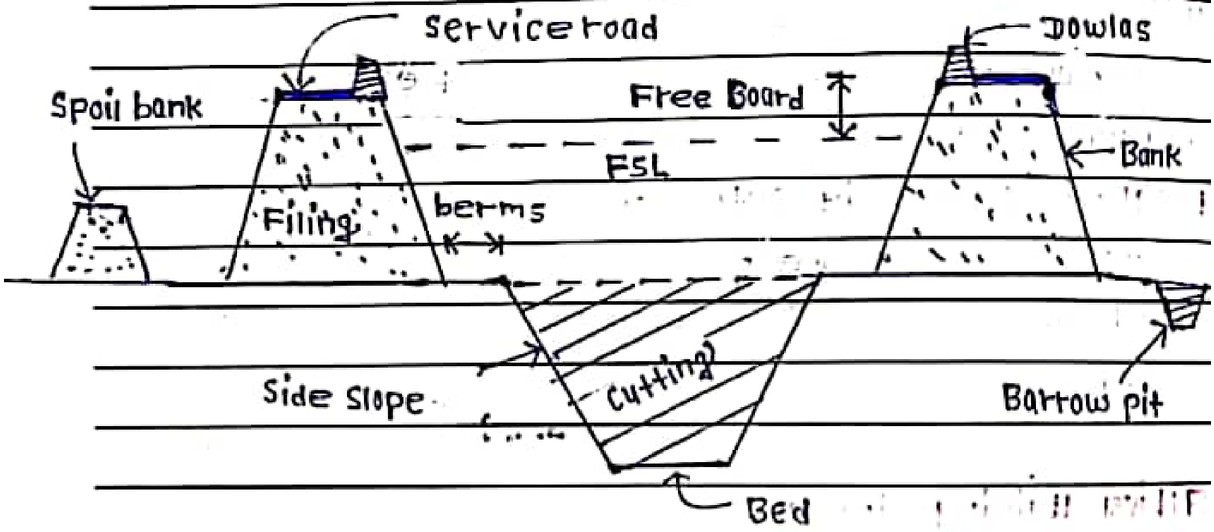


Fig: Typical Cross-section of Canal.

① Berms

→ Horizontal distance of land between inner toe of bank to top edge of cutting is called berms.

→ It provides additional strength to bank.

→ It protect banks from erosion.

→ It help in providing wider water.

Note : Minimum width of berms = 0.6 m

② Free Board

→ Vertical distance between F.S.L (full supply level) & top of bank is called free board.

→ It depends size of channel.

→ Free board is depends on discharge.

Discharge (m^3/s)	Free Board (m)
<0.3	0.3 (minor)
0.3 – 1	0.4
1 – 5	0.5 (major)
5 – 10	0.6 (branch canal)
10 – 30	0.9

Note: Minimum value of free board in canal = 0.9m

③ Banks

→ primary purpose of banks is to retain water.

④ service Roads

→ provided for the inspection purpose & communication.

→ They provided above FSL of the channel.

⑤ Dowlas

→ measure of safety in driving. → provided above inspection road.

→ Generally, height = 0.3m & Wide = 0.6m at the top.

⑥ side slope

→ side slope in cutting is slightly more then side slope in filling.

→ Side slope in cutting = 1H : 1V to 1.5H

→ side slope in filling = 1.5H : 1V to 2H : 1V

⑦ spoil banks

→ if volume of cutting is more then volume of filling, the extra earth is disposed normally parallel to Canal on the edge of embankment which is known as spoil bank.

⑧ Borrow pit

→ if volume of earthwork in filling is more then volume of cutting, the extra earth taken from borrow pit.

→ Width ≤ $\frac{1}{2}$ width of canal. → Depth $\not>$ 1m.

→ provided along center line of canal. ⇒ Internal borrow pit

→ provided outside the canal. ⇒ External borrow pit.

⑨ Balancing depth

→ if volume of cutting is equal to volume of filling, this depth is considered as balancing depth.

→ It is also known as economical depth.

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Lining of Canals

→ Laying of hard surface around the Canal Cross-section.

→ prevent erosion of bed & side slope of canal due to high velocity of water.

Canal lining Materials

① Hard surface lining

→ cement & concrete lining. → plaster lining

→ brick & tile lining. → Boulder lining.

② Earth type lining

→ Compact earth lining. → Soil Cement lining.

Advantages of Lining

→ seepage control.

→ prevention of water-logging.

→ Increase in channel capacity.

→ Increase in command area.

→ Reduction in maintenance cost.

→ Elimination of flood dangers.

According to PDSP (planning & design strengthening project)

Lining type	Maximum velocity (m/s)	
Dry stone	1.0	
Dry brick	1.0	
Dressed masonry	2.0	
Brick	1.5	
Random Rubble	1.5	
Unreinforced Concrete	2.5	
Shortcrete.	2.5	

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According to the book "Irrigation engineering & hydraulic structure by. S.K. Gerg.

Type of lining	Permissible Velocity (m/sec)
cement concrete lining	1.0 to 2.5
Burnt Clay tile lining	1.8
Boulder lining	1.5

For unlined Canal Section

Type of soil	Permissible Velocity (m/sec)
Light loose sand to average sandy soil	0.3 – 0.6
sandy loam, black cotton soil, ordinary soil	0.6 – 0.9
Mooram, Hard soil etc.	1.0 – 1.1
ordinary soils.	0.6 – 0.9
Rock & gravel	1.5

Design of Irrigation Canals

For design of irrigation canal, the method / formula used for design depends on type of canal, i.e, lined or unlined. The common formula used for design of irrigation canal are; Manning's formula, Chezy's formula & Kutter's formula.

[A] Design of Non-alluvial Canal

① Manning's Formula

→ This is most commonly used formula for canal design.

→ Discharge $\boxed{(Q) = A \times \frac{1}{n} R^{2/3} S^{1/2}}$

Where; A = flow area

n = manning's roughness constant = manning's rugosity coefficient.

R = Hydraulic mean radius $= \frac{\text{Area}}{\text{Wetted perimeter}}$

S = Longitudinal slope or bed slope

$\boxed{V = \text{Velocity} = \frac{1}{n} R^{2/3} . S^{1/2}}$

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② Chezy's Formula

→ Dischave(Q) = $A \times C\sqrt{RS}$

Where ; A = flow area
C = Chezy's Constant
R = Hydroulic mean radius
S = Channel bed slope.

V = Velocity of flow = $C\sqrt{RS}$

③ Kutter's Formula

→ $Q = A \times V$ →

$$Q = A \times \overbrace{\left(\frac{\frac{1}{n} + 23 + 0.00155}{1 + \left(23 + \frac{0.00155}{S} \right) \times \frac{n}{\sqrt{R}}} \right)}^{C} \times \sqrt{RS}$$

Where ; n = Kutter's rugosity coefficient.

④ Bazin's Formula

→ $Q = A \times V$ →

$$Q = A \times \overbrace{\left(\frac{157.6}{1.81 + \frac{m}{\sqrt{R}}} \right)}^{C} \times \sqrt{RS}$$

Where ; m = Bazin's Constant

Value of Rugosity Coefficient

Very good	Good	Low	poor
0.0225	0.025	0.0275	0.03

Rugosity Coefficient of different materials

Wood	0.011 – 0.013
Concrete	0.012 – 0.022
Asphalt	0.013 – 0.016
Brick	0.014 – 0.017
Gravel	0.017 – 0.033

B Design of Alluvial Canal

Kennedy's Theory	Lacey's Theory
→ Vertical eddies which generated from the bed of channel only.	→ Vertical eddies which generated from the bed & side of channel.
→ Introduced Critical Velocity ratio (m) = $\frac{V_0}{V}$ $\boxed{V_0 = 0.55mD^{0.64}}$	→ Introduced Silt factor $\boxed{f = 1.76\sqrt{m_r}}$
→ Not give bed slope formula.	→ Give bed slope formula
→ Kutter formula use for finding mean velocity.	→ own formula use for finding mean velocity.
→ Regime channel.	→ True, initial, final regime.
→ Design is based on trial & error method.	→ Does not involve trial & error method.

Drawbacks in Kennedy's Theory.

