SPILLWAYS

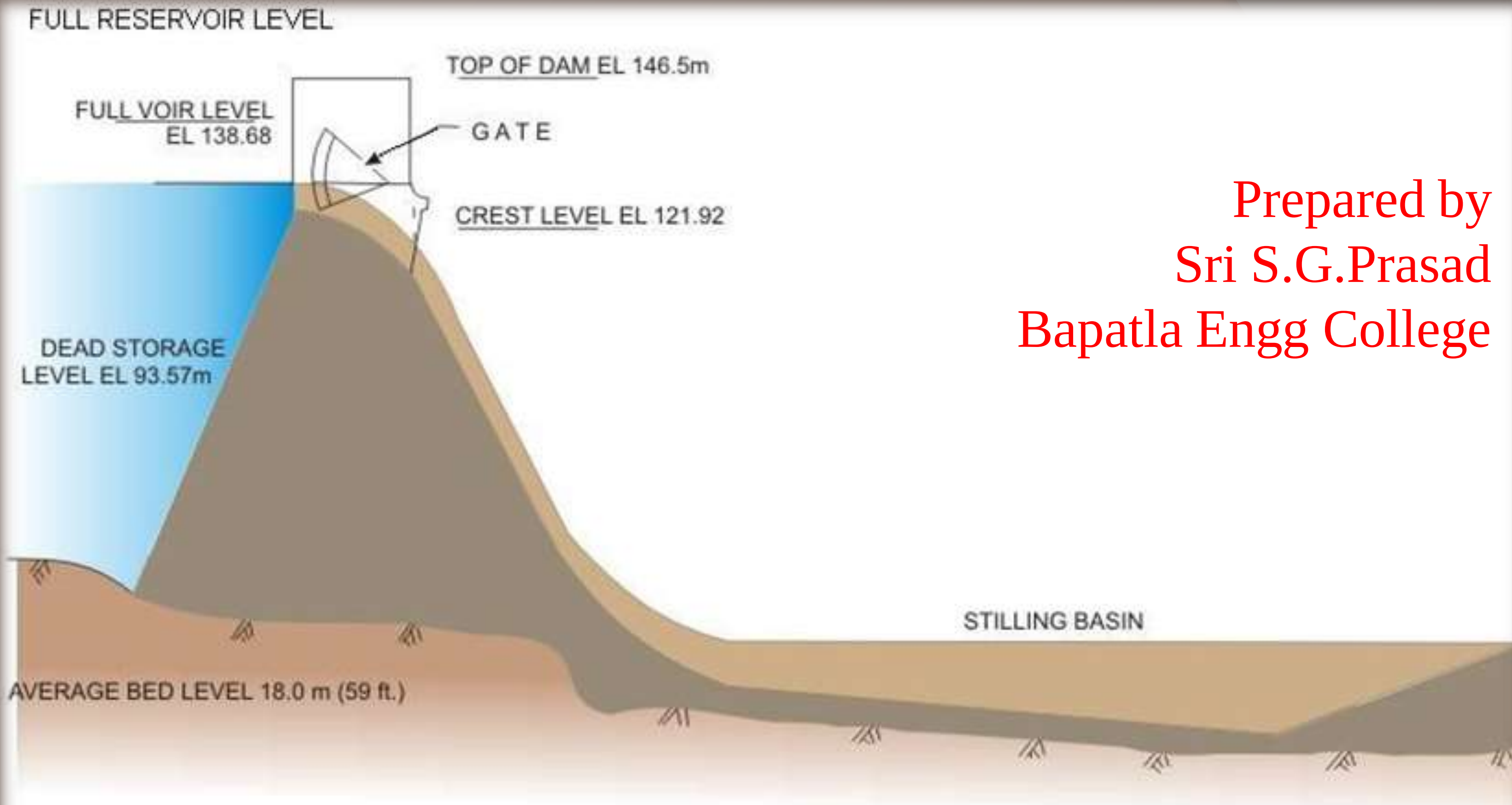

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FIGURE 7. Ogee spillway & apron of Sardar Sarovar Dam spillway

INTRODUCTION:

- The previous lessons dealt with storage reservoirs built by impounding a river with a dam.
- However, in rare cases only it is economical or practical for the reservoir to store the entire volume of the design flood within the reservoir without overtopping of dam.
- Hence, a dam may be constructed to that height which is permissible within the given topography of the location or limited by the expenditure that may be possible for investment.

- The excess flood water, therefore, has to be removed from the reservoir before it overtops the dam.
- Passages constructed either within a dam or in the periphery of the reservoir to safely pass this excess of the river during flood flows are called Spillways.
- These are very important structures; many failures of the dams have been caused by improperly design of Spillways or Spillways of insufficient capacity.

- Ordinarily, the excess water is drawn from the top of the reservoir created by the dam and conveyed through an artificially created waterway back to the river.
- The spillway must be hydraulically adequate and structurally safe and must be located in such a way that the out-falling discharges back into the river do not erode or undermine the downstream toe of the dam.
- The surface of the spillway should also be such that it is able to withstand erosion or scouring due to the very high velocities generated during the passage of a flood through the spillway.

- The flood water discharging from the spillway from a higher elevation at the reservoir surface level to a lower elevation at the natural river level on the downstream through a passage, which is also considered a part of the spillway.

- At the bottom of the channel, where the water rushes out to meet the natural river, is usually provided with an energy dissipation device that kills most of the energy of the flowing water.

- These devices, commonly called as Energy Dissipaters, are required to prevent the river surface from getting dangerously scoured by the impact of the out falling water.

Types of Spillways:

- Based on the utility , Spillways can be of two types:
  - Main Spillway
  - Subsidiary or emergency spillway

- The main spillway, also known as the service spillway is the one which is generally put into operation in passing most of the design flood.

- The crest levels of the auxiliary spillways are usually higher and thus the discharge capacities are also small and are put into operation when the discharge in the river is higher than the capacity of the main spillway.

Emergency Spillway :

- Sometimes, an Emergency or Fuse Plug types of spillway is provided in the periphery of the reservoir.
- which operates only when there is very high flood in the river higher than the design discharge or during the malfunctioning of normal spillways due to which there is a danger of the dam getting overtopped.
- These are constructed of low height earth embankments which, when overtopped during heavy floods , get washed away leaving the main dam safe.

- The capacity of a spillway is usually worked out on the basis of a flood routing study. As such, the capacity of a spillway is seen to depend upon the following major factors:

  - The inflow flood
  - The volume of storage provided by the reservoir
  - Crest height of the spillway
  - Gated or ungated

- According to IS: 11223-1985 “Guidelines for fixing spillway capacity”, the following values of inflow design floods (IDF) should be taken for the design of spillway:

  - For large dams those with gross storage capacity greater than 60 million m^3 or hydraulic head between (2m and 30m).

  - For intermediate dams those with gross storage between 10 and 60 million m^3 or hydraulic head between (2m and 30m).

  - For small dams (gross storage between 0.5 to 10 million m^3 or hydraulic head between 7.5m to 12m), IDF may be taken as the 100 year return period flood.

- Apart from spillways, which safely discharge the excess flood flows, outlets are provided in the body of the dam to provide water for various demands, like irrigation, power generation, etc.

- Spillway flows will result during floods or periods of sustained high runoff when the capacities of other facilities are exceeded.

- Where large reservoir storage is provided, or where large outlet or diversion capacity is available, the spillway will be utilized in frequently.

- Spillways are ordinarily classified according to their most prominent feature, either as it pertains to the control, to the discharge channel, or to some other component. The common types of spillway in use are the following:

1. Free Overfall (Straight Drop) Spillway
2. Overflow (Ogee) Spillway
3. Chute (Open Channel/Trough) Spillway
4. Side Channel Spillway
5. Shaft (Drop Inlet/Morning Glory) spillway
6. Tunnel (Conduit) spillway
7. Siphon spillway

1.Straight Drop Spillway:

- This is the simplest type of spillway which is constructed in the form of a low height weir having d/s face either vertical or nearly vertical.

- Water drops freely from the crest , and the undesirable of the falling nappe is ventilated sufficiently to prevent a pulsating , fluctuating , jet.

- This is constructed on sound rock. However the falling jet will form a deep plunge pool. A low secondary dam may be constructed to create an artificial pool , or a concrete apron may be provided.

- This is not recommended for high head because the vibrations caused by the falling jet might crack or displace the structure.

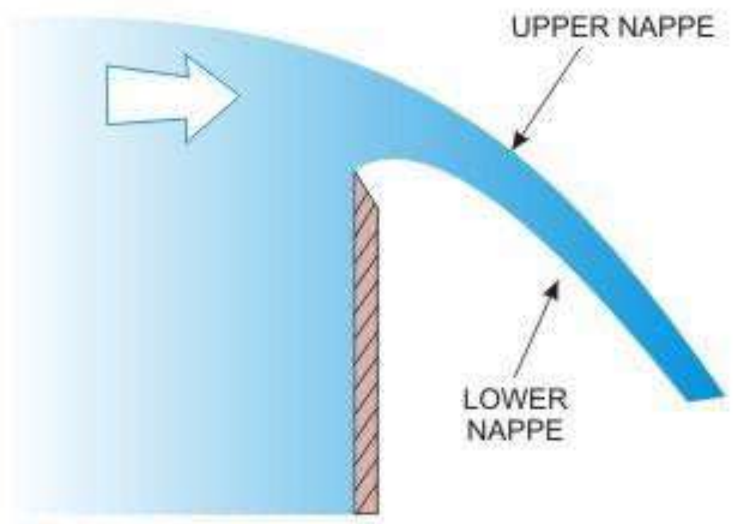
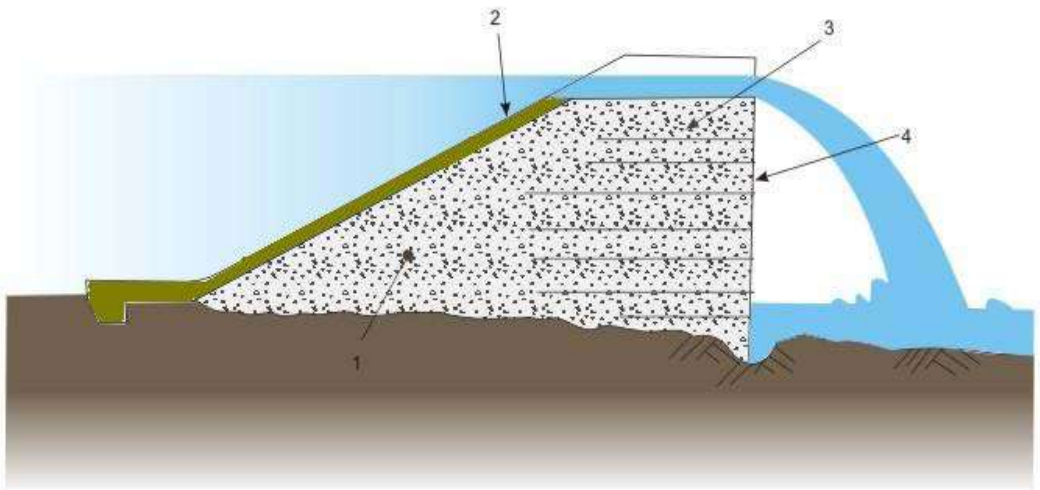


FIGURE 6. Outflow from a free-falling weir , properly ventilated from below

- Occasionally, the crest is extended in the form of an overhanging lip to direct small discharges away from the face of the over fall section. The free falling water is ventilated sufficiently to prevent a pulsating, fluctuating jet.



LEGEND

1. RANDOM FILL 2. WATERTIGHT MEMBRANE 3. STEEL TENDONS 4. CONCRETE SLABS (1.5 M X 1.5 M).

FIGURE 2. Free over fall spillway for a decked embankment dam

2. OGEE (or) OVERFLOW SPILLWAY:

- The overflow type spillway has a crest shaped in the form of an ogee or S-shape .
- The upper curve of the ogee is made to conform closely to the profile of the lower nappe of a ventilated sheet of water falling from a sharp crested weir.
- Flow over the crest of an overflow spillway is made to adhere to the face of the profile by preventing access of air to the underside of the sheet of flowing water.
- Naturally, the shape of the overflow spillway is designed according to the shape of the lower nappe of a free flowing weir conveying the discharge flood.

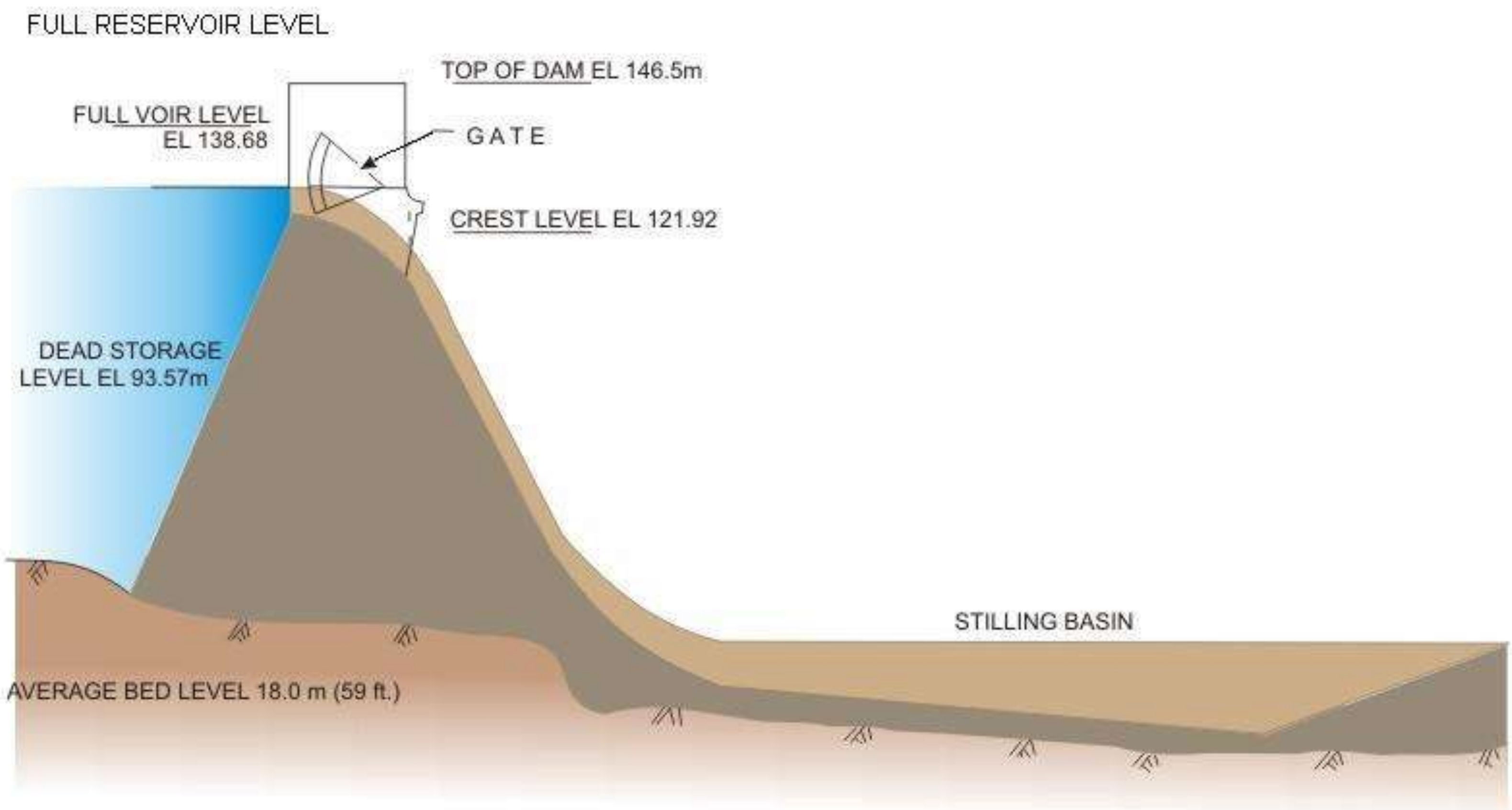


FIGURE 7. Ogee spillway & apron of Sardar Sarovar Dam spillway

- Hence, any discharge higher than the design flood passing through the overflow spillway would try to shoot forward and get detached from the spillway surface.

- which reduces the efficiency of the spillway due to the presence of negative pressure between the sheet of water and spillway surface.

- For discharges at designed head, the spillway attains near-maximum efficiency. The profile of the spillway surface is continued in a tangent along a slope to support the sheet of flow on the face of the overflow.

