

Water Resource Engineering (315314)

MSBTE K-Scheme · Model Question Paper — Set A · Model Answers

Q.1 Attempt any FIVE of the following:**10 M****a) Enlist the classification of irrigation projects on the basis of purpose.**

2 M

Irrigation projects are classified on the basis of purpose as:

1. **Protective irrigation project** – provided to protect crops against failure of rainfall / famine in drought-prone areas; financial return is not the main aim.
2. **Productive irrigation project** – provided to increase production and give financial return (revenue) on the investment.
3. **Single-purpose project** – serves only one purpose, i.e. irrigation.
4. **Multipurpose project** – serves irrigation along with hydropower, water supply, flood control, navigation, fisheries, recreation etc.

Note: On the basis of culturable command area (CCA), projects are also classified as major (CCA > 10,000 ha), medium (2,000–10,000 ha) and minor (< 2,000 ha).

(Any four, ½ M each)

b) Define: i) Hydrology ii) Runoff.

2 M

Hydrology: Hydrology is the science which deals with the occurrence, circulation and distribution of water on the earth and in the atmosphere, i.e. precipitation, evaporation, infiltration, runoff and groundwater.

Runoff: Runoff is that part of precipitation which, after meeting losses (evaporation, interception, infiltration, depression storage), flows over the ground surface and through the soil and finally reaches streams, rivers or the sea.

(Each definition 1 M)

c) Define duty and delta. State the unit of each.

2 M

Duty (D): Duty is the area of land (in hectares) that can be irrigated by a continuous supply of 1 cumec (1 m³/s) of water throughout the base period of the crop. Unit: **hectare/cumec**.

Delta (Δ): Delta is the total depth of water required by a crop from the time of sowing to harvesting (during its base period), if the water were spread uniformly over the irrigated area. Unit: **cm or m**.

(Each definition with unit 1 M)

d) State any four functions of a spillway.

2 M

Functions of spillway:

1. To pass the surplus flood water safely from the reservoir to the downstream river after the reservoir is full (at F.R.L.).
2. To prevent overtopping of the dam and so protect the dam from failure.
3. To keep the reservoir water level within the H.F.L. (limits the rise of water level during floods).

4. To dissipate the energy of the falling water safely so that the toe of the dam and river bed are not scoured.
5. Gated spillways help to regulate outflow and store extra water above the crest.

(Any four, ½ M each)

e) State any two purposes of providing galleries in a gravity dam.

2 M

Purposes of galleries in gravity dam:

1. To provide drainage of seepage water through the dam body and foundation (drainage holes discharge into the gallery), so uplift pressure is reduced.
2. To provide access for inspection of the interior of the dam and for grouting of foundation / contraction joints.
3. To house instruments for measuring temperature, stress, uplift and seepage.
4. To provide space for operating gates / valves of outlets and for cooling pipes during construction.

(Any two, 1 M each)

f) Define percolation tank and state its main purpose.

2 M

Percolation tank: A percolation tank is a small artificial tank formed by constructing a low earthen bund across a stream (nala) on permeable strata, in which runoff water is stored so that it percolates into the ground.

Main purpose: To recharge groundwater, i.e. to raise the water table in the wells located in its downstream zone of influence (water is not released through canals).

(Definition 1 M, purpose 1 M)

g) Define: i) Aqueduct ii) Siphon aqueduct.

2 M

Aqueduct: A cross drainage work in which the canal is carried over the natural drain in a trough (on piers), and the H.F.L. of the drain is sufficiently below the bottom of the canal trough, so that the drain water flows freely below under atmospheric pressure.

Siphon aqueduct: A cross drainage work in which the canal is carried over the drain, but the H.F.L. of the drain is above the canal bed, so the drain water passes through barrels under the canal under pressure (siphonic action).

(Each definition 1 M)

Q.2 Attempt any THREE of the following:

12 M

a) Define rainfall. Explain Symon's rain gauge with a neat sketch.

4 M

Rainfall: Rainfall is the precipitation of water in liquid form (drops of size 0.5 mm to 6 mm) falling on the earth surface from clouds. It is measured as the depth of water (mm) collected over a horizontal surface.

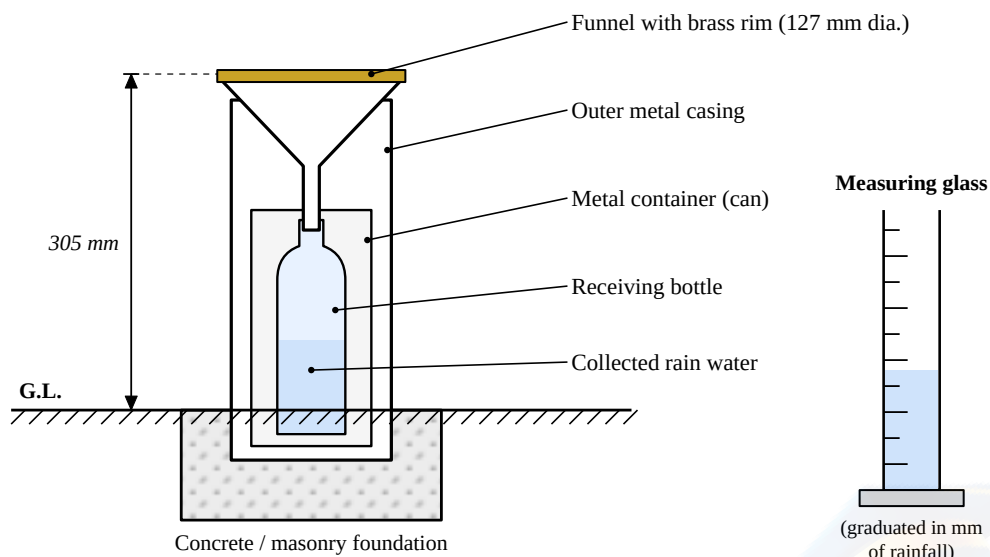


Fig.: Symon's (non-recording) rain gauge

Symon's rain gauge (non-recording type):

- It consists of a **funnel** with a sharp brass rim of 127 mm diameter, a **receiving bottle** of about 75–100 mm diameter, a **metal container** (can) and an outer **metal casing**.
- The gauge is fixed on a concrete / masonry foundation so that the rim of the funnel is 305 mm above the ground level and is kept horizontal.
- Rain falling on the funnel is collected in the receiving bottle. Every day at a fixed time (8:30 a.m. IST) the water is poured into a **measuring glass** graduated in mm of rainfall and the reading is recorded.
- If the bottle overflows during heavy rain, the water in the container is also measured.
- Gives only the total rainfall of the previous 24 hours; it does not give intensity or duration of rain.

