Spillway

Types of spillway

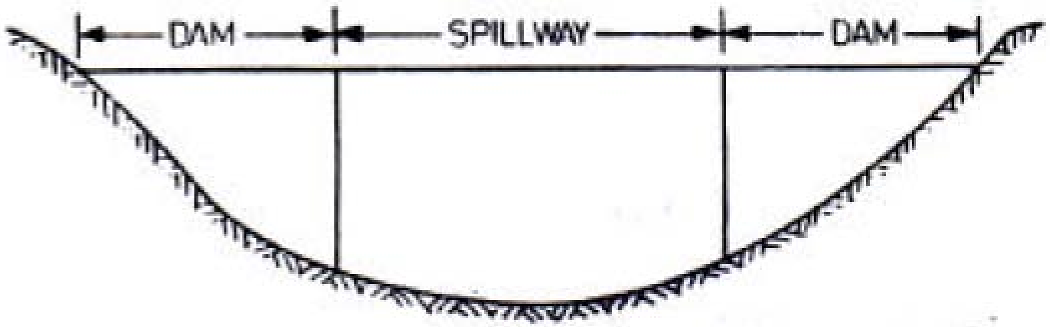
Design Flood(hydrologic design)

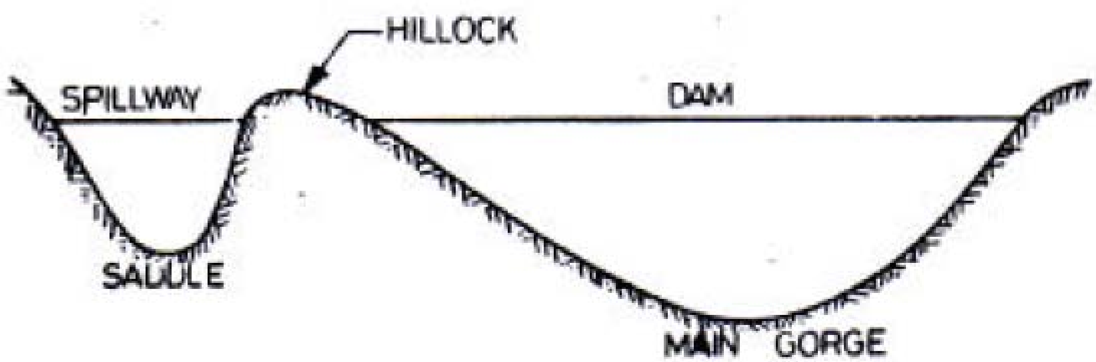
Hydraulic Design

Spillway Crest Gates

Spillway

- A spillway is a structure constructed ***at or near the dam site*** to ***dispose of surplus water*** from the reservoir to the channel downstream.





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- The essential requirements of a spillway
  - It must have ***adequate discharge capacity***
  - It must be ***hydraulically and structurally safe***
  - The surface of the spillway must be ***erosion resistant***
  - The spillway must be so located that the spillway discharge ***does not erode*** or undermine the ***downstream toe of the dam***
  - It should be provided with some device for the ***dissipation of excess energy***
  - The spillway discharge should not exceed the ***safe discharge capacity of the downstream channel*** to avoid its flooding.

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- **Types of Spillway**

  – The spillways can be classified into different types based on the various criteria

A. Classification based on purpose

– Main (or service) spillway

– Auxiliary spillway

– Emergency spillway

B. Classification based on control

– Controlled (or gated) spillway

– Uncontrolled (or ungated) spillway

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C. Classification based on prominent feature

- Free overfall (or straight drop) spillway
- Overflow or Ogee spillway
- Chute (or open channel or trough) spillway
- Side-channel spillway
- Shaft (or morning glory) spillway
- Siphon spillway
- Conduit (or tunnel) spillway
- Cascade spillway

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- **Topography and Geology**

✓ Topography and geology, with selected subsurface explorations, have greater influence on the ***location and type of spillway*** than any other factors.

