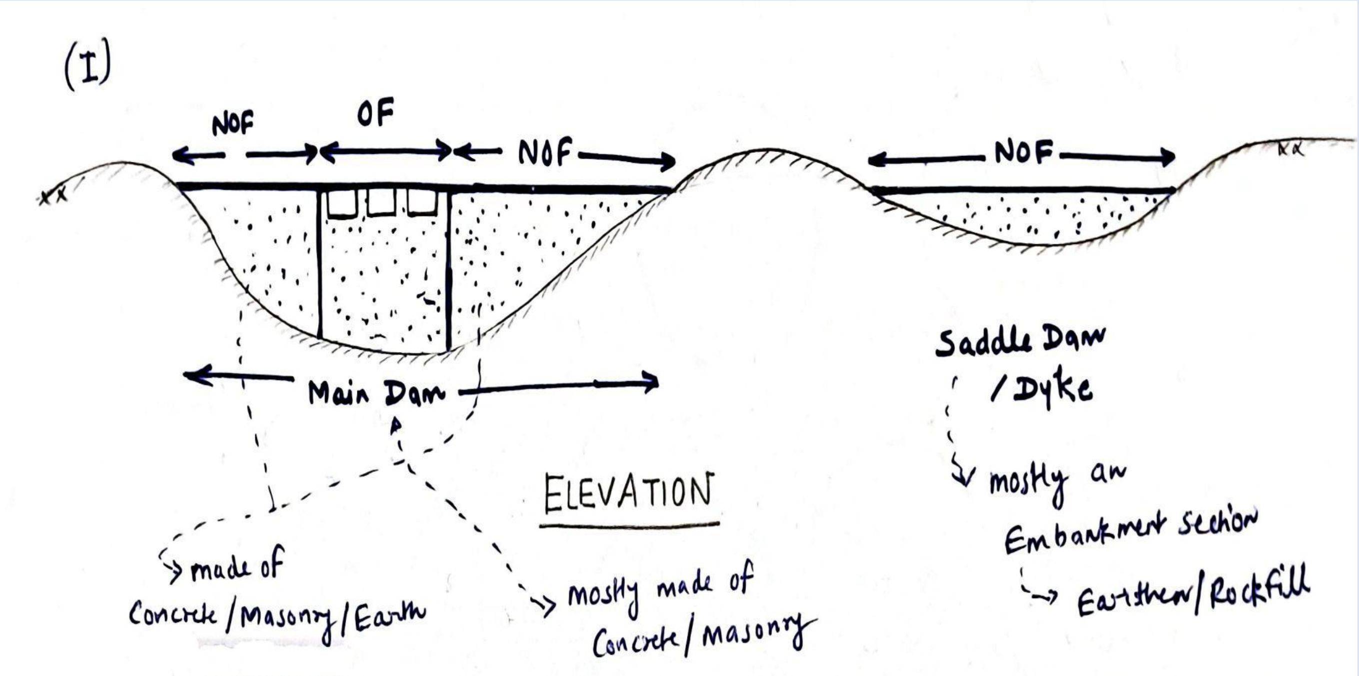
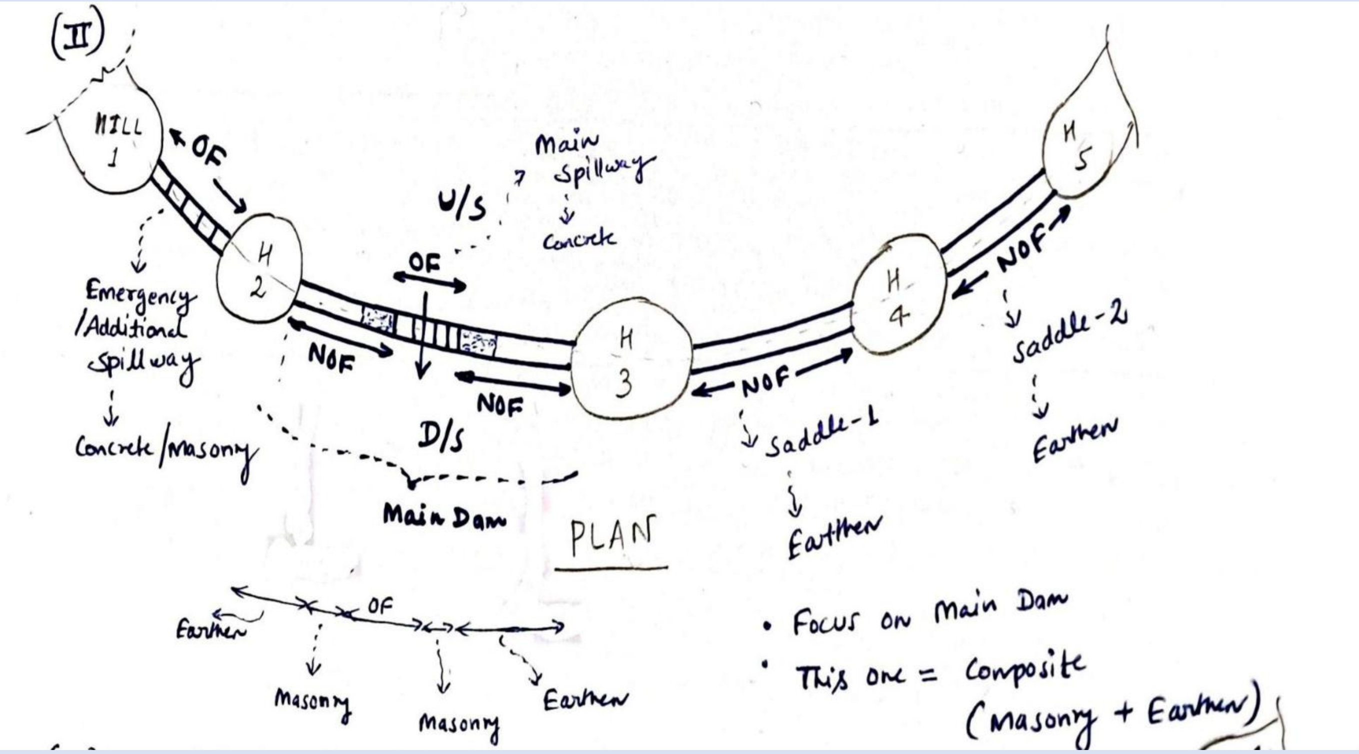
Supporting Data

❖ Dam Type

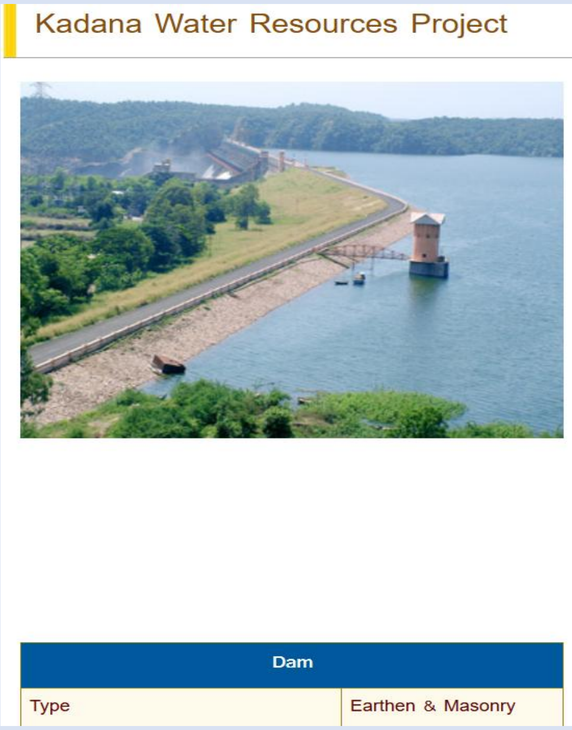


- **NOF Section** of the Main Dam shall decide about the **Type** of Dam.

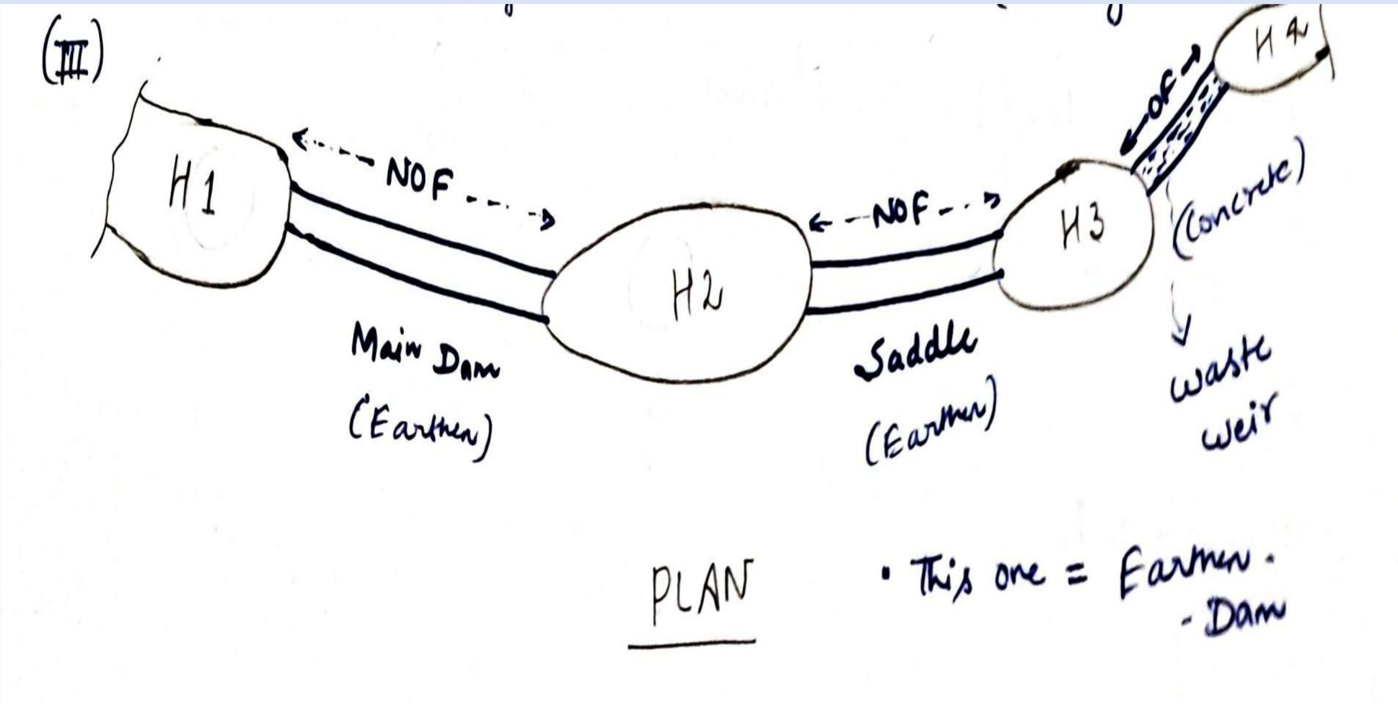


(Material with major quantity in NOF, shall lead the Name of the Dam)
(Ex. Name of Dam presented in above plan = Composite: **Earthen** + Masonry)

- Also, refer to Salient Features of the Specified Dam under focus.



(For Example: Observe the NOF Section of Main Dam Portion of Kadana WR Project)



For carrying out the RRA on RRSSD (Rapid Risk Screening of Specified Dams) Web Portal, Visit https://rrssd.cwc.gov.in/

❖ General Description/ Salient Features

It must contain three files (PDFs) -

1) **Salient Features**

2) **Layout of the Dam/ Plan** (Showing Main Dam Section & Saddle Sections, including - NOF, OF, Gated/ Ungated, Construction Material used etc.)

   Refer to the Figures shown above (Better Picture/ Figure + Bird Eye View is more suitable).

3) **Separate Note for Location & Type of Dam**

   So that the Reviewer can have a better Idea about your Dam before assessing the RRA Report.

<table>
<tr><td colspan="2">"XYZ Dam, situated at Latitude____ & Longitude ____, is a type of _ _ _ _ _ _ _ _ _ _ _ _ _ Dam, having following components -</td></tr>
<tr><td>A) NOF Sections -

1) Main Dam (Earthen/ Masonry/ Concrete) = 530 m

2) Saddle Dams (Two Nos.) = 100 m & 120 m respectively</td><td>B) OF Sections -

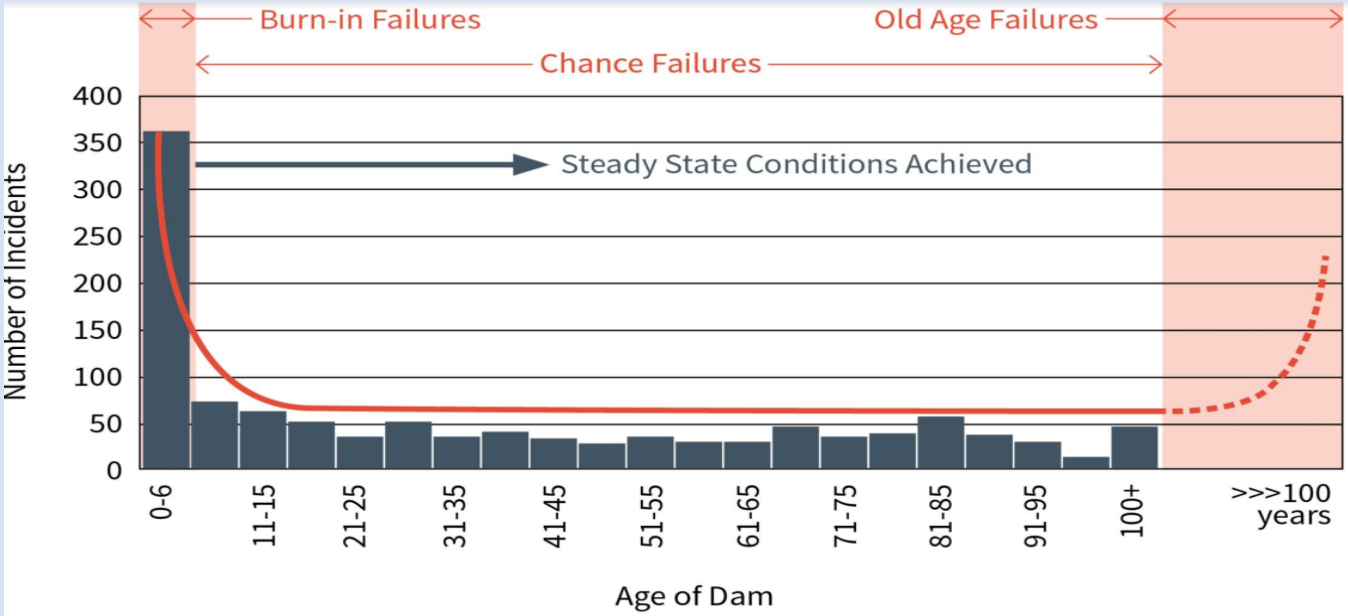
1) Gated Spillway (Concrete/Masonry) = 100 m
or
Ungated Spillway/ Waste Weir (Concrete/Masonry) = 100 m

2) Emergency/ Auxiliary Spillway (Gated/Ungated) (Concrete/ Masonry) = 40 m</td></tr>
</table>

Use Word File of this Table and convert it into PDF.

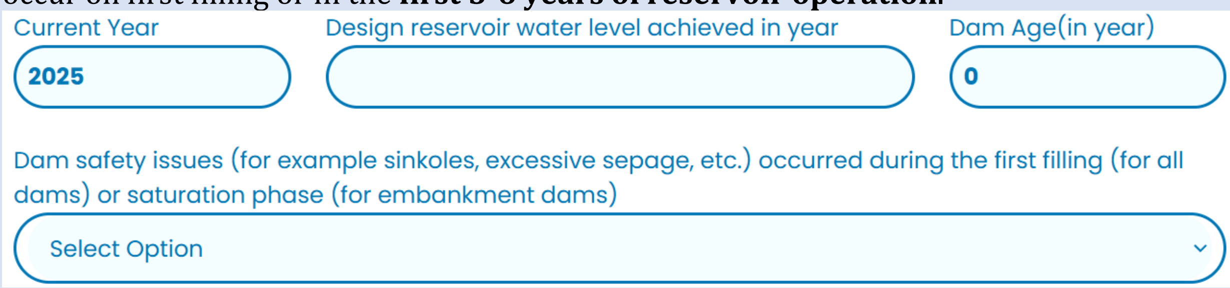
- **<u>Note</u>**: Do not attach irrelevant pages or reports. **Attach only those pages which are precisely applicable** to the question asked.

TC 1 (Age)



Dam's vulnerability vs Age

- USBR Research's Conclusion: Approximately 67% of all failures and 50% of all dam incidents occur on first filling or in the **first 5-6 years of reservoir operation**.



- Evidence of **Dam Safety Issues** (like **sinkholes, seepage, cracking, settlement and erosion** etc.), may appear when the reservoir is raised to new levels for the first time (First Filling), and it is the first indication that the future safety of the dam may be compromised.

- The "Saturation Phase" of Embankment Dams refers to the **period during and after the reservoir is filled** when the water gradually permeates and saturates the soil materials of the dam embankment and its foundation. This is a critical phase that significantly influences the stability and performance of the dam.

  For our assessment, only the safety issues identified during the first filling of the dam or till the dam reaches saturation phase are to be reported, hence consider –

Saturation Phase = Period of First Filling + 6 Years after the First Filling

Ex. If, for a Specified Dam (Embankment Type), Construction is completed in 1971 and the First Filling was started in 1971 & completed in 1973, then for our assessment here, consider – Period of Saturation phase = 1971 to 1973 + 6 Years = 1971 to 1979

(If Information/ Document regarding *Period of Saturation phase* is available with the Dam Authority, then the above method may be ignored)

In 'Design reservoir water level achieved in year' –

- Write the Year when the Dam has reached FRL for the first time (i.e., Year of Impoundment).
- If the Dam has not reached FRL yet, then write the current year i.e., 2025 (Applicable to old as well new dams)

In 'Dam safety issues' –

- For the Embankment Dams (or Embankment Dam Section of a Composite Dam), during its Saturation Phase, if any Dam safety issues *(as mentioned above)* were observed, then - Select "Yes".
- For all other kind of Dams, during its first filling (Year of Impoundment), if any Dam safety issues *(as mentioned above)* were observed, then - Select "Yes".

Comment	**Attachment** (merge these 2-3 Pages)
- Year of Construction Completion - Year of Commissioning/ Year of Impoundment - If Dam safety issues were observed, write the Year of occurrence of such issues & type of such issues.	- Document showing Year of Commissioning/ Year of Impoundment. - Document related to observed Dam Safety Issues in such period.

TC 2: Inflow Design Flood (IDF)

- IDF = Inflow Design Flood = Design Flood
- See the Type of Design Flood used for designing the Dam under consideration.

❖ **IDF = PMF/ SPF**

PMF Estimation Methodology

○ PMF estimate derived from a recent (less than 10 years) study that followed methodology outlines in 2021 Central Water Commission (CWC) Guidelines for Selecting and Accommodating Inflow Design Floods for Dams.

○ PMF estimate derived more than 10 years ago when modern methods outlined in 2021 CWC Guidelines were unknown or not applied.

- If PMF/ SPF was derived more than 10 years ago (i.e., before Year 2015); then respond Option 2.
- If PMF/ SPF is derived in or after 2015 (that followed methodology outlines in 2021 by Central Water Commission (CWC) Guidelines for Selecting and Accommodating Inflow Design Floods for Dams) and if such derived IDF is –

1) <u>Used for Construction</u> of the Dam (such dam would have been constructed after 2015); then respond Option 1.
2) If such Derived/ Revised IDF is <u>same as Older IDF</u>; then respond Option 1.
3) If such Derived/ Revised IDF is <u>more than Older IDF</u>, and measures to pass such additional Flood are already there or are created by doing modification in Gate Operation Process or by constructing an Additional Spillway, or by other means; then respond Option 1.

- If Point Nos. 1/ 2/ 3 are not applicable, then respond to Option 2.

Highest Recorded Inflow

○ The highest recorded inflow is less than 5% of the PMF

○ The highest recorded inflow is between 5% and 30% of the PMF

○ The highest recorded inflow is more than 30% of the PMF

- Highest Recorded Inflow should be taken from the available records of Inflow Flood (Yearly Registers are maintained at each Dam Office/ Dam Site)

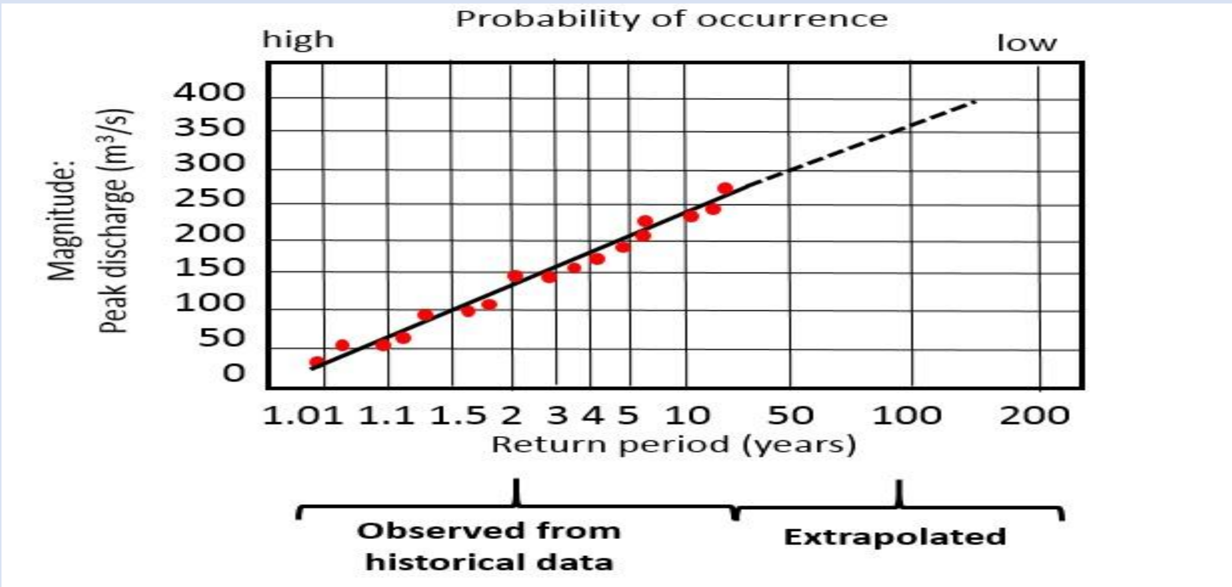
Ex.	Highest Recorded Inflow (HRI) = 1000 Cumecs, IDF = 10,000 Cumecs, Then, calculate (HRI / IDF) x 100 – = (1000 / 10,000) x 100 = 10 % (Based on such percentage, respond suitable option)

- **IDF = 100 Year Flood**

100 Year Flood

- ○ The estimate derived from the sample longer than 50 years
- ○ The estimate derived from the sample shorter than 50 years

- If the IDF is derived from a shorter sample/ Data Set (Yearly Flood Data), then more extrapolation would have been done (for finding 100 Year Flood); which may deviate significantly from the exact conditions, resulting in more inaccuracy, hence, more Risk would be there.



- Based on the Details of 100 Year Return Flood, suitable option can be responded.

- **When Type of Design Flood is not known** (i.e., not written in available records), ***(proof must be attached) –***

  - Refer IS : 11223- 1985
  - Overall size classification for the dam would be the greater of that indicated by either of the following two parameters: (Ex. GS = 7 MCM, HH = 26 m, Hence, It will be an Intermediate Dam for determining the Type of IDF, and such IDF Type would be SPF).

Classification	*Gross Storage*	*Hydraulic Head*
Small	Between 0·5 and 10 million m^3	Between 7·5 m and 12 m.
Intermediate	Between 10 and 60 million m^3	Between 12 m and 30 m.
Large	Greater than 60 million m^3	Greater than 30 m.

3.1.3 The inflow design flood for safety of the dam would be as follows:

Size as Determined in **3.1.2**	*Inflow Design Flood for Safety of Dam*
Small	100 year flood
Intermediate	SPF
Large	PMF

Comment	Attachment
- Type & value of Original IDF. - Derived or revised IDF: Its Value & Date (Month & Year). - Highest recorded Inflow: Value & Year.	- Document showing type of IDF. - Document showing Revised IDF Value and Older/ Original IDF Value (applicable for dams where IDF is revised after 2015)

EC 2 (Available Flow Discharge Capacity)

- Discharge = Outflow

Input percentage of available discharge capacity as the percentage of design discharge capacity

- **For Ungated Dams**, it will be 100 (i.e., 100%).
- **For Gated Dams –**
  - Focus on Existing or Available Flood Discharge Capacity.

- **Flow Discharge Equipment (FDE)**: Various components and systems that are used to control and regulate the flow of water through the dam. These mainly include Gates at Spillway and other Outlets.

- **Installed Discharge Capacity** at the time of Commissioning (or on completion of Construction Phase) of Dam = Capacity of FDE (or Spillways & other Outlets)
  = Design Discharge Capacity

- There may be <u>circumstances</u> when the Installed Discharge Capacity (although Flow discharge equipment being fully functional) cannot be used to the full extent.

  Therefore, in such cases, the Discharges/ Outflows allowed are lesser than the Installed Discharge Capacity, such reduced allowable Discharge is called as Available Discharge Capacity (ADC).

- So, **ADC** is Portion of the Design Flood that can be passed through the Dam (by favoring such circumstances) assuming that the Flow Discharge Equipment (Spillway & Gates) are fully functional.

  It includes, Discharge Capacity available at all spillways (service, auxiliary/ emergency) and bottom outlets.

  Therefore -
  "Available Discharge Capacity = Installed Discharge Capacity - Reduction in Installed Discharge Capacity"

- Such Reduction in Installed Discharge Capacity, could be due to following circumstances –

(i) **Insufficient downstream channel capacity** –

- Can be caused by recent construction of infrastructure in the downstream stretch (or in the floodplain) of river.

- Obstructions in Natural Channel, which were overlooked during the design and construction phase, etc. (Like – Such Obstruction may cause Overtopping of Bridge, Cross Flow through Riverbanks into the Villages/ Settlements etc.)

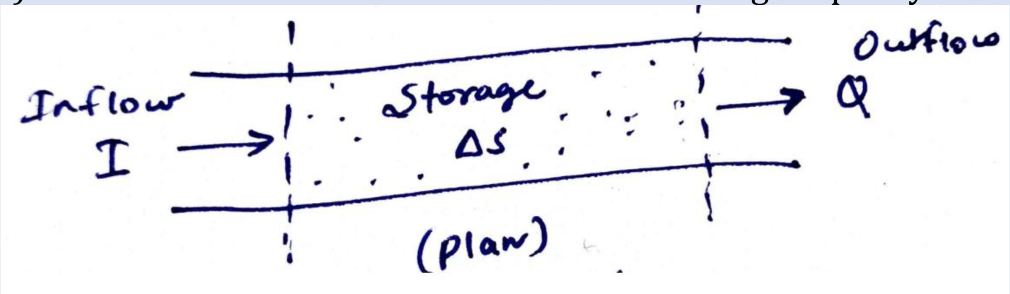
(ii) **Outside interventions** in dam operation during floods, like Political interventions aimed at reduction of possible damage by floods, in the downstream area, or

(iii) **Other restricting circumstances** in effect, or

- Part of the discharge equipment may be no longer functional.
- Low level outlets may have reduced discharge capacity due to the blockage by sedimentation.
- Sedimentation in the reservoir may also cause reduction of spillway discharge capacity by loss of approach depth when the sediment front reaches the dam.