(Definition 1 M, sketch 2 M, explanation 1 M)

b) The Thiessen polygons of a catchment with five rain gauge stations A, B, C, D and E have areas 302 km², 273 km², 292 km², 328 km², 185 km² and the rainfall recorded during a storm is 96 mm, 112 mm, 128 mm, 104 mm, 88 mm respectively. Compute the average rainfall over the catchment.

4 M

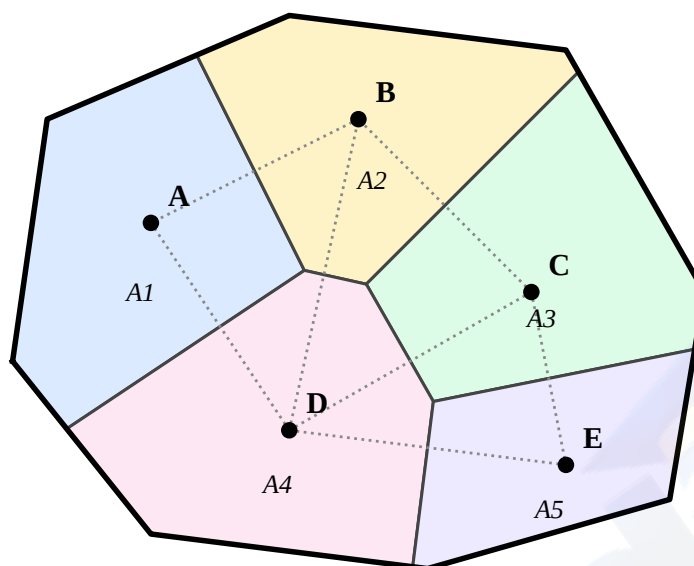


Fig.: Thiessen polygons of the catchment (areas computed from the figure)

Thiessen polygon method: $P_{av} = \Sigma(A_i \times P_i) / \Sigma A_i$, where A_i = area of the polygon round station i.

Station	Polygon area A (km ²)	Rainfall P (mm)	A × P
A	302	96	28,992
B	273	112	30,576
C	292	128	37,376
D	328	104	34,112
E	185	88	16,280
Total	1,380		147,336

$$P_{av} = 147,336 / 1,380 = \mathbf{106.77 \text{ mm}}$$

(Formula 1 M, table 2 M, answer 1 M)

c) Estimate the maximum flood discharge for a catchment of 480 km² using: i) Dicken's formula (C = 14) ii) Ryve's formula (C = 6.8) iii) Inglis' formula.

4 M

Catchment area A = 480 km²

$$1. \text{ Dicken's formula: } Q = C_D A^{3/4} = 14 \times (480)^{0.75} = 14 \times 102.549 = \mathbf{1,435.68 \text{ m}^3/\text{s}}$$

$$2. \text{ Ryve's formula: } Q = C_R A^{2/3} = 6.8 \times (480)^{2/3} = 6.8 \times 61.305 = \mathbf{416.87 \text{ m}^3/\text{s}}$$

$$3. \text{ Inglis' formula (fan-shaped catchments, Maharashtra): } Q = 124 A / \sqrt{(A + 10.4)} = 124 \times 480 / \sqrt{(490.4)} = 59,520 / 22.145 = \mathbf{2,687.74 \text{ m}^3/\text{s}}$$

(Q in m³/s, A in km²; C_D, C_R are constants depending on the region.)

(Each formula 1½ M)

d) Derive the relation between duty, delta and base period.

4 M

Let D = duty in hectare/cumec, B = base period in days, Δ = delta in metres.

Consider a field of area **D hectares** irrigated by **1 m³/s** of water flowing continuously for **B days**.

Total volume of water supplied = $1 \text{ m}^3/\text{s} \times (B \times 24 \times 60 \times 60) \text{ s} = \mathbf{86,400 B \text{ m}^3} \dots (i)$

The same water, spread over D hectares to a depth Δ : volume = area $\times$ depth = $(D \times 10^4 \text{ m}^2) \times \Delta = \mathbf{10^4 D \Delta \text{ m}^3} \dots (ii)$

Equating (i) and (ii): $10^4 D \Delta = 86,400 B$

$$\Delta = \mathbf{8.64 B / D} \quad (\Delta \text{ in m, B in days, D in ha/cumec})$$

i.e. delta is directly proportional to base period and inversely proportional to duty.

(Assumptions 1 M, steps 2 M, final relation 1 M)

Q.3 Attempt any THREE of the following:

12 M

a) Find the discharge required at the head of the field channel and the volume of water required for the following crops:

Crop	Duty at field D (ha/cumec)	Base period B (days)	Area A (ha)
Wheat	1800	120	3600
Sugarcane	750	320	1200

Discharge required $Q = A / D \text{ (m}^3/\text{s)}$; Delta $\Delta = 8.64 B / D \text{ (m)}$; Volume $V = A \times \Delta \text{ (ha-m)} = A \times 4 \text{ M} \Delta \times 10^4 \text{ m}^3$

Crop	Area A (ha)	Duty D (ha/cumec)	B (days)	$Q = A/D \text{ (m}^3/\text{s)}$	$\Delta = 8.64B/D \text{ (m)}$	$V = A\Delta \text{ (ha-m)}$	$V \text{ (Mm}^3\text{)}$
Wheat	3,600	1,800	120	2.000	0.576	2,073.6	20.736
Sugarcane	1,200	750	320	1.600	3.686	4,423.7	44.237
Total				3.600		6,497.3	64.973

(Discharge 2 M, volume 2 M)

b) Differentiate between earthen dam and gravity dam (any four points).