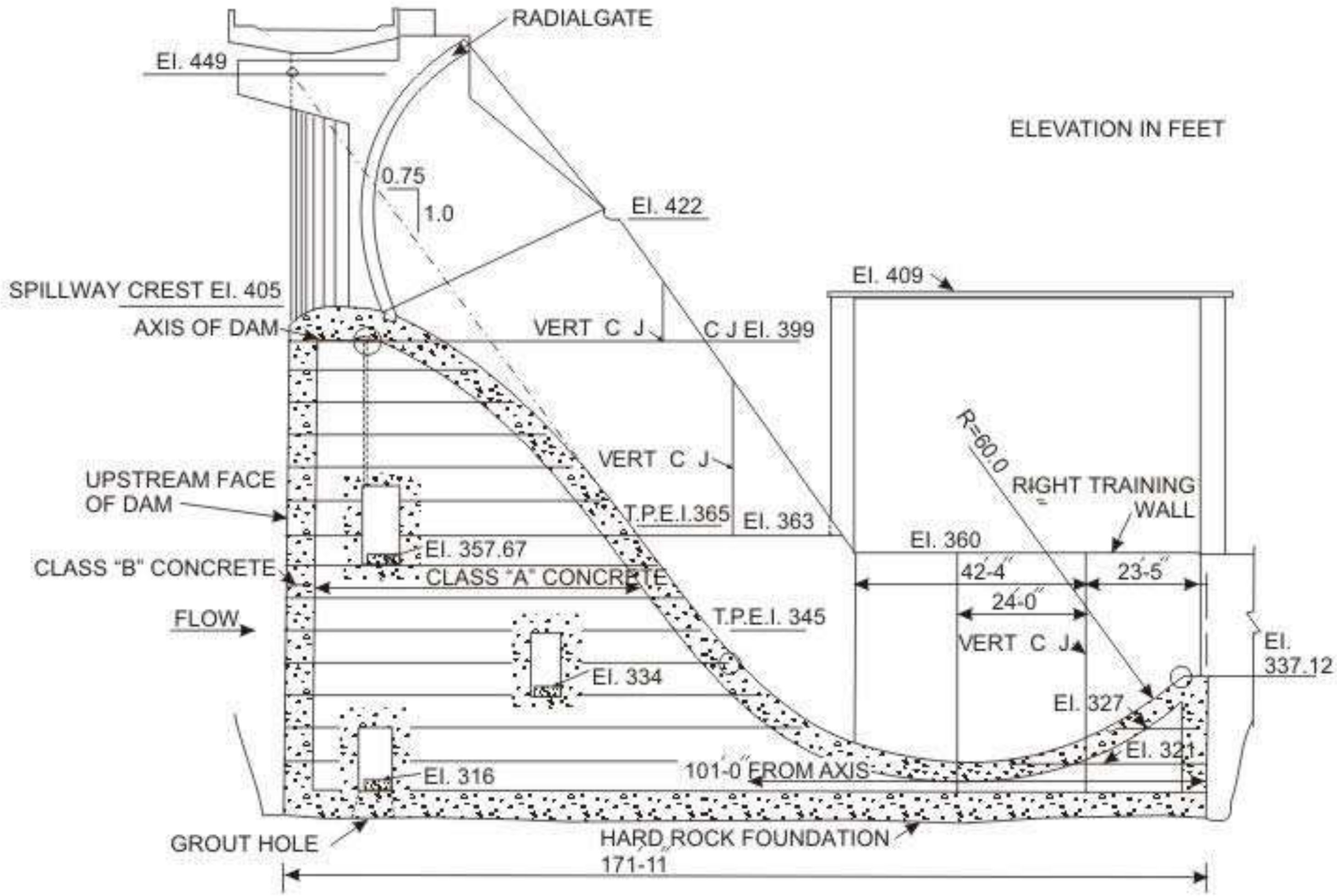


FIGURE 5. Typical overflow (ogee) spillway .Example of Panchet Dam on River Damodar

- A reverse curve at the bottom of the slope turns the flow in to the apron of a sliding basis or in to the spillway discharge channel.

- An ogee crest apron may comprise an entire spillway such as the overflow of a concrete gravity dam (or) the ogee crest may only be the control structure for some other type of spillway.

3.Chute Spillway :

- A chute spillway, variously called as open channel or trough spillway, is one whose discharge is conveyed from the reservoir to the downstream river level through an open channel.
- It was placed either along a dam abutment or through a saddle. The control structure for the chute spillway need not necessarily be an overflow crest, and may be of the side-channel type.
- Generally, the chute spillway has been mostly used in conjunction with embankment dams, like the Tehri dam.

- Chute spillways are simple to design and construct and have been constructed successfully on all types of foundation materials, ranging from solid rock to soft clay.
- Chute spillways ordinarily consist of an entrance channel, a control structure, a discharge channel, a terminal structure, and an outlet channel.
- Often, the axis of the entrance channel or that of the discharge channel must be curved to fit the topography. For further details, one may refer to the Bureau of Indian Standards Code IS: 5186-1994 “Design of chute and side channel spillways-criteria”.

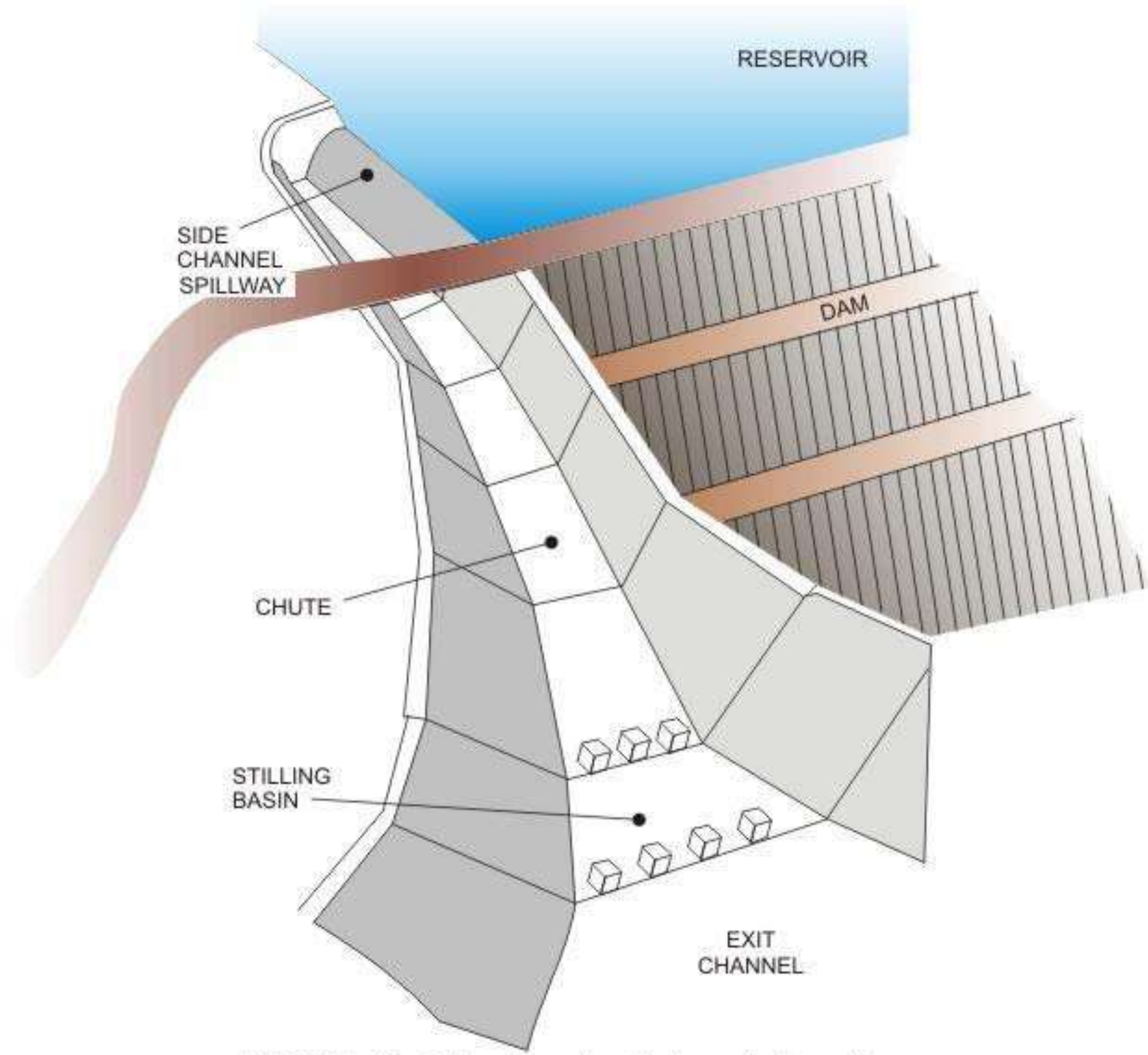


FIGURE 10. Side channel entry to a chute spillway

4. Side channel Spillway :

- A side channel spillway is one in which the control weir is placed approximately parallel to the upper portion of the discharge channel.
- The flow over the crest falls into a narrow trough opposite to the weir, turns an approximate right angle, and then continues into the main discharge channel.
- The side channel design is concerned only with the hydraulic action in the upstream reach of the discharge channel .
- Flow from the side channel can be directed into an open discharge channel or in to a closed conduit which may run under pressure or inclined tunnel.

- Flow into the side channel might enter on only one side of the trough in the case of a steep hill side location or on both sides and over the end of the trough if it is located on a knoll or gently sloping abutment.

- Discharge characteristics of a side channel spillway are similar to those of an ordinary overflow spillway and are dependent on the selected profile of the weir crest.

- Although the side channel is not hydraulically efficient, nor inexpensive, it has advantages which make it adoptable to spillways where a long overflow crest is required in order to limit the afflux (surcharge held to cause flow) and the abutments are steep and precipitous.

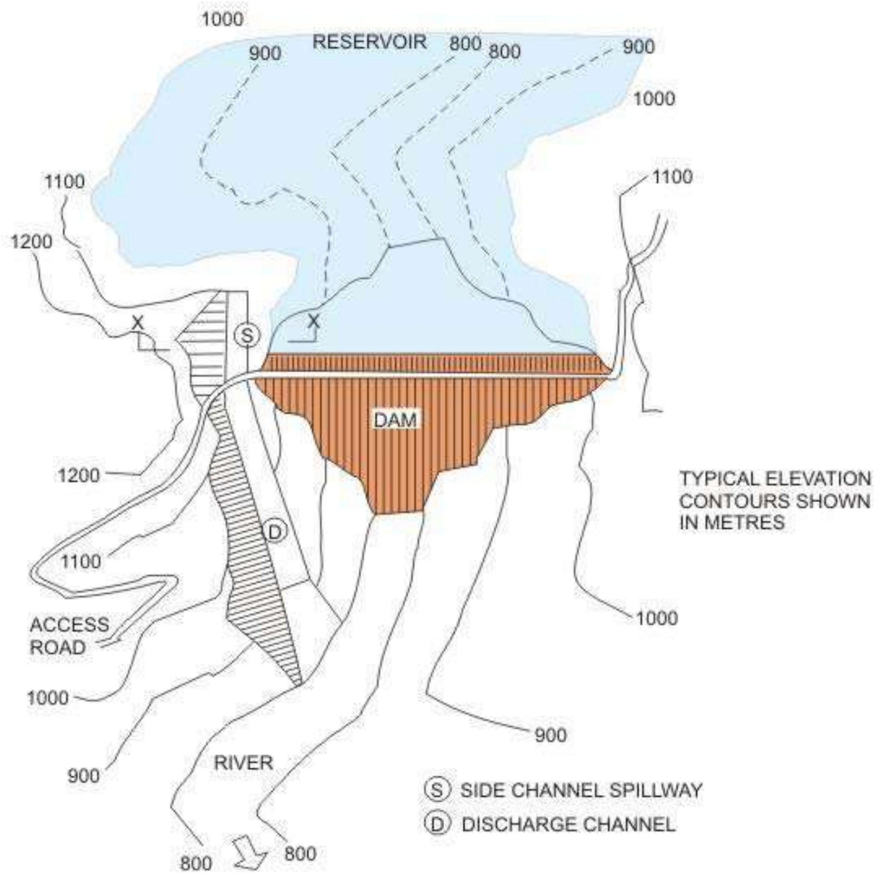


FIGURE 11. Plan of an embankment dam showing side channel spillway and chute channel

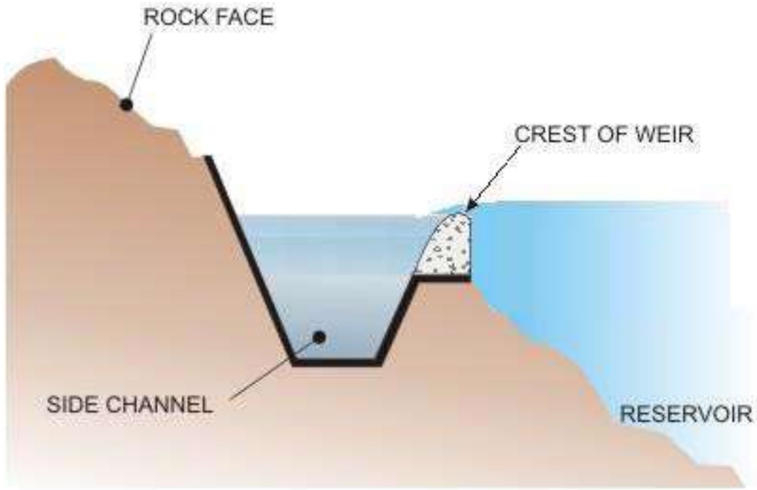


FIGURE 12. Magnified sectional view X-X through the side channel spillway shown in Figure 11

5.Shaft Spillway :

- A Shaft Spillway is one where water enters over a horizontally positioned lip, drops through a vertical or sloping shaft, and then flows to the downstream river channel through a horizontal conduit or tunnel .

- The structure may be considered as being made up of three elements, namely, an overflow control weir, a vertical transition, and a closed discharge channel.

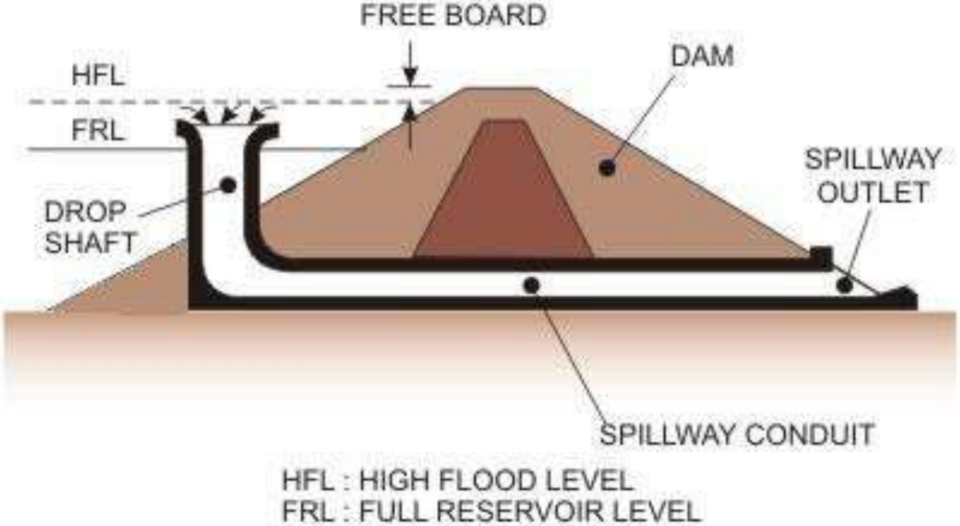


FIGURE 13. Section through a shaft spillway

- When the inlet is funnel shaped, the structure is called a Morning Glory Spillway. In which anti-vortex piers are fitted .

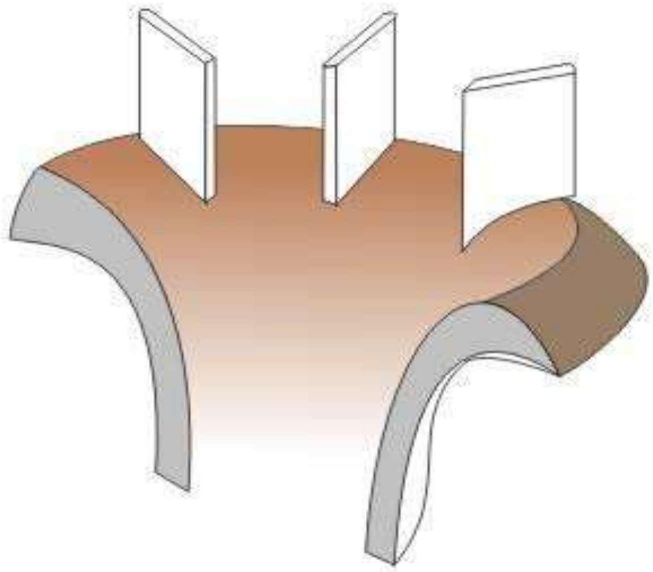


FIGURE 14. Morning glory spillway with anti-vortex piers

- These piers or guide vanes are often necessary to minimize vortex action in the reservoir, if air is admitted to the shaft or bend it may cause troubles of explosive violence in the discharge tunnel-unless it is amply designed for free flow.
- A shaft spillway can often be used where there is inadequate space for other types of spillways.
- It is generally not desirable to use a spillway over or through an Earth dam.