(iv) Uncontrolled and badly managed sedimentation downstream of the dam.

Note: Evidences like increase in Tail Water Level (TWL) {I-Q = ΔS, If TWL↑, means ΔS↑, Hence, for same value of I; Q decreases), decrease in the downstream channel carrying capacity (Q↓) - are the indicators of decrease in the discharge capacity.



(Fig. shows a stretch of river downstream the Spillway)

Ex. Design or Installed Discharge Capacity =~ IDF = 2000 Cumecs
Available Discharge Capacity = 1500 Cumecs

Then, Percentage of Available Discharge Capacity = (1500/ 2000) x 100 = 75%
Accordingly, write 75.

- The comparison of these discharge capacities should be made w.r.t. two similar quantities, like if IDC includes Discharge Capacity available at all spillways (service, auxiliary/ emergency) and bottom outlets, then ADC should also be based on these only.

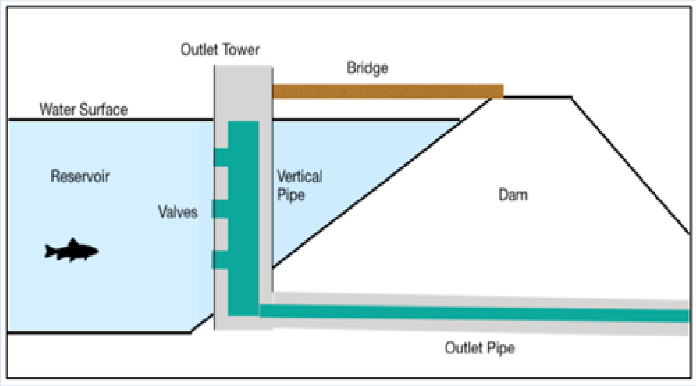
(For More Details, refer Page No. 31 & 32 of User's Manual)

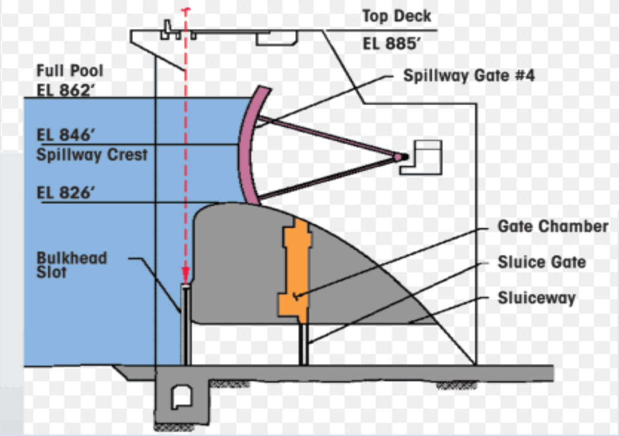
Comment	Attachment
- Suitable Comment.	- Supporting Documents, as an evidence to support the response provided.

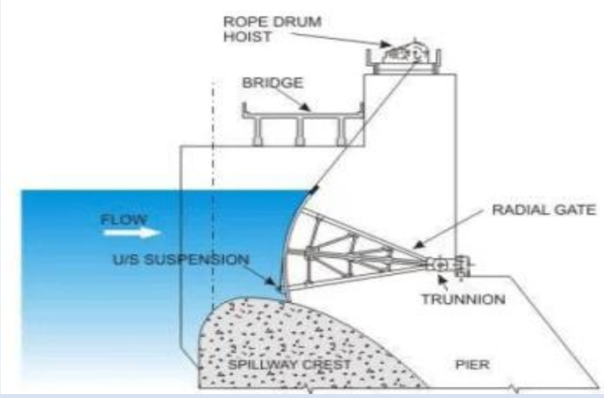
EC 3 (Flow Discharge Equipment)

- **Flow Discharge Equipment (FDE)**: Various components and systems that are used to control and regulate the flow of water through the dam. These mainly include Gates at all spillways (service/ main, auxiliary/ emergency) & bottom outlets, Sluice Gates or Valves, Stoplogs (when needed) and sometimes conduits (other than bottom conduit for supply of Canal Water) as well.

- **Gate System** = A Supporting Structure (Gates) + A Lifting Device (Hoist or Crane, Cables, Motor, Gears, and an Electrical Power Supply) = Electrical, Mechanical, Force Transmission System.







- Focus on Existing Condition of Mechanical, Electro - Mechanical and Control Components responsible for passing the outflow from the reservoir. Most of such are made of Metal.

- The current/ existing condition of discharge equipment **may present challenges**, when all such equipment need be operated **under adverse circumstances**.

- **Desirable Conditions for FDE**:
  - Mechanical and associated electrical equipment should be properly lubricated.
  - Equipment should be free of damaged, deteriorated, corroded, cavitated, loose, worn, or broken parts.
  - Rubber or neoprene gate seals should be free of deterioration or cracking.
  - Hydraulic hoists and controls should be free of oil leaks and wear.
    (Loss of Lubrication will lead to early wear & tear)
  - Wire ropes or chain connections at gates should be properly lubricated and worn or broken parts replaced.
  - The operation should be smooth, without vibration, unusual noises, and overheating.
  - Remote-control systems should be tested for adequate and reliable operation.
  - Stoplogs: The availability, operability, and locations of equipment for moving, lifting and placing stoplogs, should also be verified.

- **Assessing the condition of FDE:**
  - Corrosion (scaling or flaking), pitting, and color changes
    (Unchecked corrosion eventually leads to failure of a metal structure)
  - Fatigue (Loss of metal strength from repetitive loading, such as being bent back and forth).
    (Bulges on metal components or components with moving parts are most likely to suffer fatigue)
    Distortions or cracked paint may indicate sites where a metal structure suffers from fatigue. The process continues until the affected area cracks and/or breaks.
  - Erosion: Flow surfaces and areas around rivets and splice plates may be scoured by abrasive debris.
  - Tearing and Rupture from impact, such as a log slamming/ impacting into a steel lining. (On spillways, metal components are most likely to tear and rupture during storms or other occasions when flows are heavy).

    Tears and ruptures can cause a metal structure to fail completely, or expose the structure to corrosion, cavitation, fatigue, or other damage.

Q1:

Testing and maintenance

- ○ All hydraulic and electro-mechanical components regularly tested and maintained as per regulatory/dam owner's requirements.
- ○ No established testing and maintenance program for hydraulic and electro-mechanical components.
- ○ Testing and maintenance of hydraulic and electro-mechanical components carried out infrequently and on a sporadic basis.
- ○ No testing and no maintenance of hydraulic and electro-mechanical components.

▪ First, focus on 1st & 4th Option, and reply suitably, if not applicable, then focus on 2nd & 3rd Option, and reply accordingly.
(Sporadic Basis = Occurring occasionally, singly, or in irregular or random instances)

Q2:

Condition of Gates & Hoists

- ○ All structural components in excellent conditions.
- ○ Signs of moderate structural deterioration.
- ○ Signs of serious structural deterioration - corrosion and cavitation of metal components.
- ○ Evidence of extensive deterioration - some pieces of critical equipment approaching failure state and missing and broken non-critical parts.

▪ Focus on structural condition of such Metallic Components.

▪ First, focus on 1st & 4th Option, and reply suitably, if not applicable, then focus on 2nd & 3rd Option, and reply accordingly.

Q3:

O&M Problems

- ○ Equipment has not exhibited any operational or maintenance problems.
- ○ Minor problems that were easily and quickly fixed but frequency steadily but slowly increasing in the past 5 years.
- ○ Substantial number of moderate problems requiring longer repair times.
- ○ Frequency of equipment failures rapidly increasing in the past 5 years.

▪ Focus on operational or maintenance problems of such Equipment, like - Clogging, Blockages, Leakage, Noise and Vibration etc. (may be occurring due to Insufficient Lubrication, Improper Alignment, Corrosion & Wear, Seal Failure, Faulty wiring, damaged components, or electrical surges etc.)

▪ First, focus on 1st & 4th Option, and reply suitably, if not applicable, then focus on 2nd & 3rd Option, and reply accordingly.

Q4:

Conduits

- ○ No conduits or conduits are not rquired to pass IDF.
- ○ Conduits resent and capable of passing required portion of IDF.
- ○ Conduits present and with limted capability of passing required portion of the IDF.
- ○ Conduits present without any capability of passing required portion of the IDF.

Use of Conduits for discharging a portion of Design Flood –

- When the primary spillway capacity is insufficient to handle the Design Flood, often Conduits, are employed to supplement the discharge of Excess Flood Water.
- In extreme flood events/ emergency conditions, conduits can be used to rapidly release excess water from the reservoir, reducing the pressure on the dam and preventing potential overtopping or failure.
- Tunnel Conduits, Bottom Outlet Conduits, Penstock Conduits etc., may be used for such purpose.

Diversion Tunnels: During dam construction, tunnels are often used to divert the river flow around the construction site. These tunnels can be repurposed as conduits to pass a portion of the Design Flood (after the construction of dam is completed).

Power Tunnels/ Penstocks: These tunnels carry water from the reservoir to the power plant turbines. In some cases, they can be used to release excess water during flood events/ portion of Design Flood.

Bottom Outlet Conduits: These are located near the base of the dam and are used to release water for downstream needs. They are often used for emergency flood releases & sediment flushing.

- If Design Flood (of the Dam under consideration) is Revised and if Value of Revised Design Flood is <u>equal or more</u> than the Installed Discharge Capacity, then based on such comparison, suitable option should be replied.
- If <u>equal</u>, then respond to Option 1.
- If <u>more</u>, and –
  - If Conduits are not present, then respond to Option 1.
  - If Conduits are present, then respond to Option 2/ 3/ 4 as per suitability.

Q5:

Blockages

- ○ No potential for blockage of sluiceways or outlets by debris.
- ○ Only limited and partial blockage of sluiceways or outlets by debris is possible.
- ○ Extensive blockage of sluiceways or outlets by debris possible.
- ○ High potential for extensive blockage of sluiceways or outlets.

- Focus on the possibility of Blockage of Gates/ Sluiceways or other Outlets by debris.
- Based on past experiences of similar events (incoming of debris with the Flood Water), potential/ possibility of such blockage could be easily identified.

Comment	Attachment
- Suitable Comment.	- Supporting Documents, as an evidence to support the response provided.

EC 4 (Back-up Power)

Dam site under consideration

- ○ The back-up power at the site is inspected, tested and maintained as per regulatory/dam owners requirements.
- ○ The back-up power at the site is inspected, tested and maintained but not following regulatory/dam owners requirements.
- ○ No back-up power at the site or inspection, testing and maintenance irregular or absent

- Mainly Applicable to Gated Dams (which are Electrically Operated).
- For Ungated Dams/ Gated Dams (which are Manually Operated/ Operated by Hand), respond to Option 1.
- Sudden power outages can disrupt the operation of gates and valves. Backup power ensures that these critical systems remain operational **during emergencies.**
- The presence or absence of back-up power to operate the flow control equipment in the absence of main power source may affect the capability of the dam to safely pass the inflows.
- **Common Backup Power Solutions**:
  - **Diesel Generators:**
    - Widely used due to their reliability and ability to provide substantial power for extended periods.
    - Regular maintenance and fuel supply are essential.
  - **Uninterruptible Power Supplies (UPS):**
    - UPS systems provide immediate backup power in the event of a power outage.
  - **Battery Systems:**
    - Large battery banks can provide backup power for critical systems.
    - Advances in battery technology have made them increasingly viable for this application.
  - **Hydroelectric Backup:**
    - In some cases, smaller, independent hydroelectric turbines can be installed to provide backup power. This can be a very reliable option, as the dam itself provides the water source.

❖ For Gated Dams:
  - Option No. 1 & 2 – Self Explanatory
  - Option 3: **No back-up power at the site,** then Sub Option 4, 5 & 6 need to be suitably responded.

Neighbouring site (Fill only when no back up power is available at site)

- ○ The neighbouring site with a reliable back-up power can be easily accessed.
- ○ The neighbouring site with a reliable back-up power may be difficult to acess (access road with the history of road flooding or blockage by Landslide, fallen trees, forest fires, etc.).
- ○ No back-up power at the neighbouring site.

- Diesel Generator from neighboring site may be transported to the site under consideration. Condition of Access Road also plays important role in its transportation due to its size & weight.

Comment	Attachment
- Suitable Comment.	- Supporting Documents, as evidence to support the response provided.

EC 5 (Access to Site)

- Timely Access to Site is very important due to following reasons –

  - During the Monsoon, Communicating the Flood Warning is very critical.
  - For Gated Dams, Operation of Gates is also very crucial.
  - To carry out the Important Maintenance works.

- **Road condition:** Self Explanatory
  - ○ Access road is in good condition and there is no history of road flooding or blockage by fallen trees or forest fires.
  - ○ Access road was impassable in the past during large flood events, or due to the landslides, fallen trees blocking the road caused by storms or other high wind events, or due to the forest fires.

- **Alternative ways:** Self Explanatory
  - ○ Alternative ways to reach the site are available (boat, helicopter, second access road).
  - ○ Alternative ways to reach the site are unavailable.

- **Staff at site:** Self Explanatory
  - ○ Site has staff at the site 24/7 and time to reach the site from the outside is less than 2 hours.
  - ○ There is no permanent staff at the iste and the time to reach the site from the outide is more than 2 hours.

  - It discusses about Permanent Staff only.

- **Access to control room:** Self Explanatory
  - ○ Access to control room and other critical dam safety equipment at the site available at all conditions.
  - ○ Access to control room and other critical dam safety equipment at the site difficult or impossible in some conditions.

Comment	Attachment
- Suitable Comment.	- Supporting Documents, as evidence to support the response provided.

TC 3 (Seismic Design)

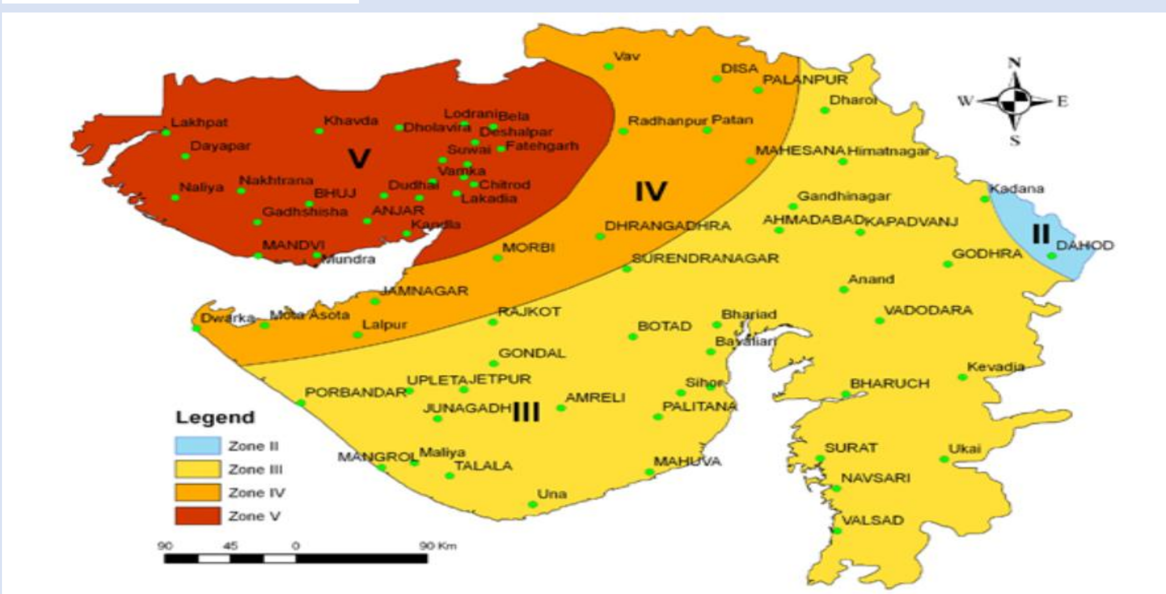
(Lower San Fernando Dam, California, USA after 1971 Earthquake – Failed due to Liquefaction)

Failure or damage to dams (and their appurtenant facilities) may result either from a **direct fault movement** across the dam foundation or from **ground motion** induced at the dam site by an earthquake.

The potential for dam failure is higher in geographic areas where seismic activity has increased.

- **Seismic Zones:**

  ○ Dam is in Zone II
  ○ Dam is in Zone III
  ○ Dam is in Zone IV
  ○ Dam is in Zone V



❖ Seismic Design Status:

○ Dam designed in accordance with the current seismic design standards.

○ Dam designed applying seismic design standards published at the time of design, but meeting requirements of current standards.

○ Dam's design not meeting current design standards but met the standards at the time of design/construction.

○ Dam not meeting current design standards and did not meet the standards at the time of design/construction.

Dam designed in accordance with the current seismic design standards –

- **Refer α_h & α_v used in the Design of the Dam under consideration.**
  - Compare your "α_h" value with the "α_h" value given in the Table below (it specifies α_h as per current standards) and respond accordingly.

Seismic Zone II	Seismic Zone III	Seismic Zone IV	Seismic Zone IV
0.08 g	0.12 g	0.18 g	0.27 g

(**Ex.**- If your Dam is in Zone V and "α_h" value used in Design is 0.26 g, whereas the Limit specified in Table is 0.27 g. Since, deviation here is very less, hence, it could be safely assumed that the Design is consistent with the Current Seismic Design Standards.)

And, if deviation is more, it could be assumed that the Design is not consistent with the Current Seismic Design Standards.

(**Ex.-** If your Dam is in Zone V and "α_h" value used in Design is 0.24 g, whereas the Limit specified in Table is 0.27 g. Since, deviation here is significant, hence, it could be assumed that the Design is not consistent with the Current Seismic Design Standards, since a factor of 'g' {=~10} is also there, which makes a large change in Lateral Force = m x a = Mass x α_h {as mass of a Dam is huge})

- Dam is designed applying seismic design standards published at the time of design: If there is evidence stating that the Dam is Designed as per applicable seismic design standards at the time of design, then attach such evidence & submit the response accordingly in Option 2 or 3.

- Dam is designed without using the applicable seismic design standards at the time of design or Dam is not designed for Seismic Aspects, then respond to Option 4.

➢ **If you don't have α_h value for your Dam** then the year 1971 may be taken as a reference w.r.t. to the year of construction, to judge whether major deviations from current seismic standards are there.

- So, if your Dam is Designed & constructed after 1971, then it could be safely assumed that the Design is consistent with the Current Seismic Design Standards.
- And, if your Dam is Designed & constructed before 1971, then it could be assumed that the Design is not consistent with the Current Seismic Design Standards.

❖ **Defensive Measures for Seismic Hazard:**

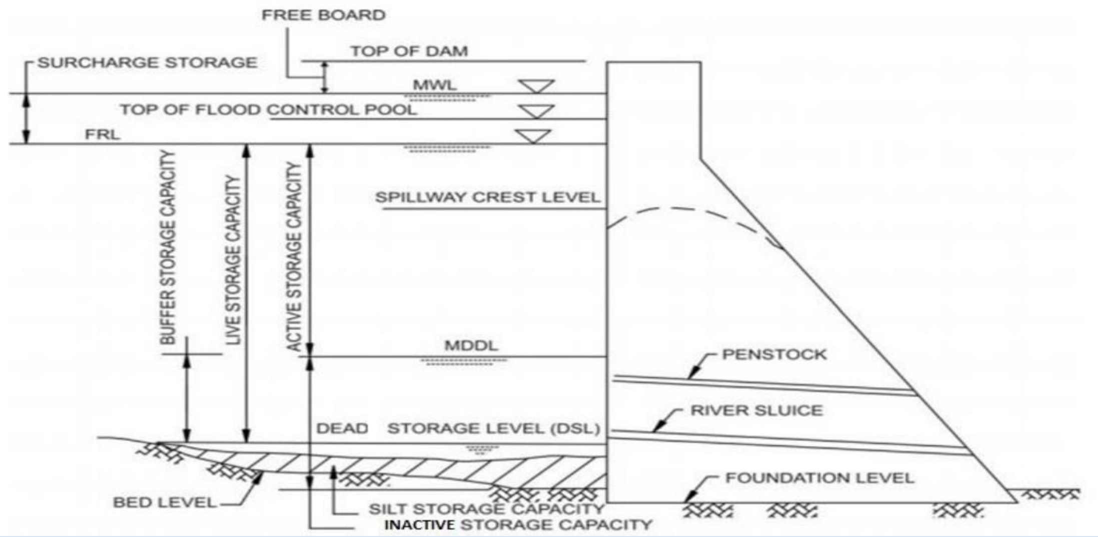
- ○ Dam has robust defensive measures appropriate to mitigate all aspects of seismic hazard.
- ○ Dam has some defensive measures appropriate to mitigate all aspects of seismic hazard.
- ○ Dam has only few and limited defensive measures appropriate to mitigate some aspects of seismic hazard.
- ○ Dam has no defensive measures mitigating effects of seismic hazard.

○ For Embankment Dams –

(During an earthquake, Embankment/ Earth dams fail due to lateral spreading and settlement, that can result in Overtopping)

➢ **Defensive measures include** - Excess Freeboard, Flat Slopes, Treatment of foundation materials (that are of low strength/ insufficient density to prevent strength loss/ Liquefaction during earthquakes of reasonable/ acceptable Intensities), and a High Factor of Safety against Seismic Loadings.

- Minimum Freeboard (as per IS 10635): (Still Water Level to Dam Top Level)
  - Freeboard at MWL (Minimum FB) = 1.5 m
  - Freeboard at FRL (Normal FB) = 2.0 m
  - Parapet wall provided is not to be considered as a part of freeboard.



- **Excess Freeboard** (for Safety against Settlement & Liquefaction):
  The Freeboard provided at a Dam, may be considered as Excess and suitable to act as a Defensive Measure when –

  - The Provided Freeboard is more than that of Freeboard due to wave action, i.e., $(FB_{provided}) > (FB_{wave}$ = FB as per IS 10635), and

  - The Provided Freeboard at MWL (i.e., Minimum FB) should be as per the following Table *(for Excess Freeboard check, use this table only).*

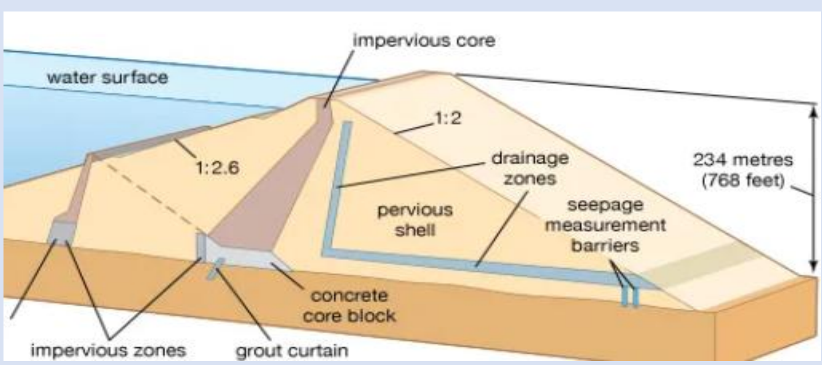
For Medium and Major Projects :			
a)	up to 20 m height of dam	–	2 m above MWL,
b)	From 20 to 60 m height of dam	–	2.5 m above MWL,
c)	Above 60 m height of dam	-	3.00 m above MWL.
For Minor Irrigation Projects :			
a)	up to 20 m height of dam	–	1.5 m above MWL,
b)	from 20 to 60 m height of dam	–	2.0 m above MWL,
c)	above 60 m height of dam	–	3.00 m above MWL.

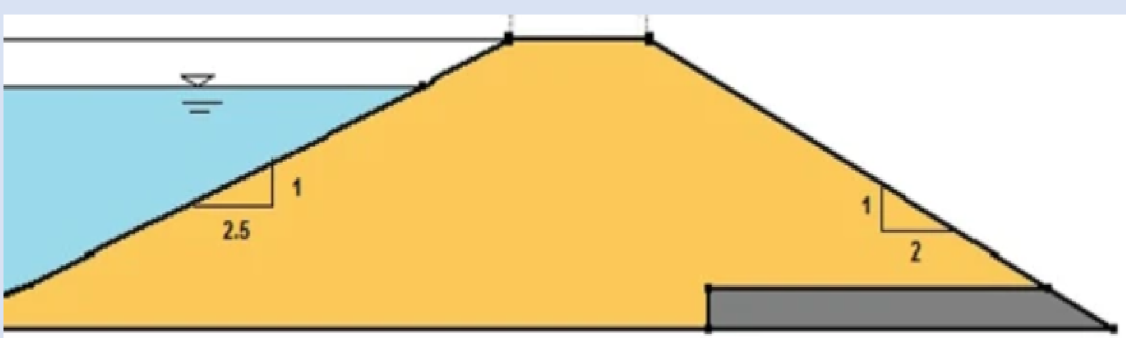
As per MHWRD's Manual on Design of Earthen Dams

(Based on Height of the Dam)

- **Flat Slopes –**
  Since Embankment Dams are constructed on Overburden Soils which do not possess good Bearing Capacities, that is why, Bearing Pressure (on Foundation) due to Structure should be minimum possible, hence Base Area should be provided accordingly. Therefore -

  - The U/S Slope should be flatter than 2.5H : 1V (Minimum Value)
  - The D/S Slope should be flatter than 2H : 1V (Minimum Value)





- **FOS = (FOS)$_{\text{against Slope Failure}}$ = 3 – 4** (As Slopes are vulnerable during Earthquake).

- <u>For Concrete Dams/ Concrete "OF" Section</u> –

  - **Defensive measures include** - Good Flexible Water Stops, Good Drainage, Good Foundation Preparation, and a High Factor of Safety.

    - The Contraction **Joints** (in Concrete/ Masonry Dams), which unless sealed, would permit the leakage of water from the reservoir to the downstream face. To prevent/ stop this leakage, water-stops are installed in the joints adjacent to the upstream face - Check the Design/ Construction Details & Existing Condition of Flexible Water Stops (Status of Quality/ Condition?)