- → Silt grade & silt charge were not defined.
- → Kennedy's not give any slope equation.
- → He aimed to findout only regime condition.
- → Kennedy's use Kutter's eqn for determination of mean velocity.
- → Design by trial & error method.
- → Only applicable to irrigation channel.

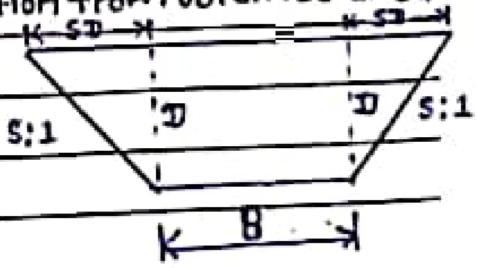
Design procedure by Kennedy's Theory

① Assume suitable depth of canal.

② Determine the critical velocity $\boxed{(V_0) = 0.55mD^{0.64}}$

③ Determine the area $\boxed{(A) = \frac{\text{Discharge }(Q)}{\text{Velocity }(V)}}$

④ Determine the channel cross section from obtained area.



$$\boxed{A = BD + SD^2}$$

$$\boxed{P = B + D\sqrt{5}}$$

⑤ Determine hydraulic mean radius

$$\boxed{R = \frac{A}{P}}$$

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⑥ Calculate actual mean velocity (V), by kutter's formula etc.

⑦ $V_0 = V$ OK, otherwise assumed depth again & Repeat.

Design procedure by Lacey's Theory

① Determine silt factor. $f = 1.76\sqrt{m_r}$

② Determine the Velocity. $V = \left(\frac{qf^2}{140}\right)^{1/6}$

③ Determine the area of channel section. $A = \frac{Q}{V}$

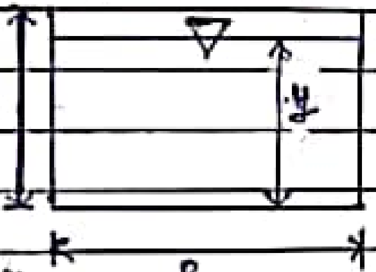
④ Determine Wetted perimeter. $P = 4.75\sqrt{Q}$

⑤ Determine hydraulic mean depth. $R = \frac{5}{2}\left(\frac{V^2}{f}\right)$

⑥ Determine bed slope, $S = \frac{f^{5/3}}{3340\,Q^{1/6}}$

Geometric Parameters for Different Canal Sections.

① Rectangular section



→ Area $A = B \times y$

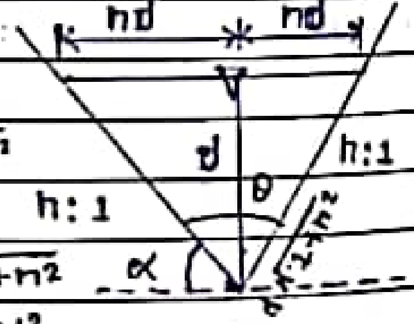
→ Wetted perimeter $P = B + 2y$

→ Top Width $T = B$

→ Hydraulic mean Radius $R = \frac{A}{P} = \frac{By}{B+2y}$

→

② Triangular channel



→ Area $A = \cancel{2} \times \frac{1}{\cancel{2}} nd^2 = nd^2$

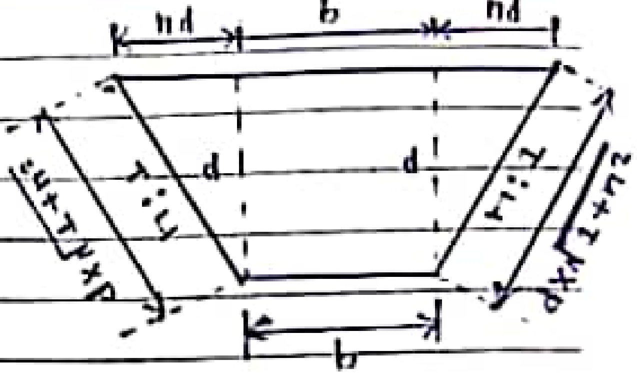
→ Wetted perimeter $P = 2 \times d \times \sqrt{1+n^2}$

→ Top Width: $T = 2 \times nd$

→ Side slope $= \sqrt{d^2+(nd)^2} = d \times \sqrt{1+n^2}$

→ Hydraulic mean Radius $R = \frac{A}{P} = \frac{nd^2}{2d\sqrt{1+n^2}}$

③ Trapezoidal Channel



→ $A = bd + nd^2$

→ $P = b + 2d\sqrt{1+n^2}$

→ $T = b + 2nd$

→ $R = \frac{A}{P} = \frac{bd+nd^2}{b+2d\sqrt{1+n^2}}$

Economic Canal section

→ The Wetted perimeter is minimum.

→ For given discharge, this canal has mininum Cross-sectional area

→ for given Cross-sectional area, this Canal has max^m discharge capacity

① Economic Rectangular section

→ $A = 2y^2$ → $P = 4y$ → $R = y/2$ → $D = B/2$

② Economic Triangular section

→ $n = 1$, → $\alpha = 45°$ → $\theta = 90°$ → $R = \frac{d}{2\sqrt{2}}$

③ Economic Trapezoidal Section

→ Top Width = 2× side slope length → $R = y/2$ → side slope = 60°

④ Economic circular section

→ flow depth = 0.95× diameter

→ Hydraulic mean depth = 0.29× diameter

→ Angle with center = 5.37 radians = 308 degrees

Canal Losses

① Evaporation Loss ② Transpiration Loss ③ Seepage Loss

ⓐ percolation ⓑ Absorption

① Evaporation Loss

→ Small percentage of total loss in canal.

→ 1–2 %. (maximum 7 % in summer)

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② Transpiration Loss

→ Loss of Water through the plants, Vegetation & Weeds. (निराना)

→ Control by keeping the banks clean from the growth of Vegetation & Weeds.

③ Seepage Loss

→ major portion of loss in an unlined Canal.

④ Percolation

→ if Water table is close to the Channel bed, flow of Water to Water table from Canal bed.

⑤ Absorption

→ if Water table is at a greater depth from Channel bed, the water seeping from the Channel is unable to reach the ground water reservoir, but saturation is formed round the channel section.

Types of Maintenance of Canal

① Routine or regular or normal maintenance

→ Normally done annually.

→ Generally two times before rabi & kharif Crop.

→ Maintenance of intake, operational gate, removal of Weeds, rodents & debris.

② Deferred maintenance

→ Including any Work necessary to regain the lost flow Capacity in Canals, reservoirs & Structure when Compared to the orginal design.

③ Special maintenance

→ Including repairs of damage Caused by major disaster such as floods, earthquakes & typhoons (आंधी).

→ Also known as emergency maintenance.

④ Periodic maintenance

→ It is done quarterly, half yearly or yearly basis to get proper service from the canal. Reshaping of canal, lining of canal, maintenance of structure, removal of sediment deposits etc.

Minimization of Losses in Canals

→ Lining of irrigational canal.
→ maintenance of irrigation canal.
→ Removal of vegetation & weeds from canals
→ Using short length canal.
→ Sprinkler & drip irrigation system can be used.

Canal Structure

① Cross Drainage Structures	④ Escapes
② Regulators	⑤ Canal outlets
③ Falls/Drops	

Cross Drainage Structures

The structure constructed at the crossing point for the easy flow of water canal & drainage in the respective direction are known as cross drainage structures.

→ The nature of cross-drainage structure may be different at different place, depending upon the bed of canal.

Types of Cross Drainage Structures

[1] Canal passes over the drainage

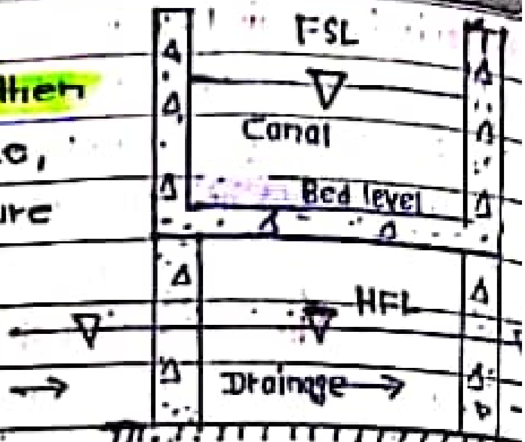
The irrigation canal passes over the drain, if full supply level (FSL) of canal is above high flood level (HFL) of drain.