- If there is no enough space or if the topography prevents the use of a Chute or Side channel Spillway the best alternative is Shaft spillway.

- Small shaft Spillway may be constructed entirely of metal or concrete pipe .

- The vertical shaft of large structures is usually made up of Reinforced cement concrete and the horizontal conduit is tunneled in rock.

6.Tunnel Spillway:

- Conduit (or) Tunnel Spillway is the one in which a closed channel is used to convey the discharge around (or) under a dam.

- The closed channel may be in the form of a vertical or inclined shaft , a horizontal tunnel through earth dam or a conduit constructed with open cut and backfilled with earth materials.

- These spillways are designed to flow partly full.

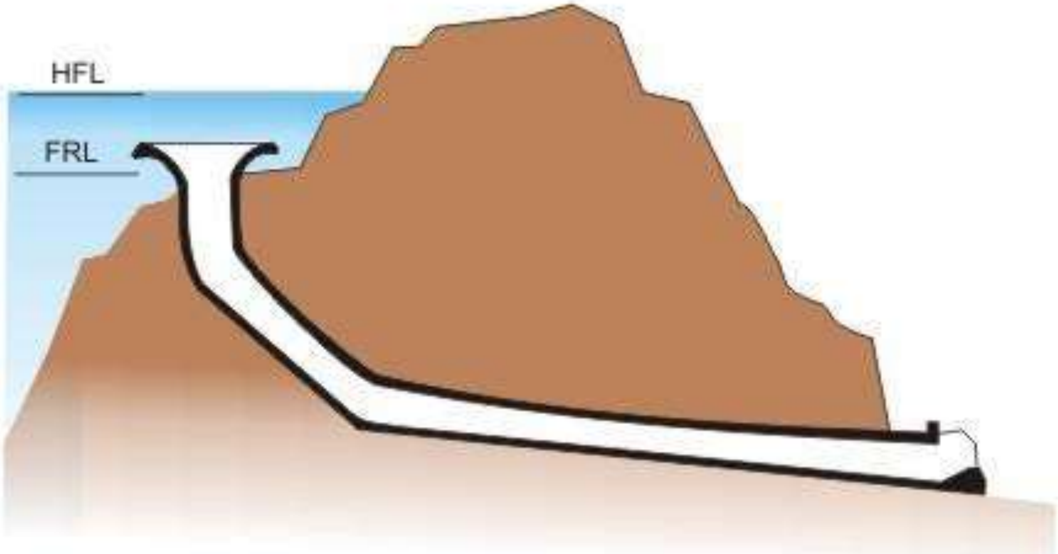


Figure 15. Tunnel spillway with a morning glory entrance.

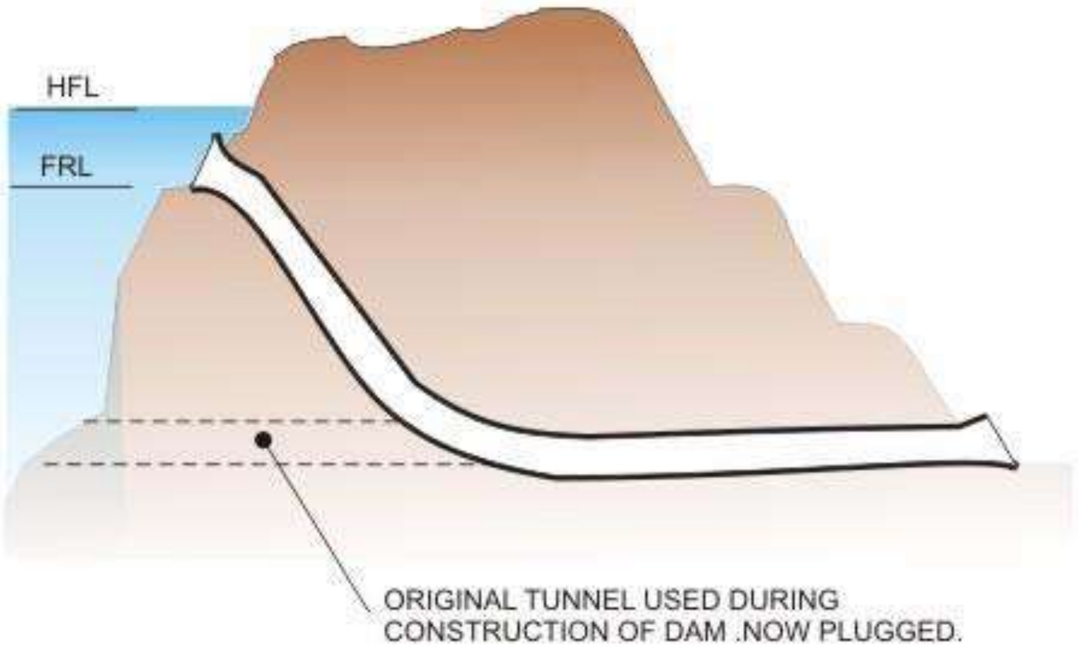


FIGURE 16. Bell mouth entry to a tunnel spillway (Gate control at entrance not shown)

- Full flow is not allowed in the tunnel or conduit, otherwise the syphonic action may develop and the negative pressures may be created in the conduit.
- To ensure free flow in the tunnel , the ratio of flow area to total tunnel area is often limited to 75%.
- Air vents are provided at critical points along the tunnel or conduit to adequate air supply which will avoid unsteady flow through the spillway.

7.Siphon Spillway :

- Instead of allowing water to spill over the crest of a dam or weir the surplus water may be discharged downstream side through a siphon spillway consist of one or more siphon units.

- A siphon spillway is the one which utilizes the siphonic action to discharge the surplus water .

- Generally , a siphon spillway consists of a closed conduit system formed in the shape of an inverted ‘U’ positioned so that the inside bend of the upper passage way is Normal reservoir level.

- When the water level rises above than the normal reservoir level , water flows over the crest, and then siphonic action takes place.

- Continuous flow is then maintained by suction affect due to gravity pull of the water in the lower leg of the siphon.

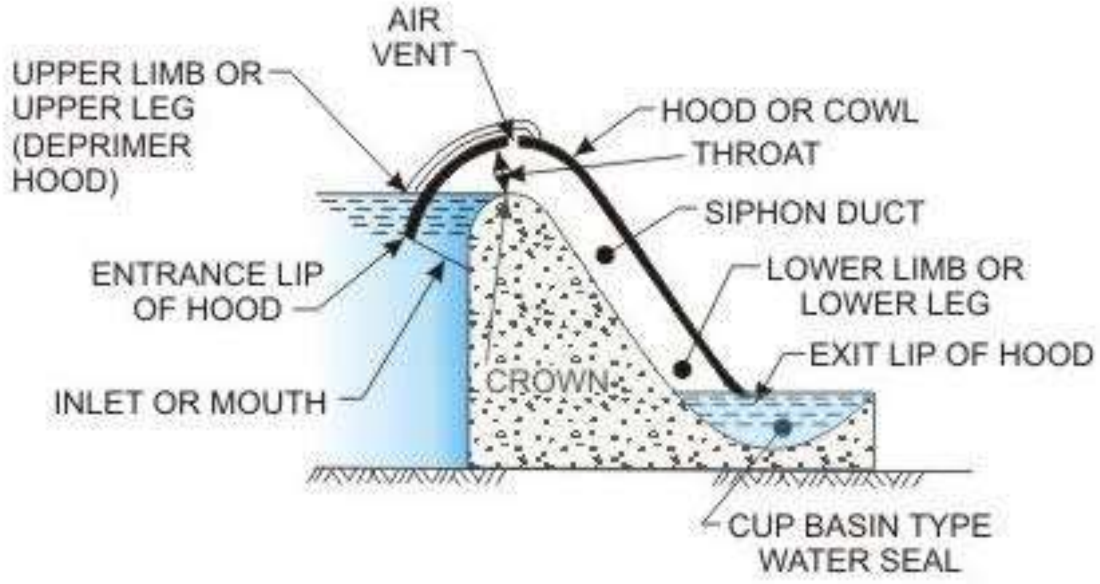


FIGURE 17. Saddle Siphon

- There are two types of siphon spillways:
  - Saddle spillway
  - Volute siphon spillway
  - Saddle spillway:
  - It is essentially consists of RCC hood constructed over an overflow section of Gravity dam.
  - The inlet or mouth is kept submerged in water so that no debris matter do not enter the siphon.
  - A small Deprimer hood is kept above the main hood, and both these hoods are connected by air vent.

- The inlet of the deprimer hood is kept just at the reservoir level.
- The lower limb or leg of the main hood is generally kept submerged in the tail water so that there is no entry from d/s end.
- When the water level in the reservoir increases, it seals the air entry through the mouth of the deprimer dome.
- since air entry is sealed both from u/s and d/s end , the spilling water sucks all the remaining air from the hood.

- Siphonic action is established after the air is exhausted.
- The siphon runs full and water is discharged to d/s under effective head.
- when the water level reduces then the air enters through the mouth of deprimer dome and siphonic action may be broken.

2.Volute siphon spillway:

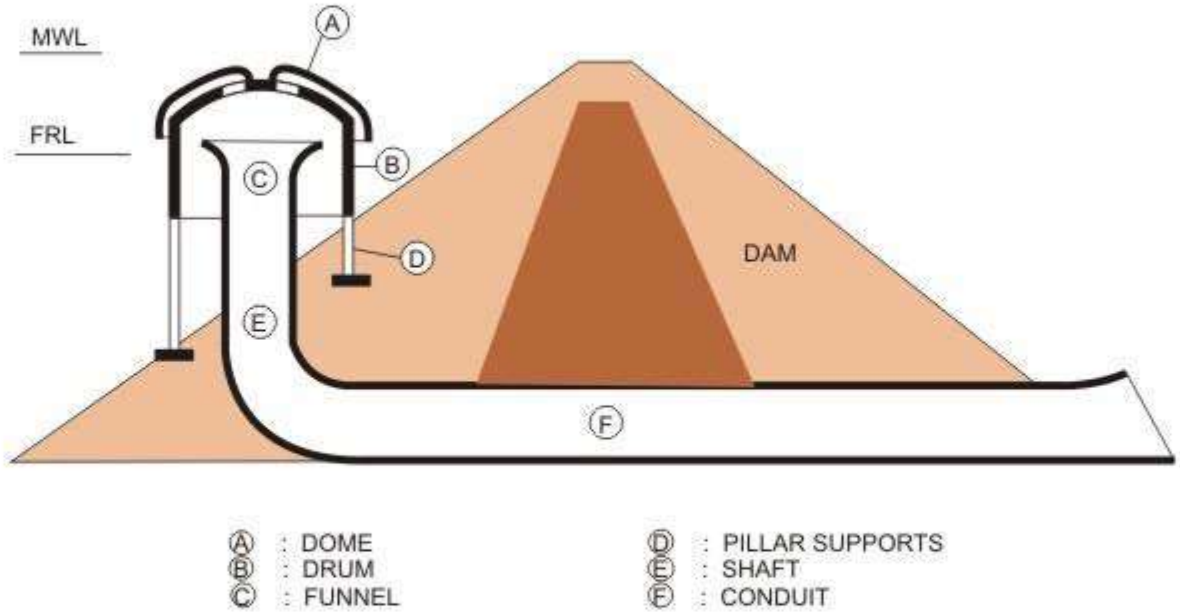


FIGURE 18. Volute of siphon spillway components

- It consists of a vertical barrel or shaft bent at the discharge end and opened out in the form of a funnel at the top.
- The top of the funnel is kept at reservoir level and a no. of volutes means blades are fixed in the funnel to induce a spiral motion to the water passing along them.
- A dome, supported on no. of pillars is placed over the funnel. Over this deprimer is kept just at reservoir level.

Selection of spillways :

- The Bureau of Indian Standards code IS: 10137-1982 “Guidelines for selection of spillways and energy dissipators” provide guidelines in choosing the appropriate type of spillway for the specific purpose of the project.

- The general considerations that provide the basic guidelines are as follows:

- Safety Considerations Consistent with Economy :

  - Spillway structures add substantially to the cost of a dam. In selecting a type of spillway for a dam, economy in cost should not be the only criterion.

  - The cost of spillway must be weighed in the light of safety required below the dam.

- Hydrological and Site Conditions :

  The type of spillway to be chosen shall depend on:

  a) Inflow flood;

  b) Availability of tail channel, its capacity and flow hydraulics;

  c) Power house, tail race and other structures downstream; and

  d) Topography

Type of Dam :

- This is one of the main factors in deciding the type of spillway.
- For earth and rock fill dams, chute and ogee spillways are commonly provided, whereas for an arch dam a free fall or morning glory or chute or tunnel spillway is more appropriate.
- Gravity dams are mostly provided with ogee spillways.

Purpose of Dam and Operating Conditions :

- The purpose of the dam mainly determines whether the dam is to be provided with a gated spillway or a non-gated one.
- A diversion dam can have a fixed level crest, that is, non-gated crest.

- Nature and Amount of Solid Materials Brought by the River :

- Trees, floating debris, sediment in suspension, etc, affect the type of spillway to be provided.

- A siphon spillway cannot be successful if the inflow brings too much of floating materials.

- Where big trees come as floating materials, the chute or ogee spillway remains the common choice.

- Apart from the above, each spillway can be shown as having certain specific advantages under particular site conditions.

- These are listed below which might be helpful to decide which spillway to choose for a particular project.

- Ogee Spillway :
  - It is most commonly used with gravity dams.
  - However, it is also used with earth and rock fill dams with a separate gravity structure;
  - the ogee crest can be used as control in almost all types of spillways; and
  - it has got the advantage over other spillways for its high discharging efficiency.

- Chute Spillway :

  a) It can be provided on any type of foundation,

  b) It is commonly used with the earth and rock fill dams, and

  c) It becomes economical if earth received from spillway excavation is used in dam construction.

The following factors limit its adaption:

a) It should normally be avoided on embankments;

b) Availability of space is essential for keeping the spillway basins away from the dam paving; and

c) If it is necessary to provide too many bends in the chute because of the topography, its hydraulic performance can be adversely affected.

- Side Channel Spillways :
  - This type of spillway is preferred where a long overflow crest is desired in order to limit the intensity of discharge.
  - It is useful where the abutments are steep, and it is useful where the control is desired by the narrow side channel.

Shaft Spillways (Morning Glory Spillway) :

- Minimum discharging capacity is attained at relatively low heads.
- This characteristic becomes undesirable where a discharge more than the design capacity is to be passed. So, it can be used as a service spillway in conjunction with an emergency spillway.

- Siphon Spillway :
  - Siphon spillways can be used to discharge full capacity discharges, at relatively low heads.
  - Great advantage of this type of spillway is its positive and automatic operation without mechanical devices and moving parts.
- Over fall or Free Fall Spillway :
  - This is suitable for arch dams or dams with downstream vertical faces; and this is suitable for small drops and for passing any occasional flood.

Tunnel or Conduit Spillway :

- This type is generally suitable for dams in narrow valleys, where overflow spillways cannot be located without risk and good sites are not available for a saddle spillway.

- In such cases, diversion tunnels used for construction can be modified to work as tunnel spillways. In case of embankment dams, diversion tunnels used during construction may usefully be adopted.

- Where there is danger to open channels from snow or rock slides, tunnel spillways are useful.

Profile of Ogee spillway:

- The ideal spillway should have the form of the underside of the nappe of a sharp crested weir when the flow rate corresponds to the maximum design capacity of spillway.
- However the head during an unanticipated flood may rise higher than the design head and lower nappe of the falling jet may leave the ogee profile , thereby causing –ve pressure and cavitation.
- On the contrary , the falling jet would adhere to the profile of Ogee , causing a +ve pressure and reducing the discharging capacity.