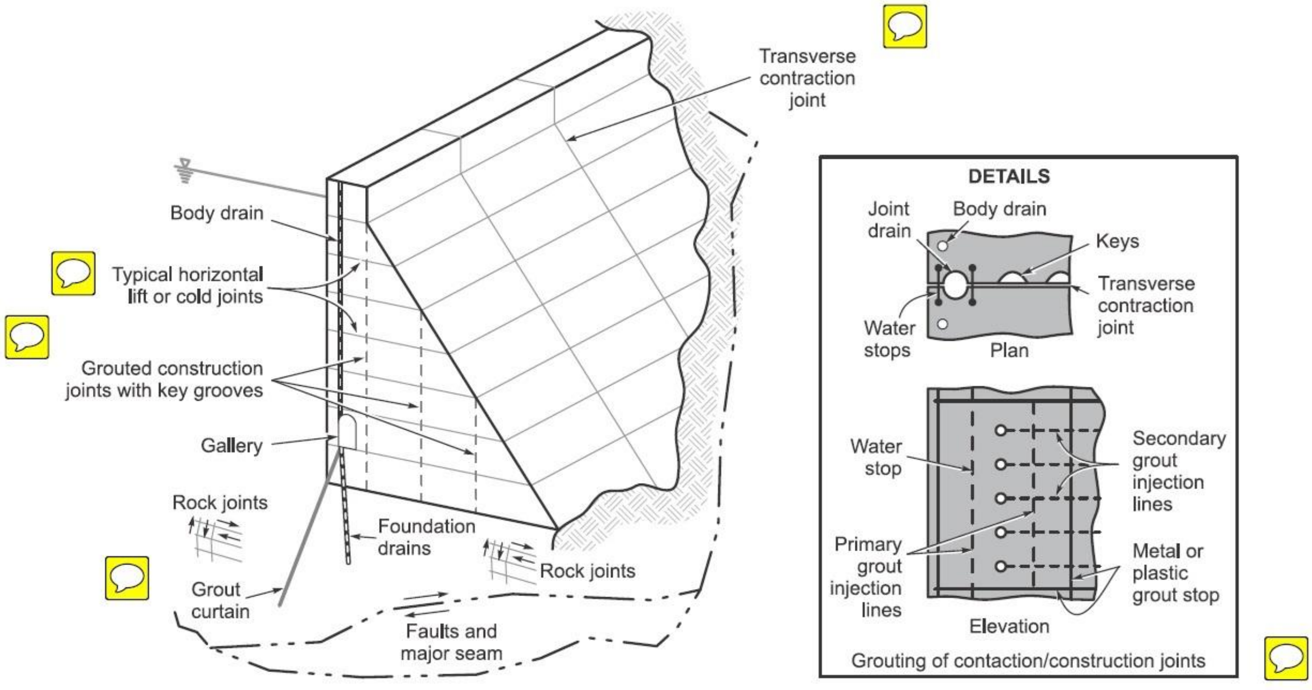


Figure 1.2.1-1 Concrete Gravity Dam.

- Regular watch should be kept on **Drainage Holes'** condition so that uplift pressures could be kept within the Limit - Check the Drainage Holes (are they choked/ unchoked) etc.

- **Good Foundation Preparation** - Improvement of the foundation may be performed by the following major methods:

  - Excavation of decayed/ weak rock & backfilling with concrete.
  - Excavation for making concrete cutoff walls across leakage channels in the dam foundation.
  - Grouting the foundation to increase its strength and imperviousness.

- **Factor of Safety** against Seismic should be high (i.e., it should be more than allowable FoS by BIS) – Design Document will be having such section and assessment can be done accordingly.

- Note: If no information is available about the above-mentioned defensive measures, then a judgement may be made depending upon the seismic zone in which the dam is located, i.e. dams in seismic zone IV & V, may be given high risk score to be on the conservative side.

Comment	Attachment
- Values of α_h & α_v used in the Design of the Dam under consideration. - Year of Construction. - Other necessary comments to justify the responses made.	- Document showing Height, 'FB above MWL' and 'FB above FRL' - (For Embankment Dam) - Drawing showing Cross-Section, U/S Slope and D/S Slope - (For Embankment Dam) - Document showing FoS against Slope Failure (For Embankment Dam), FoS against Seismic Loadings. - Document showing Details of Foundation Preparation. - Documents showing Condition of Water Stops, Drainage Holes. - FoS (For Concrete/ Masonry Dam)

EC 1 (Seismic Resistance)

❖ **Past seismic events:**

- ○ No issues with safety performance during past seismic events .
- ○ Some moderate issues with safety performance during past seismic events.
- ○ Poor safety performance during past seismic events.

○ Issues with safety performance during past seismic events –

- Focus on the Period of "Construction Completion Month of the Dam" to "Present Month", and by referring the details of Past Major Earthquakes in such period, check out the records/ discuss with the Officers/ Staff who were posted at the Dam during such Earthquakes.
- However, Bhuj Earthquake (26 Jan, 2001) may be given more focus for making such assessment as it was nearest and having highest Magnitude. Accordingly, submit your response.

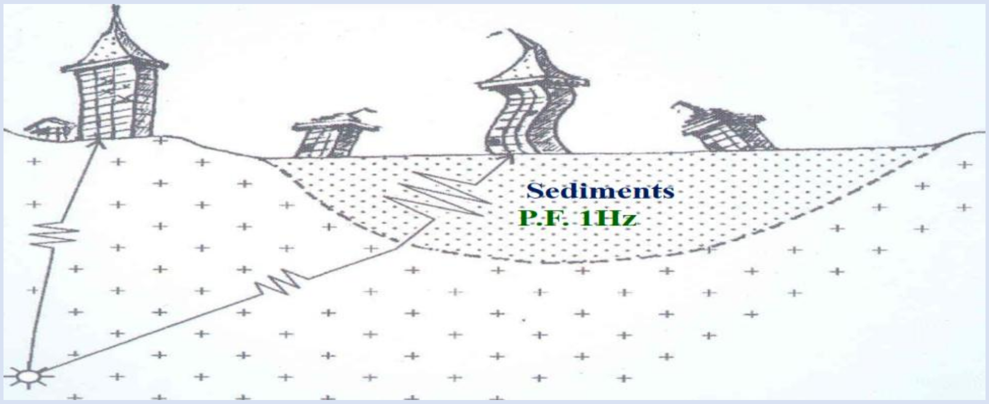
Place	Year	Magnitude
Jabalpur	June 2, 1927	6.5
Indore	March 14, 1938	6.3
Bhadrachalam	April 14, 1969	6.0
Koyna	December 10, 1967	6.7
Killari (Latur)	September 30, 1993	6.3
Jabalpur	May 22, 1997	6.0
Bhuj	January 26, 2001	7.6

(Past major Earthquakes of "Peninsular India")

- As per Location of Dams in Gujarat region - near to Bhuj/ Maharashtra/ M.P., and as per Life Span (Construction Year to Current Year), enquiries may be made. Accordingly, submit your response.

Ex. For Ukai & SSD (if they were unaffected by Bhuj Eqk), effects of Killari and Jabalpur Eqks may be enquired.

(Seismic Waves can travel to longer distances and the effect of Sub Surface Medium plays an important role in its Transmission and Final Effects)



❖ Resilience to Seismic Events:

- ○ Dam is of the type which is resilient to seismic events e.g. concrete gravity dams, embankment dams which have available freeboard as required by Dam Safety Act with associated Regulations and appropriate CWC Guidelines.
- ○ Dam is of the type which has only some resilience to seismic events, embankment dams which have available freeboard equal to or slightly less than the amount required by Dam Safety Act with associated Regulations and appropriate CWC Guidelines.
- ○ Dam is of the type which is not resilient to seismic events, embankment dams which have available freeboard significantly smaller than the amount required by Dam Safety Act with associated Regulations and appropriate CWC Guidelines.

- Following type of Dams are resilient –
  - Concrete Gravity Dams
  - Embankment Dams which have available Freeboard (as discussed in TC 3)

  - Review Option 1 & 3 of this section, if not applicable, then respond to Option 2.

❖ Requirement for upgrades:

Requirement for upgrades

- ○ Dam does not need any upgrades to improve the resistance.
- ○ Dam needs some, limited upgrades to improve the resistance.
- ○ Dam needs major upgrades to improve the resistance.

- If, during past seismic events, there were issues with safety performance or Dam behaved poorly, and if the Dam has not been Rehabilitated after such events, then, reply in Option 2 or 3 as per suitability, otherwise, reply in Option 1.

- Compare your Dam's "α_h" value with the "α_h" value given in the Table below (it specifies α_h as per current standards) and reply accordingly.

Seismic Zone II	Seismic Zone III	Seismic Zone IV	Seismic Zone IV
0.08 g	0.12 g	0.18 g	0.27 g

If deviation is more, it could be assumed that the Design is not consistent with the Current Seismic Design Standards. Hence, upgrades are required, reply accordingly.

Comment	Attachment
- Values of α_h used in the Design - Seismic Zone - Year of Construction. - Other necessary comments to justify the responses made.	- Suitable Documents, as evidence to support the responses provided.

TC 4 (Landslides and Sedimentation)

❖ **Landslides into Reservoir:**

Section A

- ○ The potential for the occurrence of landslides into reservoir is nil or very low.
- ○ There is a moderate potential for the occurrence of landslides into reservoir.
- ○ There is a high potential for the occurrence of landslides into reservoir.

- Since Landslide Hazard Assessment for almost all the vulnerable dams is not yet done, therefore we must depend on our own judgement based on the Available Geological Data, Visual Observation and Past similar Events occurred at the Specified Dam (& its Reservoir) under consideration.
- Understand the Geological Setting of the Reservoir Rim/ Periphery, including Rock Types, Structures (faults, folds, weak zones), Steepness of Slope, Condition of Slopes w.r.t. Stability etc.

  ➢ If as per site observation, it seems/ appears that Slopes may fail due to earthquake, then in Seismic Zone IV & V, provide your response in Option 3, while for Zone II & III, respond Option 2.

  ➢ And, if it seems that Slopes are fairly stable, then respond Option 1.

  ➢ If it appears that Slopes are high & steep but there is doubt about possibility of its failure (i.e., about the potential and the magnitude of a landslide hazard), a conservative approach should be taken, and depending on the judged likelihood, a higher score may be assigned, hence one may reply in Option 2 or Option 3.

Section B

- ○ No historical evidence of major events.
- ○ There is a historical evidence of major events but none in recent times.
- ○ There is a historical evidence of major events with some that occurred in recent times.

- Focus on the Period of "Construction Completion to Present Month" and discuss with the Officers/ Staff (who were posted at the Dam during such period) about the past landslide history/ observe the past official records. Accordingly, provide your response.
- If no information is available about Landslide Hazard, then Review the topographical & other information. If, for example, the dam is in an area with flat reservoir slopes/ fairly stable slopes, which indicates that the dam has a low potential for getting affected by any landslide, hence one may reply in Option 1 of both Section A & Section B.

❖ GLOF's & LLOF's

- GLOFs and LLOFs are mainly applicable for young mountainous regions, like Himalayan States. Ex. J&K, HP, UK and NE States, hence they are not applicable to Gujarat region.
- Hence, for both of them, select the Option which provides least Risk Score, which is Option 1.

Section A

○ No glacial lakes.

Section B

○ No historical evidence of major events.

Section A

○ No landslide dams and the potential for landslide dams to form is very low.

Section B

○ No historical evidence of major events.

❖ Sedimentation

Section A

○ SIltation reduced the design live storage by less than 10%.

○ Siltation in the reservoir reduced the design live storage by less than 30%.

○ Siltation in the reservoir reduced the design live storage by more than 30%.

- Go through the latest Sedimentation Survey Report & respond accordingly.

  Ex.: Design Live Storage = 6.61 MCM (Year 2009)

  Current Live Storage = 4.49 MCM (Year 2025) as per Sedimentation Survey.

  Hence, reduction in Design Live Storage = (6.61 – 4.49) MCM = 2.12 MCM

  % reduction = (2.12/ 6.61) x 100 = 32.07 % = more than 30 % (Option 3)

- In case no Sedimentation Survey is conducted till date, then if the dam age is quite old, some amount of sedimentation may be assumed to have occurred.

  Based on the judgement of Type of Material & Slope in the Catchment, one may make some assessment & reply accordingly.

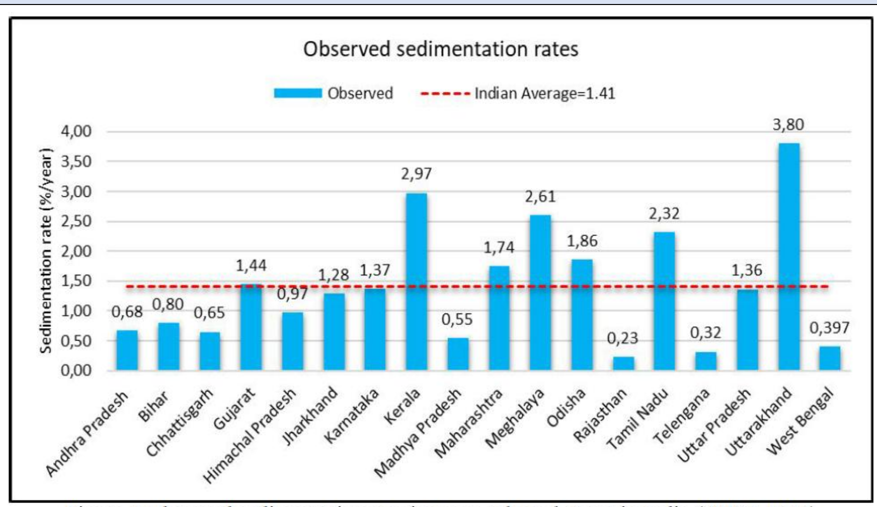


Figure 2 Observed sedimentation rate in some selected states in India (CWC, 2015)

- Based on the above Observed Sedimentation Rates, following assumption may be used for calculation.

- The observed Sedimentation Rate (in Gross Storage) in Gujarat = 1.44 %/ Year
  Assuming Sedimentation Rate (in Live Storage) =~ (1/2) x 1.44
  =~ 0.75 %/ Year

- Therefore, for a Specified Dam, if no Sedimentation Survey is conducted till date, then an approx. rate of 0.75 %/ Year in Live Storage, may be assumed for Gujarat.

Ex. Year of Reservoir Impoundment or Commissioning = 1990
Current Year = 2025
Approx. rate of Sedimentation (in Live Storage) = 0.75 %/ Year

Hence, Reduction in Design Live Storage till this date = (0.75 %) x (2025 – 1990)
= (0.75 %) x 35 = 26.25 % = Option 2

Section B

- ○ Effective sedimentation mitigation measures in place.
- ○ Only some sedimentation mitigation measures are present but are of limited effectiveness.
- ○ No sedimentation mitigation measures present or the existing measures ineffective.

- **Sedimentation Mitigation Measures** –

In the Catchment Area, Sedimentation Mitigation Measures like -"Watershed Management (Planting trees & shrubs, Grazing Management, Controlling the formation/ growth of gullies), Construction of Sediment Trapping Structures (like Check Dams/ Large Ponds/ Placing Gabions in stream channels)" - may be taken to reduce the erosion & to trap the sediments before it enters the main reservoir.

- Based on the measures provided at the Dam Project/ Reservoir under consideration, respond suitably.

- If no such measure is provided & no information is available, then consider the erosion potential of the catchment and presence of large reservoir in the upstream on the same river. Select somewhere between the best and the worst score (i.e., reply in Option 2).

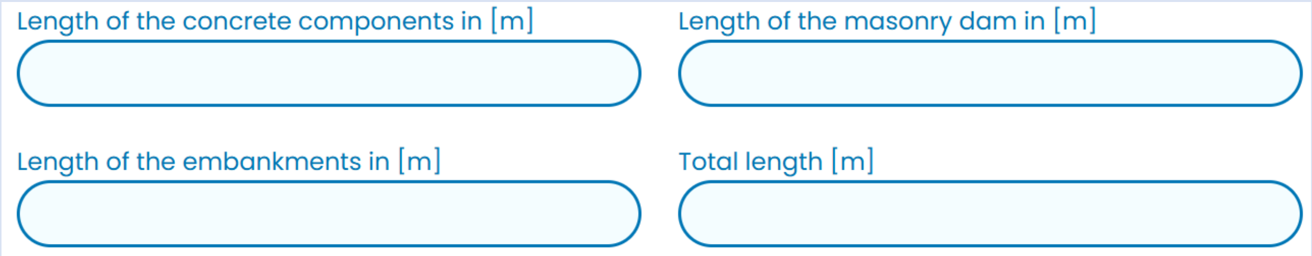
(Use Google Earth to explore the U/S stretch of River/ River System)

- If Check dams are there in the U/S, and if they are desilted regularly then reply in Option 2, but if they are not desilted regularly or are in damaged condition, then, they won't store any further silt, hence in such case reply in Option 3.

Comment	Attachment
○ Year of Impoundment/ Commissioning ○ Other Supporting Comments	○ Relevant Pages of Latest Sedimentation Survey Report

TC 5 (Length)

❖ **Length:**



- Refer the similar entries made in the “Supporting Data" Sheet.
- Observe the Constructed Sections of the Dam, which would be consisting of "OF Section" & "NOF Section".
- In most of the Project, OF Section is made of Concrete/ Masonry.
- Whereas NOF Section (includes Saddle Dams, Dykes) may vary as per site suitability –
  - In majority of the projects, it is made of Earthen/ Rockfill Dam (i.e., Embankment Dam).
  - And, in some projects, it is made of Concrete/ Masonry Dam.
- Accordingly, calculate the Length of Concrete Section, Masonry Section, and Embankment Section. Enter these values in "Meter".

Comment	Attachment
○ Supporting Comments	○ Layout/ Plan of the Dam, showing "OF Section" & "NOF Section" & their Construction Material (Concrete/ Masonry/ Embankment).

TC 6 (Conduits)

Please select only one out of the following three options

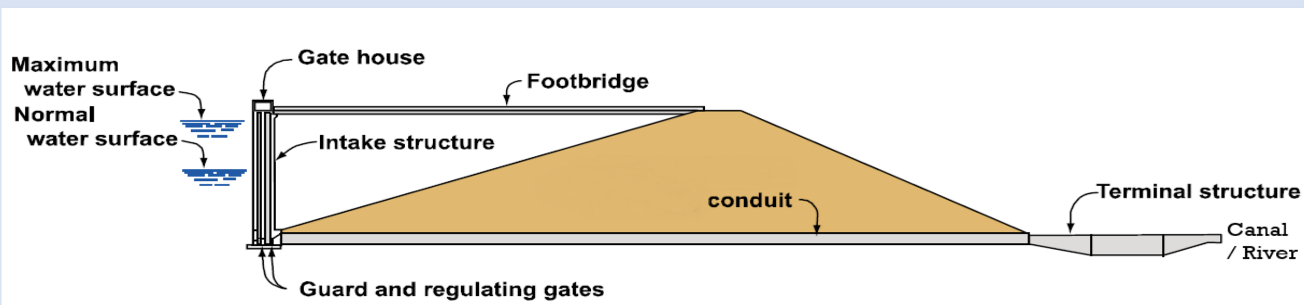
- ○ No conduit present.
- ○ Conduit having concrete cradles that extend up to the spring line of the pipe.
(If this option is selected, then based on suitability, one or more following statements may be selected.)
- ○ Conduit in direct contact or penetrating the embankment where the design is not of modern design or multiple conduits are present or not known.

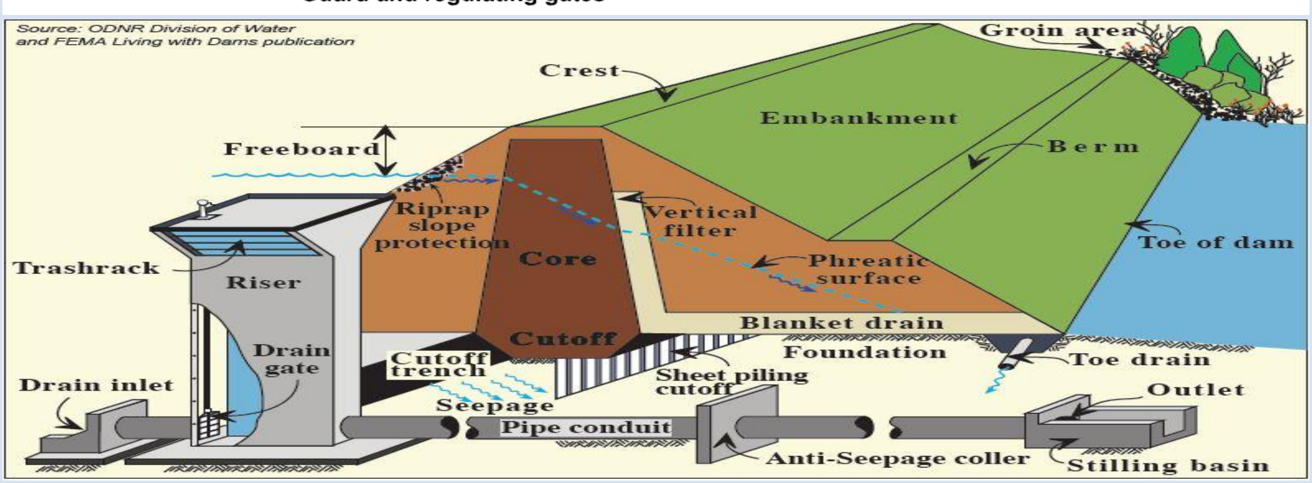
❖ TC 6 is applicable to Embankment Dams and Embankment Section of Composite Dams only.

Hence, for Dams having all Sections (OF + NOF) of Non-Erosive/ Rigid Material (i.e., Concrete/ Masonry), then select Option 1.

❖ For Embankment Dams and Embankment Section of Composite Dams, following approach is to be adopted –

- In most of our Embankment Dams, Dam Outlets which deliver water in the Canal/ Pipeline/ Stream, consist of –
  - A Head Regulator (HR) [a raised HR Well, consisting of platform & mechanical mechanism for the Operation of Outlet Gates] in the U/S.
  - One/ Multiple Conduits (Larger Diameter Pipes/ enclosed or box concrete structure), passing through the Dam Body, having entry end at U/S and exit end at D/S where it meets the Canal/ Pipeline/ Stream.

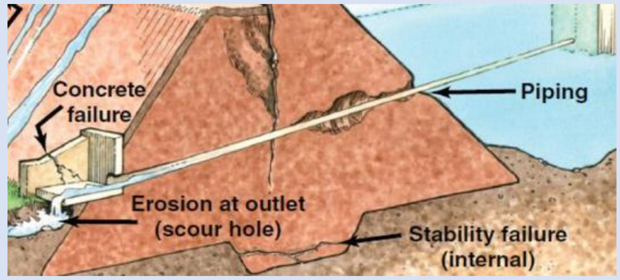




- **Associated Concerns:**

- Internal Erosion
  (due to leakage from the Conduit Joints)

- Backward Erosion Piping
  (due to Lack of density of nearby soil)



Initiation of Piping is shown here

A conduit is considered as being of poor design if any of the following five conditions is present:

1. Single line conduits.
2. Conduits with inadequate joint preparation.
3. Conduits construction in steep, narrow trenches.
4. Conduits with seepage collars.
5. Conduits that have experienced internal erosion or misalignment distress.
6. Conduits that do not have filters

Lining in Single Lined Conduits/ Pipes = It is a Coating on the Interior Surface, that forms a protective barrier which prevents Pitting, Corrosion & Erosion of pipe material, helps in providing better safety than that in Unlined Pipes.

Double Lined Conduits are better than Single Lined Conduits.

Narrow Trenches = Due to practical difficulty of limited space, mobilization of Compaction Equipment is not possible, and Hand Compaction cannot provide the desired density. Hence, in such cases, movement of pipes is possible, which in turn would create a risk of Internal Erosion Failure.

Seepage Collars = Anti Seep Collars
= Cutoff Collars = They are impermeable diaphragms, usually made of concrete, constructed at intervals. They increase the length of the seepage path along the conduit, which theoretically lowers the hydraulic gradient and reduces the potential for backward erosion piping.

However, **Anti-seep collars did not fully address the more serious mechanism of failure (internal erosion),** that **occurs when water flows through cracks and erodes the compacted earthfill** near the conduit outside the zone of influence of the anti-seep collars.

Issues:
- Anti-seep collars hindered/ obstructed compaction of soils around the conduit.
- Anti-seep collars can form a foundation discontinuity that could result in differential settlement and cracking of the conduit.
- Both issues lead to internal erosion mechanisms.


(Anti Seep Collars)

Filters - Reduces the energy of leaking pressurized water, also prevents migration of soil particles with water. Gradually, Designers achieved increased confidence in the capability and reliability of filters to prevent internal erosion failures.

▪ Modern Design:

Following points are related to Modern Design -

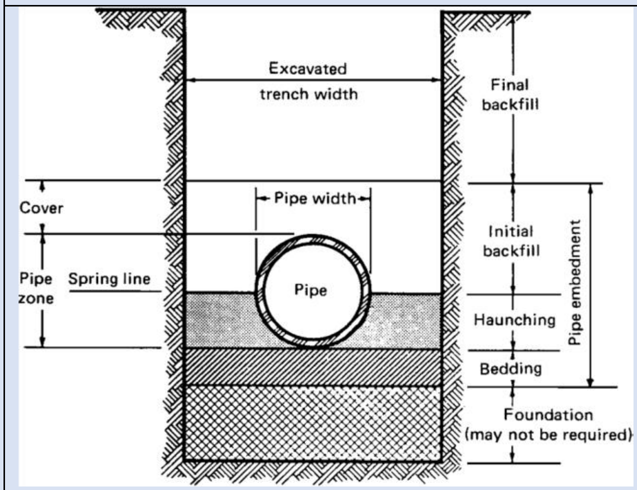
(i) Conduits designed after 1985 are better than those designed before; because in 1985, proper design standards for conduits were established.

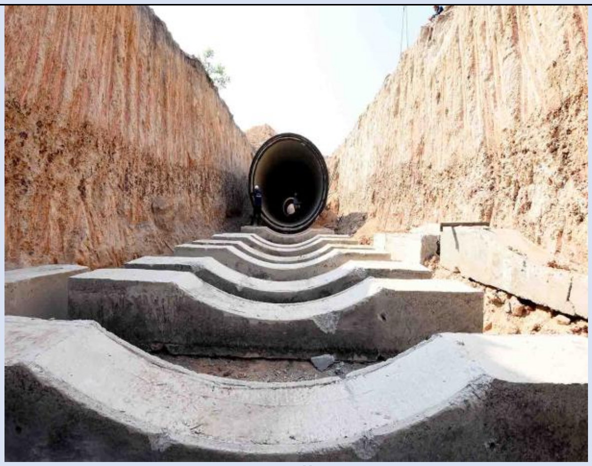
(ii) Conduits placed on rock foundation instead of 'placed on Overburden Foundation/ Passing through the Embankment Dam's body', are superior in providing resistance against interface seepage.

(iii) Rectangular/ Square conduits are better than Circular conduits because material around the periphery of circular conduits is not compacted properly and becomes a potential zone of weakness.

(iv) Conduits with filter diaphragm, cradles are always better than those without them, because conduit periphery is a candidate of seepage path.

(v) Good conduits are made of materials with long-term survivability and have favourable backfill conditions.