4 M

Point	Earthen dam	Gravity dam
1. Material	Earth (soil) — locally available, natural material.	Concrete or masonry.
2. Foundation	Can be built on weak, soil or pervious foundations.	Needs strong, sound rock foundation.
3. Section	Very wide base, flat side slopes (trapezoidal).	Narrow, nearly triangular section.
4. Stability	Stability depends on side slopes and shear strength of soil.	Resists forces by its own weight.
5. Spillway	Spillway cannot be provided on the dam; separate spillway is needed.	Spillway can be provided on the dam body itself.

6. Seepage	Seepage through body is more; core, filter and drains are needed.	Seepage is very small.
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(Any four points, 1 M each)

c) Explain with a neat sketch the various forces acting on a gravity dam.

4 M

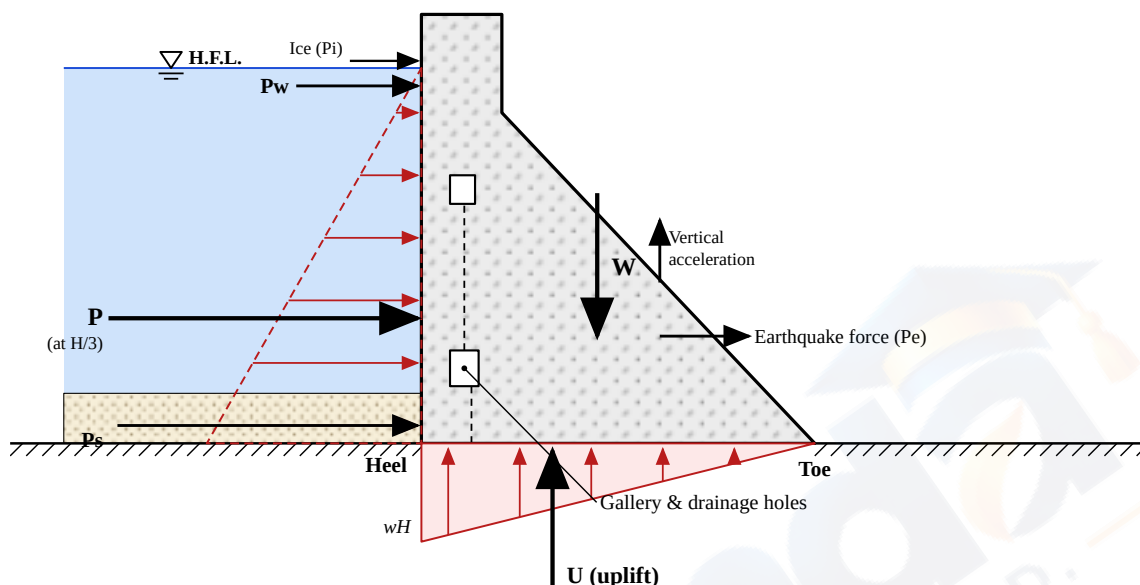


Fig.: Forces acting on a gravity dam

- Weight of dam (W)** – main stabilising force, acts vertically down through the centre of gravity of the section.
- Water pressure (P)** – horizontal pressure of reservoir water on the upstream face; $P = wH^2/2$ acting at $H/3$ above the base.
- Uplift pressure (U)** – upward pressure of water seeping under the base (and through pores); intensity wH at heel reducing to tail-water pressure at toe; reduced by drainage holes and gallery.
- Silt pressure (Ps)** – pressure of silt deposited against the upstream face.
- Wave pressure (Pw)** – pressure of waves generated by wind, acting near the top of the upstream face.
- Earthquake forces** – horizontal and vertical accelerations cause inertia forces on the dam and hydrodynamic pressure of water.
- Ice pressure (Pi)** – expansion of ice sheet in cold regions acting at the water surface.

(Sketch 2 M, explanation of forces 2 M)

d) Draw a labelled cross-section of a zoned earthen dam and state the functions of: i) Cut-off trench ii) Rock toe. 4 M

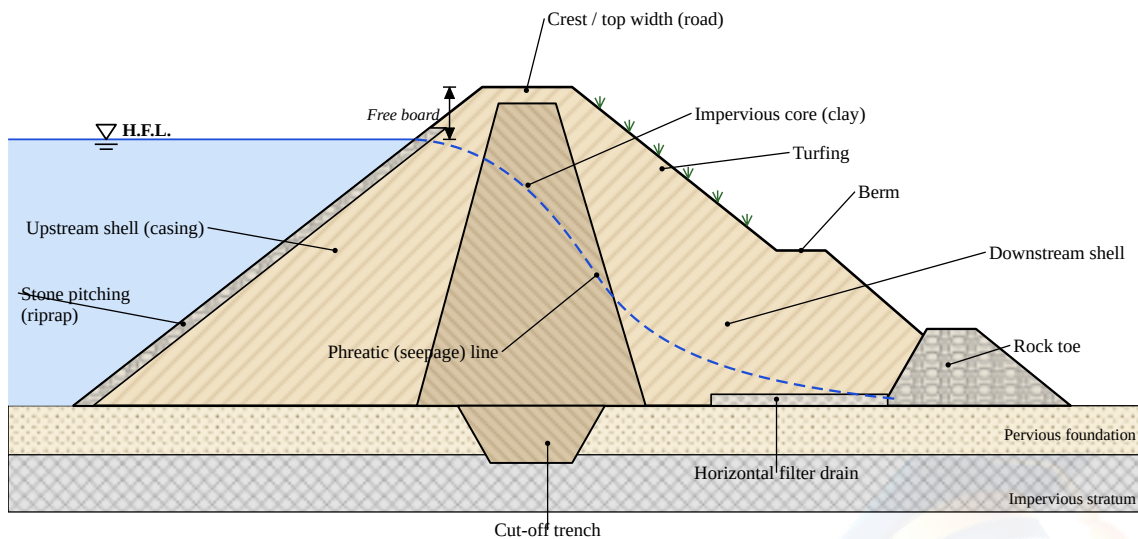


Fig.: Typical section of a zoned earthen dam showing component parts

Functions of components:

1. **Cut-off trench** – a trench below the dam filled with impervious clay, taken down to the impervious stratum; it cuts off / reduces seepage through the foundation and so prevents piping.
2. **Rock toe** – stone (rock) fill at the downstream toe with an inverted filter; it collects seepage water and drains it safely, keeps the phreatic line inside the dam and protects the toe from erosion / sloughing.
3. **Filter (horizontal filter drain)** – graded layers of sand and gravel which allow seepage water to pass but prevent soil particles from being carried away (prevents piping) and lower the phreatic line.
4. **Riprap (stone pitching)** – stone lining on the upstream slope that protects it against wave action and erosion.

(Sketch 2 M, any two functions 1 M each)

Q.4 Attempt any THREE of the following:

12 M

a) Draw the layout of a lift irrigation scheme and state the functions of its components.

4 M

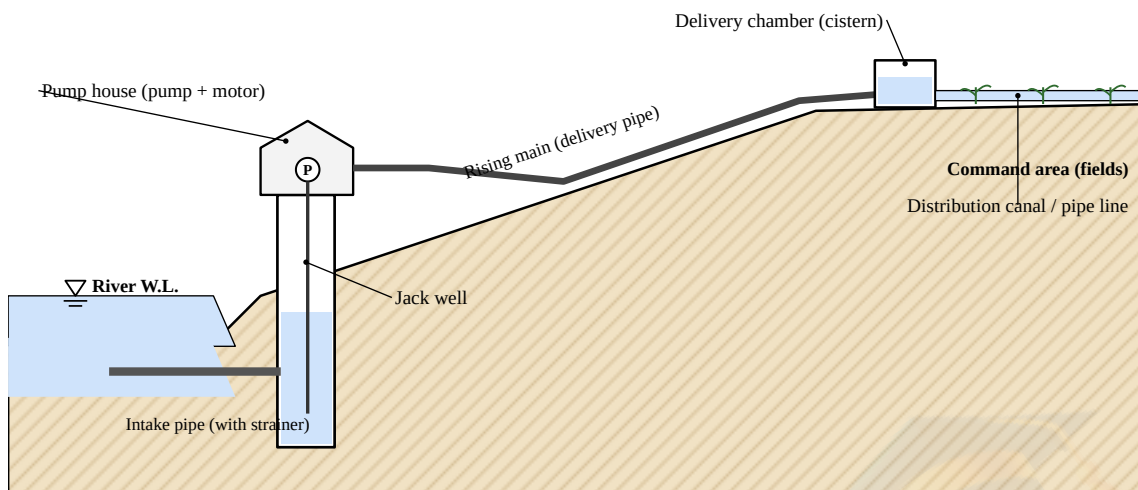


Fig.: Layout (section) of a lift irrigation scheme

Lift irrigation: water is lifted by pumps from a river, lake or well to a higher level and distributed by gravity to the command area.

- 1. Intake / jack well** – the jack well is constructed on the river bank (or in the river); water enters it through an intake pipe with a strainer. It houses the suction of the pumps.
- 2. Pump house** – contains pumps, motors, starters and panels.
- 3. Rising main** – pipe line carrying water under pressure from the pumps up to the highest point of the command.
- 4. Delivery chamber (cistern)** – receives water from the rising main, breaks its pressure and delivers it to the distribution system.
- 5. Distribution system** – canals / underground pipelines and outlets which supply water by gravity to the fields.

(Layout 2 M, components 2 M)

b) Differentiate between drip irrigation and sprinkler irrigation (any four points).

4 M

Point	Drip irrigation	Sprinkler irrigation
1. Method	Water is applied drop by drop directly at the root zone through emitters.	Water is sprayed in the air and falls on the crop like rain.
2. Area wetted	Only the root zone is wetted.	Entire field surface is wetted.
3. Water efficiency	Very high (90–95 %).	High (70–80 %).
4. Suitable crops	Row crops, orchards, vegetables, sugarcane.	Close-growing crops — wheat, pulses, groundnut, vegetables, lawns.
5. Pressure	Low pressure.	Higher pressure needed.
6. Weeds / wind	Weed growth is less; not affected by wind.	Weeds grow over whole area; affected by high wind.

(Any four points, 1 M each)

c) State the site selection criteria for a percolation tank.

4 M

Site selection criteria for percolation tank:

1. The site should be on a stream (nala) with sufficient catchment area and runoff to fill the tank every monsoon.
2. The strata below the tank should be **highly permeable** (fractured / weathered rock, sandy soil) so that water percolates quickly.
3. The downstream area should have a number of wells which will benefit (zone of influence), preferably with good cultivable land.
4. Site should give maximum storage with minimum length and height of bund (narrow valley).
5. Land submergence should be small and of low value (no houses, roads).
6. Good soil for bund and a suitable site for waste weir should be available nearby.

(Any four, 1 M each)

d) Differentiate between weir and barrage (any four points).

4 M

Point	Weir	Barrage
1. Crest level	Crest is raised above river bed; water is ponded mainly by the crest.	Crest is at or near river bed level; pond level is kept by gates.
2. Gates	No gates or only small shutters on the crest.	Gates over the full height between piers.
3. Afflux	Afflux (rise of water level u/s during floods) is high.	Afflux is low because gates are opened during floods.
4. Cost	Less costly.	More costly.
5. Silt control	Silt deposits upstream; poor silt control.	Good control of silt by opening gates.