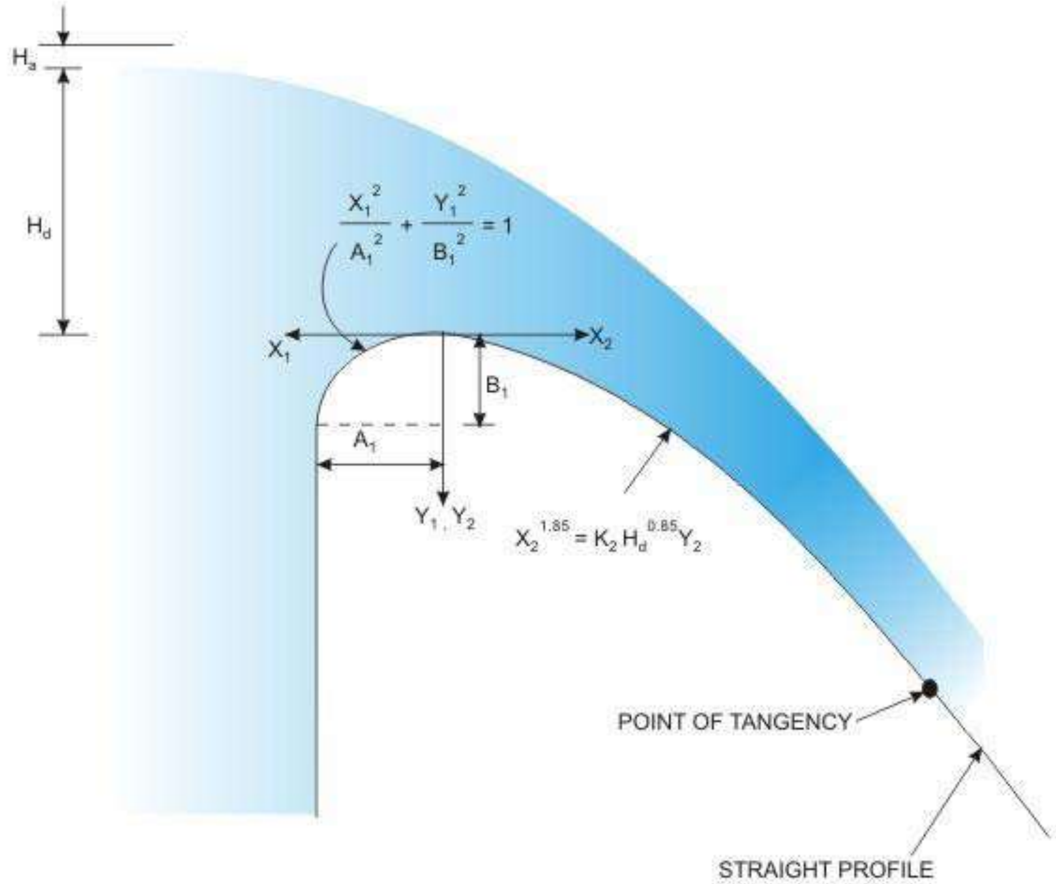


FIGURE 22. Ogee crest shape with vertical upstream wall . Coefficients to be determined from Figure 21

- The d/s profile of the Ogee has the following equation

$$x^{1.85} = 2 * H^{0.85} * y$$

where x and y are the coordinates of the crest profile measured from the apex of the crest , and H is the design head.

- According to the latest analytical studies of U.S.A Army , the u/s curve of the ogee shape has following ,

$$y = (0.724 * (x+0.27H)^{1.85})/H^{0.85} + (0.126H) - (0.4315 * H^{0.375} * (x+0.27H)^{0.625})$$

- It should be noted that The upper curve at the crest should neither be made too sharp nor too broad.

- A broader curve at crest supports the lower nappe , produces +ve hydrostatic pressure and thus reduces the discharging capacity.

- If the curve is sharp , the nappe will leave ogee profile , there by causing – ve pressure and consequent cavitation , and increasing the coefficient of discharge.

Discharge equation :

- The discharge over an Ogee spillway is given by ,

$$Q = C * L_e * H_e^{1.5}$$

Where ,

Q = Discharge ,

L_e = effective length = $L - 2(NK_p + K_a) * H_e$

H_e = Total head on the crest , including velocity of approach head

L = Net length of the crest

N = Number of piers

K_p = Pier contraction coefficient

K_a = abutment contraction coefficient

C = Coefficient of discharge.

- The discharge coefficient, C is influenced by a number of factors, such as:

1. Depth of approach
2. Relation of the actual crest shape to the ideal nappe shape
3. Upstream face slope
4. Downstream apron interference, and
5. Downstream submergence

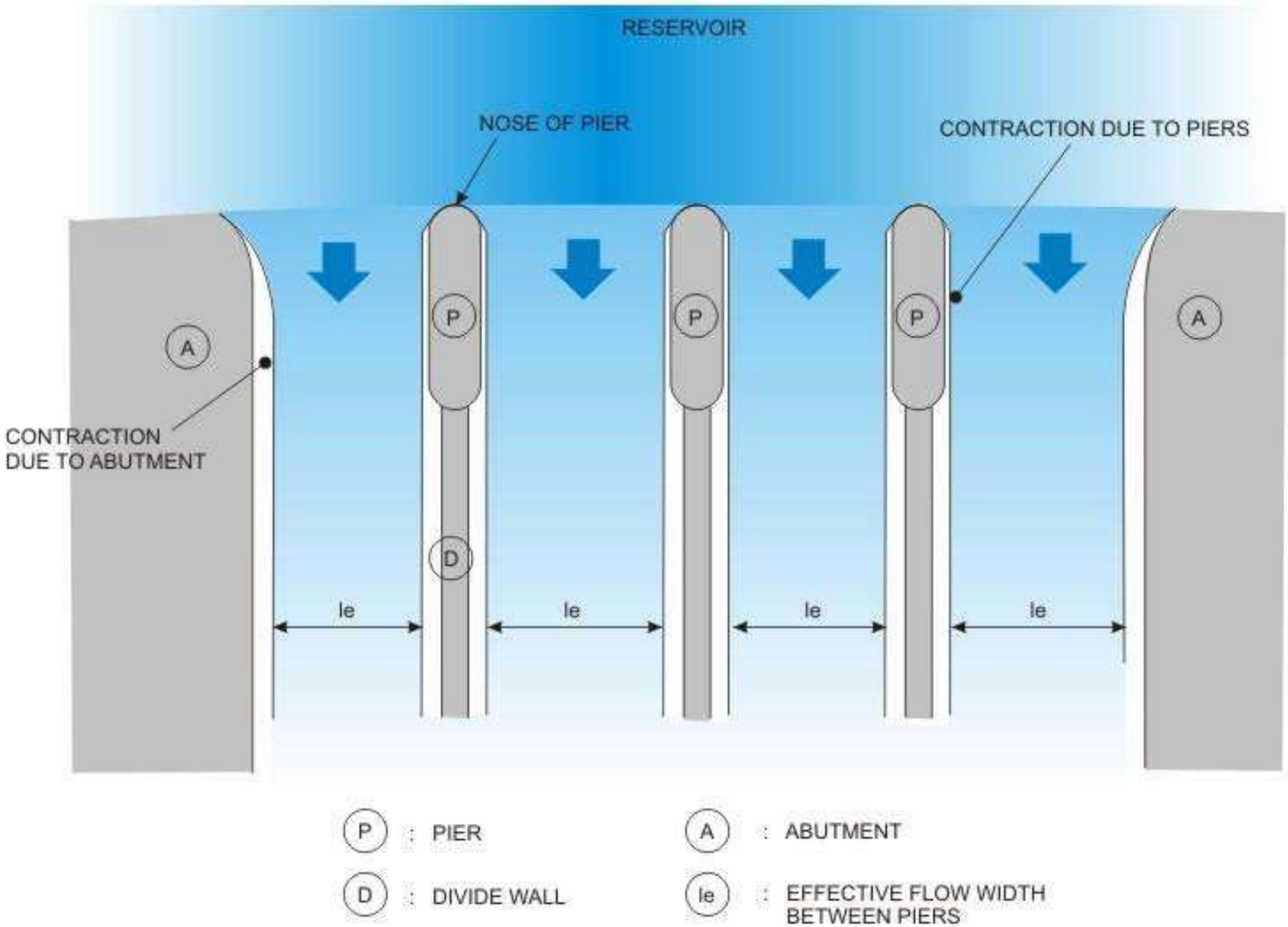


FIGURE 32. Abutment and pier contractions shown on a spillway plan

- The pier contraction coefficient K^p depends upon the following factors:

1. Shape and location of the pier nose
2. Thickness of the pier
3. Head in relation to the design head
4. Approach velocity

- The abutment contraction coefficient is seen to depend upon the following factors:

1. Shape of abutment
2. Angle between upstream approach wall and the axis of flow
3. Head, in relation to the design head
4. Approach velocity

For the condition of flow at the design head, the average values of pier contraction coefficients may be assumed as shown in Figure.

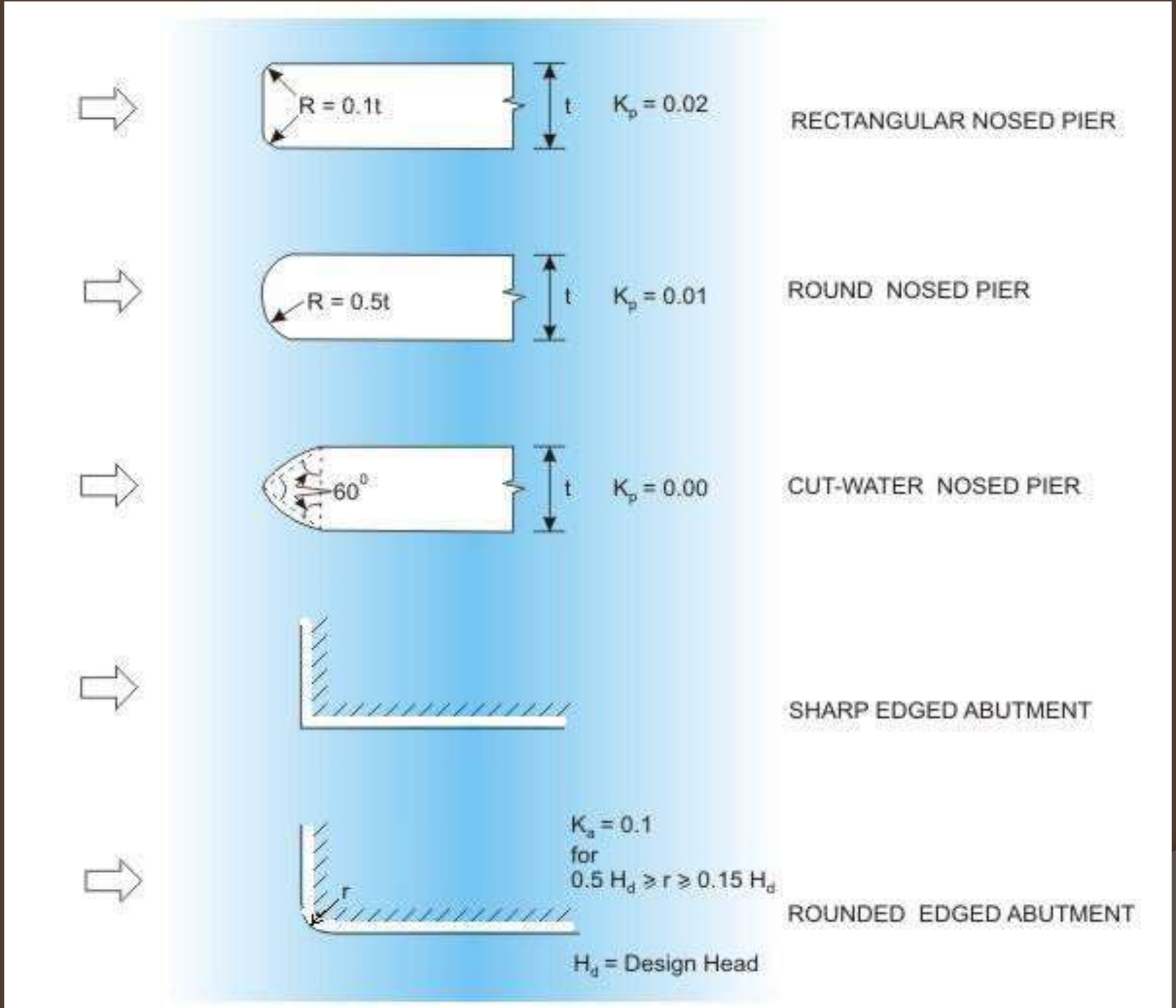


FIGURE 33. Recommended values of K_p and K_a

Energy dissipation below spillways:

- When flood discharge passes over the spillway crest , it has high potential energy which gets converted into kinetic energy as it glides along it.
- This high energy has to be dissipated otherwise it would cause erosion at the downstream toe.
- There is a varied practice regarding the extent of protection against erosion below a spillway to be provided.

- In general , the protection can be rendered by two ways :

I. By dissipating the energy by means of hydraulic jump
II. By directing the jet of water so as to fall away from the structure by a deflector bucket or lip , and dissipating the energy by impact.

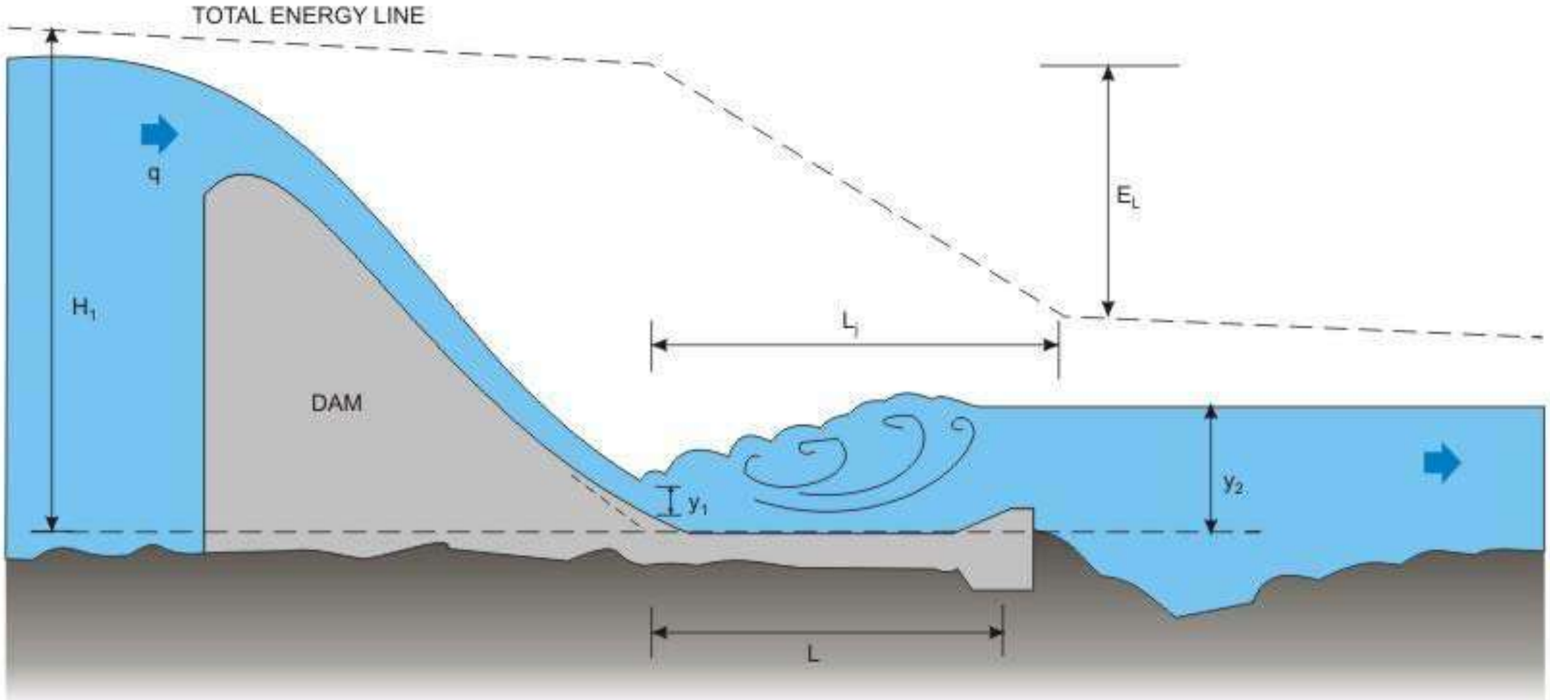
- where the energy of flow is to be dissipated before the discharge is returned to the main river channel , the hydraulic jump basin is an effective device for reducing the exit velocity to a tranquil state.

- Where the spillway discharge may be safely delivered directly to the river channel , without providing a dissipating (or) stilling device , the jet is often projected beyond the structure by a deflector bucket.

- A hydraulic jump is the sudden turbulent transition of supercritical flow to subcritical.

- This phenomena, which involves a loss of energy, is utilized at the bottom of a spillway as an energy dissipater by providing a floor for the hydraulic jump to take place.

- The amount of energy dissipated in a jump increases with the rise in Froude number of the supercritical flow.



L : LENGTH OF STILLING BASIN APRON

L_j : LENGTH OF HYDRAULIC JUMP

q : DISCHARGE PER UNIT WIDTH

H_1 : TOTAL ENERGY UPSTREAM OF JUMP

y_1 : PRE-JUMP (SUPER CRITICAL FLOW) DEPTH

y_2 : POST-JUMP (SUB CRITICAL FLOW) DEPTH

E_L : ENERGY LOST IN JUMP

FIGURE 47. Definition sketch of hydraulic jump & associated parameters

The two depths, one before (**y_1**) and one after (**y_2**) the jump are related by the following expression:

$$\frac{y_1}{y_2} = \frac{1}{2}\left(-1 + \sqrt{1 + 8F_2^2}\right) \qquad (14)$$

Where F_1 is the incoming Froude number = $\frac{V_1}{\sqrt{g y_1}}$

Alternatively, the expression may be written in terms of the outgoing Froude number F_2 $\left(= \frac{V_2}{\sqrt{g y_2}}\right)$ as

$$\frac{y_2}{y_1} = \frac{1}{2}\left(-1 + \sqrt{1 + 8F_1^2}\right) \qquad (15)$$

where **V_1** and **V_2** are the incoming and outgoing velocities and ***g*** is the acceleration due to gravity.