Cradles

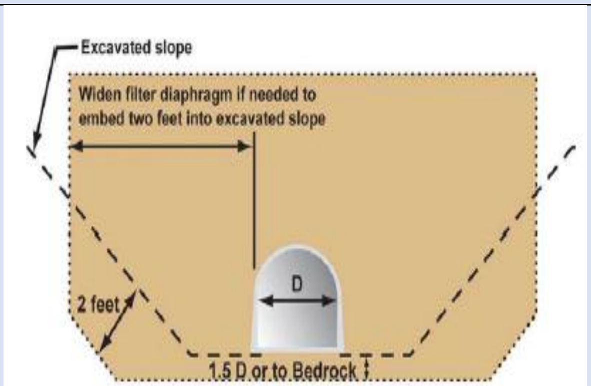
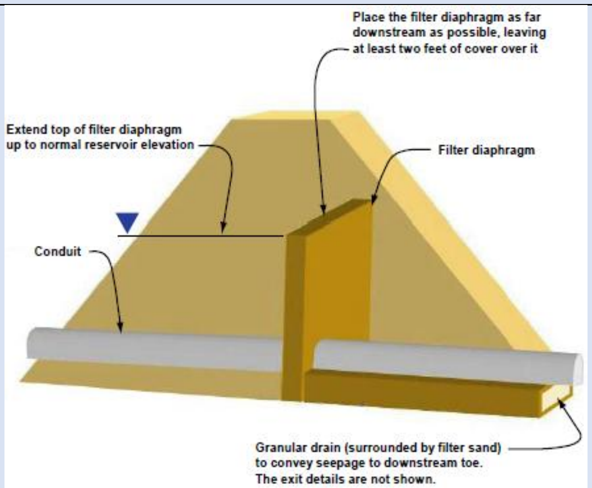


Figure 92.—Typical configuration for filter diaphragm used in design of an embankment dam. The filter diaphragm should extend into the foundation soils, where an excavation is made for the conduit.



Diaphragm filters –

- A filter diaphragm or filter collar around the conduit is recommended for all embankment dams penetrated by a conduit.

- A filter diaphragm is a designed zone of filter material constructed around a conduit. This zone can act both as a drain (to carry off water) and as a filter (to intercept soil particles being transported by the water).

The filter diaphragm will intercept/ catch the flow that originates at the discontinuities along the pipe interface or through cracks in the earth fill immediately surrounding the conduit that are caused by differential settlement associated with the conduit.

- Any fines being eroded from the earth fill/ embankment will be filtered by the diaphragm of sand that surrounds the conduit.

- The filter diaphragm must extend far enough from the conduit that it can intercept all potential water flow paths associated with the conduit.

❖ By keeping the above points in mind, examine the questions asked –

➢ Observe the As Built Drawings related to Cross-Sections & Layout/ Plan of Embankment Section and identify the location of Conduit. Verify at the Site as well.

- If No conduit is present then reply in Option 1.
- If one or multiple Conduits are present, having direct contact with the embankment or overburden foundation and their Construction was done prior to Year 1985, or Construction is as per poor design (= not of modern design), then reply in Option 3.

  If after viewing Drawings and verifying at site, it could not be concluded that Conduit is present or not, then reply in Option 3.

➢ If above two cases are not applicable (i.e., when Conduit is as per modern design), then reply in Option 2.

○ Conduit having concrete cradles that extend up to the spring line of the pipe.
(If this option is selected, then based on suitability, one or more following statements may be selected.)

☐ Wide open excavated trenches that permit the use of placement and compaction equipment.
☐ Interior and exterior joint protections.
☐ Subgrades that have been improved.
☐ Diaphragm filters on the downstream face.
☐ Double lined pipe systems.
☐ Corrosion resistant materials.

- For replying to these new options, go through the Detailed Drawings of the Conduit zone of the Dam & evaluate them as per activities carried out at the time of construction.

▪ The Material below the Bedding of Pipe is called as Subgrade/ Foundation. (Unsuitable foundation soils must be removed and replaced to prevent damage to the conduit due to Settlement etc.)

▪ Double-lined pipe system consists of two layers. The inner layer is typically smooth, while the outer layer is corrugated for added strength and protection.

▪ Corrosion resistant materials (Properly Lined Concrete Pipes, HDPE Pipes, Pipes having coatings and linings to mitigate corrosion).

Comment	Attachment
- Necessary comments to justify the responses made.	- As Built Drawings related to Cross-Sections & Layout/ Plan of Embankment Section, showing the location & details of Conduit. - Suitable Documents, as evidence to support the responses provided.

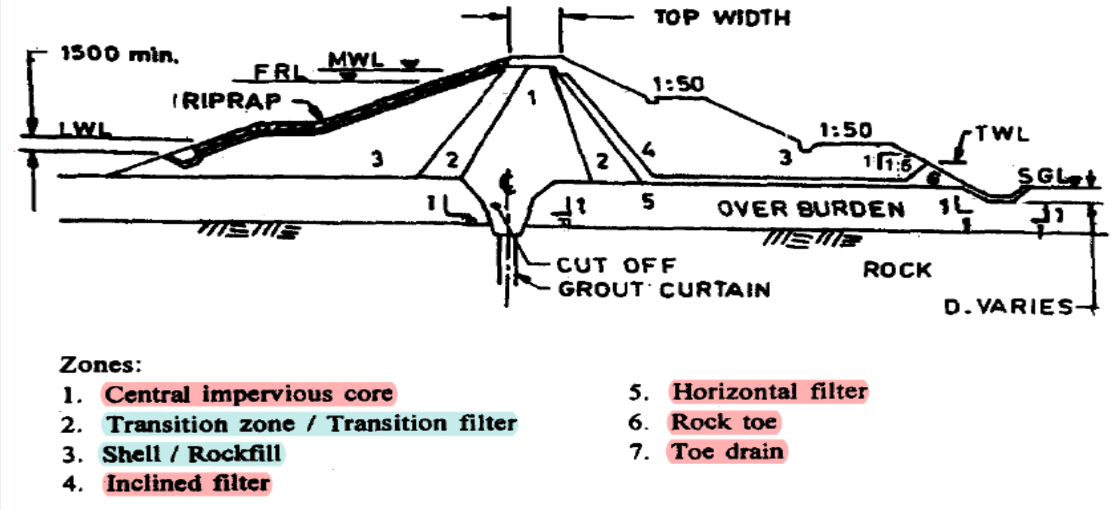
TC 7 (Filters)

- ❖ TC 7 is applicable to Embankment Dams and Embankment Section of Composite Dams only.

  Hence, for Dams having all Sections (OF + NOF) of Non-Erosive/ Rigid Material (i.e., Concrete/ Masonry), then select Option given below.

  ☐ **This section is not available in the dam**

- ❖



1A Section of Zoned Dam Showing Seepage Control Features

Observe the Filters at –

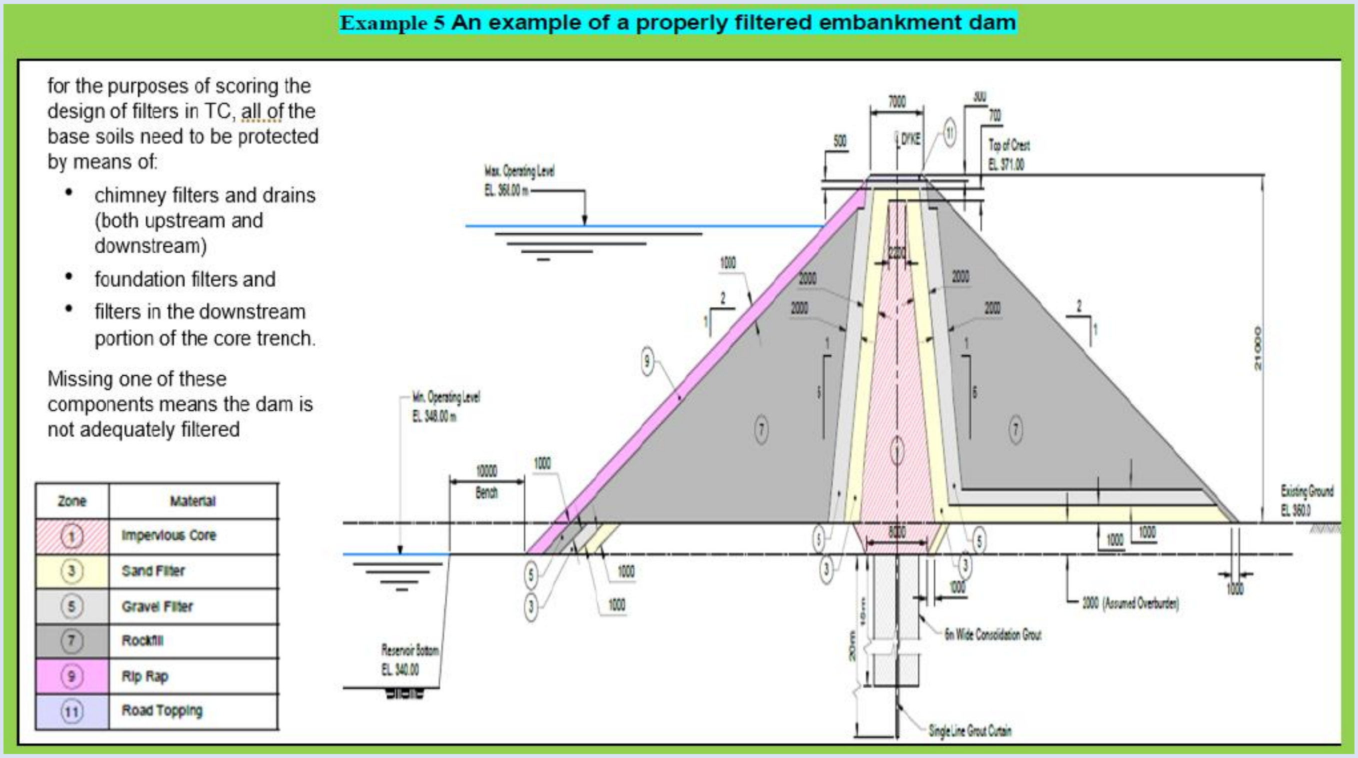
1) Chimney Filter (& Transition Filter) downstream (d/s) of the Core
2) Transition Filter at just upstream (u/s) of the Core
3) Horizontal Filter at d/s of Core (which is provided over Over-Burden, hence, may be called as Foundation Filter as well, because here foundation is Over-Burden only)
4) Rock Toe & Toe Drain

- ❖ **All the base soils need to be protected by means of Filters in following way** – [**Base Material** = Material where Filter is to be placed (e.g., Material of - Core of the Zoned Dam, or Body of Homogeneous Dam or of Foundation)

  - In the **d/s section** of the Embankment Dam (Earthen/ Rockfill) - **Chimney Filters** (Inclined or Vertical Filters) (for steady state seepage) and **Horizontal Filters**.
  - In the **u/s section** of the Rockfill Dam - **Filter along the Core** (for rapid drawdown condition, to prevent migration of Base Material), or

    For all kinds of Embankment Dams - In the **u/s section**, **Transition Filter along the Core**
  - Filters **in the d/s portion of the core trench or cutoff trench.**

- ▪ The above 4 kinds of Filters must be considered as the essentially required Filters with which you have to compare with the Filters provided in Dam under consideration.



(Properly Filtered Zoned Embankment Dam)

Q1: Are all required filters and drainage zones present? Please select

- The 4 kinds of Filters, shown in previous page, are to be considered as required Filters.
- Rock Toe and Toe Drain are to be considered as required Drainage Zones.

  - Observe the C/S Drawing of the Dam under consideration for providing the responses.

Q2: Is the documentation supporting the filter design available? Please select

  - It means, the availability of Design/ Drawing showing the Filters.

Q3: Are construction records supporting the as-built characteristics of the materials available? Please select

  - It means, the availability of Construction Records/ Documents (like, Record in Measurement Book etc.) which can prove that execution at site was done as per As-Built Design/ Drawing showing the Filters/ Materials.

Q4: No filters are present. Please select

- ➢ If Filter is present *at least* at one location (i.e., at any one of the locations which are discussed in previous 2 pages), then respond "No", otherwise respond "Yes".

Q5: Critical filter in a high gradient zone is absent.
Please select

❖ **High Gradient Zones**:

- "High Gradient Zones" are areas where Hydraulic Gradient [$i = (\Delta H/\Delta L)$] is high, i.e., where there is a rapid change in the hydraulic head (ΔH is more) over a short distance (ΔL is less).
- These zones are critical because high gradients can lead to increased seepage velocities [$V = K \times i$, where $i = (\Delta H/ \Delta L)$] and potentially cause internal erosion (piping) within the dam.
- Typical locations of high gradient zones:

  At the interface between zones of significantly different permeability:

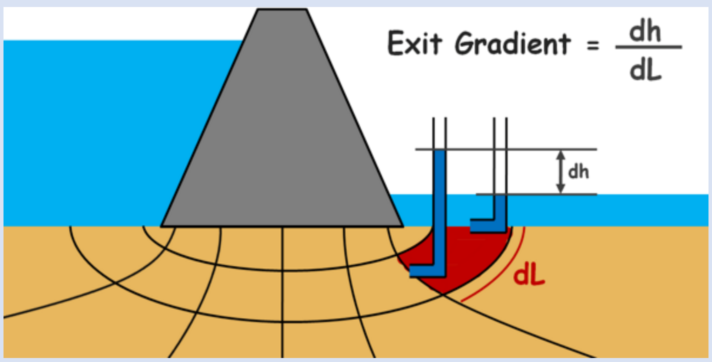
  - Where the impervious core material meets the more pervious shell material or filter zones. The water flowing through the dam will experience a sudden drop in head as it moves from a low permeability zone to a high permeability zone, resulting in a high gradient = **Chimney Filter** on **d/s face of Core**
  - Similarly, at the interface between the core and the foundation if the foundation has a higher permeability = **Inclined Filter** on **d/s face of Core near the foundation (i.e. in the d/s portion of the core trench or cutoff trench)**
  - Where the relatively impervious foundation material meets the more pervious shell material = **Horizontal Filter** at **d/s of Core**
- In these high gradient zones, Filters are specifically designed to prevent the migration of fine particles from the less pervious zones into the more pervious zones under these high gradients, thus preventing piping failures.

Critical filter in a high gradient zone is absent.
Please select

➢ If at least one of the Filter, from the Group of following is missing, then select "Yes"-

1. Filter at d/s face of Core **= Chimney Filter on d/s face of the Core**
2. Filter at d/s face of Core near the foundation = **Inclined Filter on d/s face of Cutoff Trench**
3. Horizontal Drainage Blankets at **d/s of Core = Horizontal Filters over the Foundation** or Over Burden **= Foundation Filters**

Q6: Is this a homogeneous dam with a toe drain and low exit gradient? Please select



(Source: elementaryengineeringlibrary dot com)

- Exit Gradient (i_e) = ($\Delta H/\Delta L$) at the downstream end where water leaves the soil mass = slope of the last flow line in a flow net.

  ΔH = Change in Head between the last two equipotential lines
  ΔL = Length of the flow path between those lines

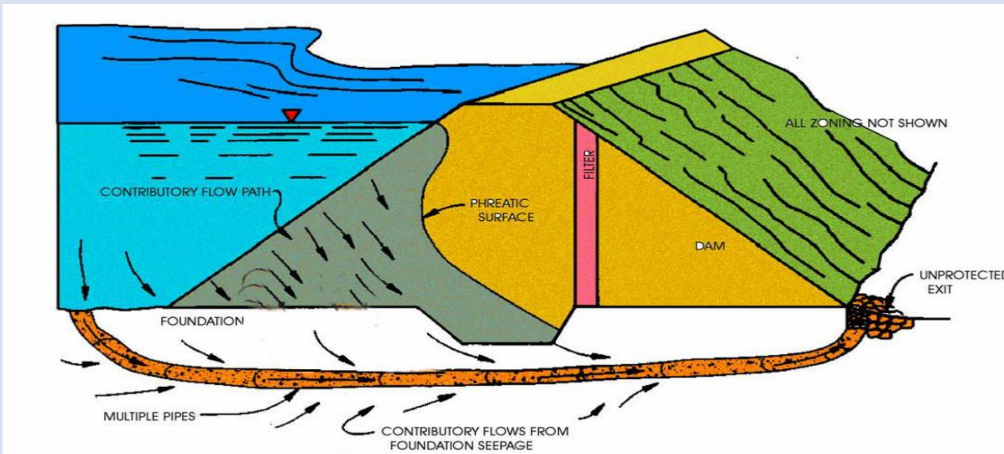
- The acceptable exit gradient can vary depending on the soil type and the specific design considerations.

- We use high FoS (Factor of Safety), as magnitudes & Impacts of Dam Failure could be severe, hence a **FoS of 6 to 7 may be considered safe for most soils, including sands**. Hence, **an exit gradient < 0.15 [i.e., (1/6) or (1/7)] is considered safe.**

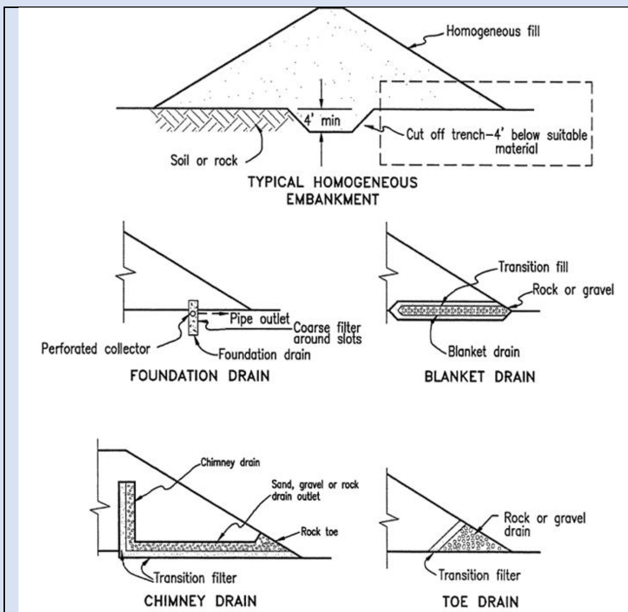
  In critical situations, a lower exit gradient (i.e., more conservative design) may be required.

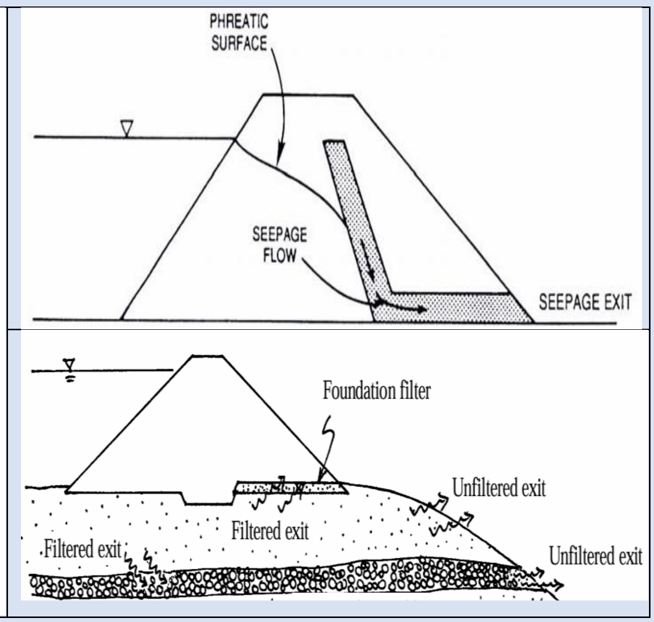
- **As a thumb rule** –

- For **unfiltered exit**, Exit Gradient should not be more than 0.1 (i.e., **Exit Gradient < 0.1)**, hence FoS should be > 10
- For **filtered exit**, Exit Gradient should not be more than 0.5 (i.e., **Exit Gradient < 0.5)**, hence FoS should be > 2



Unfiltered/ Unprotected Exit





Filtered Exit

Filtered Exit (above), Both type of Exits (below)

- Observe the As-Built Cross-Section of the Dam, and find out if the Dam is Homogeneous or not? Does it have Toe Drain?

  Check the Design Documents and observe the value of Exit Gradient of the Dam along with type of Exit (Unfiltered/ Filtered/ Both).

  Based on such observation and comparison with above values, respond suitably.

Q7: If neither of the above questions are applicable for Dam under consideration, then the final score must be interpolated (& such score is to be typed manually) for following Sub Questions.

Q7.1: Adequate filters were designed and constructed but neither the documentation nor other evidence is available. ☐

- If As-Built Drawing is not available (hence, the presence of Filters could not be confirmed) then the scoring may be done based upon the behavior of Dam.

- The **presence of continuous seepage/ large wet area on the d/s face of Dam** or in the further downstream region **are indications of improper drainage system** in the dam.

- The change in patterns of these problems w.r.t. varying reservoir levels shall invite a high-risk score.

➢ Observe the d/s face of Dam during various water levels (decreasing from FRL with time) or Discuss with the Dam Staff about existence of such behaviours in previous years during November to March period (i.e., Post-Monsoon Period).

If **any large wet area is not found**, then above Option should be responded and a suitable Score between 1 to 10 is to be assigned manually.

Or, if some senior Dam Staff is available who was there when Dam was being constructed then a discussion with him about provision of Filters during Construction may give a better insight to respond suitably.

Q7.2: Some filters were designed and constructed but neither the documentation neither other evidence is available. ☐

➢ Observe the d/s face of Dam during various water levels (decreasing from FRL with time) or Discuss with the Dam Staff about existence of such behaviours in previous years during November to March period (i.e., Post-Monsoon Period).

If a few wet areas are found, then above Option should be responded and a suitable Score between 10 to 24 is to be assigned manually.

Or, if some senior Dam Staff is available who was there when Dam was being constructed then a discussion with him about provision of Filters during Construction may give a better insight to respond suitably.

Q7.3: One of the required filtersis missing from a lower gradient boundary (gradient less than 0.5). ☐

❖ **Low Gradient Zones/ Boundaries**:

- A low gradient indicates a gradual drop in pressure or head over a longer distance, resulting in lower seepage velocities.
- The actual hydraulic gradient within a zone depends significantly on the permeability of the material. **Highly permeable materials will naturally exhibit lower gradients** for a given flow rate.
- Low Gradient Zones are primarily found within the designed pervious and semi-pervious zones, including the **outer shells and internal drainage systems**, where the materials are chosen to allow relatively easy flow of water and dissipate seepage pressures gradually.
- **Location of Low Gradient Zones:**
  - **Outer Pervious Zones (Shells):** These zones, made of materials like gravel or rockfill, have high permeability. Water can flow through them relatively easily, resulting in a gradual dissipation of seepage pressure and thus a low hydraulic gradient. This prevents saturation of the downstream slope and enhances stability.
  - **Internal Drainage Systems (Toe Drains):** These are specifically designed zones of highly permeable material (gravel, coarse sand) located within the downstream section of the dam. They intercept seepage water that passes through the core and transition zones and allow it to drain out safely with a minimal build-up of pressure. The gradient within these drains is very low due to their high permeability.

One of the required filtersis missing from a lower gradient boundary (gradient less than 0.5). ☐

➢ If at least one of the Filter, from the Group of following is missing, then select "Yes"-

1. **Rock Toe & Toe Drains**.
2. **Inclined Filter/ Transition Filter on u/s face of the Core.**

Q7.4: It is a homogeneous dam without the toe drain and low exit gradients. ☐

- It is discussing about a Homogeneous Dam **without the toe drain** and **without low exit gradients.**
- Check the Design Documents and observe the value of Exit Gradient of the Dam along with type of Exit (Unfiltered, < 0.1/ Filtered, < 0.5/ both).
  - ➢ Self-Explanatory. A suitable Score between 10 to 24 is to be assigned manually.

Note: 1) In case of Homogeneous Earthen Dams (i.e., having no Filters), having CL type material (Clay with Low Plasticity), but Toe Drains are provided, then a score 12 may be given.

2) For Minor Tanks, if Filter related Data is not available, then a score 12 may be given.

Comment	Attachment
- Necessary comments to justify the responses made.	- As Built Drawings related to Cross-Sections of Embankment Section, showing the location & details of Filters. - Suitable Documents, as evidence to support the responses provided.

TC 8 (Foundation)

- Generally, Embankment Dams/ Embankment Section of Composite Dams/ Saddle Dams (Embankment) are sited on Overburden.
- Just observe the Written/ Drawing Records (Longitudinal Sections etc.) related to Foundation of both NOF as well OF sections of the Dam. This will give an idea about the Base Soil over which the Dam Foundation is resting. Such Base soil may be consisting of following –
  1) Overburden in the entire length - Mainly, Embankment Dams are sited in such situations.
  2) Bedrock in the entire length - Both Concrete/ Masonry Dams and Embankment Dams could be sited in such situations.
  3) Overburden in the stretch of Embankment Sections (NOF) and Bedrock in the stretch of Concrete/ Masonry Section (OF)
  4) Other similar combinations.
- If you have Concrete/ Masonry Sections in both NOF & OF parts, then it is highly likely that 'Bedrock' is there as Base Soil to support the Foundation.
- In other combinations, the presence of Overburden cannot be ignored without any proof.

❖ Based on above analysis, choose the suitable option in -

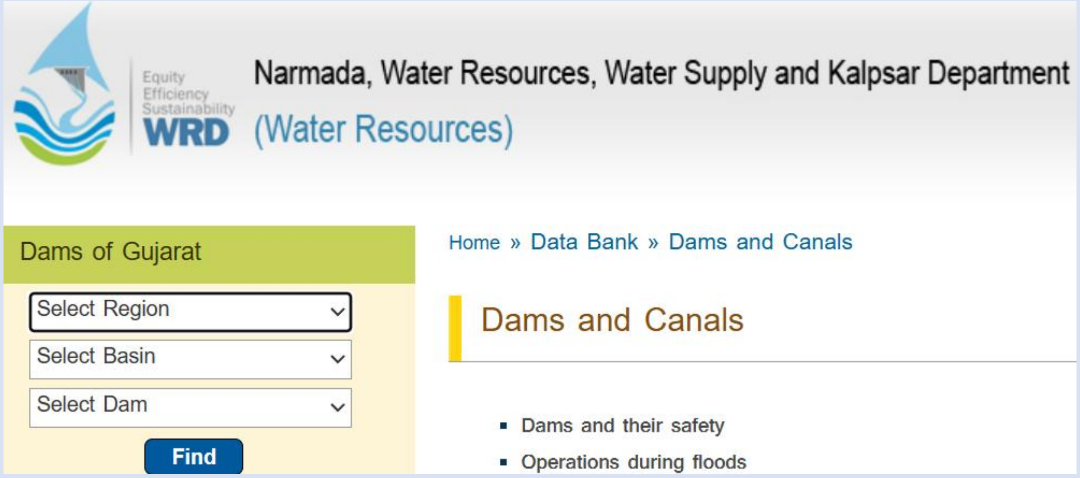
Select Any One

○ BEDROCK (all structures) ○ OVERBURDEN (all structures) ○ BOTH

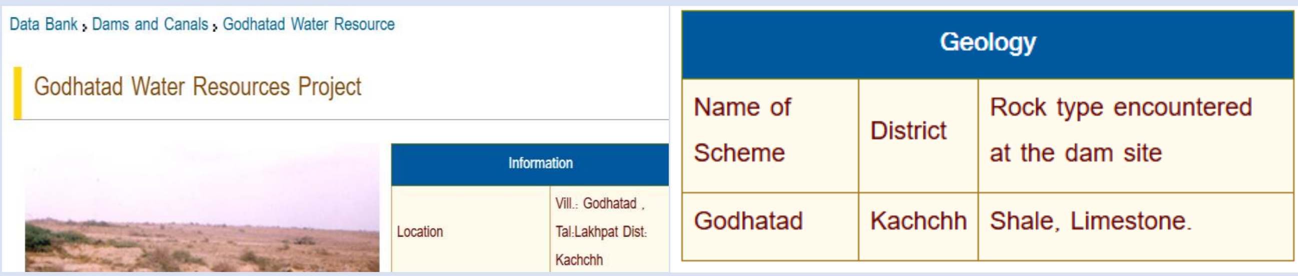
❖ Following Question will appear for any of the options chosen -

No knowledge about the geology of the site and the subsurface conditions.	Select

- ➢ Observe the Records available at Sub-Division/ Division/ Circle/ Geology Circle/ CDO for knowing about the actual geology of the site over which the Dam under assessment is constructed.
- ➢ In case of unavailability, Data Bank section of nwrws website [Dams and Canals | Data Bank | Narmada (Gujarat State)] may also be explored.