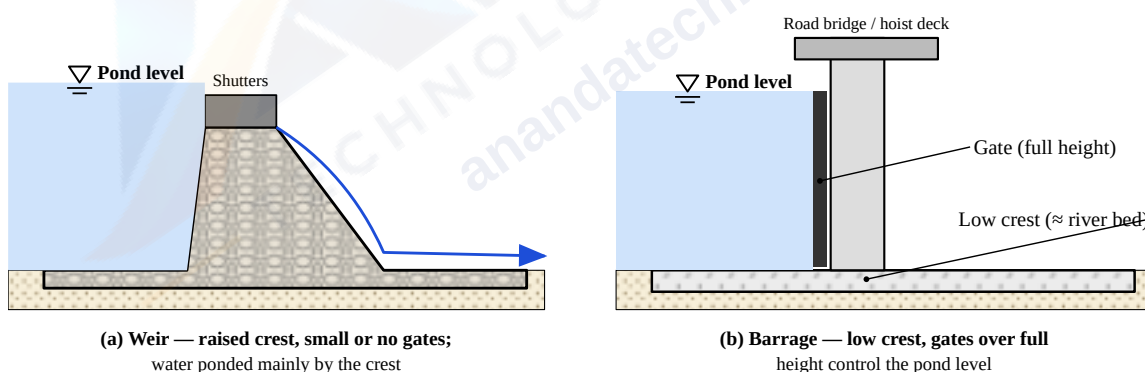


Fig.: Weir and barrage (sections)

(Any four points, 1 M each)

e) State any three advantages of canal lining and name the materials used for lining.

4 M

Advantages of canal lining:

1. Reduces seepage losses, so more area can be irrigated.
2. Prevents water logging and salinity of adjoining land.
3. Higher velocity is permitted, so smaller section and lower cost of earthwork / land.

4. Prevents weed growth and reduces maintenance cost.
5. Gives stable section; prevents erosion and breaches of banks.

Materials: cement concrete (in-situ or precast), bricks / tiles, stone masonry, soil-cement, shotcrete, asphalt, compacted clay, polythene (LDPE) film.

(Any three advantages 3 M, materials 1 M)

Q.5 Attempt any TWO of the following:

12 M

a) Fix the control levels (D.S.L., F.R.L., H.F.L. and T.B.L.) of a reservoir from the following data: effective storage required for crops = 22 Mm³; tank losses = 15 % of effective storage; carry-over allowance = 10 % of effective storage; dead storage = 10 % of gross storage; maximum flood discharge = 600 m³/s; length of waste weir = 120 m (use $Q = 1.84 L H^{3/2}$); free board = 2.0 m.

Contour R.L. (m)	600	603	606	609	612	615	618
Capacity (Mm ³)	0.8	2.6	6.2	11.5	18.8	27.4	37.9

1. **Live (useful) storage** = 22.00 (effective storage for crops) + 3.300 (tank losses 15 %) + 2.200 (carry-over 10 %) = **27.500 Mm³** 6 M

2. **Gross storage:** dead storage = 10 % of gross storage, so live storage = 0.90 × gross.
Gross storage = 27.500 / 0.90 = **30.556 Mm³**; Dead storage = 30.556 – 27.500 = **3.056 Mm³**

3. **D.S.L. (dead storage level / sill level)** – capacity 3.056 lies between 2.60 (R.L. 603.00) and 6.20 (R.L. 606.00). By linear interpolation:

D.S.L. = 603.00 + (3.00) × (3.056 – 2.60) / (6.20 – 2.60) = **603.38 m**

4. **F.R.L.** – gross storage 30.556 lies between 27.40 (R.L. 615.00) and 37.90 (R.L. 618.00):

F.R.L. = 615.00 + (3.00) × (30.556 – 27.40) / (37.90 – 27.40) = **615.90 m**

5. **Flood lift (head over waste weir)** by Francis formula $Q = 1.84 L H^{3/2}$:

$600 = 1.84 \times 120 \times H^{3/2} \rightarrow H^{3/2} = 2.7174 \rightarrow H = (2.7174)^{2/3} = \mathbf{1.947\ m}$

6. **H.F.L.** = F.R.L. + flood lift = 615.90 + 1.947 = **617.85 m**

7. **T.B.L. (top of bund / dam level)** = H.F.L. + free board = 617.85 + 2.00 = **619.85 m**

Control level	R.L. (m)
Dead storage level (D.S.L.)	603.38
Full reservoir level (F.R.L.)	615.90
High flood level (H.F.L.)	617.85
Top of bund level (T.B.L.)	619.85

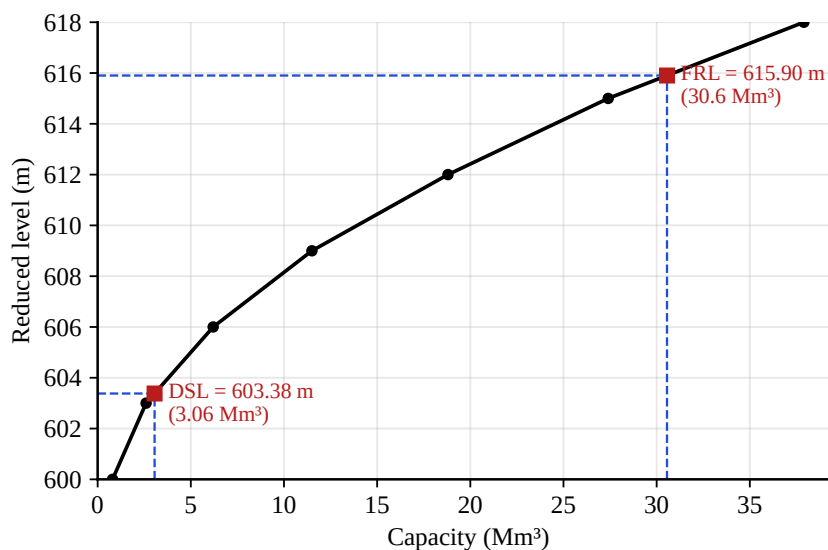


Fig.: Elevation–capacity curve (plotted from given data)