The energy lost in the hydraulic jump (**E_L**) is given as:

$$E_L = \frac{(y_2 - y_1)^3}{4 y_1 y_2}$$

- In most cases, it is possible to find out the pre-jump depth (y_1) and velocity (V_1) from the given value of discharge per unit width (q) through the spillway.
- This is done by assuming the total energy is nearly constant right from the spillway entrance up to the beginning of the jump formation.
- (V_1) may be assumed to be equal to $\sqrt{2gH_1}$, where H_1 is the total energy upstream of the spillway, and neglecting friction losses in the spillway. The appropriate expressions may be solved to find out the post-jump depth (y2) and velocity (V2).

- The length of the jump (L_j) is an important parameter affecting the size of a stilling basin in which the jump is used.

- There have been many definitions of the length of the jump, but it is usual to take the length to be the horizontal distance between the toe of the jump up to a section where the water surface becomes quite level after reaching a maximum level.

- Because the water surface profile is very flat towards the end of the jump, large personal errors are introduced in the determination of the jump length.

- Bradley and Peterka (1975) have experimentally found the length of hydraulic jumps and plotted them in terms of the incoming Froude number (F_1) and post-jump depth (y_2) as shown in Figure .

- It is evident that while L_j/y_2 varies most for small values of (F_1) at higher values, say above 5 or so, L_j/y_2 is practically constant at a value of about 6.1.

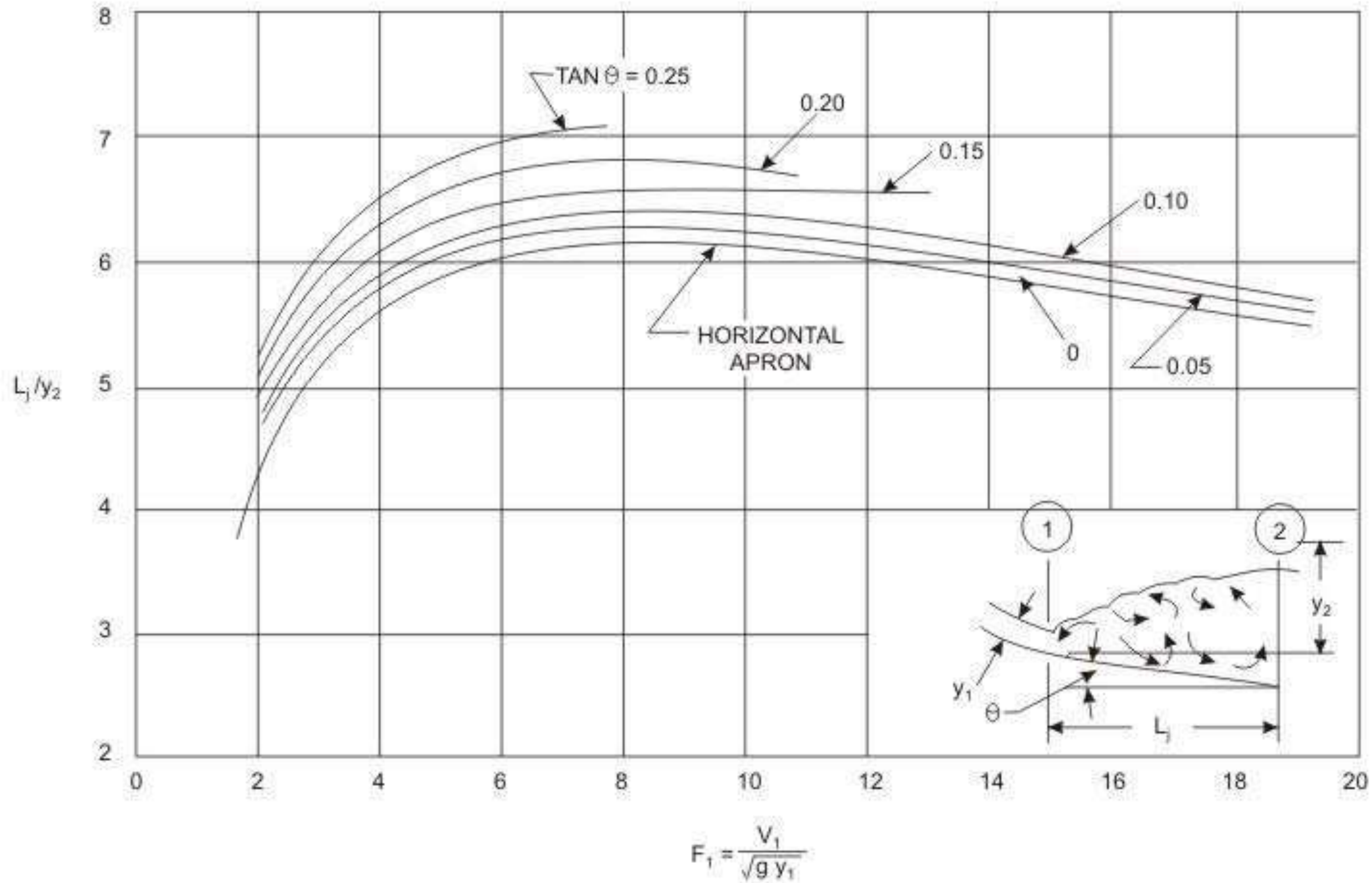


FIGURE 48. Length of hydraulic jump on a horizontal or inclined floor

- The depth of water in the actual river downstream of the stilling basin (y_2^*) is determined from the river flow observations that have been plotted as a stage-discharge curve .

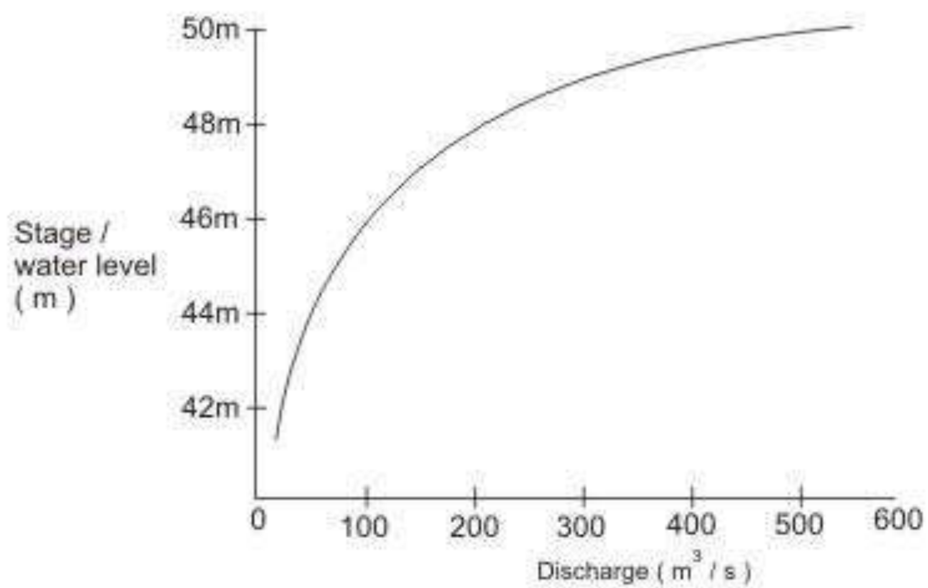
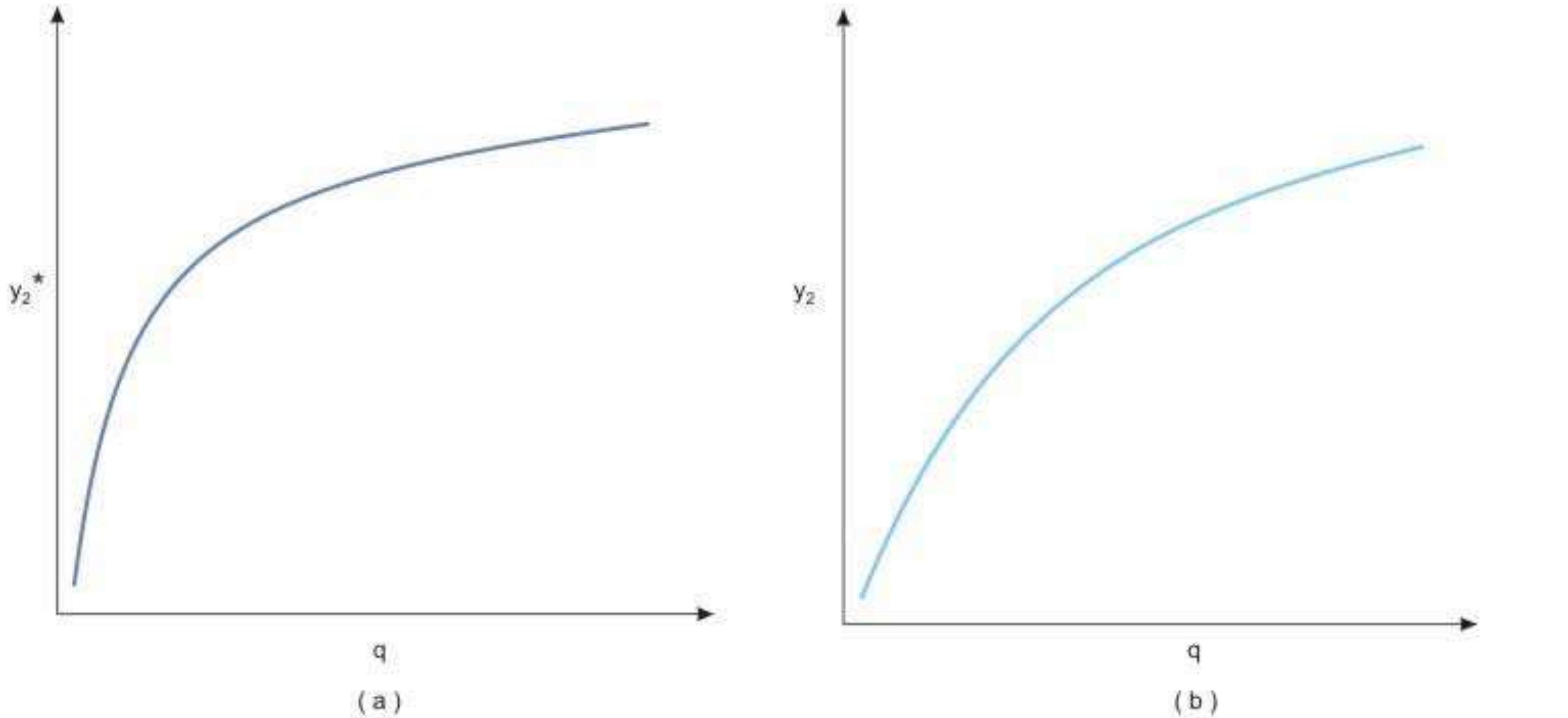


FIGURE 49. A typical stage-discharge curve for a river

- Subtracting the stilling basin apron level from the stage or water level corresponding to the total discharge passing through the spillway gives the tail-water depth (y_2^*).

- Since the stage-discharge curve gives indications about the tail-water of the spillway, it is called the Tail-Water Rating Curve (TRC), usually expressed as the water depth (y_2^*) versus unit discharge (q), as shown in Figure.

- At the same time, using the formula relating unit discharge (q) with the post-jump depth (y_2), a similar graph may be obtained, as shown in Figure. Since this graph gives indication about the variation of the post-jump depth, it is called the Jump Rating Curve (JRC).



q : DISCHARGE PER UNIT WIDTH

y_2^*: WATER - DEPTH OF RIVER DOWNSTREAM OF STILLING BASIN MEASURED ABOVE APRON LEVEL

y_2 : WATER - DEPTH CORRESPONDING TO HYDRAULIC JUMP

FIGURE 50. Water Level curves
(a) : Tail - water Rating Curve (TRC)
(b) : Jump Rating Curve (JRC)

- Case I:
- In general, the JRC and TRC would rarely coincide, if plotted on the same graph, as shown in Figure .

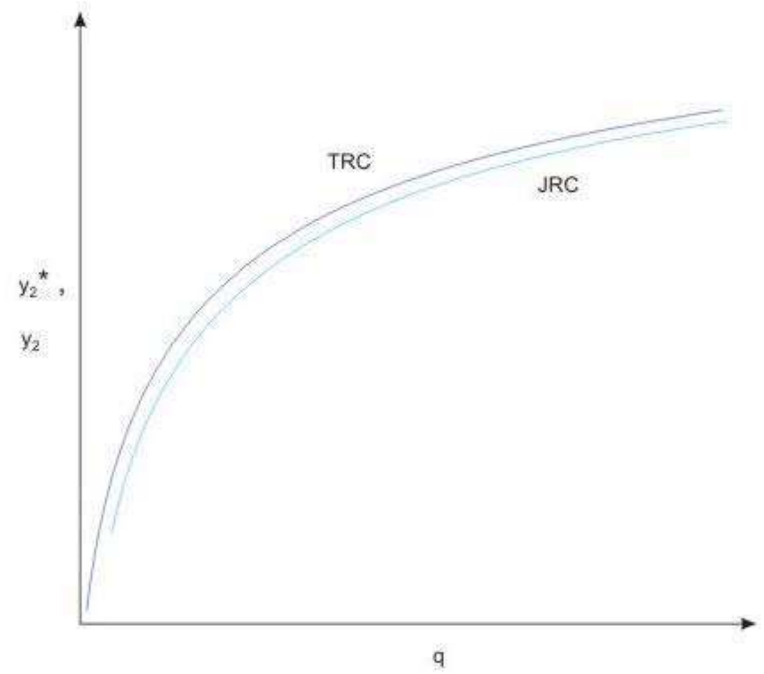


FIGURE 51. TRC & JRC coinciding

- This is the ideal case in which the horizontal apron provided on the riverbed downstream from the toe of the spillway would suffice.
- The length of the apron should be equal to the length of the jump corresponding to the maximum discharge over the spillway.

- <u>Case II :</u>
- At times, the TRC may lie completely below the JRC , for all discharges, in this case the jump will be located away from the toe of the spillway resulting in possible erosion of the riverbed.

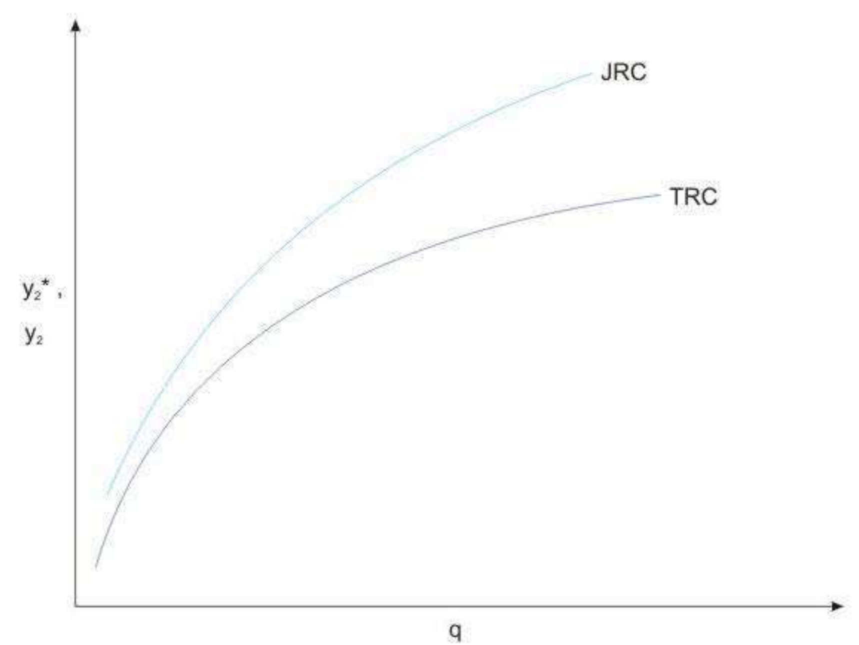


FIGURE 52. TRC below JRC for all discharges

- It is apparent that the tail water depth as provided by the natural river is not sufficiently for the jump to form.

- This may be over come by providing a stilling basin apron that is depressed below the average riverbed level or by providing a sill or baffle of sufficient height at the end of the spillway .