→ Irrigation canal is taken over the drainage.

ⓐ Aqueduct

→ Bed level of Canal is higher then the high flood level (HFL) of drainage, then the Cross-drainage structure provided is said to be aqueduct.

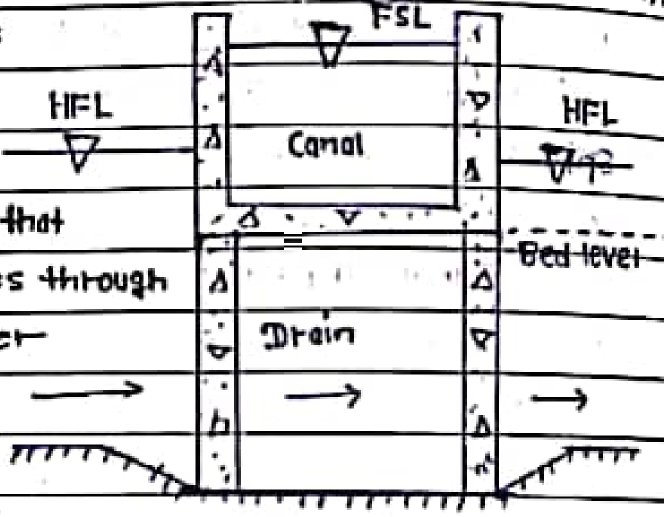
→ Drainage water passes clearly below the Canal.



→ drainage water flow freely under gravity. (open channel flow).

ⓑ Syphon aqueduct

→ Bed level of canal is lower then high flood level (HFL) of drainage, so that the drainage water passes through the aqueduct barrels, under syphonic action, then the structure provided is known as syphon aqueduct.



→ Drainage water flow under pressure.

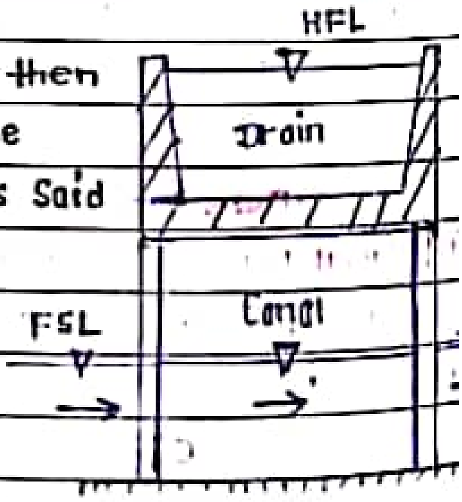
B Drainage passes over the Canal.

The drainage passes over the Canal, if High Flood level (HFL) of drainage is above Full Supply level (FSL) of canal.

ⓐ Super passage

→ Bed level of drainage is higher then the Full supply level of Canal, then the cross drainage structure provided is said to be super passage.

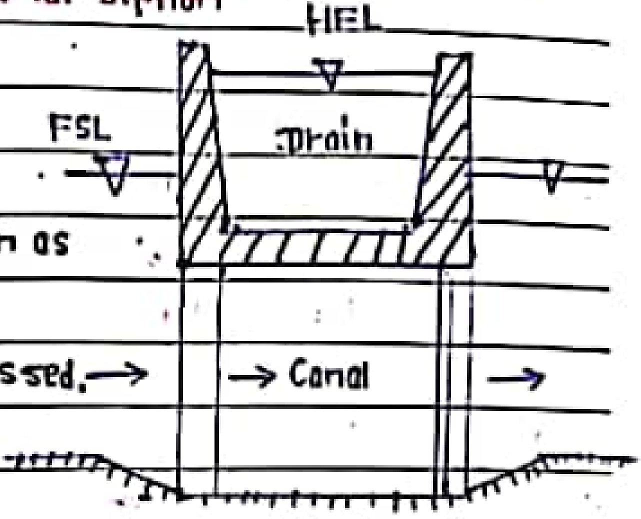
→ Canal water passes clearly below the Canal.



→ Reverse of aqueduct.

→ Canal water flow freely under gravity.

ⓑ siphon super passage / Canal siphon



→ Bed level of drainage is lower then the full supply level of Canal, then the structure provided is known as Canal syphon.

→ Flooring of canal is depressed.

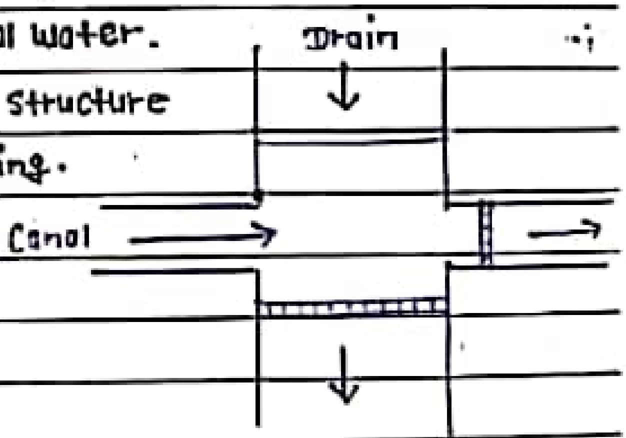
→ Canal water flows under pressure.

→ Reverse of Syphon aqueduct.

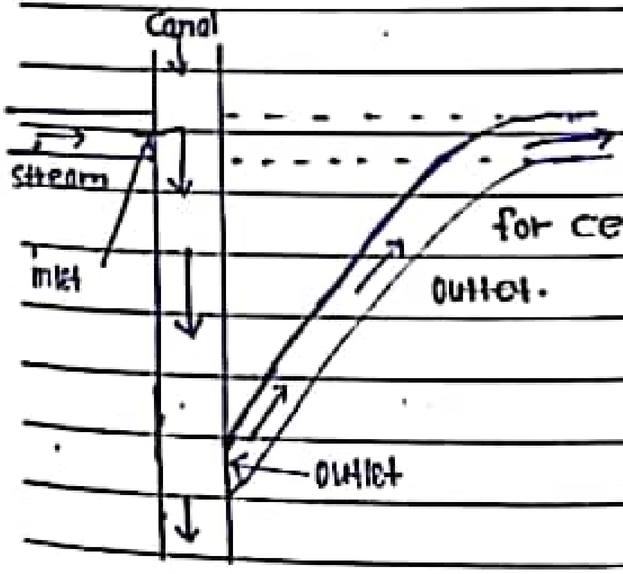
C Drainage admitted into Canal

The bed level of Canal is equal to the bed level of drainage. drain water mixed with Canal water.

ⓐ Level Crossing ↗ the structure provided is called level crossing.



ⓑ Inlet & outlet



→ Drain water is mixed in Canal at inlet & allowed to travel for certain time & taken out of the outlet.

Regulators

→ Regulators are constructed to distribute the water to branch canal, distributaries to provide the required discharge at the required time.

Types of Regulators

① Canal head regulator

→ Canal head regulators is provided at the head of main canal to withdraw the required amount of discharge from the river.

→ There is only one canal head regulator in canal system.

② Head regulator / Distributary head regulator

→ Regulator constructed at the off taking point. or head of distributary or off taking canal.

Functions

→ To control discharge of off taking canal or branch canal.

→ To control the entry of silt into off taking canal.

→ To serve as meter for measuring discharge.

③ Cross Regulators / Distributary Cross regulators

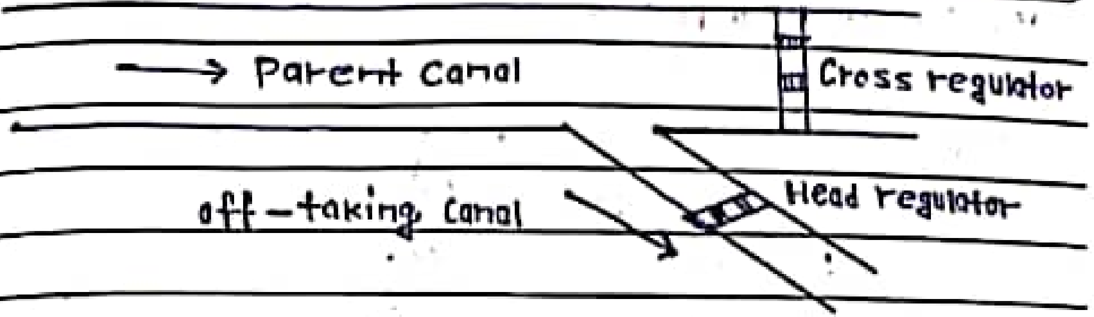
→ Regulator constructed in parent canal downstream of an off-taking canal.