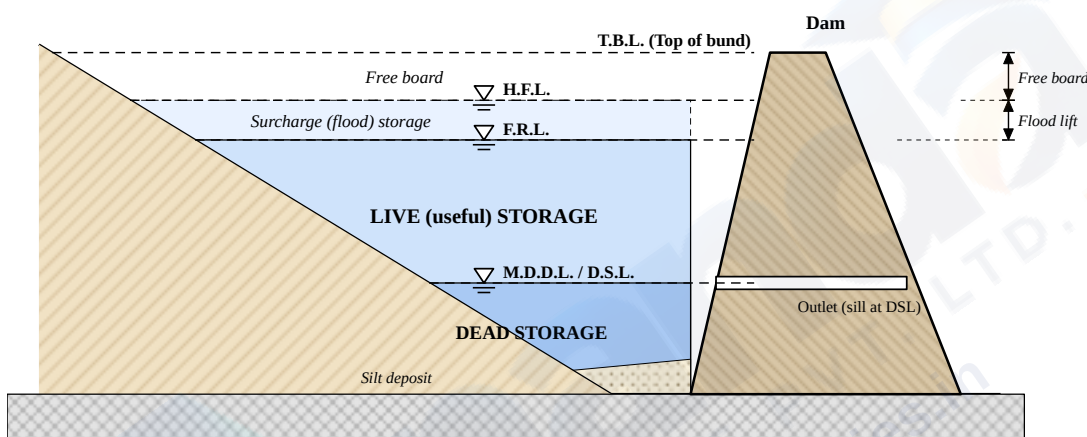


Fig.: Storage zones and control levels of a reservoir

(Live & gross storage 1 M, DSL 1 M, FRL 2 M, HFL & TBL 2 M)

b) Find the design discharge and capacity of a canal from the data below. Transit losses = 15 % of discharge at the canal head, time factor = 0.75, capacity factor = 0.80.

Sr. No.	Crop	Season	Area (ha)	Duty at field (ha/cumec)
1	Sugarcane	Perennial	420	730
2	Rice	Kharif	600	800
3	Jowar	Kharif	900	1600
4	Wheat	Rabi	1500	1800
5	Gram	Rabi	700	2000
6	Groundnut	Hot weather	350	900

Step 1 – Discharge at field (outlet) for each crop: $Q = A / D$

6 M

Crop	Season	Area A (ha)	Duty D (ha/cumec)	$Q = A/D$ (m³/s)
Sugarcane	Perennial	420	730	0.5753
Rice	Kharif	600	800	0.7500

Jowar	Kharif	900	1,600	0.5625
Wheat	Rabi	1,500	1,800	0.8333
Gram	Rabi	700	2,000	0.3500
Groundnut	Hot weather	350	900	0.3889

Step 2 – Season-wise requirement (perennial crop needs water in every season):

- Kharif: $0.5753 + 1.3125 = \mathbf{1.8878 \text{ m}^3/\text{s}}$
- Rabi: $0.5753 + 1.1833 = \mathbf{1.7587 \text{ m}^3/\text{s}}$
- Hot weather: $0.5753 + 0.3889 = \mathbf{0.9642 \text{ m}^3/\text{s}}$

Maximum requirement is in the **Kharif** season: $Q_{\text{field}} = 1.8878 \text{ m}^3/\text{s}$

Step 3 – Allow for transit losses (15 % of the discharge at head): $Q_{\text{head}} = Q_{\text{field}} / (1 - 0.15) = 1.8878 / 0.85 = \mathbf{2.221 \text{ m}^3/\text{s}}$

Step 4 – Time factor = 0.75 (canal runs only 75 % of the days): design discharge = $Q_{\text{head}} / \text{time factor} = 2.221 / 0.75 = \mathbf{2.961 \text{ m}^3/\text{s}}$

Step 5 – Capacity factor = 0.8 (mean supply / full supply): canal capacity = $2.961 / 0.8 = \mathbf{3.702 \text{ m}^3/\text{s}}$

(Crop discharges 2 M, season-wise 1 M, losses 1 M, time & capacity factor 2 M)

c) Explain the failures of earthen dams with their preventive measures.

6 M

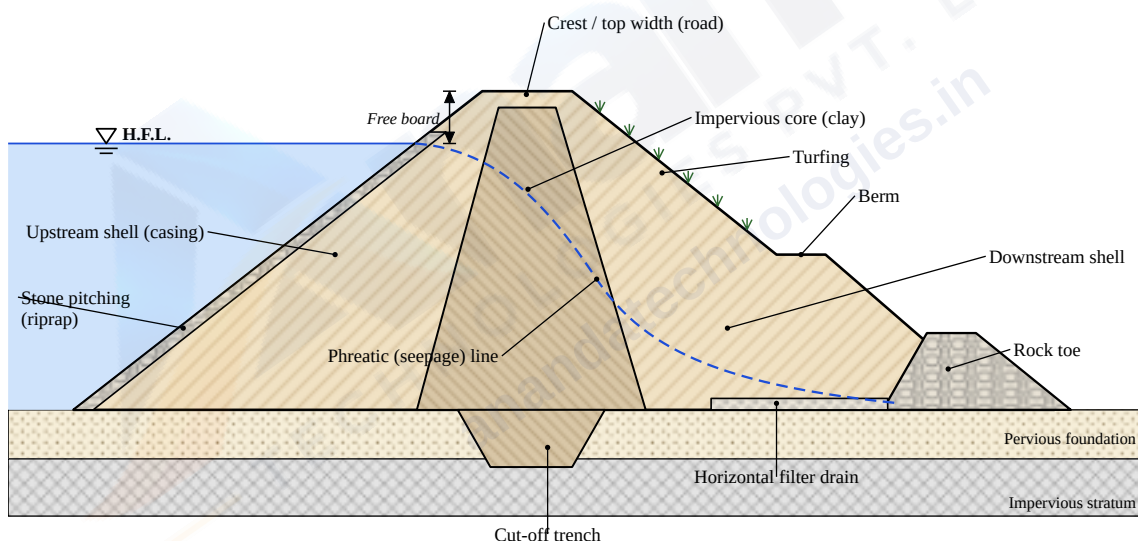


Fig.: Earthen dam — phreatic line, filters and cut-off (preventive features)

Failures of earthen dams are of three types:

A. Hydraulic failures (about 40 %)

- **Overtopping** – flood water flows over the top due to insufficient spillway capacity or free board. *Prevention:* adequate spillway capacity and free board.
- **Erosion of upstream face** by waves. *Prevention:* stone pitching / riprap.
- **Erosion of downstream face** by rain water (gullies). *Prevention:* turfing, berms with surface drains.
- **Erosion of toe** by tail water / spillway flow. *Prevention:* rock toe and training walls.