On selecting the Region, Basin and Dam Name, one may find suitable data if it had been uploaded in the past.



(Example)

- ➢ If Records regarding Geology are available, then respond 'False'.
- ➢ And if, after going through all above ways, no information regarding Geology could be obtained, then respond 'True'.

OVERBURDEN (all structures)

OVERBURDEN (all structures)

No knowledge about the geology of the site and the subsurface conditions.	False

- ❖ Following Sub Questions will appear –
  (Select only if any one or more following risky conditions is/are present in your dam)

- ☐ Foundation composed of inadequately treated dispersive soils.
- ☐ Permeability in excess of 10-3 cm/s with no seepage control measures.
- ☐ No foundation filter when exit gradient in excess of 0.1
- ☐ Unfiltered exit gradient greater than 0.5 in highly weathered or highly fractured rocks.
- ☐ The dam is located in seismic zone IV or V and has liquefiable soils? in the foundation.

- **Dispersive soils:**
  - Dispersive soils are a type of clay soil.
  - Unique Chemical Makeup**:** Dispersive soils have a higher proportion of sodium ions compared to other clay soils. This imbalance in ions causes the clay particles to repel each other. Hence, better bond strength cannot be expected.
  - These soils can be challenging to compact properly during construction, leading to a less dense and more permeable foundation.
  - These soils can become soft and unstable when saturated with water.
  - Erosion Prone**:** When exposed to water, these soils don't clump together like regular clay. Instead, they disperse or break apart into individual particles that can easily be carried away by flowing water. This process is called "dispersion."
  - Hence, unless treated, they would be problematic in dam foundations, creating chances of Reduced Stability and Internal Erosion (or Piping).

☐ Foundation composed of inadequately treated dispersive soils.

- ➢ Since such soils are problematic, hence during Construction, Treatment must have been done but later on during the service life of the Dam, if issues were observed and on further exploration/ investigation it is understood that Treatment done was not of sufficient quantity and quality (i.e., it was inadequately treated), then the above option should be responded.

- **Permeability:**
  - Permeability (K) value depends on - soil type, average size of the pores/ distribution of particle sizes, particle shape and soil structure.
  - (K_{Sands}/ K_{Clays}) or ($K_{Gravels}$/ K_{Clays}) is of the order of 10^6 (i.e., 10 Lakh Times).
  - A small proportion of fine material in a coarse-grained soil can lead to a significant reduction in permeability.
  - For different soil types as per grain size, the orders of magnitude for permeability are as follows:

Soil	k (cm/sec)	Permeability in reducing order (Gravel > Sand > Silt > Clay)
Gravel	10^0	For Gravel, K = (10) to (1) cm/s
Coarse sand	10^0 to 10^{-1}	K = (1) to (1/10) cm/s
Medium sand	10^{-1} to 10^{-2}	K = (1/10) to (1/100) cm/s
Fine sand	10^{-2} to 10^{-3}	& so on..
Silty sand	10^{-3} to 10^{-4}	
Silt	1×10^{-5}	
Clay	10^{-7} to 10^{-9}	

☐ Permeability in excess of 10-3 cm/s with no seepage control measures.

➢ If Permeability (K) > 10^{-3} cm/s, i.e., Soil may have types ranging from Fine Sand to Gravel (& other materials with higher size particle, e.g., Cobbles and Boulders) and any combination of such Coarse Grained Soils.

  - If such a type of Foundation Soils are there, then chances of excessive seepage through foundation are very high, which requires provision of Seepage Control Measures (like - Core Trenches to rock, Cutoffs/ Cutoff walls, Alluvial grouting, Jet grouting etc.), so that seepage through such permeable soils, could be avoided.

➢ If Foundation Soils/ Materials are of such type which have Permeability - (K) > 10^{-3} cm/s and along with that, no seepage control measures (in foundation) is provided; then the above option should be responded.

- **Exit Gradient in excess of 0.1:**

☐ No foundation filter when exit gradient in excess of 0.1

  - Just remind what was discussed in TC_Filters –
  "For unfiltered exit, Exit Gradient should not be more than 0.1"

➢ If Foundation Filter (i.e., Horizontal Filter) is not provided, and Exit Gradient > 0.1 (then FoS would be < 10, making the foundation more vulnerable to Piping), then the above option should be responded.

- **Exit Gradient greater than 0.5:**

☐ Unfiltered exit gradient greater than 0.5 in highly weathered or highly fractured rocks.

  - Just remind what was discussed in TC_Filters –
  "For filtered exit, Exit Gradient should not be more than 0.5"

Highly weathered or highly fractured rocks –

  - These are rocks that have been significantly changed/ transformed or broken down by physical/ chemical processes.
  - **Highly weathered rocks** have undergone extensive decomposition and disintegration due to weathering.
  - **Highly fractured rocks** have many cracks or fissures (splits/ openings/ gaps)
  - These kinds of rocks provide reduced Strength and Stability, increased Permeability, Seismic Vulnerability and have many Durability related concerns (Further, weathered rocks may contain minerals that can further decompose or react with the concrete in the dam, leading to long-term deterioration of the foundation.).

➢ In this case, exit is unfiltered, also, foundation soil/ rocks are already highly permeable and Exit Gradient > 0.5 (i.e., FoS would be < 2), making the foundation Super Vulnerable to Piping & Internal Erosion type Failures; then the above option should be responded.

- **Liquefiable Soils :**

☐ The dam is located in seismic zone IV or V and has liquefiable soils? in the foundation.

  - Liquefaction = Strength and Stiffness of a soil is reduced by earthquake shaking or other rapid loading.

- Liquefaction occurs in saturated soils (in which the space between individual particles is completely filled with water). This water exerts pressure on the soil particles that influences how tightly the particles themselves are pressed together.
- Prior to an earthquake, the water pressure is relatively low. However, earthquake shaking can cause water pressure to increase to the point where the soil particles can readily move with respect to each other.

Characteristics of Liquefaction-Prone Soils:

Loose, saturated sands: These soils have a loose structure with a high void ratio, meaning there is a lot of space between the individual soil particles. When saturated, the spaces between these particles are filled with water & makes it vulnerable to Liquefaction.

Silty sands: Sands with a significant proportion of silt particles can also be vulnerable to liquefaction, especially if they are loose and saturated.

Silty soils: Some silty soils can also be susceptible to liquefaction, particularly if they are loose and saturated.

Non-plastic silts: Some silts, particularly those that are non-plastic (exhibit little to no plasticity), can liquefy under seismic loading.

Uniformly graded soils: Soils with a limited range of particle sizes are more prone to liquefaction than well-graded soils with a wider range of particle sizes.

Recently deposited soils: Newly deposited soils haven't had time to compact and gain strength, making them more susceptible to liquefaction.

- If dam is located in seismic zone IV/ V and Foundation Soil is vulnerable to Liquifaction; then the above option should be responded.

Soil Condition (Permeability)

- ○ Dense, generally low permeability (less than 10-3 cm/s) aeolian, colluvial, lacustrine, marine, glacial or alluvium.
- ○ Dense to locally loose aeolian, colluvial, lacustrine, marine, glacial or alluvium of moderate to high permeability Most of the foundation is situated on dense soils but locally loose of soft soils exist that cannot or were not adequately treated. Foundation may have local areas with permeabilities higher than 10-3 cm/s.
- ○ Generally loose, moderate to highly permeable overburden or dispersive soils or volcanic ash. Foundation may have local areas with permeabilities higher than 10-2 cm/s that are not adequately sealed.

- Based upon the Permeability value; suitable option may be responded.

Residual Soil

- ○ Only very little residual soils present.
- ○ Significant amount of residual soils.
- ○ Large amount of residual soils.

- **Residual soils –**
  - Residual soil can be defined as a soil material which is the result of weathering and decomposition of rocks that has not been transported from its original place. It retains characteristics of the parent rock.
  - The type of bedrock & degree of weathering strongly determines the properties of the residual soil. For example, granite bedrock will produce sandy soils, while shale will produce clayey soils. Further, residual soils derived from granite tend to be more suitable than those derived from shale.
  - Residual soils can vary significantly in depth, from a few meters to over 100 meters in some regions.
  - Examples - Lateritic soils, Black cotton soils etc.

  Challenges of Using Residual Soils for Dam Foundations –

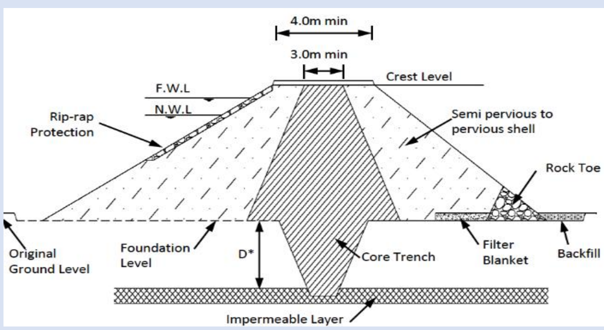
  - **Variability:** Residual soils can be incredibly heterogeneous, even within a small area. This makes it difficult to predict their engineering properties and how they will behave under the load of a dam.
  - **Compressibility:** Some residual soils, especially those with high clay content, can be highly compressible. This can lead to excessive settlement of the dam, potentially causing cracks and leaks.
  - **Shear Strength:** The shear strength of residual soils can vary significantly. Low shear strength can lead to instability and failure of the dam foundation.
  - **Permeability:** Some residual soils can have high permeability, allowing water to seep through the foundation. This can lead to erosion and weakening of the soil.

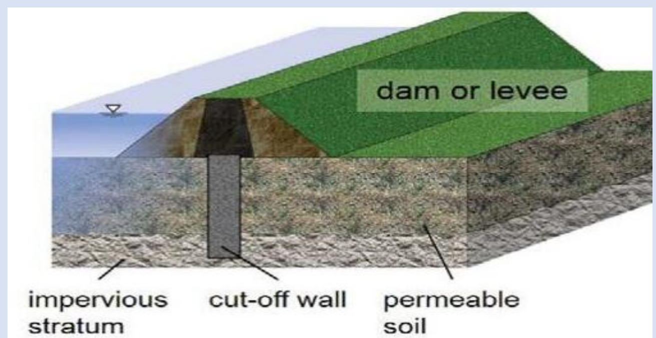
➢ Based on the amount of Residual Soils present in the foundation; suitable option should be responded.

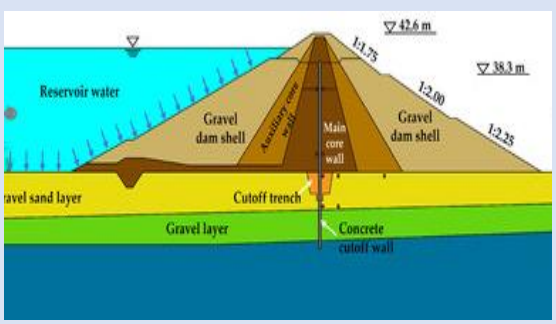
Cutoff

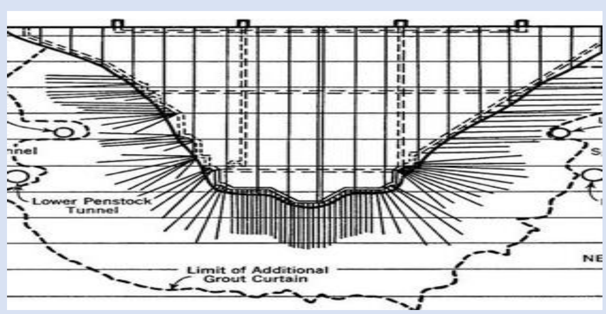
- ○ Permeability issues addressed by appropriate measures (full cutoff to bedrock or impervious soil achieved by core trenches to rock or cutoffs, alluvial grouting, jet grouting, cutoff walls or other to reduce permeability to 10-4 cm/s or less at the seal zone). Seal contact width a minimum of 0.5 H for cutoffs founded on overburden.
- ○ Partial cutoff.
- ○ Permeability issues not adequately addressed.

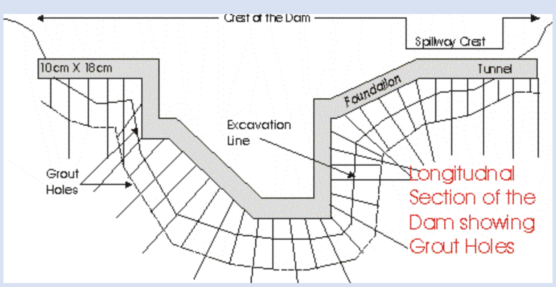
- **Measures to tackle Permeability issues -**
  - Full Cutoff (Cutoffs/ Cutoff walls) to bedrock or impervious soil.
  - Core trenches to rock
  - Alluvial grouting
  - Jet grouting
  - Other measures are taken to reduce permeability to 10^{-4} cm/s or less in the seal zone. Seal contact width a minimum of 0.5 H for cutoffs founded on overburden.
  - Partial Cutoffs (Where Cutoff doesn't meet Hard Rock/ Impermeable Layer)











- The seal zone is a vital part of the overall design of an earthen dam.
- The **seal zone** is to seal the dam foundation/ to control seepage through its foundation by creating an impervious barrier. This is often achieved by –
    - Cutoff Trenches: Excavating a trench and filling it with impervious material.
    - Grout Curtains: Injecting grout into the foundation to fill cracks and voids.
    - Clay Blankets: Placing a layer of low-permeability clay on the upstream side of the dam.

➢ Based on the above information; suitable option should be responded.

➢ If the downstream toe drain is receiving high discharge and general ground water level of downstream area increases when the reservoir is full, consider it as high permeability. Accordingly, for such a similar situation, Option 3 may be responded.

Shear Strength and Bearing Capacity

- ○ Adequate shear strength and bearing capacity.
- ○ Suspect shear strength and bearing capacity.
- ○ Inadequate or inferior shear strength and bearing capacity.

- **Shear strength and Bearing Capacity.**
  - In case of lack of availability of shear strength and bearing capacity, the sum of the upstream and downstream slopes may be used to decide the correct option for the question. The following table may be useful in this regard:

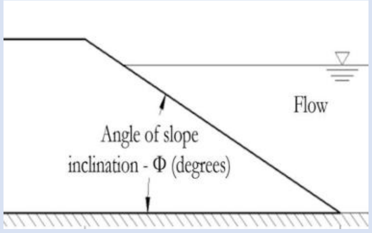
Sum of upstream and downstream slopes	>1.0	0.95-1.0	0.95-0.85	0.85-0.80	<0.80
Equivalent to:	Very good to excellent shear strength and bearing capacity.	Very good to excellent shear strength and bearing capacity.	Adequate shear strength and bearing capacity or foundation reinforced and stabilized.	Suspect shear resistance or not known.	Inadequate or potentially inferior shear strengths or bearing capacity.
Suitable Option:	1	1	1	2	3

- **Ex.** U/S Slope = 2.5 H : 1 V,
  then take Slope = tan ϕ_u = (Vr Offset/ Hz Offset) = (1/2.5) = 0.4

  D/S Slope = 2 H : 1 V,
  then take Slope = tan ϕ_d = (1/2) = 0.5

  Φ is angle taken from Horizontal Direction.

  Hence, Sum of U/S & D/S Slopes
  = 0.4 + 0.5 = 0.9



- For Barrages, compare the value of Shear Strength and Bearing Capacity with Limiting values provided in relevant IS Codes.

Foundation Preparation

- ◯ Foundation preparation in accordance with modern practice.
- ◯ Foundation preparation measures suspect or inadequate.
- ◯ No foundation preparation or not known.

- **Foundation preparation in accordance with modern practice –**
  - Preparing a dam foundation in overburden requires meticulous (very careful) planning and execution to ensure the dam's long-term stability and safety.
  - Modern practices emphasize thorough site investigations, precise treatment techniques, and advanced monitoring, some of which are as follows –

1. Comprehensive Site Investigation:

- **Geological and Geotechnical Surveys**:
  - Detailed mapping of the overburden materials, including soil types, layering, and potential weaknesses.
  - Borehole drilling and sampling to determine the properties of the overburden, such as density, permeability, and shear strength.
- **Hydrogeological Studies:**
  - Assessment of groundwater levels and flow patterns to evaluate potential seepage and uplift pressures.
  - Permeability testing to determine the rate of water flow through the overburden.

2. Foundation Treatment Techniques:

- **Excavation**:
  - Removal of unsuitable materials, such as loose soil, organic matter, and highly permeable layers.
  - Shaping the foundation to create a stable and uniform surface.
- **Grouting:**
  - Injection of grout materials (e.g., cement, chemical grouts) into voids and fractures to reduce permeability and increase strength.
  - This is particularly crucial in overburden with high permeability or potential seepage paths.
- **Drainage:**
  - Installation of drainage systems (e.g., drainage blankets, vertical drains) to control seepage and reduce uplift pressures.
  - This helps to prevent erosion and instability.

- **Compaction:**
  - Compacting the remaining overburden material to increase its density and strength.
  - This is essential for ensuring adequate bearing capacity.
- **Cutoff Walls:**
  - Construction of cutoff walls, which are vertical barriers that are built to restrict the flow of water through the foundation.
  - These are often used when grouting alone is insufficient.

3. Advanced Monitoring:

- Installing instruments (e.g., piezometers, settlement gauges) to monitor the performance of the foundation during and after construction.

➢ By adhering to these modern practices, engineers can effectively prepare dam foundations in overburden, ensuring the safety and longevity of such critical structures.

Drainage System

○ Adequate drainage system in place.

○ Suspect or inadequate drainage system in place.

○ No or drainage system in place or not known

- **Drainage System in Foundation**

  A robust and well-maintained drainage system is a fundamental safety feature for any dam, particularly those built on overburden foundations, as it directly mitigates the risks associated with water pressure and seepage. A few such features are mentioned below:

  - **Toe Drains:** Located at the downstream toe of an Embankment Dam, it collects seepage from Foundation & Horizontal Filters; and conveys it away from the dam to a natural drainage channel.
  - **Relief Wells:** These are vertical wells drilled into the foundation downstream of the dam. They penetrate permeable layers in the overburden and allow trapped water to move out or get discharged (hence relieving uplift pressure). They are particularly important in areas with high groundwater levels.
  - **Drainage Trenches**: Excavated trenches filled with permeable material (like gravel) that collect and transport groundwater or seepage.

➢ Based on availability of such Drainage System/ Features, suitable option should be responded.

Foundation Filter

- ○ Adequate foundation filter where one is required.
- ○ Inadequate foundation filter where one is required.
- ○ No foundation filter when one is required.

- **Foundation Filter**

  These are Layers of granular material designed to control water seepage and prevent soil erosion within the dam's foundation. Such filters are strategically placed in areas where seepage from foundation is likely to occur:

  - **At the Foundation Interface:** They can be placed at the interface between the dam and its foundation to control seepage through the underlying soil. Horizontal Filter may be considered as a Foundation Filter.

➢ Based on the availability of such feature, suitable option should be responded to.

Exit gradients levels

- ○ Exit gradients at all unfiltered exits below modern accepted levels (0.1 or less).
- ○ Exit gradient levels at unfiltered exits within tolerable limits but above modern practice.
- ○ Exit gradient levels at unfiltered exits above acceptable level.

- **Exit gradients levels:**

  "Unfiltered Exits" imply that in the foundation, Foundation Filter and Drainage Systems might be absent, hence a target of 0.1 or less for unfiltered exits is a conservative measure to ensure a significant factor of safety against the critical hydraulic gradient, especially considering the variability of soil properties and potential for preferential flow paths.

➢ If Exits are filtered; or if unfiltered, then if Exit Gradient is ≤ 0.1, select Option 1.
➢ If Exits are unfiltered and if Exit Gradient ∈ [0.1 to 0.25], select Option 2.
➢ If Exits are unfiltered and if Exit Gradient ≥ 0.25, select Option 3.

Exit gradients and uplift pressures

- ○ High exit gradients and uplift pressures not anticipated or managed with adequate foundation pressure relief or drainage system.
- ○ High exit gradients and uplift pressures with inadequate foundation pressure relief or drainage system possible.
- ○ Anticipated high exit gradients and uplift pressures with inadequate foundation pressure relief or drainage system.

- **Uplift pressures & High Exit Gradients:**

  Water from the reservoir can infiltrate the foundation through pores, cracks, and fissures in the underlying rock or soil, such seeping water causes Uplift pressure.

  Further, High exit gradients in the foundation of an embankment dam are a critical concern because they can lead to piping and internal erosion, which can ultimately cause dam failure.

  Pressure Reduction/ Relief Systems:
  - Cutoff Walls/ Grout Curtains
  - Upstream Impervious Blanket

  Drainage Systems:
  - Horizontal Filter/ Drainage Blanket
  - Toe Drain
  - Relief Wells
  - Drainage Trenches

- If the anticipated Exits Gradients are within the limits (0.1 for Unfiltered Exits and 0.5 for Filtered Exits), or if anticipated Exit Gradients are out of limits but adequate Pressure Reduction/ Relief Systems & Drainage Systems are provided; then, select Option 1.

- Option 2 & 3 are similar and self-explanatory.

Comment	Attachment
- Write necessary comments to justify the responses made.	- As Built Drawings related to Cross-Sections of Embankment Section, showing the location & details of Filters. - Suitable Documents, as evidence to support the responses provided.

References:
- Foundation/ Soil Investigation Report/ History Document of Completed Project
- Drawings (L/S & C/S).

TC 8 (Foundation and Abutments): Part 2
BEDROCK (all structures)

BEDROCK (all structures)	
No knowledge about the geology of the site and the subsurface conditions.	False

❖ Following Sub Questions will appear –
(Select only if any one or more following risky conditions is/are present in your dam)

- ☐ Foundation composed of inadequately treated highly weathered or highly fractured rock.
- ☐ Foundation composed of inadequately treated karstic limestone.
- ☐ Foundation composed of inadequately treated rock with gypsum or other soluble minerals.

Due to the inherent risks with these kinds of rocks, sites with significant amount of Highly Weathered/ Highly Fractured Rocks, or Karstic Limestone, or Rock with Gypsum/ other highly soluble minerals; are generally **avoided** for major dam construction where possible.

However, when no alternative site exists, then before taking up the construction, adequate treatment to such rocks is an essential activity.

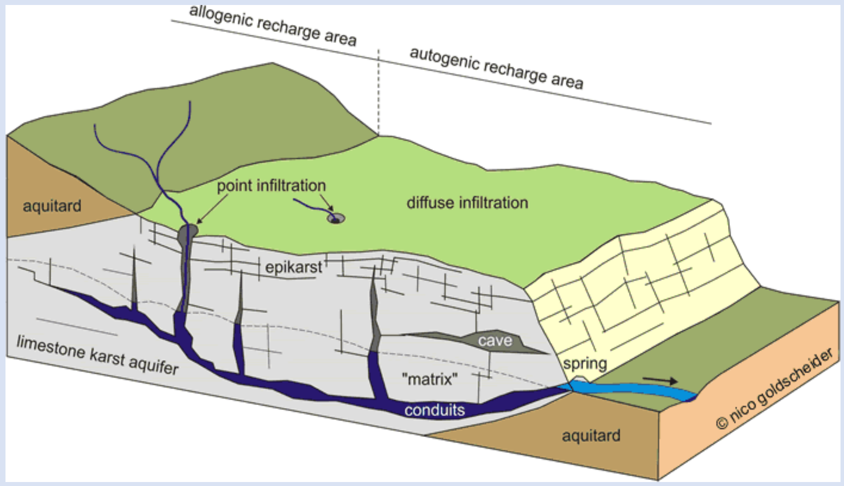
- **Highly weathered or highly fractured rocks** –

  - These are rocks that have been significantly changed/ transformed or broken down by physical/ chemical processes.
  - **Highly weathered rocks** have undergone extensive decomposition and disintegration due to weathering.
  - **Highly fractured rocks** have many cracks or fissures (splits/ openings/ gaps)
  - These kinds of rocks provide reduced Strength and Stability, increased Permeability, Seismic Vulnerability and have many Durability related concerns (Further, weathered rocks may contain minerals that can further decompose or react with the concrete in the dam, leading to long-term deterioration of the foundation.).

- **Karstic Limestone:**

  - Limestone (Calcium Carbonate) dissolves relatively easily in slightly acidic water (formed when rainwater absorbs carbon dioxide from the atmosphere and soil). This is the fundamental process driving karst formation/ Karstic Limestone, which is also soluble in acidic water.

- Due to its solubility, it has an extensive network of interconnected conduits, fissures, and channels. Water preferentially flows through these openings, enlarging them over time, leading to very high Permeability and Seepage, hence makes the dam (resting on such foundation/ rock) highly vulnerable to Excessive Leakage, Piping, and Foundation Instability.
- Due to large cavities, there exist high chances of collapse of overlying material (into these underground cavities), leading to formation of Sinkholes. The potential for new sinkholes to form, either in the reservoir area or near the dam foundation, poses a direct threat to the integrity of the dam.



- **Rocks with gypsum or other soluble minerals:**

- Such rocks also show similar characteristics to that of Karstic Limestone.