Functions

→ To control the flow of water in entire canal irrigation system

→ To act as discharge meter to measure discharge flowing in the parent canal.

→ When water level in main canal is low, it helps in heading up water on the upstream & to feed off-taking channels to their full demand in rotation.



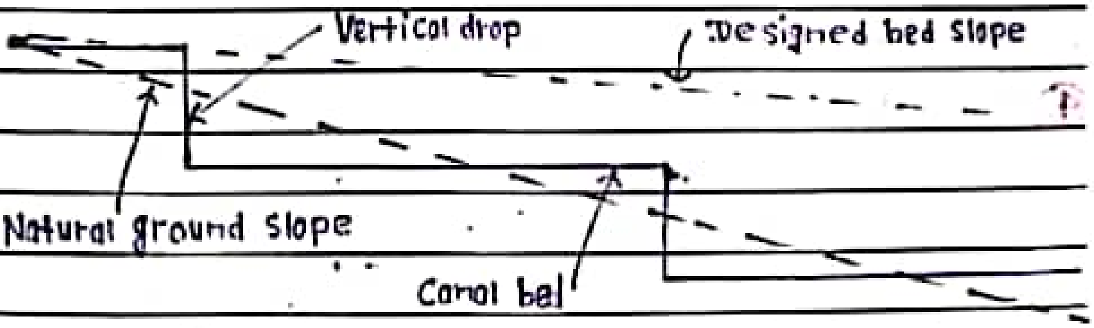
Falls & Drops Structures

→ Whenever the available natural ground slope is steeper then design bed slop of channel, the difference adjusted by constructing Vertical fall in Canal bed at suitable intervals.

→ Such a fall in a natural Canal bed without any structure will not be stable. & retain this fall, a masonry/concrete structure is constructed. Such structure is Called Canal fall.

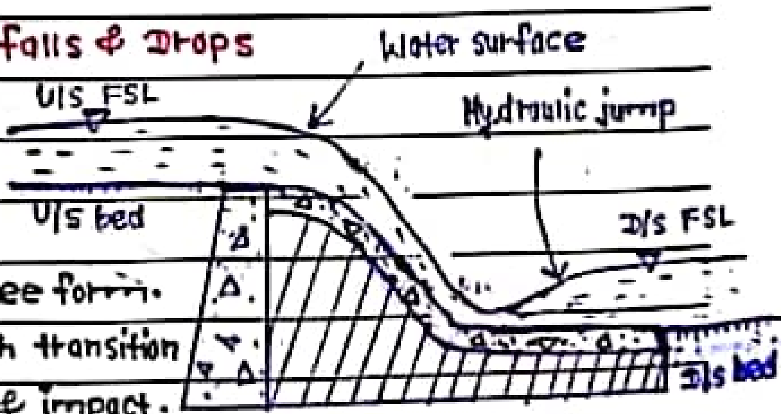
→ Canal fall should be provided with energy dissipating structure.

→ Fall & drop structure are more required in watershed & side slope canal as compared to Contour canals.



Types of falls & Drops

① Ogee Fall



→ This type of fall has gradual convex & Concave surface. ie, ogee form.

→ Ogee provide Smooth transition & reduce disturbance & impact.

→ A hydraulic jump is formed which dissipates a part of K.E.

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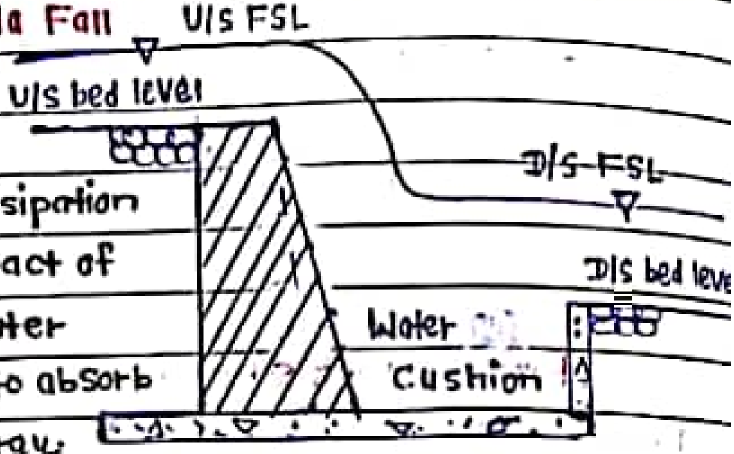
② Vertical fall / Sarda Fall



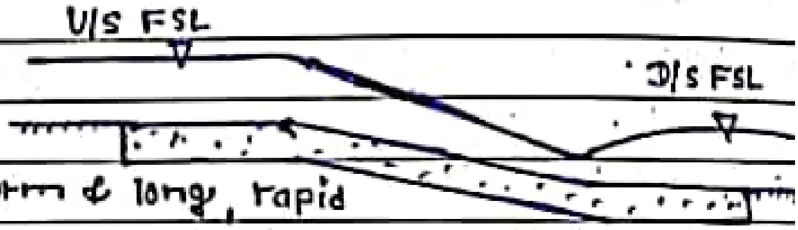
→ the Water drops Vertically.

→ The energy dissipation is achieved by impact of drop on the floor, water cushion is provided to absorb the impact of energy.

→ Suitable for discharge upto 15 m³/sec.

→ Suitable for drop height upto 1.5m.

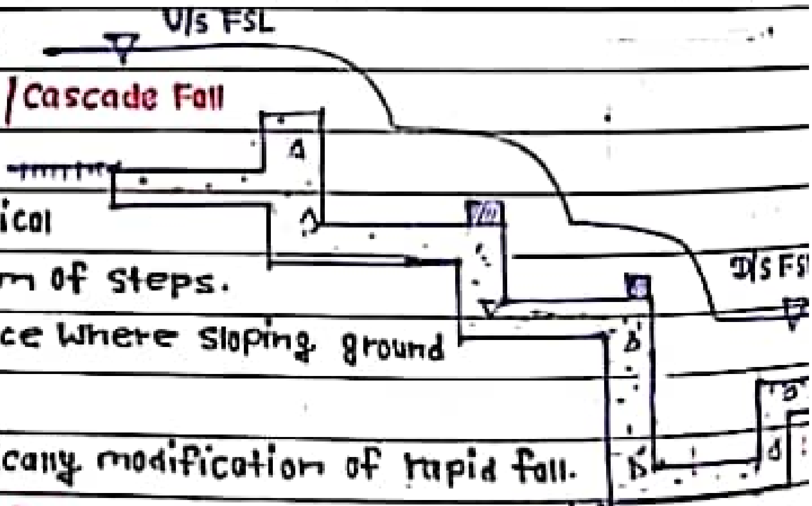
③ Rapid Fall



→ The slope of natural ground surface is uniform & long, rapid fall is suitable. → It Consists of long sloping glacis.

→ The energy dissipation is achieved by formation of hydraulic jump.

④ Stepped Fall / Cascade Fall

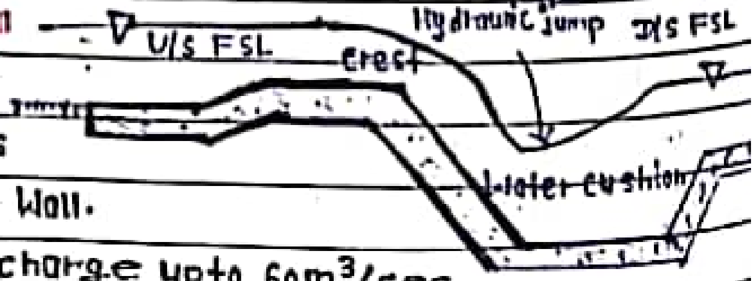


→ It Consists of series of Vertical drops in the form of steps.

→ Suitable in place where sloping ground is very long.

→ It is practically modification of rapid fall.