B. Seepage failures (about 33 %)

- **Piping through dam body or foundation** – seepage water carries soil particles and forms a pipe. *Prevention:* impervious core, cut-off trench, inverted filters, relief wells.
- **Sloughing of downstream toe** – saturated toe slides away. *Prevention:* rock toe and filter drain to keep the phreatic line inside.

C. Structural failures (about 25 %)

- **Sliding of slopes** (upstream slope during sudden drawdown, downstream slope when reservoir is full). *Prevention:* flatter slopes, proper compaction, berms.
- **Foundation slide** on weak clay / fissured strata. *Prevention:* foundation investigation and treatment, flatter slopes.
- **Cracking** due to settlement or earthquake. *Prevention:* proper compaction and good construction control; cracks grouted immediately.

(Hydraulic 2 M, seepage 2 M, structural 2 M)

Q.6 Attempt any TWO of the following:

12 M

a) Enlist the types of spillways and suggest the suitability of each according to site conditions.

Types of spillways:

6 M

1. **Free overfall (straight drop) spillway** – water falls freely from the crest; suitable for low thin arch dams / weirs where the downstream bed is rocky.
2. **Ogee (overflow) spillway** – crest and downstream face shaped to the nappe; most suitable for concrete / masonry gravity dams with wide valley and good rock; can be built on the dam itself.
3. **Chute (trough) spillway** – water flows over a short crest into a steep open channel (chute) to the river; suitable for earthen / rockfill dams where a saddle or flank is available.
4. **Side channel spillway** – water flows over a crest into a channel running parallel to the crest; suitable for narrow valleys with steep sides where there is no space for an overflow crest across the flow.
5. **Shaft (morning glory) spillway** – water enters a funnel-shaped inlet into a vertical shaft and a tunnel; suitable where there is no space for other types (narrow gorge) and a diversion tunnel is available.
6. **Siphon spillway** – a closed duct working on siphonic action; suitable where space is limited and close control of reservoir level is needed (small discharges).

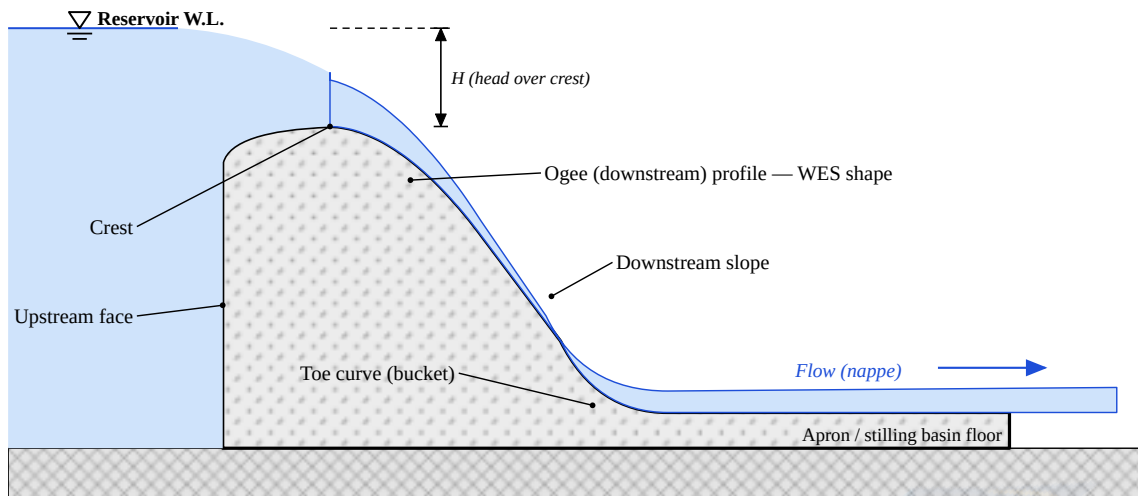


Fig.: Ogee spillway (most common type for gravity dams)

(Types 2 M, suitability 4 M (any four))

b) Draw a neat layout of diversion headworks and state the functions of: i) Weir ii) Divide wall iii) Silt excluder iv) Guide banks.