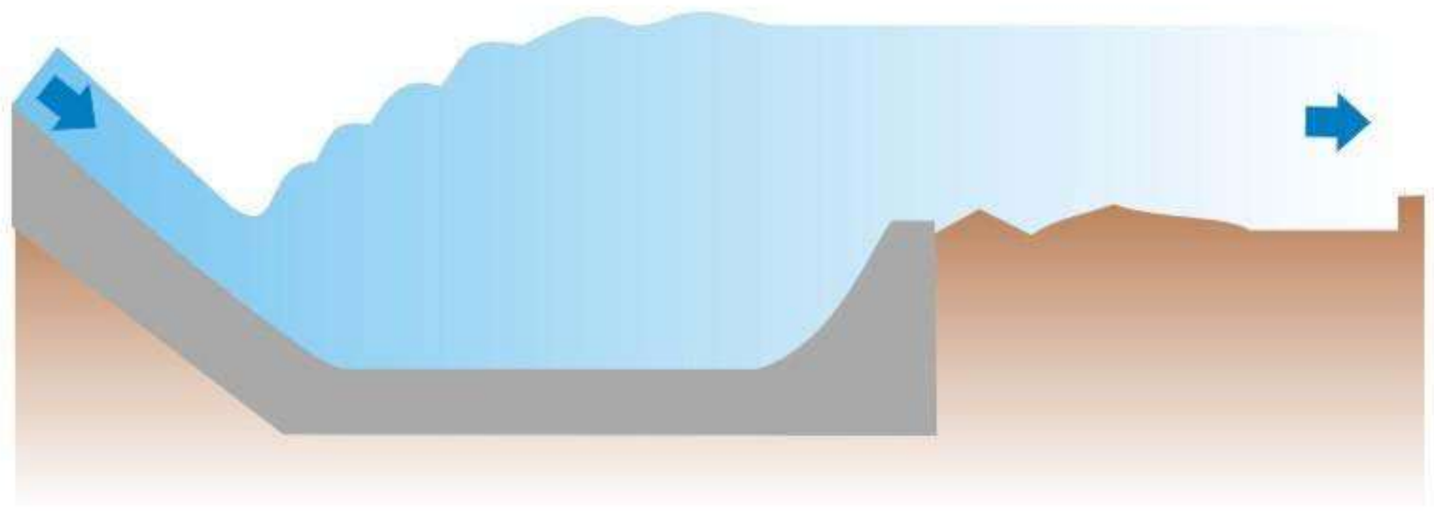


FIGURE 56. Depressed floor of stilling basin apron

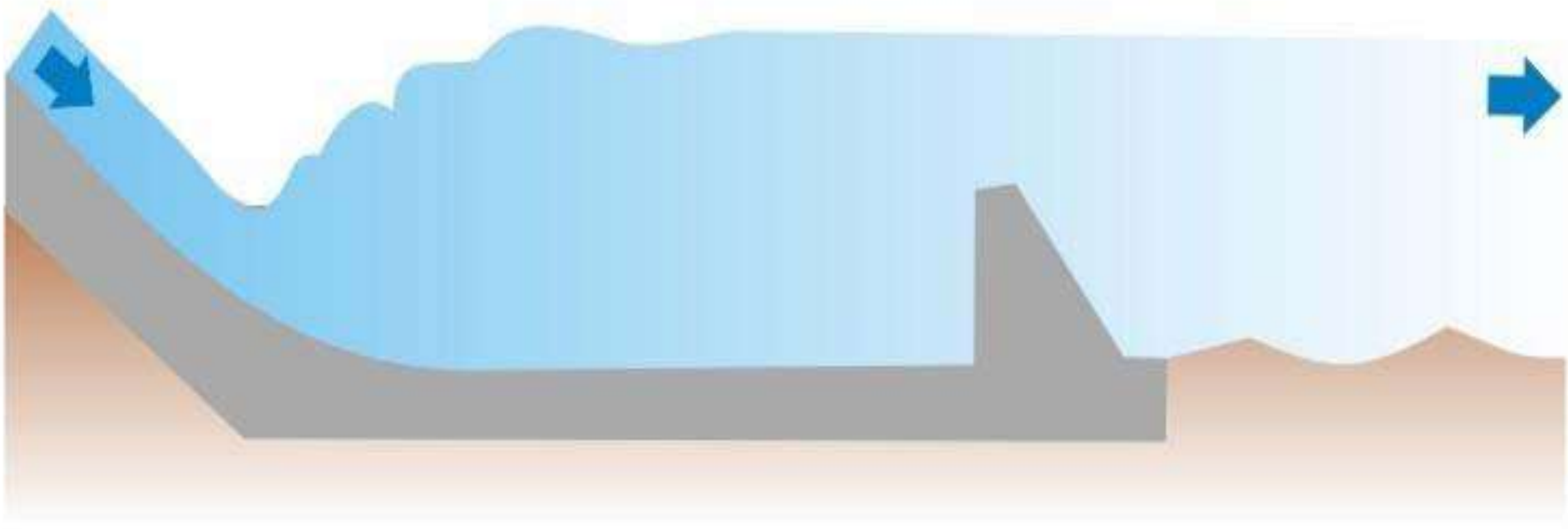


FIGURE 57. High end - sill or baffle at toe of stilling basin

Case III:

- If the TRC is completely above the jump would be located so close to the spillway to make it submerged which may not dissipate the energy completely.

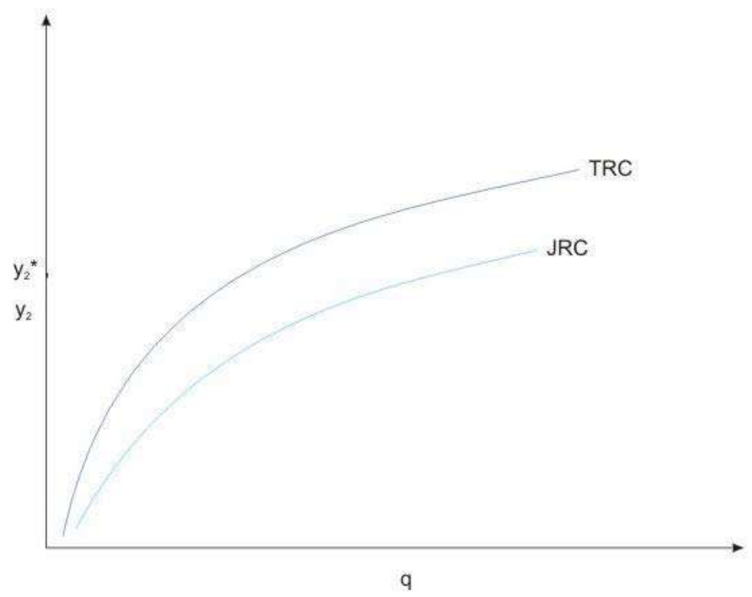


FIGURE 53. TRC above JRC for all discharges

- Since this situation results in submergence of the jump, it is necessary to raise the floor in order to form a clear jump.

- In practice, it is done by providing an inclined apron of the stilling basin .

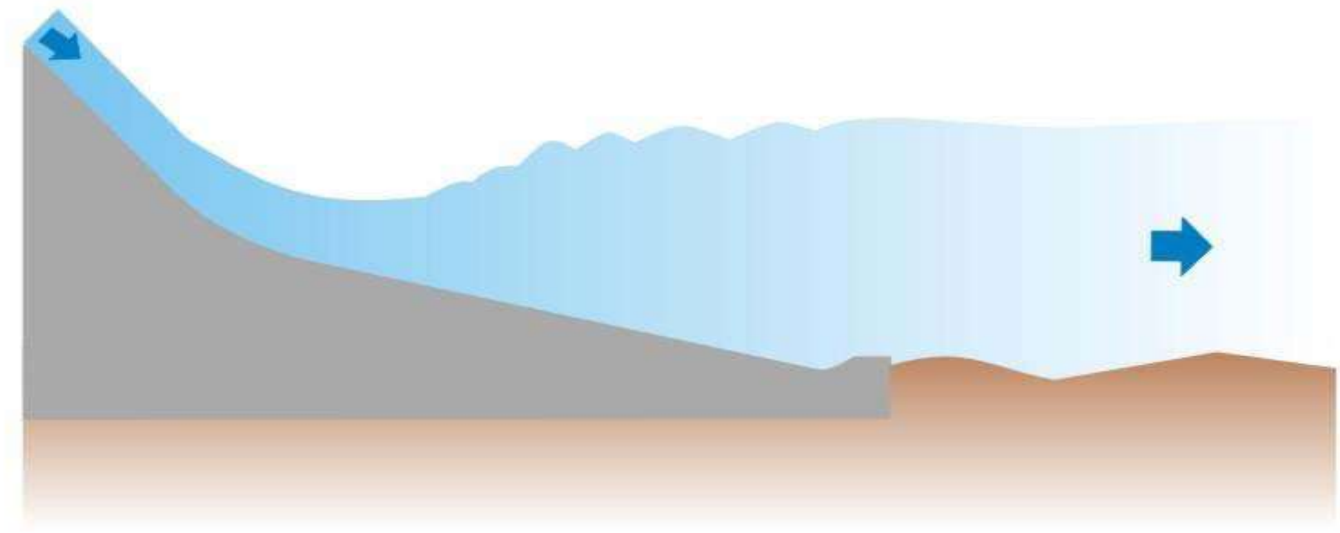


FIGURE 58. Inclined stilling basin

Case IV:

- _It may also be possible in actual situations that the TRC may be below the JRC for some discharges above for the rest, as shown in Fig.

- In these cases two, favorable location of jump may not be possible.

- In view of the above situations, the following recommendations have been made for satisfactory performance of the hydraulic jumps.

- This situation may be taken care of by providing an inclined floor in the upper portion of the stilling basin and providing either a depressed floor in the lower portion of the basin or provide a baffle at the end of the basin.

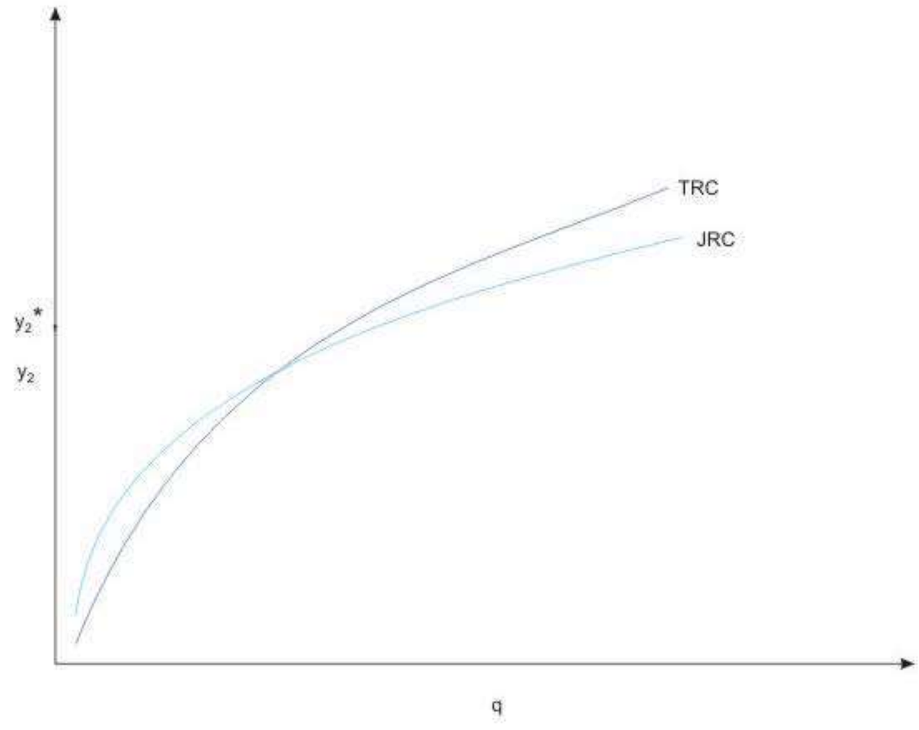


FIGURE 54. TRC below JRC for low discharges and above for high discharges

Case V:

In this case a sloping apron may be provided which lies partly above and partly below the riverbed. So that the jump will form on the higher slope at low discharges and on the lower slope at high discharges.

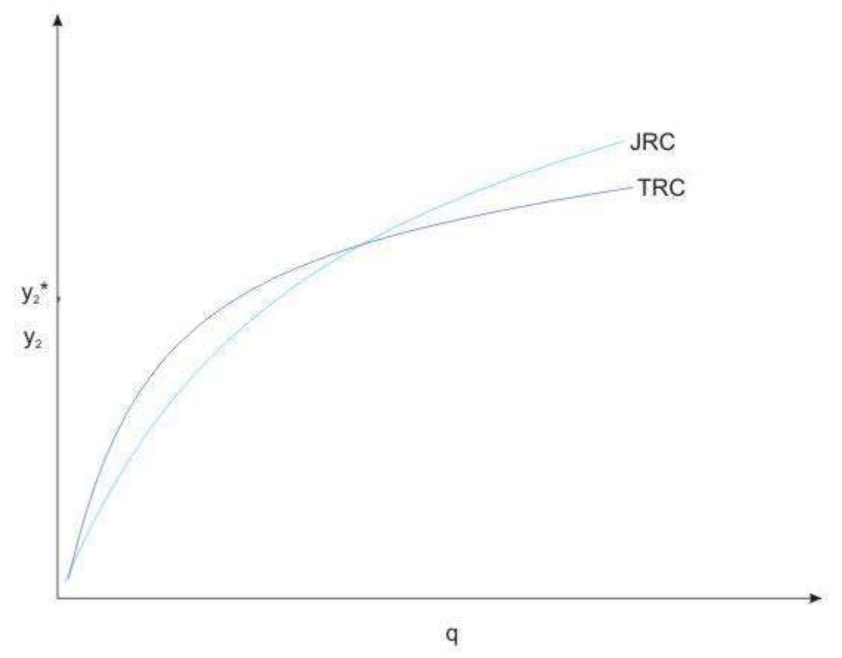


FIGURE 55. TRC above JRC for low discharges and below for high discharges

IS on criteria for design of hydraulic jump type stilling basins with horizontal and sloping aprons:

- The type of Stilling Basins that may be provided under different situations is recommended by the Bureau of Indian Standards code IS: 4997-1968 "Criteria for design of hydraulic jump type stilling basins with horizontal and sloping aprons".

- In all, these four types of basin shapes recommended. Types I and II are meant for basins with horizontal floors and types III and IV for basins with inclined floors.

- Hydraulic jump type stilling basins with horizontal or sloping apron utilizing various energy dissipaters such as chute blocks , basin or floor blocks and end sill.
- A stilling basin is a structure in which all or part of the energy dissipating action is confined.
- In a stilling basin the kinetic energy first causing the turbulence and is ultimately lost as heat energy.
- A hydraulic jump type stilling basin may be either with horizontal apron or with sloping apron.

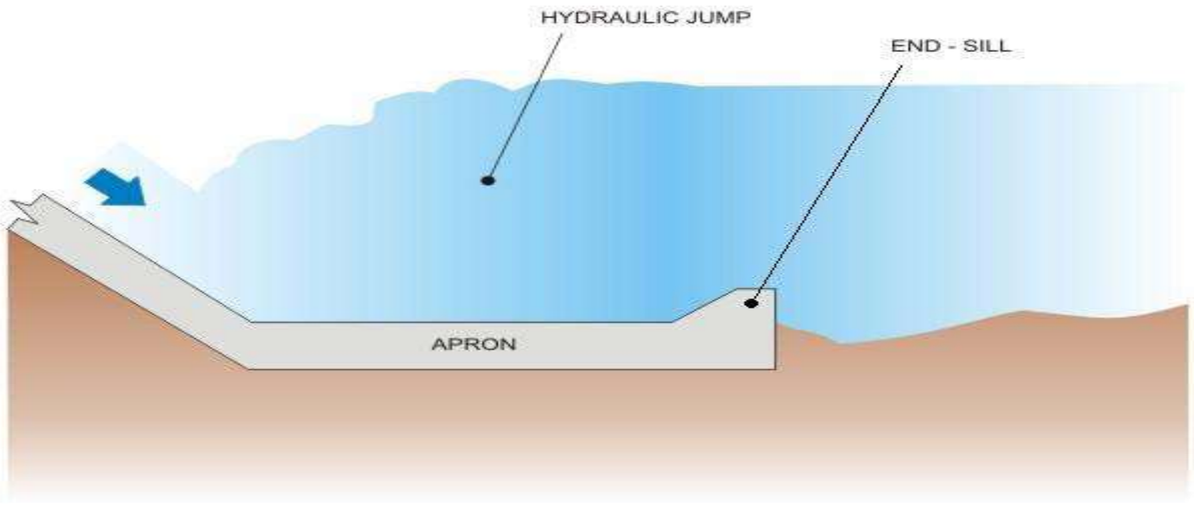


FIGURE 38. Horizontal apron stilling basin with end-sill

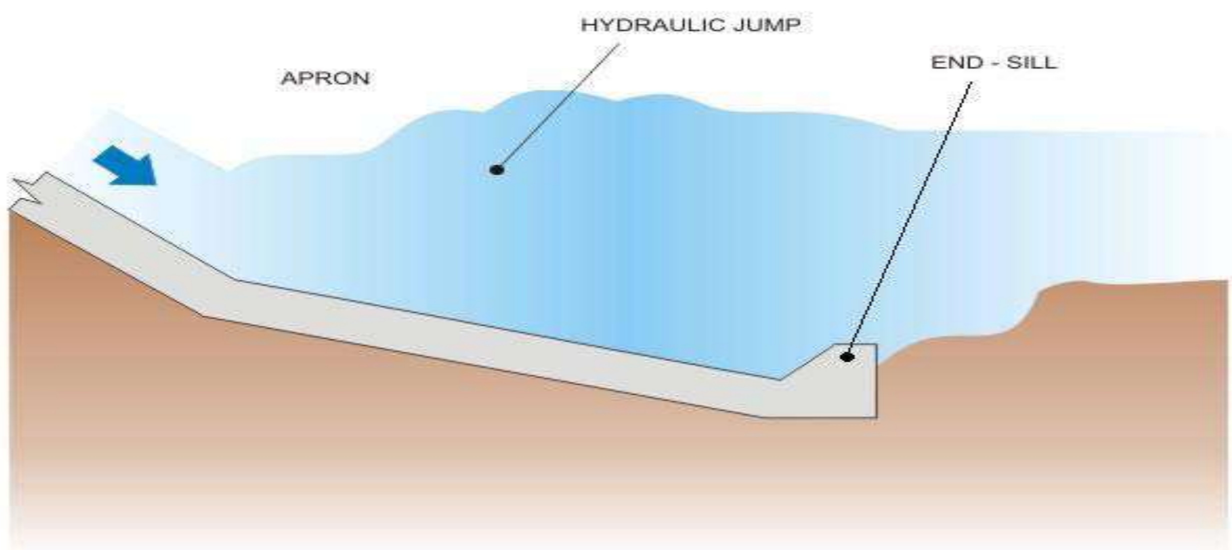


FIGURE 39. Sloping apron stilling basin with end-sill

hydraulic jump type stilling basin with horizontal apron:

- When the tail water curve follows the hydraulic jump curve or is only slightly above or below it.
- Then hydraulic jump type stilling basin with horizontal apron provides the best solution for energy dissipation.
- For spillways on weak bed conditions , end weirs , and barrages on sand and loose gravel , hydraulic jump type stilling basins are recommended.