⑤ Straight glacis Fall

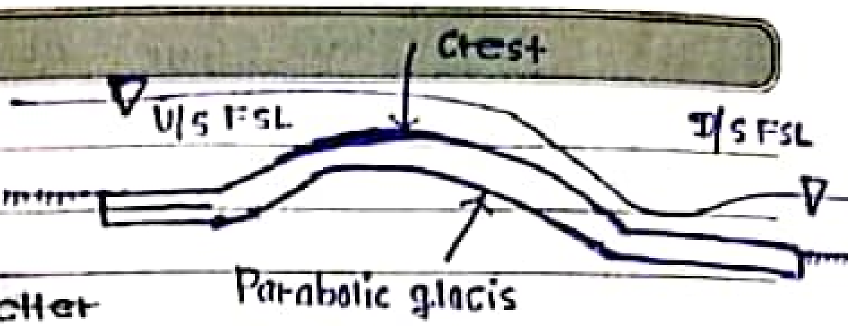


→ It Consists of Straight sloping glacis provided with Crest Wall.

→ Suitable for discharge upto 60m³/sec.

→ drop height = 1.5m.

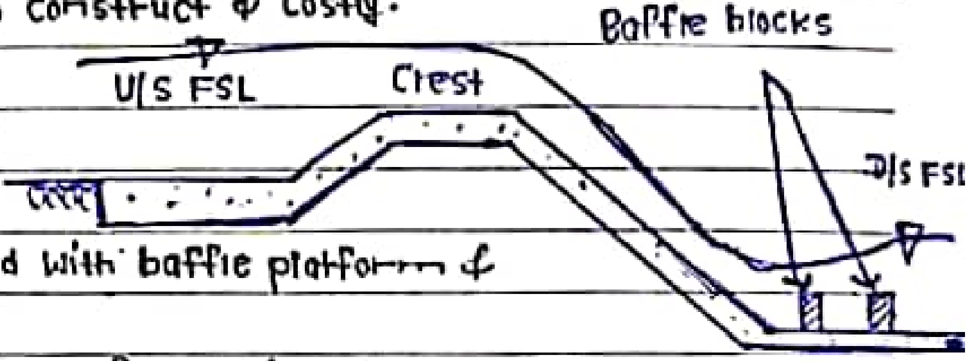
⑥ Montague Fall



→ The Profile is slightly modified to parabolic type for better energy dissipation.

→ difficult to Construct & Costly.

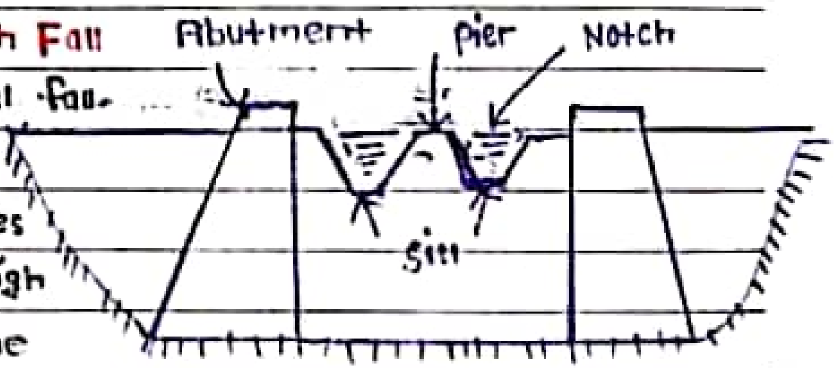
⑦ Baffle Fall



→ A Straight glacis type fall when added with baffle platform & baffle wall.

→ quite suitable for all discharges. & drops more then 1.5m.

⑧ Trapezoidal notch Fall



→ The trapezoidal fall. Consists of number of trapezoidal notches constructed on a high Crest Wall across the Channel with a smooth entrance & flat Circular lip projecting down stream from each notch to spread out the falling jet.

→ These falls do not affect the depth of water in the Canal on upstream of the fall.

Canal Escapes

→ It is a side Channel constructed to remove surplus Water from an irrigation channel into a natural drain.

→ Surplus due to

① Mistake in design or operation.

② Difficulty in regulation at the head

③ Excessive rainfall in upper reaches.

④ Outlet being closed by

Types of Escapes

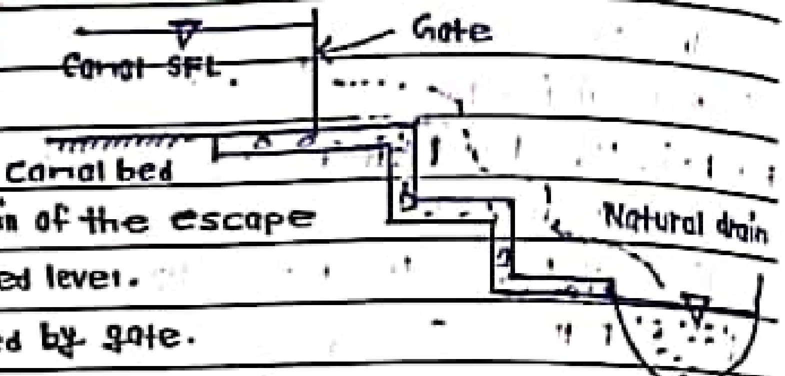
① Surplus escape

→ It is also called regulator type.

→ In this type sill of the escape is kept at canal bed level.

→ flow is controlled by gate.

→ preferred now days. → Give better control.

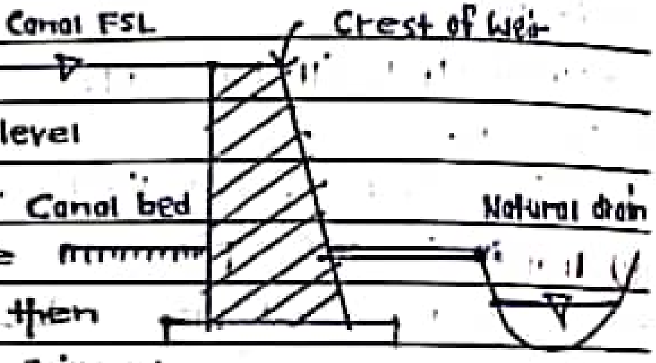


② Weir/Tail escape

→ The crest of the weir wall is kept at same level as Full supply level of canal.

→ When water level in the channel become more then designed FSL, the water spills out.

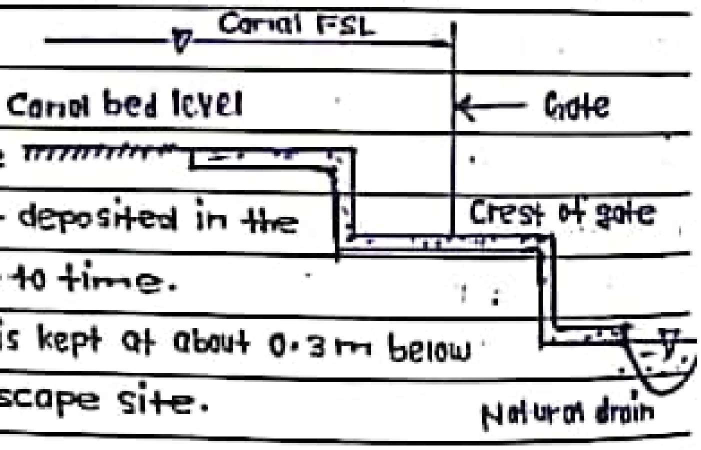
→ tail escape provided at the tail end of the canal.



③ Scouring escape

→ This escape is constructed for the purpose of scouring of excess silt deposited in the head reaches from time to time.

→ sill of the regulator is kept at about 0.3 m below the canal bed level at escape site.



Outlets/Modules

→ Canal outlet is a small structure built at the head of water course. → It is provided to supply water to the watercourses from the distributary.

Types of outlets.

① Non-modular outlets

→ Discharge depends upon the water level of distributary & water course. → The discharge through the outlet varies with change in water level of watercourse & distributary both. eg; open sluice, Drowned pipe outlet

② Semi-modular outlets or Flexible modules

→ Discharge depends only water level of distributary & not water course. → The discharge changes with the change in water level of distributary only. example; pipe outlet, open flume etc.