6 M

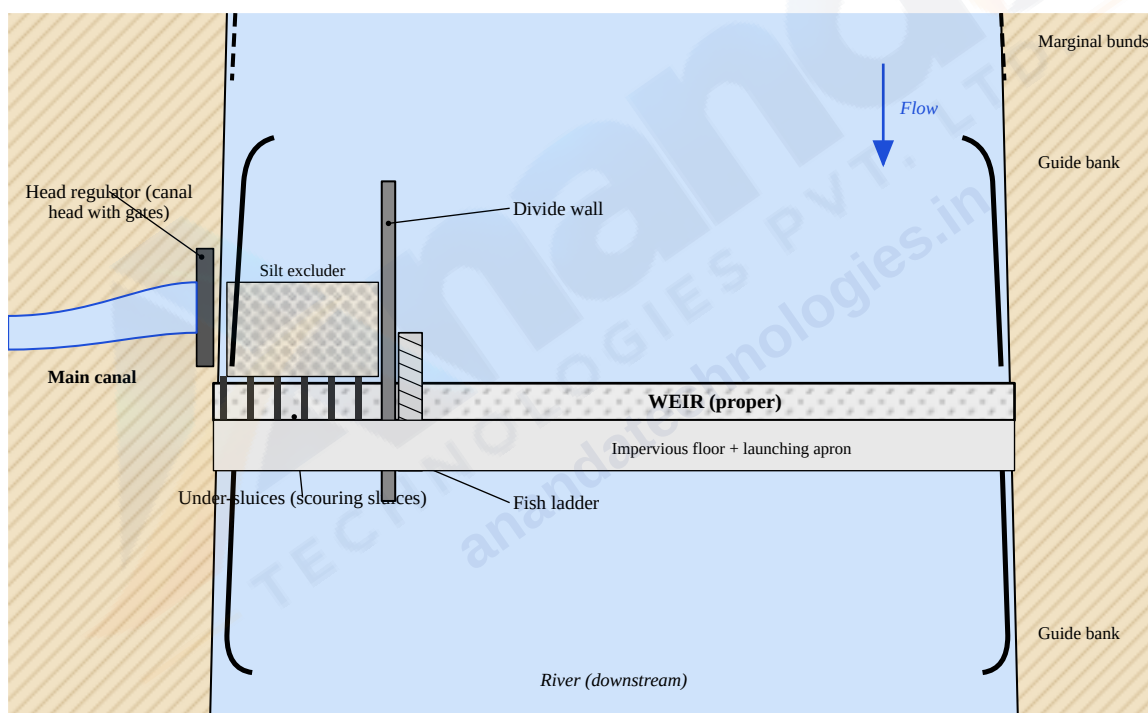


Fig.: Layout (plan) of diversion headworks

- Weir** – raised barrier across the river which raises the water level so that water can be diverted into the canal.
- Divide wall** – a wall at right angles to the weir separating the under-sluices from the weir proper; it creates a still pocket in front of the head regulator so that silt settles there and is scoured by the under-sluices, and prevents cross flow.
- Silt excluder** – tunnels in the floor of the pocket in front of the head regulator through which the silt-laden bottom water is passed to the downstream, so that relatively clear water enters the

canal.

4. **Guide banks** – earthen banks with stone pitching on both sides which guide the river to flow axially through the weir and protect the structure from out-flanking.

(Layout 2 M, functions 4 M)

c) Suggest the suitable type of cross drainage work and draw its sketch when: i) Canal bed level is much above the H.F.L. of the drain. ii) H.F.L. of the drain is above the canal bed level (canal over drain). iii) F.S.L. of the canal is below the bottom of the drain trough. 6 M

Suitable cross drainage (CD) works:

1. **Canal bed level is well above the H.F.L. of the drain** → **Aqueduct**. The canal is carried over the drain in a trough supported on piers and the drain water flows freely below.
2. **H.F.L. of the drain is above the canal bed (canal over drain)** → **Siphon aqueduct**. The drain water passes through barrels below the canal trough under pressure (siphon action).
3. **Canal F.S.L. is below the bed of the drain trough (drain above canal)** → **Super passage**. The drain is carried over the canal in a trough and the canal flows freely below.

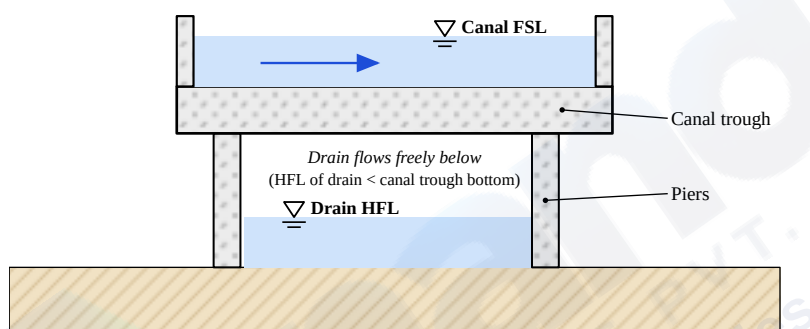


Fig.: Aqueduct — canal carried over the drain (HFL of drain below canal bed)

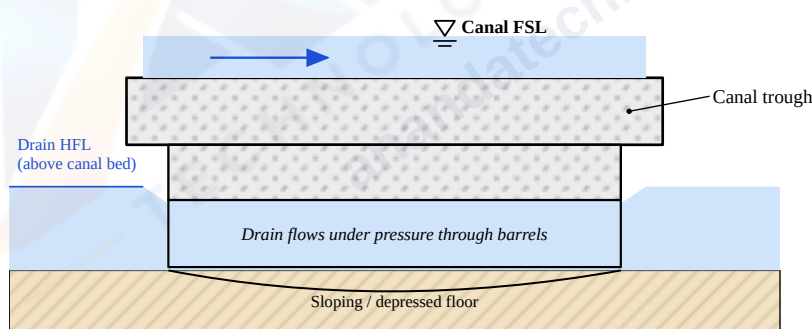


Fig.: Siphon aqueduct — drain passes under the canal as a siphon

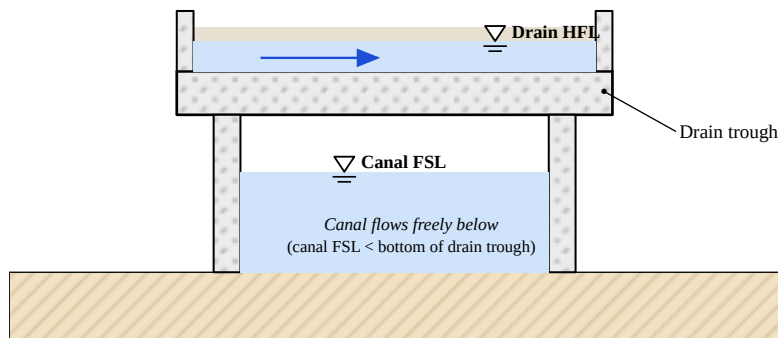


Fig.: Super passage — drain carried over the canal

(Each correct CD work 1 M, each sketch 1 M)

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