- Water depths at the beginning and the end of the hydraulic jump are related by the following formula , for horizontal aprons :

$$\frac{y_2}{y_1} = \frac{1}{2}\left(-1 + \sqrt{1 + 8F_1^2}\right)$$

Where F_1 is the incoming Froude number = $\frac{V_1}{\sqrt{g y_1}}$

- This may be again classified into two types:

- <u>Basin type I:</u> Stilling basin in which Froude number of the incoming flow in less than 4.5 .This case is generally encountered on weirs and barrages.
- <u>Basin type II:</u> Stilling basin in which Froude number of the incoming flow is greater than 4.5. This case general feature for dams.

- Stilling basin type I:

The factors involved in the design of stilling basin are :

- Determination of the elevation of basin floor
- Basin length , and
- Basin appurtenances.

(i) Elevation of basin floor:

- First we have to calculate the total head loss and pre jump and post jump depths.
- The elevation of the basin floor may calculated by deducting the sp. Energy at section -1from T.E.L.

Basin length and depth :

- The length of the basin can be calculated by using the graph between the (L/y2) to Froude number .
- Generally the floor should not be raised more than level reqd. for sequent depth consideration. If it is reqd. should not exceed 15% of y2 and the basin supplemented by chute blocks and basin blocks.
- The basin blocks should not be used if the velocity of the flow at the location of basin blocks should not exceed 15 m/s.

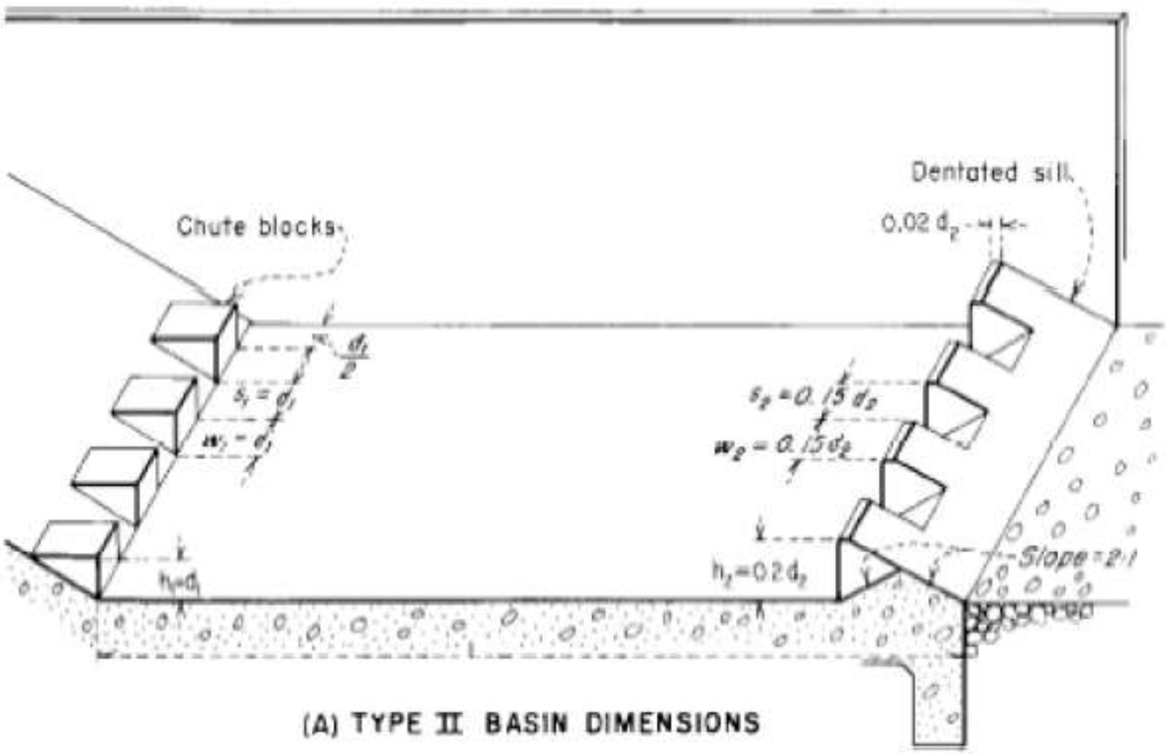
iii). Basin appurtenances:

- Chute blocks: The height, length and width of blocks are in times of D1 as shown in fig.

- Basin blocks :The dimensions of block as shown in fig.

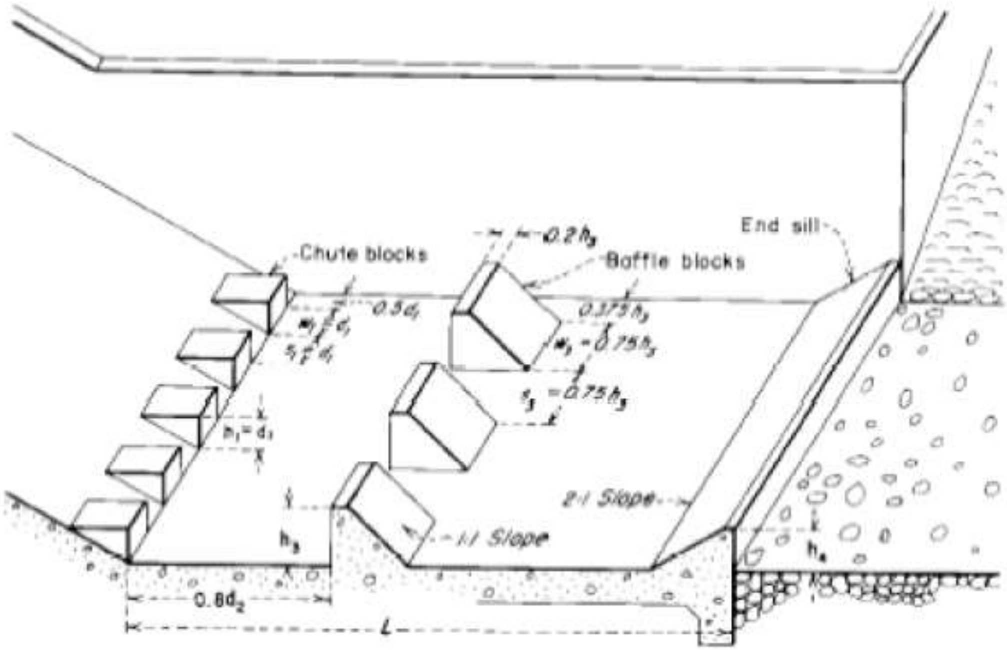
- End sill : The ht. of dentated end sill is recommended as 0.2D2.The max. width and spacing of dents shall be acc.to fig.

Type II Basin Dimensions



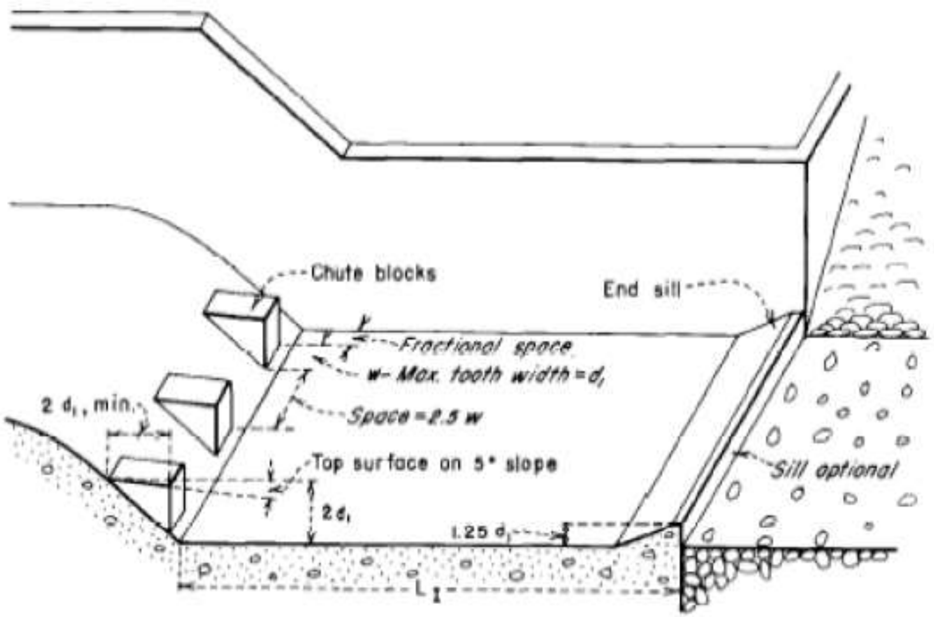
(A) TYPE II BASIN DIMENSIONS

Type III Basin Dimensions



(A) TYPE III BASIN DIMENSIONS

Type IV Basin Dimensions



(A) TYPE IV BASIN DIMENSIONS

FROUDE NUMBER

Spillway crest gates :

- As stated earlier , spillways are of two types :
  - Controlled spillway
  - Uncontrolled spillway
- Controlled spillway is the one the flow over which is controlled by using gates over its crest.

- By installing gates over spillways , additional storage can be made available , specially during low water flow.

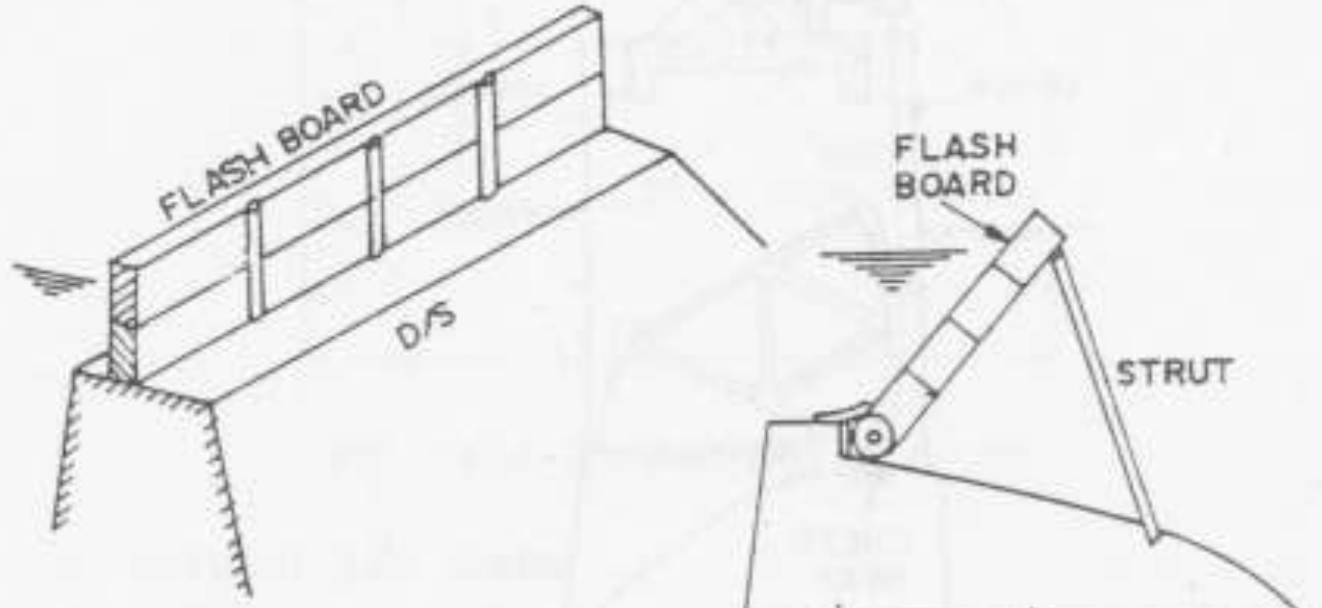
- However , crest gates over spillways for earth dams should be used with caution since faulty operation may cause the rise in the reservoir water level and subsequent overtopping of the earth dam.

- The common types of gates used for spillways :

  - Flash boards , stop legs , and needles
  - Radial gates
  - Drum gates
  - Vertical lift gates
  - Bear trap gates
  - Rolling gates.

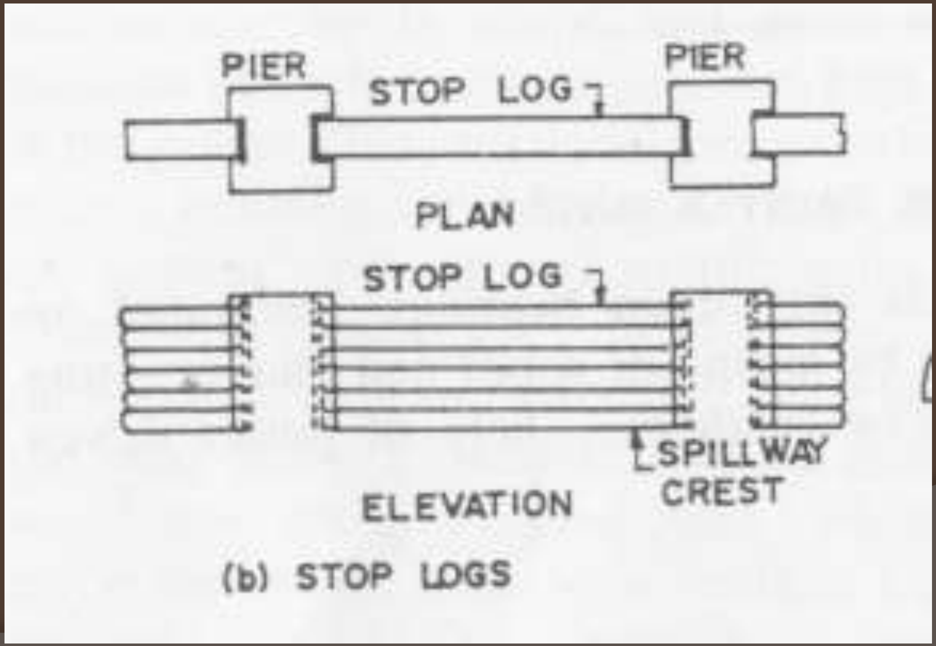
1. Flash boards , stop legs , and needles :

- Flash boards are the temporary gates used only for small spillway of minor importance.
- They consists of wooden panels supported by pins on the edges. The pins are supported on pipe sockets along the crest of the dam.
- These may be either braced or hinged or automatic. They fall automatically at a certain head.