③ Modular outlets or Rigid modules

→ Discharge is constant & does not depend on the water level of distributary & watercourse. → Example; Gibb's module, Khanna module, foote module etc.

Spillways

Spillway is a structure constructed at a dam site for effectivey disposing surplus water from the reservoir.

→ Just after the reservoir gets filled upto the normal pool level, water start flowing over the top of the spillway crest.

→ Spillway constructed on the dam body or outside dam body.

→ Spillway are also constructed on canals to release excess water in the canal.

Need of Spillways

→ To remove surplus water from the reservoir.

→ To save the dam from failure due to overflow of water.

→ To remove excess water from the canal.

→ To dissipate the energy of water flows in main channel.

Component of spillway

① Control Structure : major component of a spillway which regulates the outflows from the reservoir.

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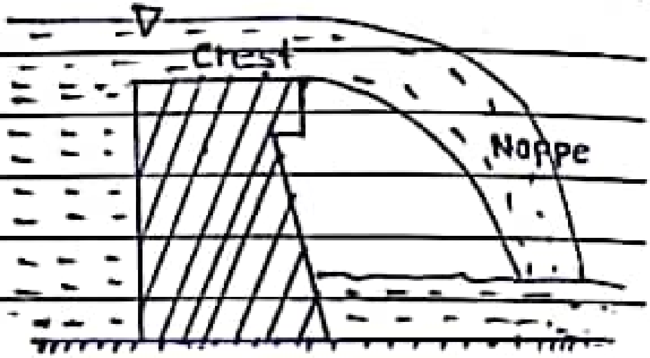
② **Discharge Channel** main function of this is to convey the water safely from the reservoir downward to the river.

③ **Terminal structure** Energy dissipators provided on the downstream side of the spillway.

④ **Entrance & outlet channel** Entrance channel to draw water from the reservoir & convey it to control structure. Outlet channel to convey the spillway flow from the terminal structure to river channel below the dam.

Types of Spillways

① **Straight drop Spillway**



→ Simplest type of spillway.

→ Water drops vertically from crest of spillway.

→ The downstream face of spillway is vertical or nearly vertical.

→ It is provided on low height dams or thin arch dams.

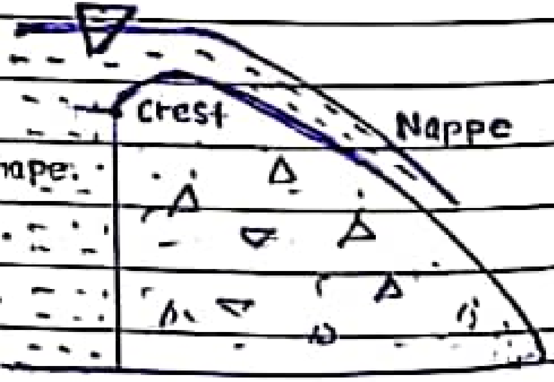
→ To avoid erosion on the downstream, a plunge pool is provided.

→ $\boxed{\text{Discharge}(q) = C_d \times L \times H^{3/2}}$

Where : C_d = Coefficient of discharge
L = length of spillway.
H = head over spillway crest.

$\therefore \boxed{q \propto H^{3/2}}$

② **Ogee or overflow spillway**



→ The surface of spillway over which water flows has ogee shape.

→ Suitable for all types of dams.

→ Generally used for high dams.

→ $\boxed{q = C_d \times L \times H^{3/2}}$

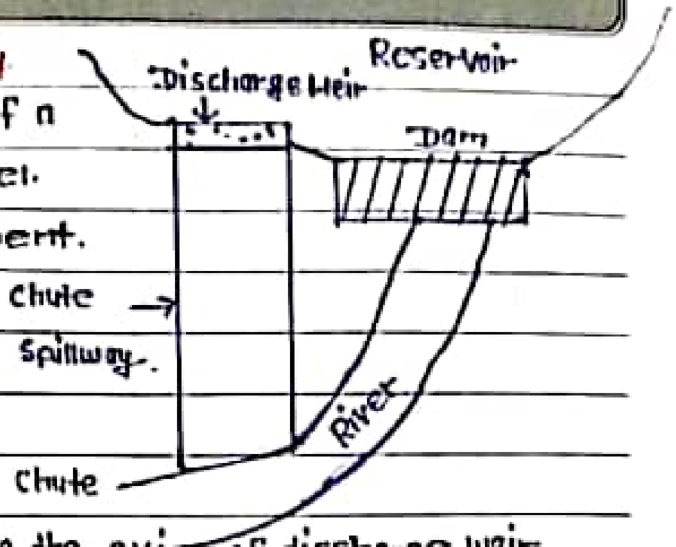
$\therefore \boxed{q \propto H^{3/2}}$

③ Chute or Trough spillway

→ Chute spillway consist of a steeply sloping open channel.

→ placed along a dam abutment.

→ The flow over a chute spillway is super critical flow.



→ The direction of flow in a chute spillway is perpendicular to the axis of discharge weir.

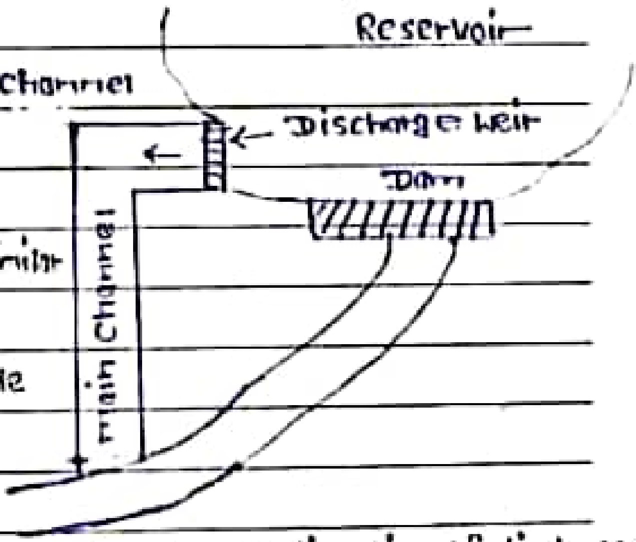
→ $\boxed{Q = C_d \times L \times H^{3/2}}$ ∴ $\boxed{Q \propto H^{3/2}}$

④ Side channel spillway

→ Water first flow in side channel & then turns 90° & then flow in main channel.

→ Except side channel, it is similar to chute spillway.

→ The choice betn chute & side channel spillway depends on site condition.

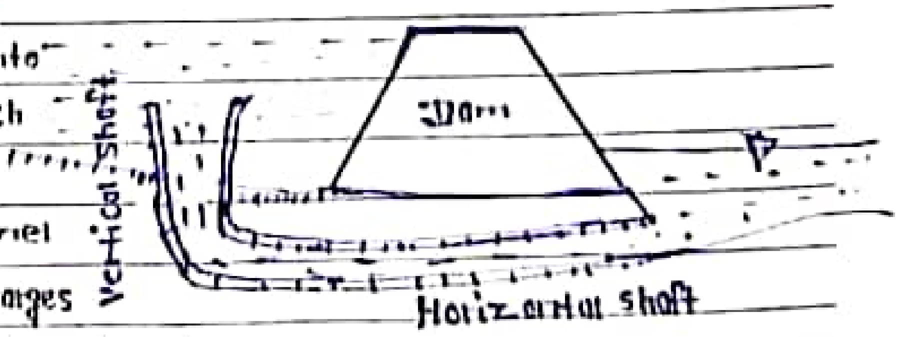


→ Water in main channel flows parallel to the direction of discharge W

→ $\boxed{Q = C_d \times L \times H^{3/2}}$ ∴ $\boxed{Q \propto H^{3/2}}$

⑤ Shaft spillway

→ Water enters into a vertical shaft which conveys this water in horizontal tunnel which finally discharges water into the river downstream.



→ It is also called morning glory spillway.

→ Most beautiful spillway.