Rock Condition (Permeability)

- ○ Very good to excellent quality, low permeability granitic, sandstone, shale, siltstone, basalt, claystone, mudstone or hornfels bedrock. Other rock types may be considered as very good if they are fresh, impervious and massive with few discontinuities
- ○ Quality generally good , low permeability granitic, sandstone, shale, siltstone, claystone, mudstone or hornfels bedrock or permeability reduced by modern foundation grouting methods. Other rock types may be considered as good if they are fresh, impervious and widely jointed with few filled discontinuities that can be treated by grouting.
- ○ Fair to good quality and moderate permeability granitic, sandstone, shale, siltstone, claystone, mudstone or hornfels bedrock. Rock mass with permeabilities as high as 10-3 cm/s but that can be adequately sealed.
- ○ Poor to fair quality tuff, basalt, dolomite, marble, quartzite or rhyolite. Rock mass may have local areas with permeabilities higher than 10-3 cm/sec.
- ○ Poor quality, highly weathered or fractured rock or a karst limestone foundation or a foundation containing gypsum or other soluble materials. Rock mass may have local areas with permeabilities higher than 10-2 cm/s that cannot be adequately sealed.

- The question is self-explanatory.
- A suitable option could be selected based on the availability of type of Foundation Rock.

Shear Strength and Bearing Capacity

- ○ Very good to excellent shear strength and bearing capacity.
- ○ Shear resistance and bearing capacity considered as adequate.
- ○ Adequate shear strength and bearing capacity or foundation reinforced and stabilized.
- ○ Suspect shear resistance or not known.
- ○ Inadequate or potentially inferior shear strengths or bearing capacity.

- ➢ The question is self-explanatory. A suitable option could be selected based on the availability of type of Foundation Rock.

- ➢ Foundation/ Soil Investigation Report should be referred. Or, in case of unavailability of such report but knowing the type of rock present, adequacy of Shear Strength/ Bearing Capacity may be checked using Internet searches.

  For some of the rocks, such a qualitative categorization is presented below -

Type of Rock	Shear Strength/ Bearing Capacity
○ Granite ○ Basalt/ Dolerite ○ Quartzite ○ Gneiss (Sound, Unweathered)	Very Good to Excellent
○ Sandstone ○ Limestone (Sound, massive) ○ Schist (Moderately weathered/ foliated) ○ Gneiss (Moderately weathered/ fractured)	Adequate
○ Shale/ Mudstone ○ Phyllite ○ Highly Weathered Rocks (of any type) ○ Rocks with prominent weak discontinuities ○ Highly Fractured Rocks (of any type) ○ Soft Limestones/Chalk ○ Karstic Limestone/ Rocks with Gypsum	Inadequate or Potentially Inferior

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Foundation Preparation

- ○ Very good to excellent foundation preparation in full accordance with modern practice.
- ○ Foundation preparation generally in accordance with modern practice.
- ○ Adequate foundation preparation, including grouting of local moderate to high permeability.
- ○ Foundation preparation measures suspect or inadequate.
- ○ No foundation preparation or not known.

- **Foundation preparation in accordance with modern practice –**
  - Preparing a dam foundation requires meticulous (very careful) planning and execution to ensure the dam's long-term stability and safety.
  - Modern practices emphasize thorough site investigations, precise treatment techniques, and advanced monitoring, some of which are as follows –

1. Comprehensive Site Investigation:

- **Geological and Geotechnical Surveys**:
  - Detailed mapping of subsurface materials, including soil types, layering, and potential weaknesses.
  - Borehole drilling and sampling to determine the properties of the subsurface materials, such as density, permeability, and shear strength.
- **Hydrogeological Studies:**
  - Assessment of groundwater levels and flow patterns to evaluate potential seepage and uplift pressures.
  - Permeability testing to determine the rate of water flow through the foundation rocks/ soils.

2. Foundation Treatment Techniques:

- **Excavation**:
  - Removal of unsuitable materials, such as loose soil, organic matter, and highly permeable layers.
  - Shaping the foundation to create a stable and uniform surface.
- **Grouting:**
  - Injection of grout materials (e.g., cement, chemical grouts) into voids and fractures to reduce permeability and increase strength.
  - This is particularly crucial in highly weathered rocks & fractured rocks which have high permeability or potential seepage paths.
- **Drainage:**
  - Installation of drainage systems (e.g., drainage blankets, vertical drains) to control seepage and reduce uplift pressures.
  - This helps to prevent erosion and instability.

- **Compaction:**

- Compacting the foundation material to increase its density and strength.
- This is essential for ensuring adequate bearing capacity.

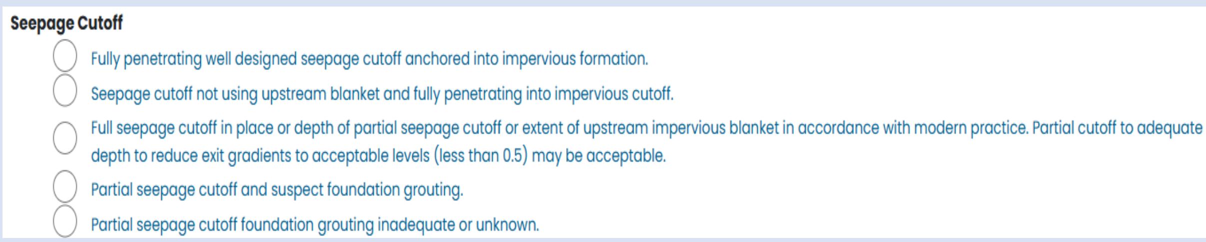
- **Cutoff Walls:**

- Construction of cutoff walls, which are vertical barriers that are built to restrict the flow of water through the foundation.
- These are often used when grouting alone is insufficient.

3. Advanced Monitoring:

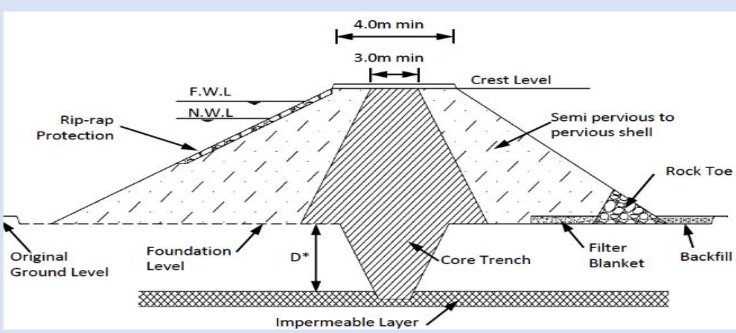
- Installing instruments (e.g., piezometers, settlement gauges) to monitor the performance of the foundation during and after construction.

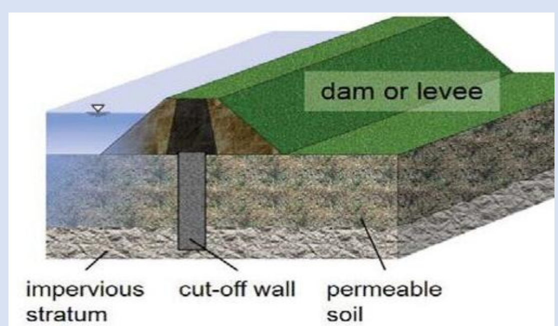
➢ By adhering to these modern practices, engineers can effectively prepare dam foundations, ensuring the safety and longevity of such critical structures.

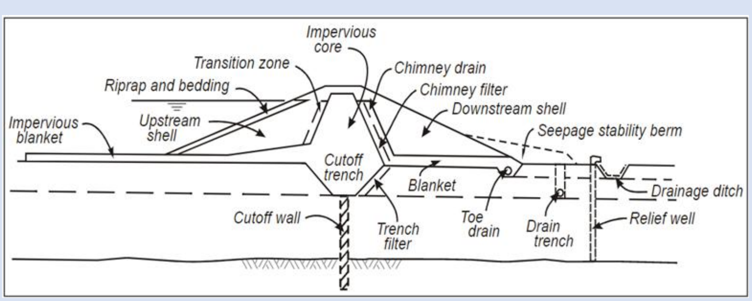

Seepage Cutoff

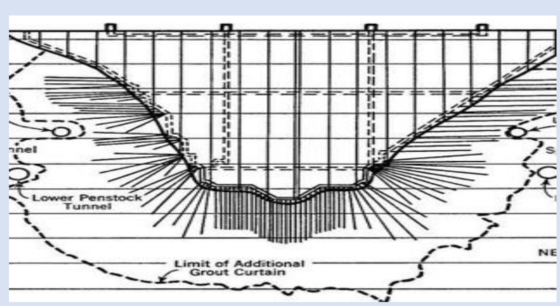
- Fully penetrating well designed seepage cutoff anchored into impervious formation.
- Seepage cutoff not using upstream blanket and fully penetrating into impervious cutoff.
- Full seepage cutoff in place or depth of partial seepage cutoff or extent of upstream impervious blanket in accordance with modern practice. Partial cutoff to adequate depth to reduce exit gradients to acceptable levels (less than 0.5) may be acceptable.
- Partial seepage cutoff and suspect foundation grouting.
- Partial seepage cutoff foundation grouting inadequate or unknown.

- **Measures to tackle Permeability issues -**
  - Full Cutoff (Cutoffs/ Cutoff walls) to bedrock or impervious soil.
  - Upstream Impervious Blanket
  - Core trenches to rock
  - Alluvial grouting
  - Jet grouting
  - Partial Cutoffs (Where Cutoff doesn't meet Hard Rock/ Impermeable Layer)









- ➢ Based on the availability of type of Cutoff, suitable option should be responded.
- ➢ When no such information is available, then site observation may give some information. If the downstream toe drain is receiving high discharge and general ground water level of downstream area increases when the reservoir is full, consider it as high permeability. Accordingly, for such a similar situation, Option 4 or 5 may be responded.

Joints

- ○ Generally closed fractures or localized factures infilled with non-erodible materials.
- ○ Limited number of open joints infilled with non-erodible substances or localized joints, generally discontinuous joints filled with erodible materials that have been adequately treated.
- ○ Some continuous open joints in foundation generally infilled with non-erodible substances. Local open joints filled with erodible materials of limited continuity that have been adequately treated.
- ○ Many open joints or some joints filled with erodible materials.
- ○ Many open joints filled with erodible materials.

- o For preparing dam foundations, joints and fractures in the bedrock are always treated with non-erodible materials, as they provide impermeability, resistance to erosion, strength and durability to the foundation material.
- o Treatment of such joints/ fractures with erodible materials does not guarantee reliable properties, making the foundation vulnerable to excessive seepage, erosion & instability.
- o Based on the type of treatment provided to joints/ fractures, suitable option should be responded.

Drainage System

- ○ Very good and reliable drainage system in place.
- ○ Adequate drainage system in place.
- ○ Drainage system in place but not fully adequate.
- ○ Drainage system inadequate.
- ○ Drainage system absent.

- ▪ **Drainage System in Foundation**

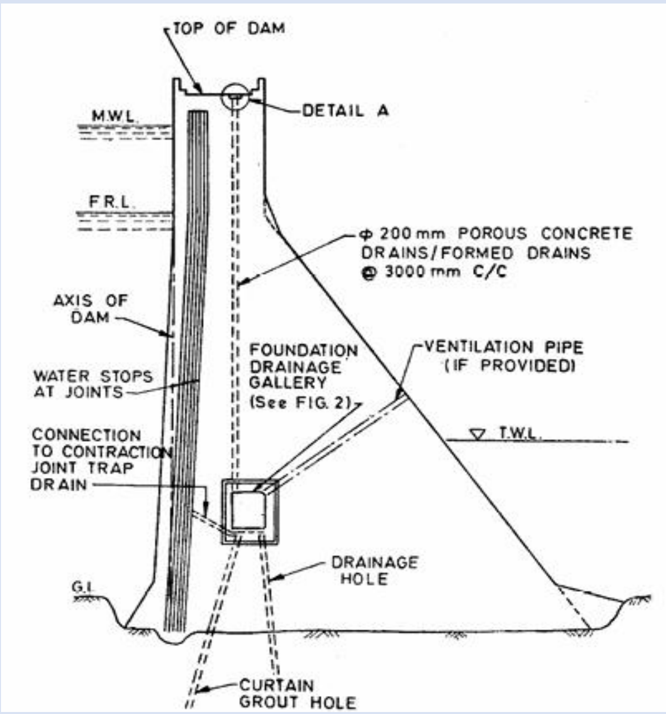
- o An adequate drainage system in the bedrock foundation of a dam is crucial for its long-term stability, safety, and performance.
- o The primary purpose of such a system is to control and relieve uplift pressure, manage seepage, and prevent deterioration of the foundation.
- o Most common and effective type of drainage system in bedrock foundations (of Gravity Dams) are as follows –

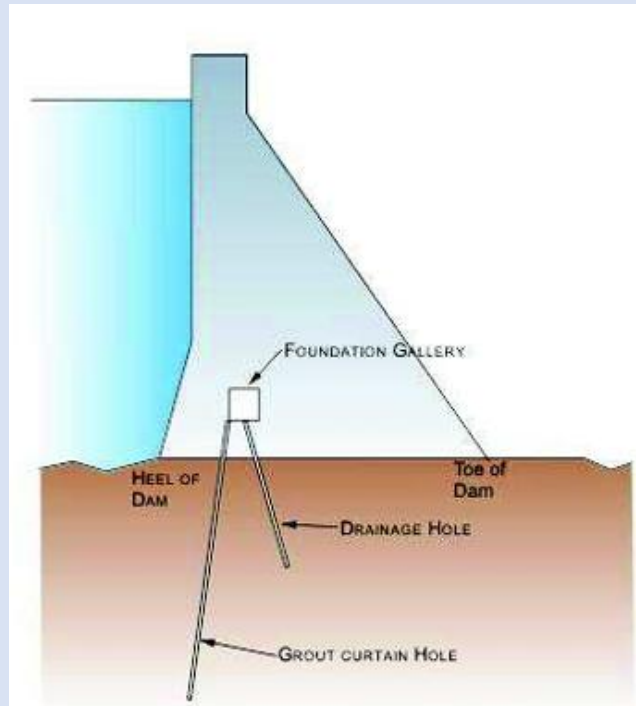
1) **Drainage Gallery (Foundation Gallery):**

- These are horizontal or slightly sloping tunnels excavated within the dam body, close to the upstream face and the bedrock foundation.
- They collect seepage water intercepted by the drain holes and direct it to a safe outlet.

2) Drain Curtain (Relief Wells/ Drain Holes):

- These are a series of vertical or inclined boreholes drilled from the drainage gallery into the bedrock foundation.
- They extend deep enough to intercept potential seepage paths and relieve uplift pressure.





➢ Based on availability of such Drainage System/ Features, suitable option should be responded.

Exit gradients and uplift pressures

- ◯ Only low exit gradients and uplift pressures present.
- ◯ Only medium exit gradients and uplift pressures present and fully managed with adequate foundation pressure relief and drainage system.
- ◯ High exit gradients and uplift pressures not anticipated or managed with adequate foundation pressure relief or drainage system.
- ◯ High exit gradients and uplift pressures with inadequate foundation pressure relief or drainage system possible.
- ◯ Anticipated high exit gradients and uplift pressures with no foundation pressure relief or drainage system.

- **Uplift pressures & Exit Gradients:**

Water from the reservoir can infiltrate the foundation through pores, cracks, and fissures in the underlying rock or soil, such seeping water causes Uplift pressure.

Further, High exit gradients in the foundation of dam are a critical concern because they can lead to piping through foundation, which can ultimately cause dam failure.

Pressure Relief Systems & Drainage Systems:

- Cutoff Walls/ Grout Curtains
- Foundation Gallery
- Drainage Holes

- If the anticipated Exits Gradients are within the limits (0.1 for Unfiltered Exits and 0.5 for Filtered Exits), or if anticipated Exit Gradients are out of limits but adequate Pressure Reduction/ Relief Systems & Drainage Systems are provided; then, select Option 1.
- Other Options are similar and self-explanatory.

Comment	Attachment
- Write necessary comments to justify the responses made.	- As Built Drawings related to Cross-Sections of Dam Section - Suitable Documents, as evidence to support the responses provided.

References:

- Foundation/ Soil Investigation Report/ History Document of Completed Project
- Drawings (L/S & C/S).

EC 7 (Spillway Structure)

Refer the Supporting Data Section and observe Components of the Specified Dam under consideration, which were categorised into *NOF Sections* and *OF Sections.*

Let's focus on OF Section/ Spillway in EC 7, whereas NOF Sections (of Main Dam portion) will be assessed in EC 6, EC 8 and EC 9.

☐ **This section is not available in the dam**

- All kinds of Spillway, be it Gated/ Ungated/ Waste Weir, will be assessed here.
- There could be some sort of Power Dams where Spillway may not be needed as the Water during Monsoon/ Flood may be suitably utilized for the Power Generation/ released through Penstocks. Otherwise, almost all kinds of Dams are equipped with Spillways.
- Hence, for almost all the Specified Dams of Gujarat, above Option is not to be responded.

Displacements and offsets

○ None.
○ Only minor.
○ Small number of medium size.
○ Large and numerous.

- Displacements:

  In a Spillway, these are accidental **movements from the original designed position**, which can be caused by several factors:

  Settlement: Uneven settling of the foundation beneath the spillway structure can lead to vertical or horizontal displacements. (This is particularly relevant for spillways founded on compressible soils).

  Seismic Activity: Earthquakes can induce significant displacements in the spillway structure, potentially causing cracking, sliding, or overturning.

  Hydrostatic and Hydrodynamic Forces: The pressure of the water against the spillway (hydrostatic) and the forces exerted by the flowing water (hydrodynamic) can cause deflections and minor displacements. While these are usually accounted for in the design, extreme flood events could lead to larger-than-anticipated displacements.

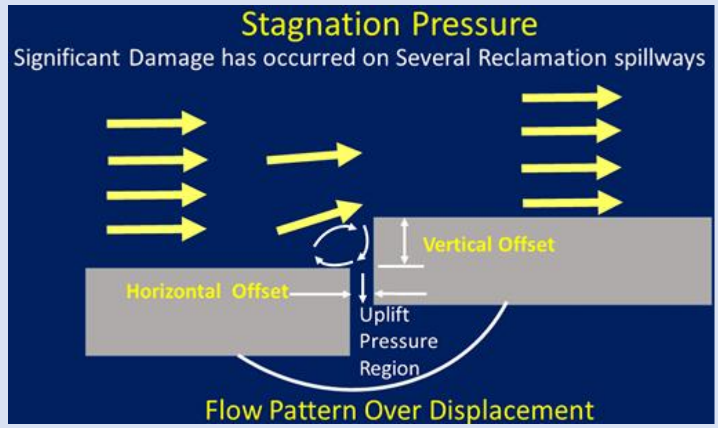
  Thermal Expansion and Contraction: Temperature variations can cause the spillway materials (especially concrete) to expand and contract, leading to small movements at joints and within the structure.

Creep and Shrinkage: Concrete can experience long-term deformation (creep) under sustained load and volume changes due to moisture loss (shrinkage), which can result in minor displacements.

Joint Movement: Spillways are often constructed with joints to accommodate some of the movements mentioned above. However, excessive or unexpected movement at these joints can be considered a displacement issue if it compromises the spillway's function or water tightness.

- <u>Offsets</u>:

These are deviations/ relative displacements in the profile of the Concrete Surface, which are created intentionally/ unintentionally during Construction (Construction related offsets – due to Slipping/ Misalignment of Formwork or due to poor construction practices etc.) or caused accidently due to Active Forces, Differential Settlement etc.

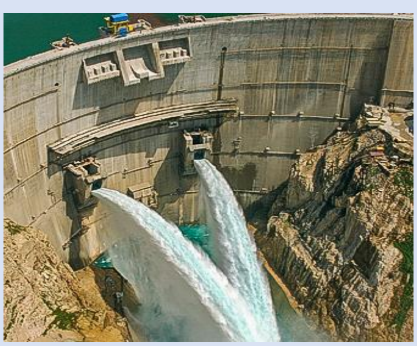


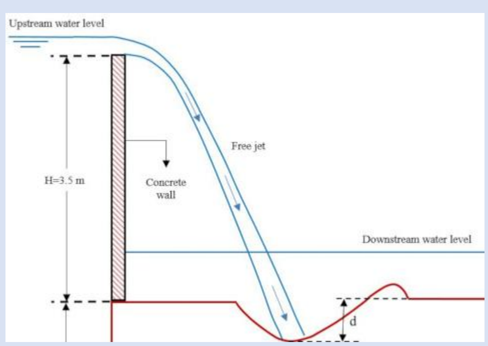
Observe Horizontal Offset & Vertical Offset

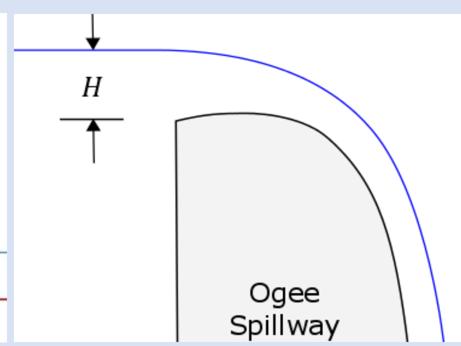
- This Relative displacement or offset between adjacent sections of concrete, can be readily detected at the joints (construction joints, monolith lines etc.).
  Ex. When the forms slip during construction, they can produce slightly offset blocks and uneven joints and surfaces.

- These offsets or irregularities produce turbulence which cause/ intensify the Cavitation (a form of erosion, is the result of the formation of excessive negative air pressures), leading to deterioration/ damage of Concrete.

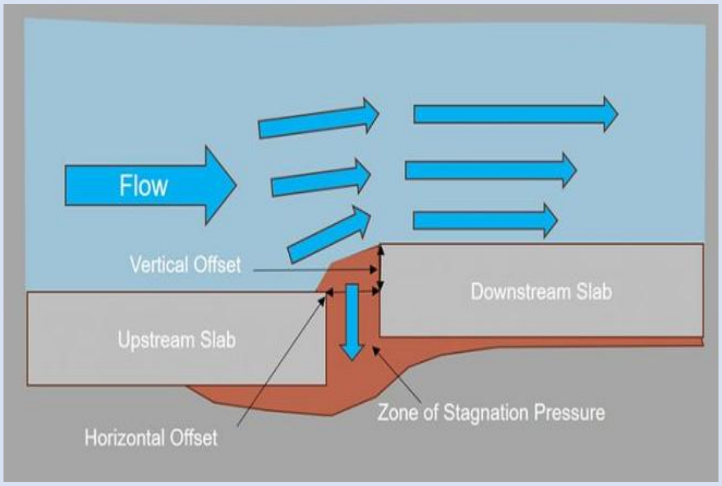
Ex.: **Flow Surface/ Spillway Profile**: The downstream face of an Ogee Spillway is often shaped based on the trajectory of a freely falling jet (Parabolic profile).







While constructing the Spillway by providing the Joints (Construction Joints - Construction joints in concrete are unavoidable as we cannot finish the work at once, Expansion/ Contraction Joints etc.), Offsets at such joints may be created which may cause conditions favorable to Cavitation.



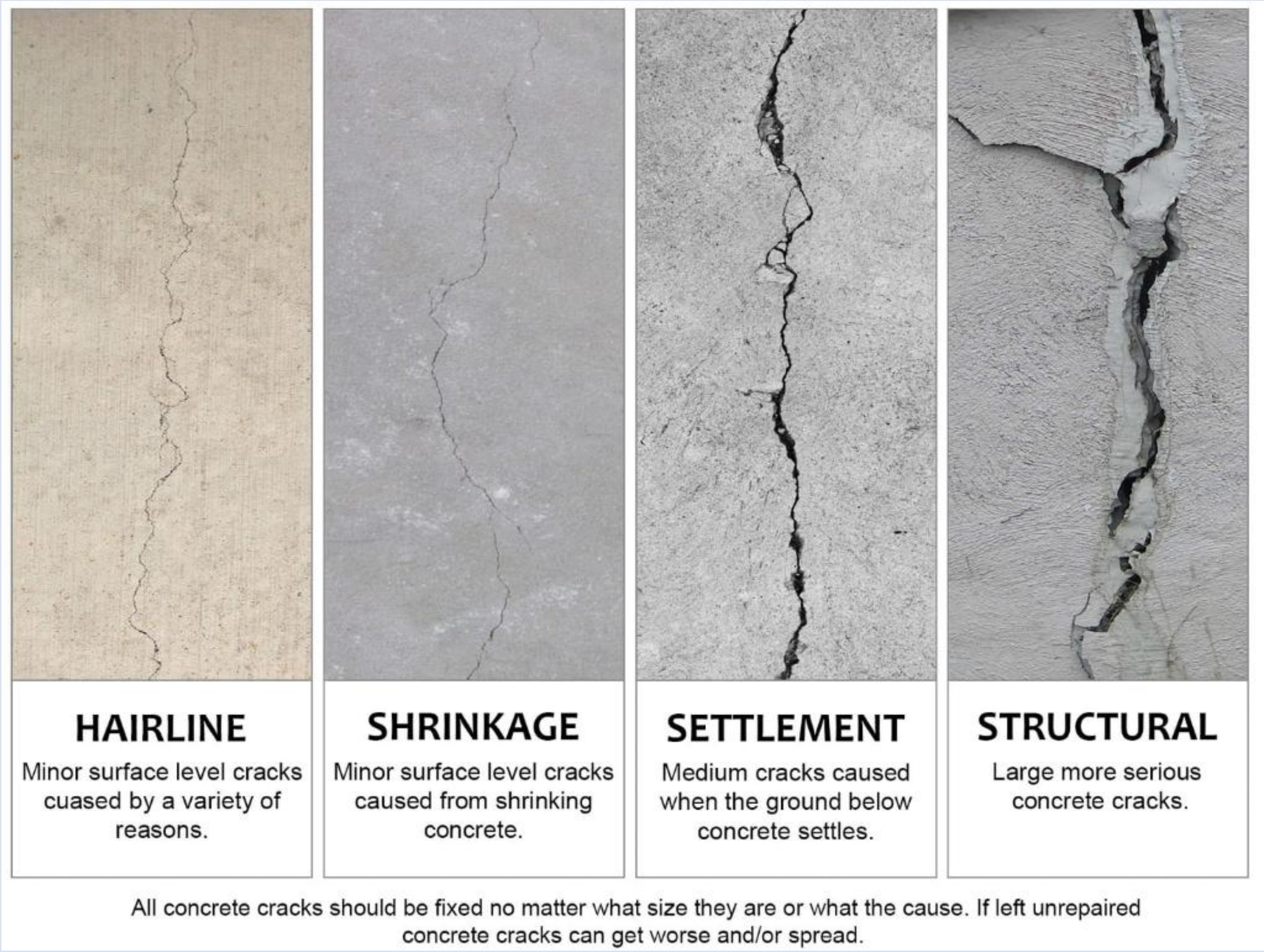
Ex.: **Joint Details**: The design of joints in a spillway often includes specific offsets or configurations of waterstops and joint fillers to ensure water tightness.

- Observe the existing condition of Spillway very carefully and respond to the suitable option. Further, a latest yet comprehensively filled Pre/ Post Inspection Report may also be referred to know the condition of Spillway.

❖ Cracking:

- ○ None or only hairline.
- ○ Minor increase in size of limited number of cracks.
- ○ Large cracks present.
- ○ Extensive and deep cracking with exposed rebars.