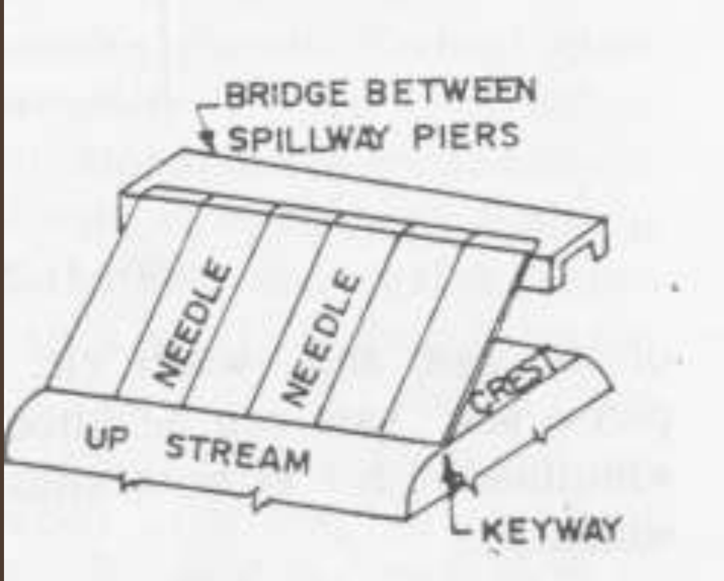
(a) FLASH BOARDS

* Stop legs :
  * They consists of horizontal timber planks spanning across piers having grooves.
  * These planks are kept over one another as shown in fig. and can be removed either by hand or with help of any hoisting equipment.



- Needles:

- Needles consists of wooden planks kept in inclined position , with lower ends resting in key way on the spillway crest and upper ends at the top of a bridge girder.



(c) NEEDLES

2.Radial gates :

- A radial gate also known as a ‘tainter gate ‘ has its water supporting face , made of steel plates , in the shape of sector of a circle , properly braced and hinged at the pivot .

- The gate can thus be made to rotate about fixed horizontal axis. The load of the gate and water etc. is carried on bearings , mounted on piers.

- The gate can be lifted by means of ropes and chains acting simultaneously at both ends or with the help of power driven winches.

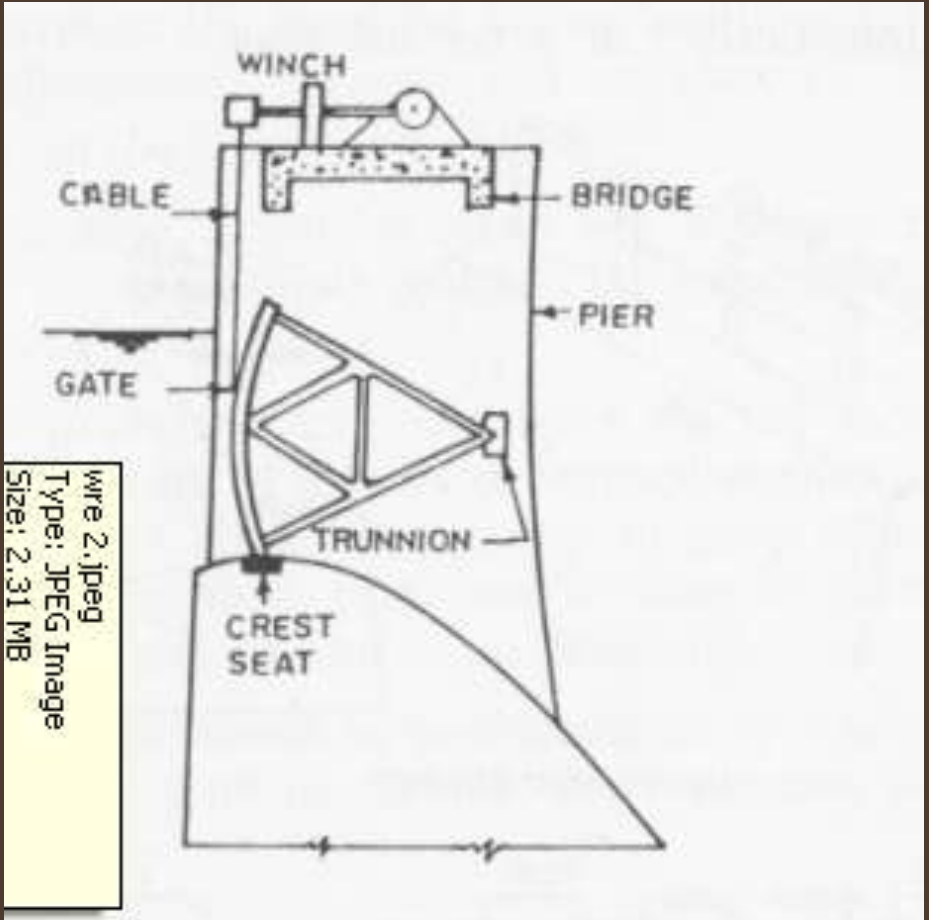


FIG. 11.29. TAINTER GATE.

3.Drum gates:

- These are normally used for long span. Fig. shows the U.S.B.R type drum gate which consists of a circular sector in c/s formed by skin plates attached to internal bearings.
- It is hinged at the centre of curvature in such a way that the entire sector may be raised above the crest or may be lowered so that upper surface becomes coincident with the crest line.
- The buoyant forces due to head water pressure underneath aid in its lifting.
- It is enclosed on all the three faces and at ends to form a water tight vessel.

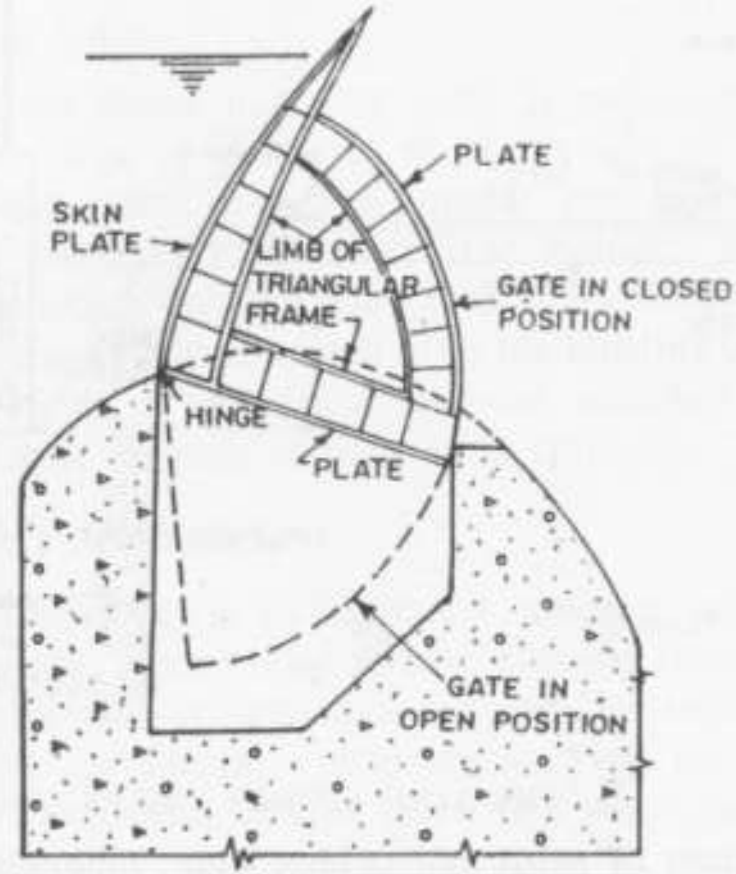
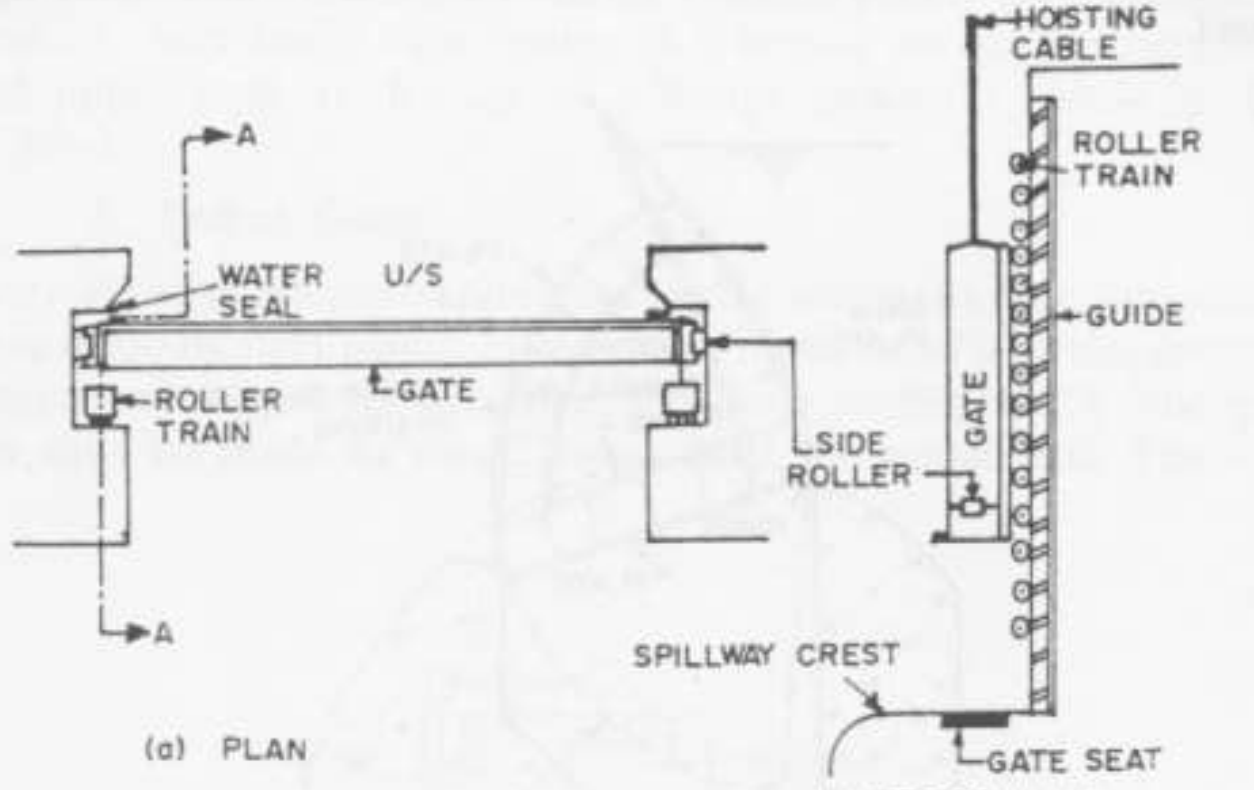


FIG. 11.30. U.S.B.R. DRUM GATE.

4. Vertical lift gates :

- A vertical gate consists of a frame work of skin plate at the u/s face along with beams and girder suitably placed.
- These are rectangular in shape and move vertically in their own plane. Because of hydrostatic pressure high frictional forces are developed in the guides.
- These frictional forces can be reduced by placing cylindrical rollers between the bearing surfaces of the gate and guides.



(a) PLAN

(b) SECTION A-A

- There are several types of vertical lift gates:
  - Sliding gates
  - Fixed wheel gates
  - stoney gates
  - In the case of sliding gates the frame of the gate bears directly on the d/s guide members , the seal being formed in contact between the two.
  - In the Fixed wheel type the gates have fixed wheels mounted on each side to carry the water load to a vertical track on d/s of gate groove.
  - The gate is hoisted by horizontal lifting beam , the ends of which travel in the gate guides.

- The moving train of rollers is substituted for fixed wheel. These rollers are independent of gates and guides , thus eliminating axle friction.

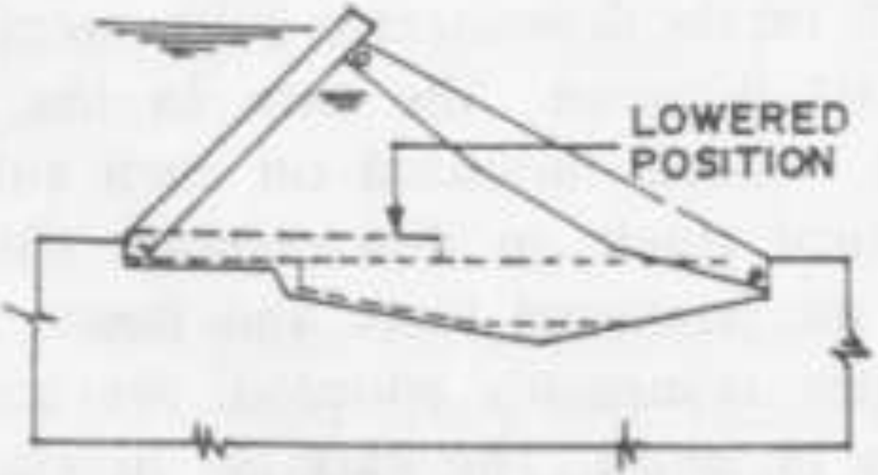
- The rollers transmit the entire load from a bearing strip on the gate to a roller path on the guide.

5. Bear trap gates :

- It consists of two leaves of either timber or steel hinged to the dam. These gates are lifted up by a admitting water to the space under the leaves.

- The downward or d/s leaf is often made hollow so that its buoyancy aids in the lifting operation.

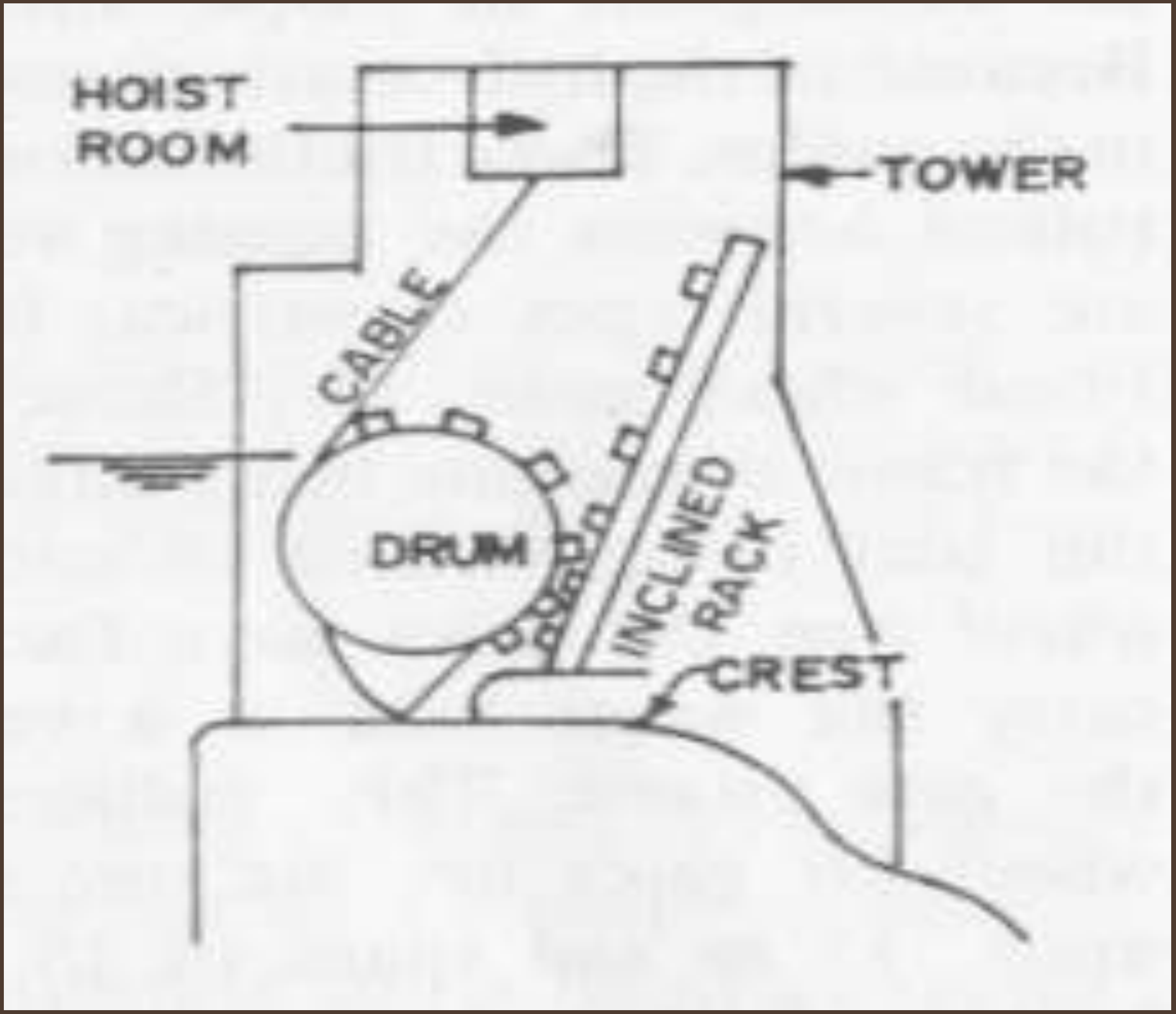
- These gates are often used for low navigation dams



(a) BEAR TRAP GATE

6 . Rolling gates :

- It consists of steel cylinder as large in diameter as the height of opening and spanning between piers.
- A heavy annular rim having gear teeth at its periphery encircles each end of the cylinder. Each pier has an inclined rack by means of pull from the hoisting cable operated from the hoist room.
- A cylindrical segment , attached to the lower portion of the gate , makes contact with spillway.


HOIST
ROOM
TOWER
CABLE
DRUM
INCLINED
RACK
CREST