→ $\boxed{q = C_d \times A \times \sqrt{2gH}}$

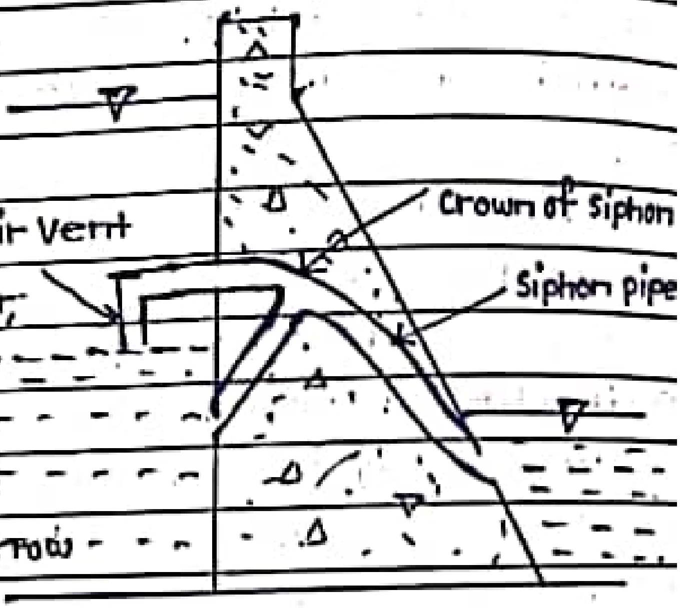
Where: C_d = coefficient of discharge

A = Area of shaft.

H = Head difference

⑥ Siphon spillway.

→ Consists of siphon pipe, one end of which is kept on the upstream & in contact with reservoir, while other end discharge water on the downstream side.



→ When the valley is narrow & no space is available for constructing a separate spillway, siphon pipes can be installed in the dam body.

→ $\boxed{q = C_d \times A \times \sqrt{2gH}}$

River Training

River training work can be define as the hydraulic structure constructed in the river so as to train & regulate the flow in desired way. → main purpose is to establish the river channel along certain alignment.

→ River training work is generally required when the river is meandering type.

Objective of River Training

→ To protect river banks from erosion.

→ To ensure effective disposal of sediment load.

→ To provide minimum water depth required for navigation.

→ To provide safe passage of the flood discharge without overtopping the banks.

→ To protect the surrounding area from flooding.

→ To prevent the river from changing its path.

Classification of River Training

① High Water Training

→ Also called as training for discharge.

→ Primary purpose of flood control.

→ The structure constructed for the purpose of quick & safe disposal of floods during high flood period to protect the adjoining land from inundati

② Low Water Training

→ Also, called as training for depth.

→ Purpose of providing sufficient water depth in the channels during low water periods. for navigation or transportation purpose.

③ Mean Water Training

→ Also called as training for sediment.

→ The structure constructed for the efficient disposal of suspended load & bed load & preserve the channel in good shape.

Method of River Training

Ⓐ Marginal embankments or Levees or dykes

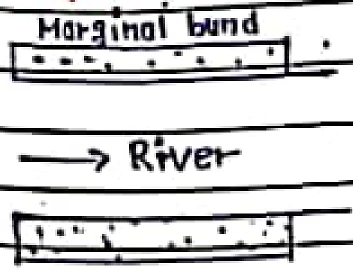


fig: plan of marginal bund

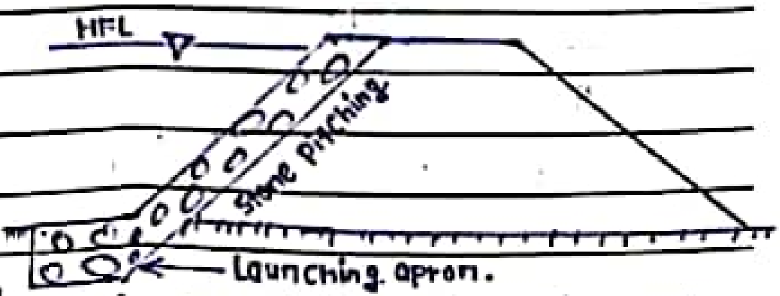


fig: cross-section of marginal bund.

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→ It is an embankment structure which runs parallel to the river either on both sides or on one side for some suitable length.

→ These embankments prevent the entry of the flood wata to adjoining towns, important land etc.

→ A leeves or dyke is mainly used for flood control mainly by controlling the river & not by training the river.

Ⓑ Guide Banks or Guid bunds or 'Bell's' bunds

→ The guide banks are the embankment structure constructed along the river to guide the river flow in the axial path.

→ Guide banks prevent the meandering of river.

→ They are constructed upstream of every hydraulic structure like bridge, weir, barrage etc.

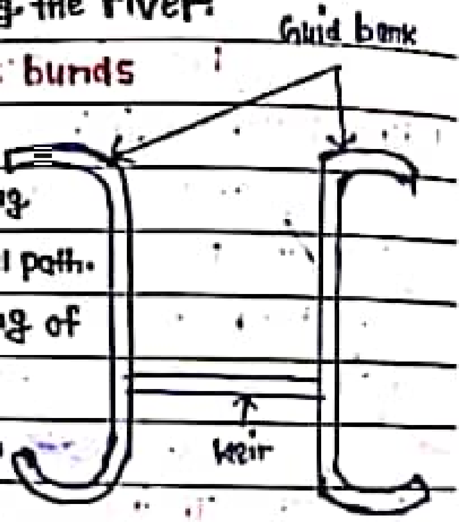

fig: plan of guid bank

Ⓒ Spurs or Groynes

A Spurs is the structure which is constructed at the bank of the river & is projected towards the river.

→ It is constructed to keep the flow away from the river bank & to avoid the bank cutting.

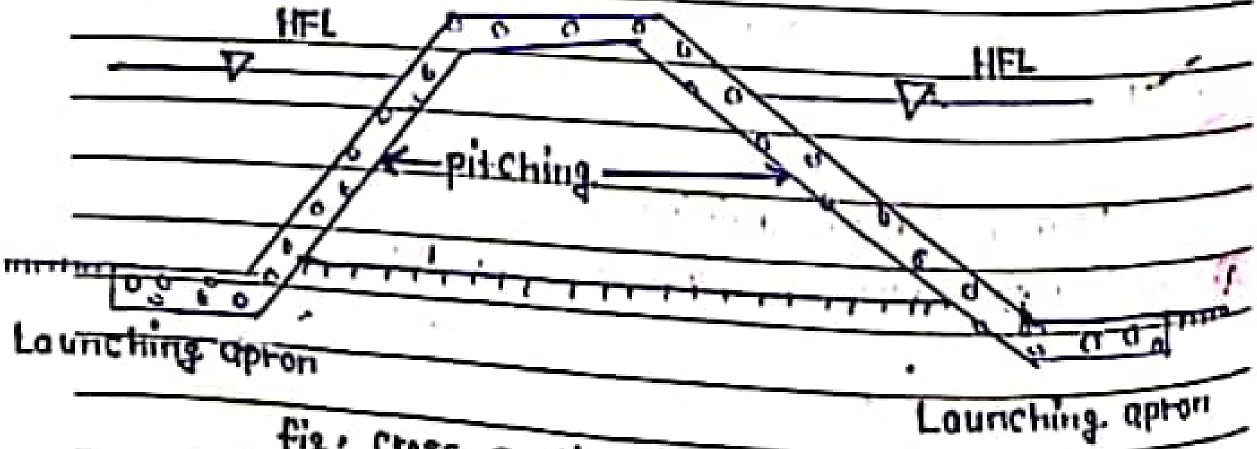

fig: Cross-section of spurs

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Objective of spurs construction

→ To train the river along the desired course by attracting or deflecting or repelling the flow in the desired direction.

→ To reduce concentration of flow at particular point of attac

→ To create slack zone for silting up the area.

→ To protect a bank by keeping the flow away from it.

→ To contract a wide river for the purpose of increasing theirive width for navigation.

Classification of spurs

① Based on the method & materials of construction

ⓐ **Impermeable spurs** These spurs do not allow the flow of water through them. → They consists of either rock fill or core of sand & graver or alluvial soil available in the river.

→ Top & sides are protected by the pitching of stones & Concret

ⓑ **Permeable spurs** These spurs allow the flow of water through the

→ They obstruct the flow & allow the deposition of the sediments Carrie by the river. → They are also called sedimentation spurs.