- Hairline cracks are very small fissures, typically less than 0.1 mm wide, that can appear on the surface of the concrete.
  - <u>Indicator of Underlying Issues</u>**:** Hairline cracks can sometimes be a sign of more significant problems like improper curing, excessive stress, or ongoing chemical reactions within the concrete.
  - They could be formed due to Shrinkage, Thermal Contraction, Alkali-Aggregate Reaction (ASR), Minor Settlement etc.
  - While hairline cracks are often <u>non-structural</u> and don't immediately compromise the dam's integrity, they <u>can have potential long-term impacts</u> like - Negatively affecting the visual appearance of the dam, Increased Permeability, Weakening of Concrete, Reduced Durability.
  - While they might seem insignificant, understanding their causes, their regular monitoring and <u>timely repair of even small hairline cracks are essential</u> for maintaining the long-term health and safety of concrete dams/ spillways.



- Any kind of Crack, be it Non-Structural or Structural, should be properly identified, monitored and repaired.

➢ Observe the existing condition of Spillway very carefully and respond to the suitable option.

Joints

- ○ No loss of joint material.
- ○ Minor loss of joint material.
- ○ Loss of joint material significantly increasing with time.
- ○ Loss of substantial amount of joint material.

➢ Observe the existing condition of Spillway very carefully and respond to the suitable option. Options are Self-Explanatory.

Erosion

- ○ No erosion (e.g. undercutting).
- ○ Signs of initiation of erosion (e.g. undercutting).
- ○ Progressing erosion (e.g. undercutting).
- ○ Signs of accelerated erosion.

- Undercutting erosion in a concrete spillway primarily occurs due to the erosion of the soil or foundation material at the downstream end or beneath the concrete structure. This loss of supporting material creates voids, leading to instability and potential collapse of the spillway components. Here are the main causes:

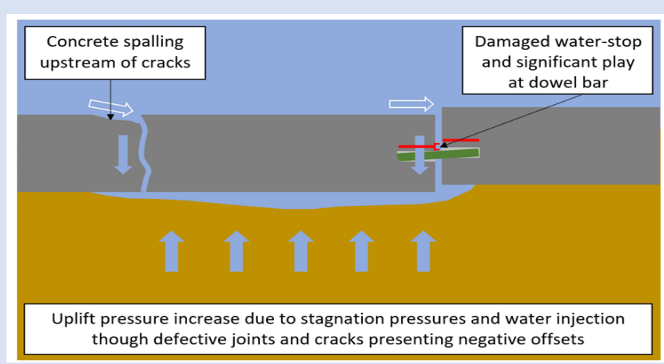
  - **Turbulent Flow and Scour:** High-velocity water exiting the spillway can create significant turbulence at the downstream. This can erode the unprotected soil or weaker/ erodible foundation material like silt, sand, or loosely consolidated rock.

  - **Hydraulic Jump:** If a hydraulic jump is not adequately contained within a stilling basin, the intense turbulence and energy associated with the jump can erode the foundation material beyond the designed protection. When the jump occurs further downstream than intended, is particularly problematic.

  - **Poorly Designed or Damaged Energy Dissipation Structures:** Stilling basins, plunge pools, and other energy dissipation structures are designed to control the erosive power of the discharged water. If these structures are inadequate for the flow conditions or have been damaged, they may not effectively protect the downstream foundation from erosion and undercutting.

  - **Stagnation Pressures and Uplift:** Irregularities or offsets in the spillway surface (like joints or cracks) can create stagnation pressures. These pressures can force water underneath the concrete slabs. If there are unfiltered exits in the foundation (like underdrains), this water flow can carry away foundation material, creating voids and undermining the slabs. This can also lead to **Hydraulic jacking**, where the uplift pressures lift the concrete slabs.

  Therefore, Hydraulic Jacking refers to the phenomenon where high-velocity water flow, particularly at an offset or joint in the spillway chute, can create significant uplift pressures beneath the concrete slab, potentially leading to its lifting or movement.



- **Geological Factors:** They play a crucial role. Softer or fractured rock, or unconsolidated soils, are inherently more susceptible to erosion and undercutting than hard, intact bedrock. The presence of joints, bedding planes, or faults can also provide pathways for water to seep and erode the foundation.

  If erosion of the foundation materials initiates and progresses, this could lead to undermining of the chute slab foundation and collapse of the chute slab.

  If a chute slab fails due to Hydraulic Jacking, headcutting and upstream progression of erosion will depend on the erodibility of the foundation materials. If the foundation consists of competent rock, upstream progression of erosion may be limited.

- **Impact of Debris:** Large debris carried by floodwaters can impact the downstream end of the spillway or the adjacent foundation, causing fracturing and making the material more susceptible to erosion.

➢ Observe the existing condition of whole Spillway Flow Surface, i.e., from Crest to Energy Dissipation Arrangement (EDA) to Stilling Basin to Endsill or to Plunge Pool, in very careful manner and respond to the suitable option.

Uplift

○ Uplift pressures are low and stable.
○ Moderate increase in uplift pressures.
○ Significant increase in uplift pressures.
○ Uplift pressures are very high.

➢ Reply it based on own judgement.

Energy dissipators

○ No damage to energy dissipators.
○ Minor damage to energy dissipators.
○ Damaged energy dissipators but still functional.
○ Destroyed energy dissipators.

➢ Self-Explanatory.

Instrumentation

Section A

- ○ Adequate instrumentation (as required by Dam Safety Act with associated Regulations and appropriate CWC Guidelines) exists with established design limits.
- ○ Instrumentation not meeting requirements of Dam Safety Act with associated Regulations and appropriate CWC Guidelines. Some instruments missing or not working. Design limits not established for all instruments.
- ○ Requirements of Dam Safety Act with associated Regulations and appropriate CWC Guidelines. Many instruments missing of not working. Numerous design limits missing.
- ○ No instrumentation or instrumentation grossly inadequate.

- At present, at almost all the existing Specified Dams, properly functioning Structural Instruments are not available.

➢ All Options are Self-Explanatory. For most of the dams, the right response would be the 4th Option.

Comment	Attachment
○ Supporting Comments	○ Supporting Documents/ Pictures, as evidence to support the responses provided.

Safety Plans

- It is the responsibility of Dam owner to effectively **identify, track and address** all existing and potential problems that can affect the safety of the dam, i.e., the Dam owner must have a system to address all the issues related to Dam Safety.

- Lack of such a system brings ineffectiveness and increases the risks significantly.

- Even the dam that poses a low risk to downstream populations, may prove to be riskier if there is an absence of an active owner who periodically and continually monitors the safety.

- Hence, for each Specified Dam, owner must have a system to address all the issues related to Dam Safety, which will include –

  1) Organizational Structure
  2) Clearly defined responsibilities
  3) Records/ Documents control
  4) Dam Safety Inspections & Reviews (General Requirements, Analysis, Documentation and Follow-up Actions).
  5) Maintenance and repairs
  6) Operational activities
  7) Emergency preparedness and Response Plan

SP-1: Documentation

- Availability of Documentation:

  ○ Detailed design drawings, plans, specifications and complete constructions records including as-built documentation.
  ○ Only basic design drawings and specs or conceptual design level documentation.
  ○ No or partial, incomplete and very limited records.

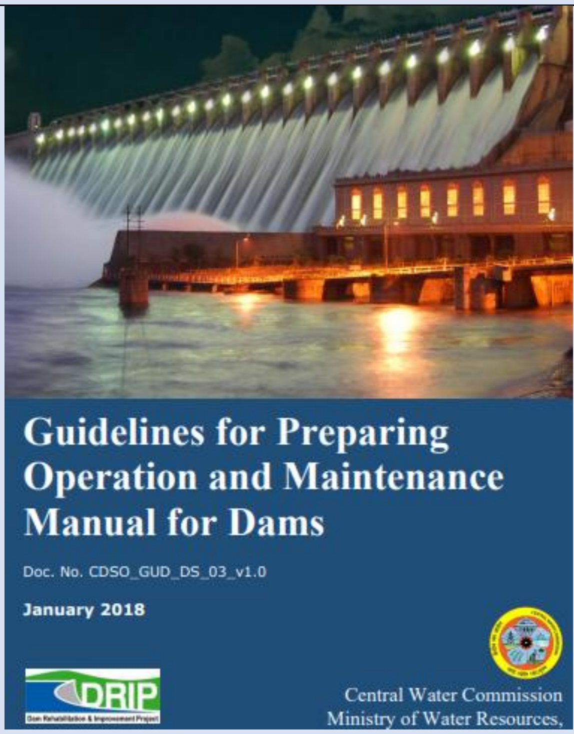
  - It discusses about the Design – Drawings, Specifications etc., of Sub-Structure (Foundation) as well as Superstructure, related to First/ Original Construction as well as major Maintenance or Rehabilitation/ Retrofitting Work carried out afterwards.

  - Options are Self-Explanatory.

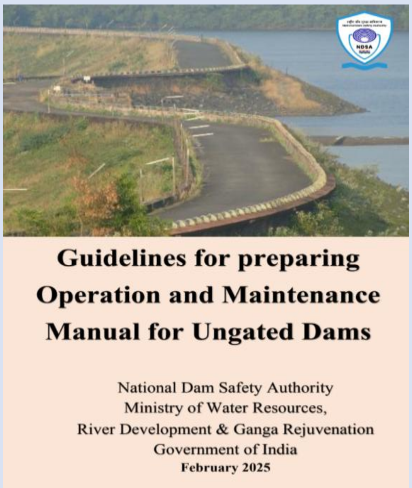
Attachment: Document/ Supporting Evidence	**Comments**
Not Required/ Not Applicable	Write the Comment, based on the availability of such Design & Construction Documentation.

SP-2: Operations and Maintenance Manual

Q1: ◯ Implemented O&M Manual was prepared according to Dam Safety Act and with associated Regulations and appropriate CWC Guidelines.

Associated provisions of Dam Safety Act (DSA)	Applicable CWC Guidelines
Section 4 (r.) "Operation and Maintenance manual" means the <u>written instructions</u> that provide operation procedures, maintenance procedures, emergency procedures and any other <u>features necessary for the safe operation of dam</u>.	
Section 28 (2) Every owner of the specified dam shall ensure that a well-documented operation and maintenance manual is kept <u>at each of the specified dams</u> and are followed at all times.	
Conclusion: For all kind of Specified Dams (be it a Gated Dam, or Ungated Dam, or Barrage, or Weir), a detailed O&M Manual must be there.	

- If the O&M Manual being used at the Specified Dam under consideration, is prepared as per above provisions & guidelines, then only, Q1 is to be responded.



Q3: ◯ O&M Manual not developed or implemented.

- Self-Explanatory.
- If an O&M Manual was developed in the past, but at present, it is not being used (as it is not fit as per provisions mentioned above in Q1)/ it is missing, then as well, respond Q3.

Q2:

◉ Information limited(location, and the description of dam with basic drawings and photos, collection and reporting of dam and reservoir data, public safety arrangements, supporting documents and reference material).

If this is selected it means O&M Manual is incomplete, then select one or more of the following elements which are present in the Manual

- ☐ Assignment of roles and responsibilities, staffing, communication and warning.
- ☐ Schedule of operations and maintenance duties.
- ☐ Operation (general operation plan, normal operation, instructions for operation of control mechanisms, operation of the reservoir, flood release procedure, inflow forecasting, emergency operation, drawdown facility and procedure, first filling of reservoir, record keeping).
- ☐ Inspections (informal, scheduled, special, comprehensive evaluation).
- ☐ Maintenance (plan, priorities, material and staffing requirements).
- ☐ Instrumentation and monitoring (instrumentation types and usage, Automated Data-Acquisition Systems, frequency of monitoring, data processing and evaluation).

- If an O&M Manual was developed in the past, and at present, it is being used, then, respond Q2.
- If such O&M Manual, is incomplete/ completed to some extent (as per CWC Guidelines), then one/ more options may be responded based on their presence in this O&M Manual.

  Each such Option forms an individual chapter/ component/ element of the O&M Manual.

Attachment: Document/ Supporting Evidence	**Comments**
Attach the Existing/ In Place O&M Manual	Write the Comment supporting your response (s).

SP-3: Emergency Action Plan

Q1: **Emergency Action Plan in place?(Yes/No)**

- If Answer is "No", then just write suitable Comment & move ahead to SP-4.
- If Answer is "Yes", then one/ more options may be responded based on their presence in the Existing/ In Place EAP.

Please select if the Plan contains detailed information on one or more below options

- ☐ Identification of owner?s personnel and outside organizations that can render assistance in interventions arresting developing dam failure.
- ☐ Location and quantities of supplies and equipment available for use in remedial actions, preferably as close as possible to the dam.
- ☐ Arrangements for emergency procurement of supplies and equipment needed for remedial actions.
- ☐ Identification of remedial construction and other activities that should be done to prevent a failure of the dam together with identification of personnel who will carry them out (including specific contact names along with their function, their business or agency, and contact information).

- Each such Option forms an individual element of the EAP.

Attachment: Document/ Supporting Evidence	**Comments**
Attach the Existing/ In Place EAP	Write the Comment supporting your response (s).

SP-4: Organization, Staffing and Competence

Q1:

Organizational Structure

- ◯ Well developed organizational structure led by dam safety engineer.
- ◯ Incomplete organizational structure led by dam safety technician.
- ◯ No or inadequate organizational structure, insufficient leadership.

- Each Specified Dam should have an active and professional organization with sufficient staffing of qualified personnel for efficient Dam Safety Management.
- Normally, such organizations include –
  - The Personnel working at the dam site, who are charged with operation and maintenance of the dam on a day-to-day basis.
  - Persons responsible for periodic and continuing safety of the structure.
  - Persons measuring, reporting, and acting on needed safety improvements.
  - Persons overseeing safety.
- For any Specified Dam, concerned Sub-Division's (or similar level office's) Organizational Structure (i.e., <u>Organization Structure looking after the Dam Site</u>) may be considered, for submitting the response in Q1. Such Organizational Structure may be having above mentioned kind of Personnel/ Persons.
- So, if it is headed by DEE, then Option 1 may be responded.
- Option 2 may be selected, when it is headed by some Work Assistant or similar level person.
- If Option 1 or 2 is not suitable, then go for Option 3.

Q2:

Staff

- ◯ Sufficient staff in place.
- ◯ Not all staff in place.
- ◯ Insufficient staffing.

- This Question is discussing about the Staff posted at the Dam Site, in Permanent Capacity.
- These are Sub Ordinate Staff under the Sub-Division (or similar level office's), who are given Dam Site related responsibilities regarding Day to Day activities.

Q3:

Staff Competence

- ○ All staff fully competent with appropriate training and experience.
- ○ Not all qualifications are in place.
- ○ Insufficient qualifications of staff.

- Self-Explanatory.

Attachment: Document/ Supporting Evidence	**Comments**
Attach the Original Organizational Structure and Current/ Existing/ Active Organizational Structure of the Sub-Division.	Write the Comment supporting your response (s).

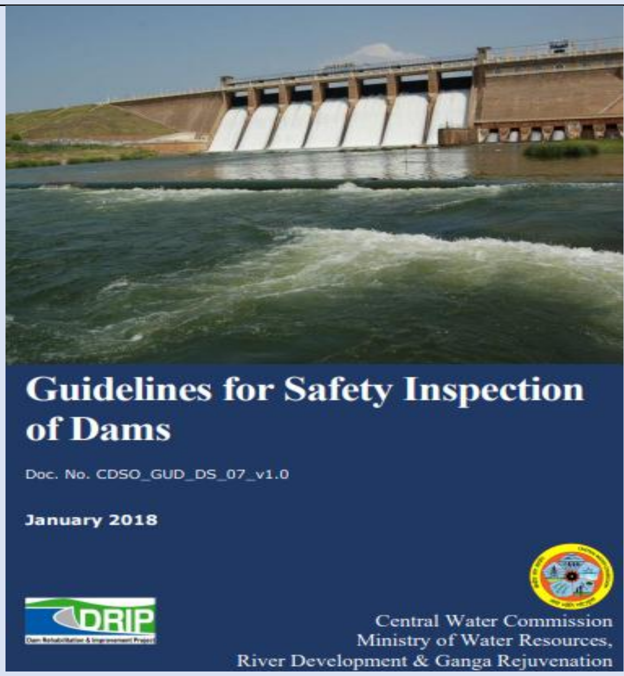
SP-5: Safety Inspection & Reporting

Q1:

Inspection, surveillance and monitoring program

- ◯ Inspection, surveillance and monitoring program has been developed and implemented following Dam Safety Act and associated Regulations and appropriate CWC Guidelines.
- ◯ Inspection, surveillance and monitoring program has been developed followingDam Safety Act and associated Regulations and appropriate CWC Guidelines as well as O&M Manual but the implementation is still ongoing.
- ◯ Inspection, surveillance and monitoring procedures are incomplete.
- ◯ No inspection, surveillance and monitoring procedures.

- For preventing dam failure related disasters; Surveillance, Inspection, Operation & Maintenance, are must. Same is the purpose of DSA.
- Option No. 3 & 4 are Self-Explanatory.
- Inspection, Surveillance and Monitoring Program:

Associated provisions of Dam Safety Act (DSA) & its Regulations	*Applicable CWC Guidelines*
Inspection = On-site examination of all the components of a dam and its appurtenant structures.	
Concerned Dam Safety Unit (DSU) shall do following Inspections: **1) Pre-Monsoon Inspection :** - Shall be conducted during March and completed before 30^{th} April of the same year. - Report shall be sent to SDSO before 15^{th} May of that year. **2) Post-Monsoon Inspection :** - Shall be conducted during October and completed before 30^{th} November of the same year. - Report shall be sent to SDSO before 15^{th} December of that year. **3) Event Based Inspection :** - Inspections during or after every '1 in 50-year return period flood for barrages' and '1 in 100-year return period flood for dams'. - Inspection immediately after an earthquake (or other natural calamities) or other natural calamities. - Inspection in case of any sign of Distress or any Unusual Behaviour if noticed in the dam body or any of its appurtenant structures for whatsoever reason.	4) These Inspection shall be carried out in accordance with the **Guidelines and Checklist** specified in the Regulations of DSA. Refer – ○ Page No. 10 of DSA ○ Page No. 25 & 26 of Regulation, Dt. 13.03.2024 ○ Page No. 61, 62, 72 to 107 of Regulation, Dt. 24.04.2024 ○ Page No. 3 of Regulation, Dt. 20.05.2024 After assessing the Safety Status as per Inspection carried out, the Dam would be given a Category, i.e., Category I/ II/ III and accordingly Actions (Repair/ Rehabilitation etc.) are prioritized.

- If a DSU is following the directions given in the above Table, then Option 1 may be responded.
- Option 2 is Self-Explanatory now. Where, "Implementation is Ongoing" may be understood as "Such program is being followed currently on irregular basis, however its Implementation is yet to be regularized".

Q2:

Frequency

- ○ Frequency and extent of application following Dam Safety Act and associated Regulations and appropriate CWC Guidelines.
- ○ There are some deviations from frequency and extent of application as required by Dam Safety Act and associated Regulations and appropriate CWC Guidelines.
- ○ Frequency and extent of application not following the Dam Safety Act and associated Regulations and appropriate CWC Guidelines.
- ○ Inspections are irregular or ad hoc.

- If frequency and extent of application for "Safety Inspections & their Reporting", are as required by DSA, associated Regulations and CWC Guidelines (i.e., if it is as per above Table), then Option 1 should be responded.
- Option 2, 3 & 4 are Self-Explanatory.
- Ad Hoc = Done suddenly/ without Proper Planning etc.

Q3:

Analysis

- ○ Analysis of results and reporting executed in timely manner.
- ○ Analysis of results and reporting sometimes delayed.
- ○ Significant delays in analysis and reporting.
- ○ Analysis of results not always done or large delays in analysis and reporting.

- For the Inspections being carried out during the year, does the DSU make timely "Analysis of the Inspection Report" and timely "Submission of Inspection Report"?
- All Options are Self-Explanatory.

Attachment: Document/ Supporting Evidence	**Comments**
Not Required	Write the Comment supporting your response (s).

SP-6: Dam Safety Reports

- These questions are discussing about Reports of Inspections, as already discussed in SP 5.

Q1:

Reporting

- ◯ Reports submitted periodically in accordance with Dam Safety Act and associated Regulations and appropriate CWC Guidelines.
- ◯ Reports submitted irregularly.
- ◯ Reports not submitted.

- It is Self-Explanatory.

Q2:

Adequacy of reports

- ◯ Complete safety assessment is included.
- ◯ Reports incomplete in terms of adequate safety characterization.
- ◯ Reports inadequate in termsd of safety characterization.

- It discusses about comprehensiveness/ detail in the filling of Inspection Report (i.e., for each applicable Inspection Item; Response, Observations & Recommendations, and Conditions, should be properly written).

S. No.	Inspection Item	Response[a]			Observations and recommendations, if any, of the authorized inspecting officer	Condition[b] (Unsatisfactory/Poor/Fair/ Satisfactory)
		Y	N	NA		
1.2.3	Problems of inadequate drainage (slippery stairs, water logging of gallery, clogged porous or foundation drains)?					
1.2.4	Evidence of differential settlement (displaced/offset/open joints)?					

- It also discusses about the Inspection Report's completion up to assigning the Safety Status, i.e., Category I/ II/ III.

*Category I– deficiencies in dams which, if left unattended, may lead to failure;

Category II – major deficiencies requiring prompt remedial measures;

Category III – none or minor deficiencies which are rectifiable

Q3:

Tracking of recommendations

- ◯ All recommendations are tracked.
- ◯ Not all recommendations are tracked.
- ◯ Report recommendations are not tracked.

- It discusses about tracking of remedial measures/ observations/ recommendations given by DSU.

S. No.	Inspection Item	Response[a]			Observations and recommendations, if any, of the authorized inspecting officer	Condition[b] (Unsatisfactory/Poor/Fair/ Satisfactory)
		Y	N	NA		
1.3.1	Evidence of differential settlement (displaced/offset/open joints)?					
1.3.2	Presence of cracking (structural, thermal, along joints)?					
1.3.3	Profuse growth of weeds/grass/plants at any location?					

Part 2c

Consolidated Dam Health Status Report (as per the current inspection):

S N	Observations/SignificantDeficiencies Noticed	Remedial Measures Suggested
1.		
2.		
3.		

Part 2b

Action taken on Remedial Measures suggested in the previous Inspection Report

Previous Inspection Report Date:

SN	Observations/ Significant Deficiencies Noticed	Remedial Measures Suggested	Action Taken After Last Inspection Report
1.			
2.			

(Refer: Page No. 72 to 107 of Regulation, Dated 24.04.2024)

Attachment: Document/ Supporting Evidence	**Comments**
Not Required	Write the Comment supporting your response (s).

SP-7: Follow-up Actions

Option 1 & 4:

◯ All actions taken as per Dam Safety Report and all critical deficiencies eliminated

◯ No corrective actions taken.

- Dam Safety Report = Report which identifies the Issues in Dam and suggested solutions = Report of Inspections done by DSU
- In case, any Special Inspection is done by an Experts' Panel (formed by Govt.), then Dam Safety Report also means "Report of Inspection done by such Panel".
- Both of these options are Self-Explanatory.

Option 2:

◯ The plan for timely elimination of all critical deficiencies has been developed but not implemented.

- It is Self-Explanatory.
- Responding it will open two further options.

◯ The corrective actions have been prioritized based on criticality and urgency of deficiencies.

◯ Prioritization based on criticality and urgency of addressed critical deficiencies not completed.

- These two questions point towards "Whether Prioritization of corrective actions is done or not?"

Option 3:

◯ The plan for elimination of only most critical deficiencies still under development.

- It is Self-Explanatory.
- Responding it will open two further questions.

◯ The corrective actions have been prioritized based on criticality and urgency of deficiencies.

◯ Prioritization based on criticality and urgency of addressed critical deficiencies not completed.

- These two questions point towards "Whether Prioritization of corrective actions is done or not?"

Attachment: Document/ Supporting Evidence	**Comments**
Not Required	Write the Comment supporting your response (s).

SP-8: River System Operation

Is the spillway ungated? (If 'No' go to gated spillways)

Select

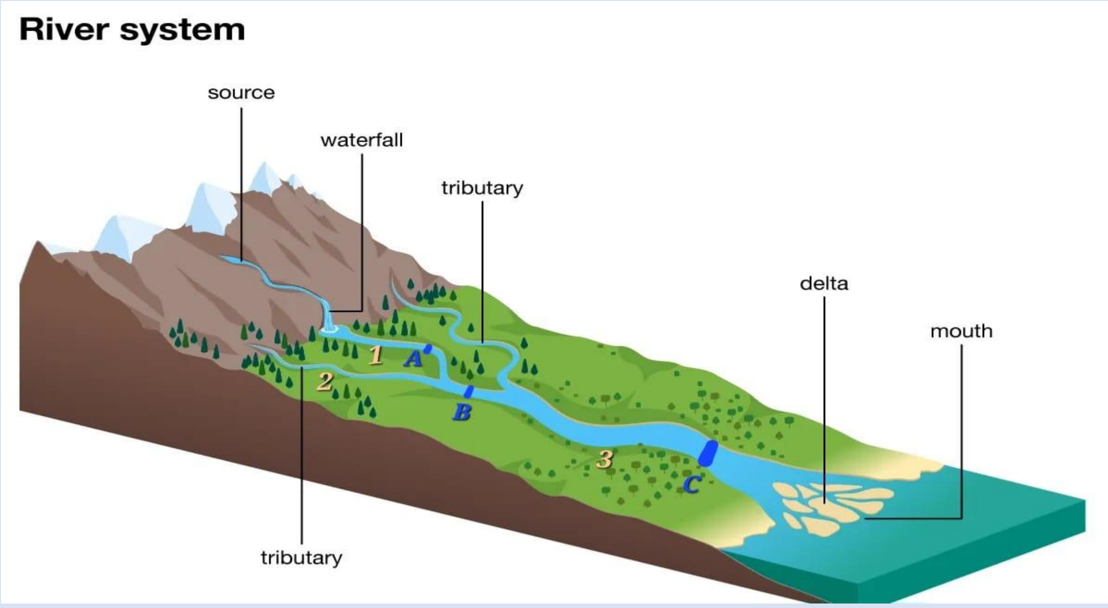
- If the Answer is "Yes", then it will open one more question.

Is the ungated spillway only the dam on the river system?

- Which means, that "In the concerned river system, there is only one dam, which is this Ungated Dam, Yes or No?"

River System:

- A river system is a network of natural water courses which consists of a main river and all of its tributaries.



- For our assessment, consider the upstream & downstream of the Stream (which may be a main river or a tributary) over which the concerned Specified Dam is located.

Examples:

1) For Dam 'A', consider –
   - The upstream region of the Stream '1' up to the Source.
   - The downstream region of the river system, i.e., Stretch 'A – B – C – Delta' (End of the river system).