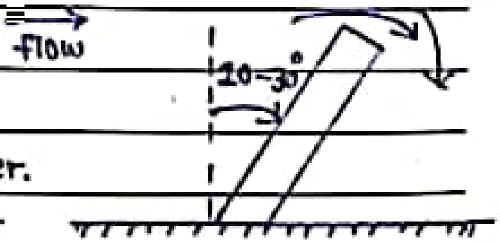
② Based on height of spurs

ⓐ **Submerged spurs** if depth of water is sufficient in the river & spu are in submerged condition.

ⓑ **Unsubmerged spurs** if spurs are large enough & are not submerg

③ Based on function

① **Attracting spurs**



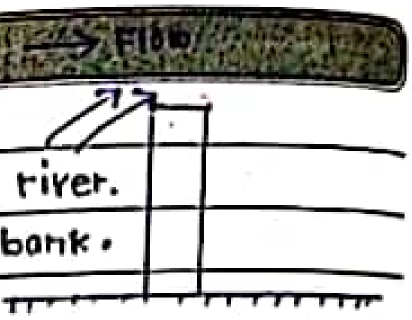
→ pointing on the downstream of river.

→ They attract flow of water.

→ They create the scour holes on the downstream.

→ Provided on the opposite side of bank which is to be protected.

→ They make acute angle with direction of flow.



(ii) Normal Spurs:

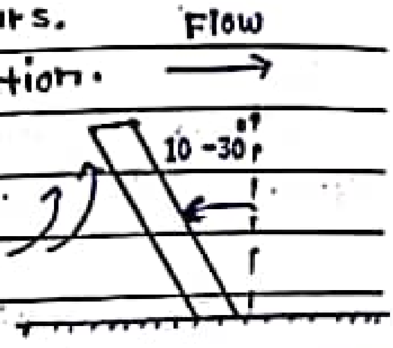
→ They are aligned perpendicular to river.

→ They deflect the water away from the bank.

→ They are also called as deflecting spurs.

→ These are the mostly used type of spurs.

→ They make right angle with flow direction.



(iii) Repeling Spurs

→ pointing on the upstream of river.

→ They repel flow away from the bank.

→ They create still water pocket on upstream side & suspended sediment gets deposited in the pocket. → They make obtuse angle with flow direction.

→ They are more effective & do not cause any problems as compared to the attracting groynes.

Note: **Spacing** for convex bank — 2 – 2.5 times, length of spurs.
for concave bank — equal to length of spurs.

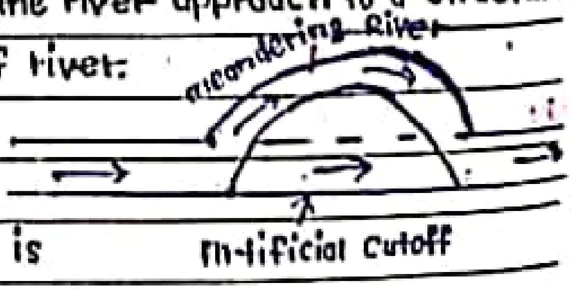
(D) Artificial Cutoff

An artificial cutoff is constructed in the meanderings river to divert the flow along the fixed watercourse.

→ It is constructed when the meander is regularly increasing & valuable land & property is about to be wasted.

→ It is used for straightening the river approach to a structure.

→ Artificial cutoff decrease length of river.

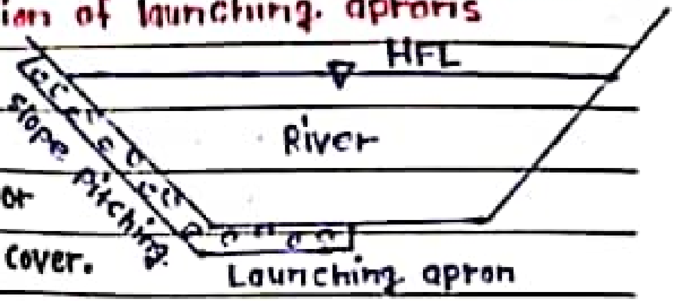


(E) pitched Island

A pitched island is a artificially constructed island in the river bed & is protected by stone pitching.

→ Due to the turbulence constructed in the vicinity, the river channel around the island gets deepened & thus, attracting the river water towards itself & holding the water permanently.

(F) pitching of banks & provision of launching aprons



→ Banks of the river are directly protected by the stone pitching or by concrete blocks or by brick lining or by vegetative cover.

→ The slope of the pitching may vary from 1V : 1H to 1V : 2H.

→ The launching apron may also be provided to prevent the scour at the toe.

Water Logging

Water logging is the process due to which the productivity of the crops gets decreased due to rise in water table. Waterlogging results in ill aeration & salinity that is why growth of plants is affected.

Ill Aeration : plant needs different nutrients like nitrates, phosphate for their growth & development. nitrates are provided by bacteria under a process called nitrification. these bacteria need oxygen for their survival. the supply of oxygen gets cut off when land becomes ill aerated resulting in death of bacteria & fall in the production of nitrates. As a resut, the growth of plant reduce.

Salinity : when water table rises up to the root zone of plant, there is evaporation by capillarity. due to this, the salt present in water get deposited in the root zone of crops. the concentration of these alkali salt present in the root zone of crop has corroding effect on the plant which prevent growth & ultimately plant fades away. such soil is called saline soil & the phenomenon is called salinity.

Effect of Water Logging

→ Rise of salt.

→ Fall of temperature

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- → Disease of crops. → Difficulty in cultivation.
- → Decrease in capillary water. → Defective air circulation
- → Affecting soil nutrients. → Effect on human helth.
- → Growth of weeds & aquatic plants.

Causes of Water Logging

- → over & Intensive irrigation. → Excessive rains.
- → Impervious obstruction. → Submergence due to floods
- → seepage from canal system. → Irregular or flat topograph
- → seepage of water through adjoining high lands.

Preventive Measures of Water Logging

- → Reducing intensity of irrigation. → optimum use of water.
- → Adopting crop rotation. → providing intercepting.
- → Provision of artificial drainage system.
- → Improving natural drainage of the area.
- → Lining canals & watercourses.
- → Introduction to special irrigation Method.

Remedial measure of Water Logging.

- → Construction of surface drains.
- → Construction of subsurface drains.
- → Construction the outlets. → Leaching.

Status of Irrigation Development in Nepal

Total area of country = 147181 km

Water Resources & Hydropower potential of Nepal

→ Nepal is gifted with large water potential as compared to the size of the country.

→ There are more then 6000 rivers in nepal.

→ The four major river basins in nepal are Koshi, Gandaki/ Narayani, Karnali & Mahakali river basins.

→ Average annual runoff within the Country is 225 Billion cubic meter

→ Ground water in the country is approximately around 11.5 Billion Cubic meters.

Water Resources potential of Karnali province

→ The exact water resource potential of Karnali province alone is not to the information of author.

→ The major water resource in karnali province is karnali river.

→ The river originates from south of mansarowar & rokas lakes in tibet, China

→ The river flow through Karnali province .

→ The river also flow through Sudurpashchim province.

→ The major river system in Karnali river basin are West seti river, bheri river, humla Karnali, mugu Karnali, Sinja, tila, lohore & thuli gad.

→ The average annual runoff in Karnali river at Chisopani is estimated to be 44 Billion Cubic meters.

→ The ground water potential in Karnali basin is around 3.36 Billion Cubic meters per year.

→ The Karnali province is also gifted with number of lakes.

→ Rara lake, Shy-phoksundo lake, bulbule lake, Sarpu Daha (Rukum), mato tal, etc.

→ There are 936 lakes & ponds in Karnali province.

According to "Water & energy Commission Secretariat" (WECS)

Province	power potential (MW)	% power potential
Koshi	22,619	31.2
Madhes	275	0.4
Bagmati	10,568	14.6
Gandaki	14,981	20.7
Lumbini	2,677	3.7
Karnali	13,702	18.9
Sudurpashchim	7,772	10.6
	72,544	100

Ealier; Estimated Gross hydropower potential of Nepal is 83,000MW. The latest Study, 72,544 MW.

Hydropower potential of Karnali province

The WECS has Conducted hydropower at recent. As per the report, the gross hydropower potential of Karnali province is 13,702 MW, which is 18.9% of the total hydropower potential of the Country. the rivers which contribute to the hydropower potential in the province are mainly Karnali & bheri.

There are no. of projects under study & under Construction in the basin. there are number of projects with Capacities ranging from 0.5 to 1000 MW.