2) For Dam 'B', consider –
   - The upstream region of the Stream '2' up to the Source.
   - The whole stretch of Stream '1'.
   - The downstream region of the river system, i.e., Stretch 'B – C – Delta'

3) For Dam 'C', consider –
   - The whole stretch of Stream '1'.
   - The whole stretch of Stream on LHS of Stream '1'.
   - The whole stretch of Stream '2'.
   - The whole stretch of Stream '3' upto 'Delta'.

Is the ungated spillway only the dam on the river system?

- Which means, that "In the concerned river system, there is only one dam, which is this Ungated Dam, Yes or No?"

  {Use Google Earth for exploring the river network. Further, Ignore the Check Dams}

- If the answer is "Yes", then assessment for SP-8 would be completed,
- If the answer is "No", then following questions will appear –

Section A

- ◯ Are meteorological and inflow forecasts are available.
- ◯ Only reliable inflow forecasts are available.
- ◯ Poor quality of forecasts.

It discusses about the 'Availability of Meteorological Forecasts (Rainfall) and Inflow Forecasts'.

- If at the Dam under consideration, Inflow Forecasts are available from the –
  1) Upstream dam, about their discharges,
  2) CWC (for Interstate Basins),
  3) Inflow Forecasting System Installed at Dam/ Catchment,

  Then, in such case, *Option 2* may be responded.

  If in addition to above, "Meteorological Forecasts from IMD, for Rainfall etc." are also available, then *Option 1* should be responded.

- Otherwise, Option *3* should be responded.

Section B

- ◯ Are good communications available with downstream Dam operators
- ◯ Comminications are not always relieable
- ◯ Poor commiunication with downstream downstream dam owners

- The options under Section B are Self-Explanatory.
- And assessment for Ungated Dam completes here.

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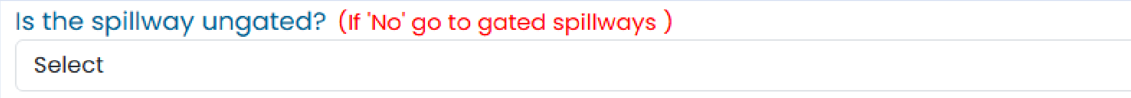
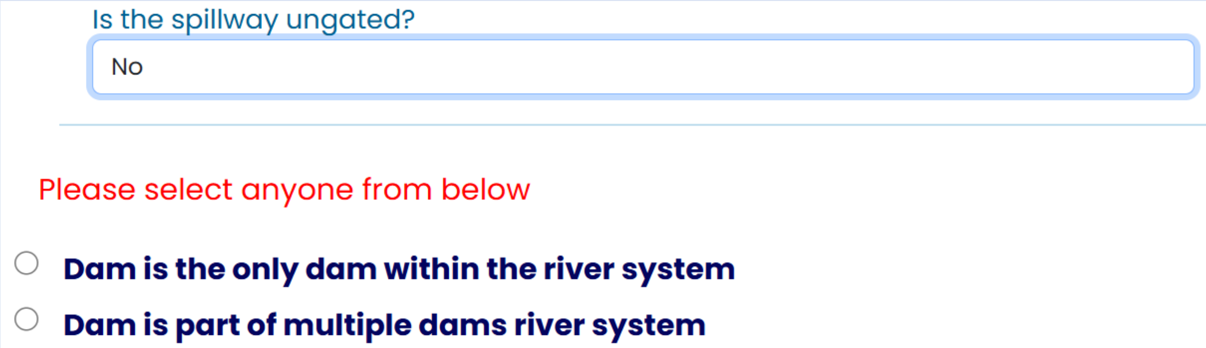
- If the Dam under consideration is not "Ungated" then, in such case follow the below mentioned steps:



Its answer will be "No", then it will open more questions.



- In the previous page we have learnt about what is to be considered in the River System related to the Specified Dam under consideration, by focusing on such concept & process; suitable options could be responded.
- If, Option 1 is chosen, then it will open some Self-Explanatory questions, which can be easily replied.
- Integrated Flood Management Plan (IFMP) = Realizing that the operation of one dam affects the other dams in entire river system, upstream and downstream, an IFMP has its importance (in a system of multiple dams on a river system).
- An IFMP requires a coordinated approach that considers the entire river basin/ river system and involves various stakeholders & Dam Authorities.
- Hence, If, Option 2 is chosen, then it will also open some questions, which are Self-Explanatory only & can be easily replied.

Attachment: Document/ Supporting Evidence	**Comments**
Not Required	Write the Comment supporting your response (s).

Potential Impacts

- Consequences/ Impacts of a dam failure can be catastrophic/ disastrous.
- The number of people residing downstream of the dam represents such potential (for disastrous consequences), called Population at Risk (PAR).
- The presence of a large city directly downstream of a dam increases the possibility of large number of casualties as opposed to a dam which has only a small number of residents downstream.
- Other impacts resulting from dam failure are (i) environmental impacts and (ii) socio-economic impacts.
- **Socio-Economic Impacts**: The suddenness and unmatched (beyond compare) intensity/ strength/ force (remember, Dam Break Floods are the severe most floods received in the region) of such catastrophic event does not fit the usual event pattern upon which most regional economic models are based.

  A failure of a large dam in a densely populated area can result in extensive harm to its socio-economic system and spreading an unusual disturbance throughout the entire system.

PI-1: Population at Risk (PAR)

This data shall not be entered at this stage!

- Once the correctly filled RRA Report is approved by NDSA, then this PAR value would be entered by NDSA Team itself.

Attachment: Document/ Supporting Evidence	**Comments**
Not Required	Not Required

PI-2: Environmental Impacts

- Morphological Processes in rivers (like - Erosion, Transportation and Deposition) are actions that create/ change the physical form of river channels and their surrounding landscapes. These processes are dynamic and interconnected.

  Such Morphological Processes are dominating factors in forming natural habitats for flora and fauna (plants and animals) in the river valley region.

  Sudden change (like - Intense Erosion or Deposition etc.) **resulting from dam failure may lead to loss of such habitats and biodiversity.**

  Other important impacts may include:
  - Loss of rare, protected or endangered species.
  - Destruction of Forest & Terrestrial/ Land Ecology.
  - Destruction of Aquatic Ecology.
  - Changes in the configuration/ shape of streams or the floodplain (Morphological changes)
  - And many other environmental impacts.

- "Protected Species" refers to "populations of animals or plants" that are given special legal protection to prevent them from becoming extinct.

- "Protected Area" means a National Park, Wildlife Sanctuary, Biosphere Reserve, Conservation Reserve, Reserved and Protected Forests, Eco-Sensitive Areas.

- The full list of Endangered Species protected by the Wildlife Act (WPA, 1972) can be referred to in Schedule I (Page No. 65 onwards) of the Act.

- For responding to the questions under PI-2, please refer to Inundation Maps *(Such Maps may have been created during Design Phase or at later stage by conducting Dam Break Analysis etc.)*, and focus on the 'Regions under Inundation or Area inside the Periphery of Inundation Maps'.

In this example, "Regions under Inundation" are shown in shades of Blue & Light Blue.

- For the Specified Dams, where Inundation Maps are not available, in such cases, at minimum, "List of Villages/ Towns likely to be affected by Floods in XYZ River on the basis of Gauge of ABC Dam's Spillway/ Waste Weir" shall be referred to.

  Such a List would be available with the Dam Authority, and for a few Dams, it is also included in Disaster Management Plan (Flood Warning Arrangements), *(published by Flood Control Cell of Water Resources Department, GoG on a yearly basis)* and its Chapter No. 6 to 19 may be referred to. *(Downloading Link: Reservoir Data Management System - National Informetics Center)*

ANNEXURE - 8 (A-3)

List of villages likely to be affected by floods in **Sukhi River** on the basis of **Sukhi Dam Spillway**

CHHOTAUDEPUR DISTRICT

Sr. No.	PAVI JETPUR (JABUGAM) TALUKA	Sr. No.	PAVI JETPUR (JABUGAM) TALUKA
1.	Moti bej	12.	Sithol
2.	Amadra	13.	Dungarwant
3.	Waghwa	14.	Khandia
4.	Kikawada	15.	Koliyari
5.	Hood	16.	Lodhan
6.	Vadesia	17.	Gambhirpura
7.	Moti Rasli	18.	Gutanvad
8.	Ghutia	19.	Palia
9.	Nani bej	20.	Sajod
10.	Thalki	21.	Sihod
11.	Nani Rasli		

For example, "List of Vulnerable Villages in respect of Sukhi Dam" are included in Chapter 8 of DMP (FWA).

- After Identifying the 'Region likely to be under Inundation/ Flooding' or 'Number of Villages likely to affected by Floods in respect of particular Specified Dam', focus should be made on such likely inundated region or likely affected villages only, and accordingly Staff at Dam Site having knowledge of downstream region/ villages (Ex. Working/ Retired Rojamdars or Work Charge Staff etc.) and concerned Taluka's RFO (Range Forest Officer) or other knowledgeable Forest Officials may be consulted, so that Q1 & Q2 of PI-2 could be responded in more accurate manner.

Q1:

Protected Species

- ○ No presence of rare, protected or endangered species protected under the WPA
- ○ Only sporadic and limited presence of rare, protected or endangered species protected under the WPA and there are no protected areas.
- ○ If rare, protected or endangered species protected under the WPA are present the numbers are not more than 10 species or 100 individuals.
- ○ If rare, protected or endangered species protected under the WPA are present the numbers are not more than 50 species or 500 individuals.
- ○ Extensive (more than 50 species or more than 500 individuals) presence of rare, protected or endangered species protected under the WPA.

- Sporadic = Occurring in scattered places/ Occurring at Irregular Interval.
- All Options are Self - Explanatory.
- Take Help of concerned Taluka's RFO Office/ District's Forest Office.

Q2:

Protected Area

- ○ There are no protected areas (national park, wildlife sanctuary, biosphere reserve, conservation reserve, reserved and protected forests, eco-sensitive area of any size).
- ○ Only a single protected area (national park, wildlife sanctuary, biosphere reserve, conservation reserve, reserved and protected forests, eco-sensitive area smaller than 10 km2).
- ○ Presence of a single protected area (national park, wildlife sanctuary, biosphere reserve, conservation reserve, reserved and protected forests, eco-sensitive area larger than 10 km2.
- ○ If protected areas (national park, wildlife sanctuary, biosphere reserve, conservation reserve, reserved and protected forests, eco-sensitive area) are present the numbers are not more than 2 areas, each less than 20 km2 or less than 40 km2, if only one present.
- ○ Presence of 3 or more protected areas (national park, wildlife sanctuary, biosphere reserve, conservation reserve, reserved and protected forests, eco-sensitive area) each larger than 20 km2 or larger than 50 km2, if only one present.

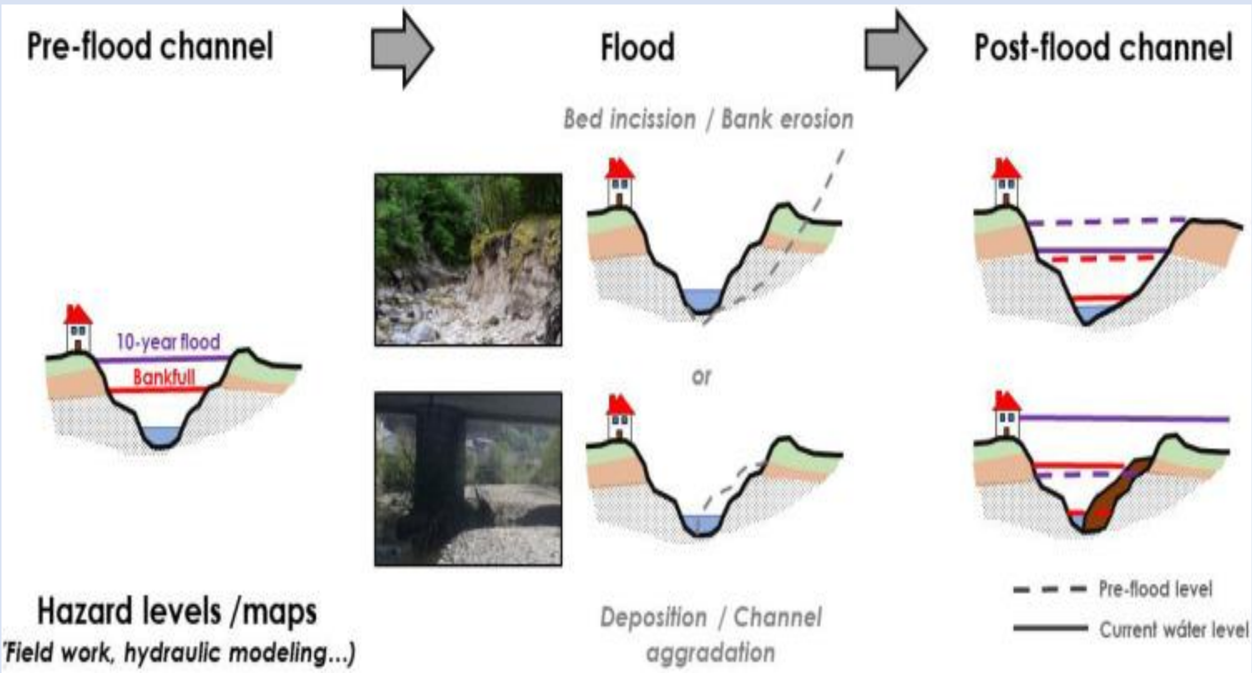
- All Options are Self - Explanatory.
- Take Help of concerned Taluka's RFO Office/ District's Forest Office.

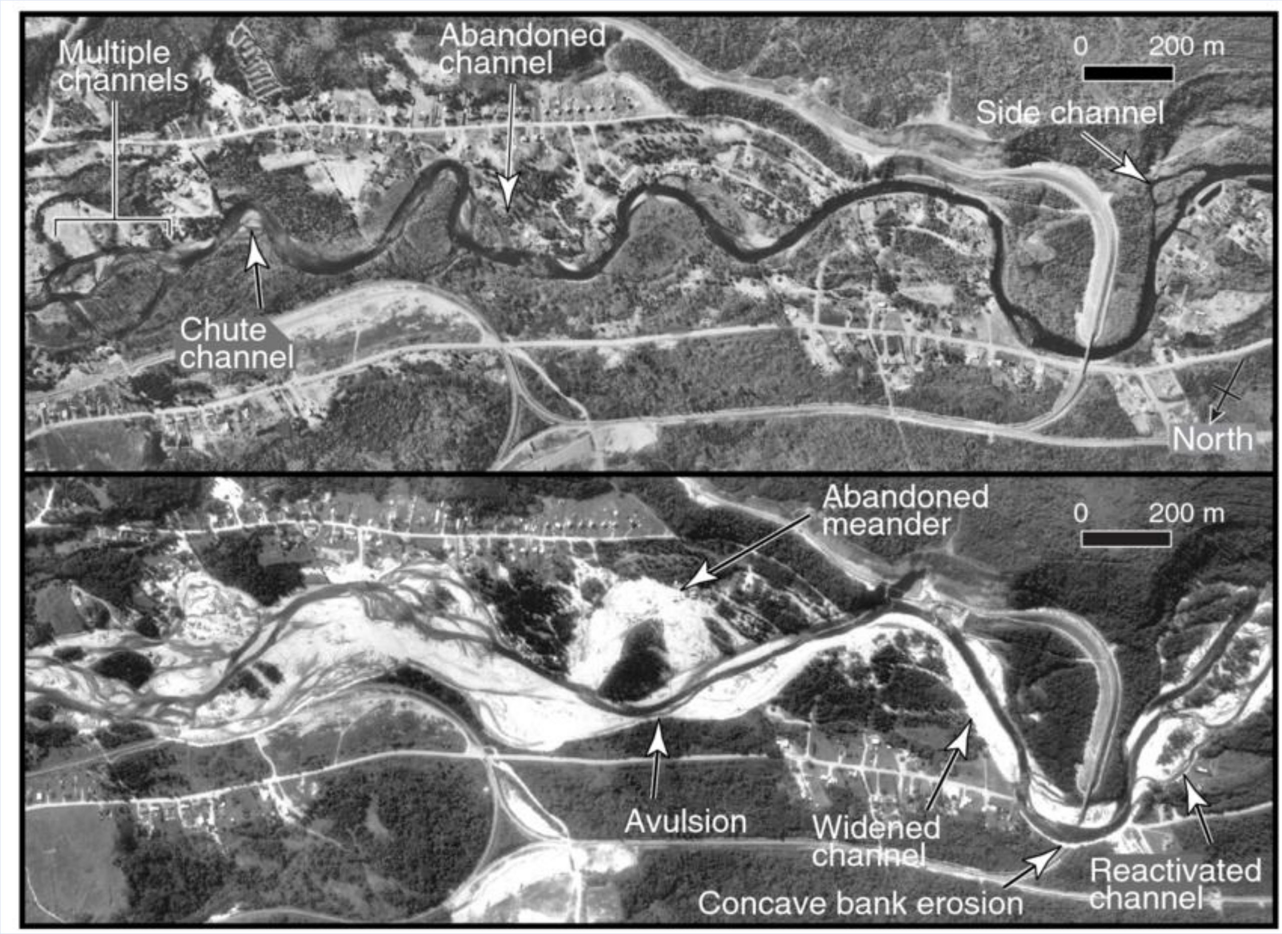
Q3:

Morphological Changes

- ○ Negligible morphological changes along the river channel, the valley and the inundated area.
- ○ Minor morphological changes along the river channel, the valley and the inundated area.
- ○ Morphological changes significant but not extensive ? limited to some flow regime alteration, localized erosion and loss of topsoil.
- ○ Extensive morphological changes ? new river channel and/or some landscape fragmentation.
- ○ Catastrophic morphological changes ? extensive re-arrangement of river channel and hydraulic conditions, extensive landscape fragmentation.

- Morphological Changes = Likely changes/ reshaping in the physical form of river channels and their surroundings, caused by Erosion/ Transportation/ Deposition, due to Discharge of Flood Water on account of Dam failure.
- Focus on the River Channel downstream of the concerned Specified Dam.
- Alluvial rivers, flowing over loose sediment, generally exhibit higher intensity of morphological changes compared to rocky rivers, which are restrained by bedrock.
- Based on likely Intensity of such Morphological Changes due to Dam Break Flood, respond the suitable Option.





Pre-Flood (above) and Post-Flood (below) aerial photographs of a River, after getting subjected to severe/ intense flooding event. Several Morphological Changes could be observed here.

- Further, for the Specified Dam where DBA (Dam Break Analysis) is not done, in such case, focus on the Height of the Dam and following table may be referred –

Height (H)	*Respond to Option No. __ of Q3*
H ∈ [10 m to 15 m)	1
H ∈ [15 m to 30 m)	2
H ∈ [30 m to 60 m)	3
H ∈ [60 m to 100 m)	4
H ∈ [100 m to above)	5

Q4:

Loss of Fish or Wildlife Habitat

- ○ No or minimal loss of fish and/or wildlife habitat with high capability of natural restoration resulting in a very low likelihood of negatively affecting the status of the population.
- ○ Moderate loss of fish and/or wildlife habitat with high capability of natural restoration resulting in a low likelihood of negatively affecting the status of the population.
- ○ Significant loss of fish and/or wildlife habitat but with moderate capability of natural restoration resulting in a moderate likelihood of negatively affecting the status of the population.
- ○ Significant loss of fish and/or wildlife habitat with low capability of natural restoration resulting in a high likelihood of negatively affecting the status of the population.
- ○ Little or no possibility of restoration.

- Here, Population = Population of Fish/ Wildlife.
- Focus on the <u>likely inundated region or likely affected villages</u> (as done for responding Q1 & Q2) and Take Help of concerned Taluka's RFO Office/ District's Forest Office, to identify the existing wildlife habitats in such area.
- If it is identified that wildlife habitats/ fish habitats are present in such area, then by focusing on the likely intensity of Morphological Changes (as responded in Q3), suitable option could be replied.

Attachment: Document/ Supporting Evidence	**Comments**
Attach supportive documents (For Example, if a letter has been written from Dam Authority to Forest Office, regarding enquiring about information needed for replying Q1, Q2 & Q4; like Protected Forest Areas, Protected Species' (etc.) presence in the likely inundated region or likely affected villages, then reply made by Forest Office Letter, may be attached here.)	Attach supportive comments to the responses made.

PI-3: Socio-Economic Impacts

Q1:

Concentration of residential developments, industrial, commercial or agricultural activities

- ○ No or very few small residential developments and only small scale industrial, commercial or agricultural activities.
- ○ No or very small residential developments and only medium scale industrial, commercial or agricultural activities.
- ○ Medium to large concentration of residential developments and industrial, commercial or agricultural activities.
- ○ Very large concentration of residential developments and, industrial, commercial or agricultural activities.
- ○ Major municipal areas with extensive industrial, commercial activities and very large agricultural areas.

- Focus on the likely inundated region or likely affected villages/ towns (as done for responding PI-2) and by observing such area, suitable option could be easily replied.
- For exploring the likely affected downstream area, help of Google Earth/ Google Maps may also be taken as per requirement, for all the questions of PI-3.
- Ex. Search in Google Maps about "Power Plants near XYZ Dam" and then view the location of such facilities in Google Maps, in sync with likely affected downstream area.

Q2:

Infrastructure and Navigation

- ○ Infrastructure and navigational services do not exist in the affected area.
- ○ Only minor infrastructure and navigational services in the affected area.
- ○ Some infrastructure in the affected area (local roads and railways, small and medium size power plants, water treatment and waste treatment plants, local power system installations).
- ○ Important infrastructure in the affected area (state highways, major railways, large water treatment and waste treatment plants, local airports,regional power system installations).
- ○ Major national and inter-state highways and major railways, multiple large water treatment and waste treatment plants, large power plants, international and national airports) , navigational services in the affected area.

- Focus on the likely inundated region or likely affected villages and by observing such area, suitable option could be easily replied.
- Here, **Infrastructure Services** = Power System Installations, Power Plants Water Treatment Plants, Waste Treatment Plants
- And **Navigational Services** = Local Roads, State Highways, National Highways, Expressways, Local Railways, Major Railways, Airports (Regional, National and International) etc.

Q3:

Ports

- ○ No ports or any other navigational services
- ○ Port and navigational services unaffected.
- ○ Short-lasting interruptions in ports and navigational services.
- ○ Long-lasting interruptions in ports and navigational services.
- ○ Long-lasting interruptions in ports and navigational services.

- Focus on the likely inundated region or likely affected villages and by observing such area, suitable option could be easily replied.

Q4:

Schools, hospitals and other public facilities

- ◯ No chools, hospitals or other public facilities.
- ◯ Only few small schools, hospitals and other public facilities.
- ◯ Several schools, hospitals and other public facilities.
- ◯ Several large schools, hospitals and other public facilities.
- ◯ Multiple large schools, hospitals and other public facilities.

- Focus on the <u>likely inundated region or likely affected villages</u> and by observing such area, suitable option could be easily replied.

Q5:

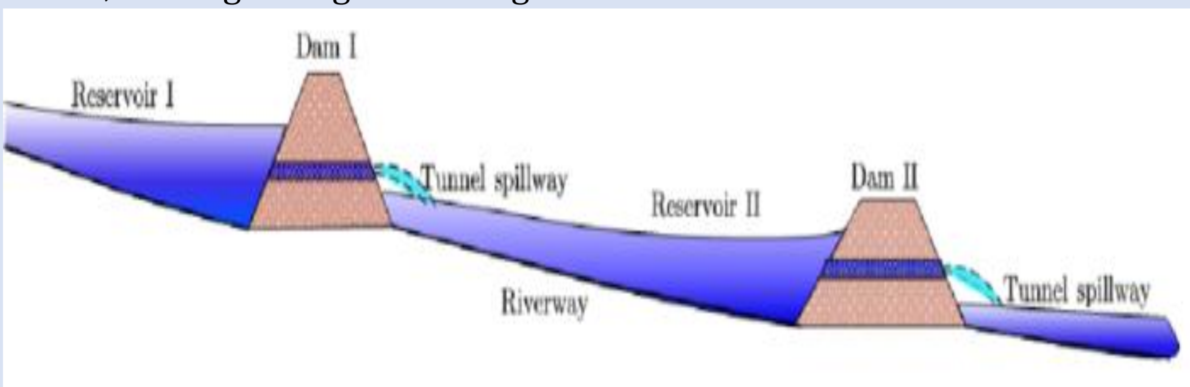
Downstream Dams

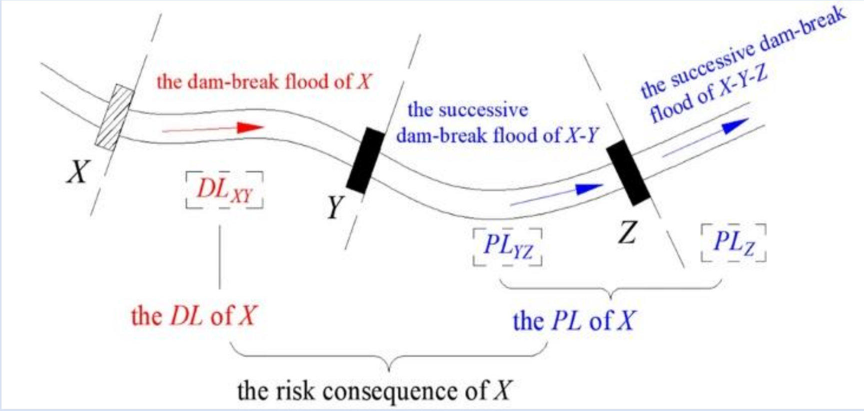
- ◯ No dams downstream.
- ◯ Potential for failure of single small downstream dam.
- ◯ Potential for failure of medium downstream dam.
- ◯ Potential for cascading failure of small and medium size dams downstream.
- ◯ Potential for cascading failure involving large downstream dam.

- Focus on the <u>likely inundated region or likely affected villages</u> and by observing such area & observing the location of Dams *(ignore Check Dams)* in such downstream area, suitable option could be easily replied.

- **Cascading Failure of Dams** = A cascading (one after one) failure of dams occurs when the failure of one dam leads to the subsequent failure of one or more downstream dams.

  This domino effect can happen due to the increased water flow from the initial breach overpowering the structural integrity of the next dam in the sequence. The consequences can be far more severe than a single dam failure, causing enlarged flooding and destruction downstream.





Q6:

Nuclear facilities

- ◯ No power plants or nuclear facilities downstream.
- ◯ Nuclear power plant or other nuclear facility downstream.

- Focus on the <u>likely inundated region or likely affected villages/ towns</u> and by observing such downstream area, suitable option could be easily replied.
- Only Nuclear Power Plants & Nuclear based facilities are being discussed here.

Q7:

Critical industry downstream

- ◯ No Industry of critical national importance downstream.
- ◯ Industry of critical national importance downstream.

- Focus on the <u>likely inundated region or likely affected villages</u> and by observing such downstream area, suitable option could be easily replied.

Attachment: Document/ Supporting Evidence	**Comments**
Attach supportive documents	Attach supportive comments to the responses made.