  – ***Ogee spillway :*** Most commonly used as the integral overflow section of a concrete dam
  – ***Chute spillway:*** Adopted in a site where a suitable foundation with moderate depth of excavation is available where ***topography of the site*** permits the use of ***a relatively short channel***
  – ***Side channel spillway:*** Suitable for ***earth or rock-fill dams*** in ***narrow canyons*** and for other situations where direct overflow is not permissible

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- ***Shaft spillway/Tunnel spillway :*** Used advantageously at dam sites in narrow canyons where abutments rise steeply

- ***Siphon spillway:*** Used when there is a desire for an automatic operation without mechanical parts and the discharge to be passed is small

- ***Free over-fall spillway:*** Suitable for arch

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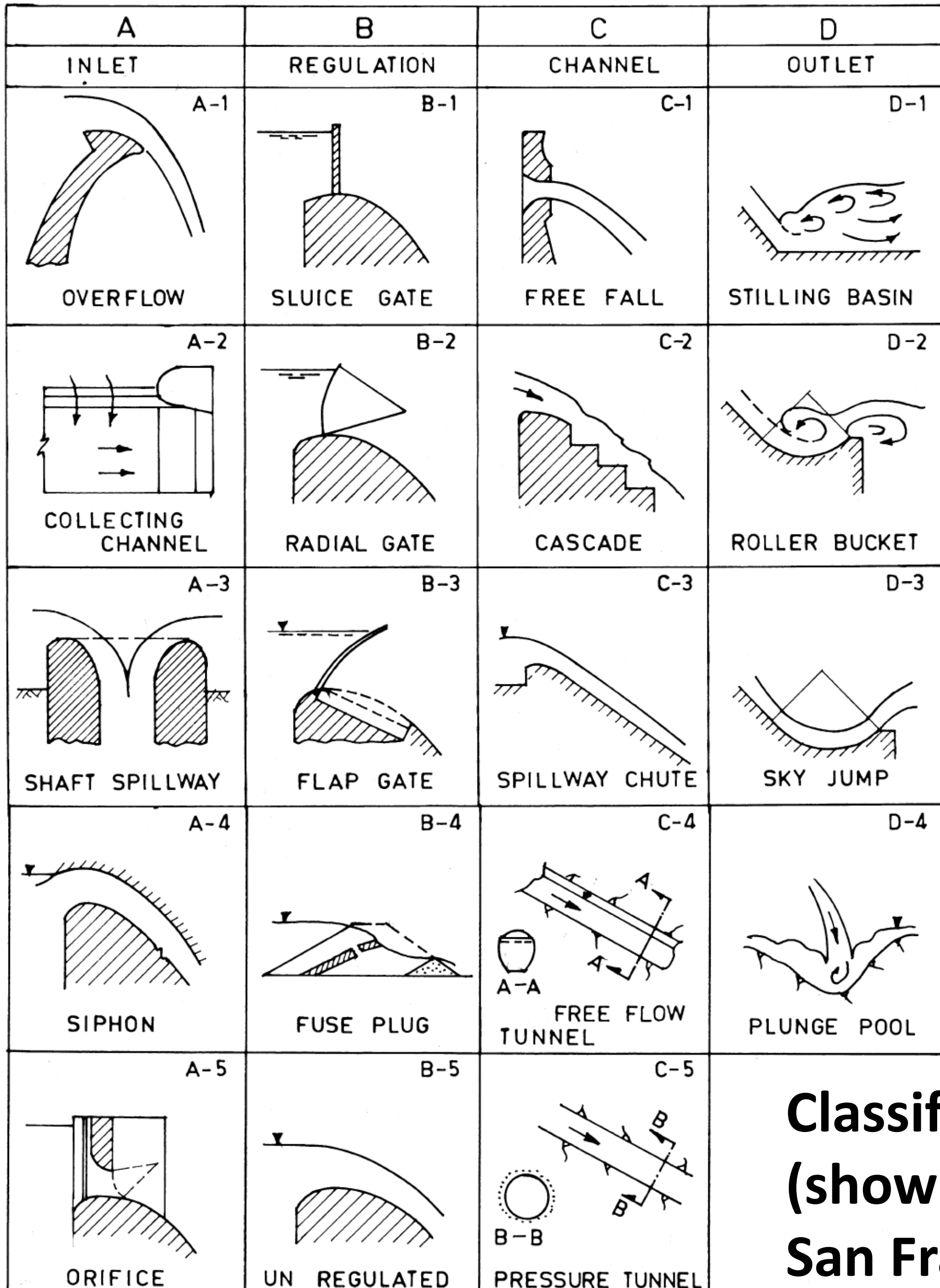

Classification of Spillway (shown in Vischer et al, San Francisco,1988).

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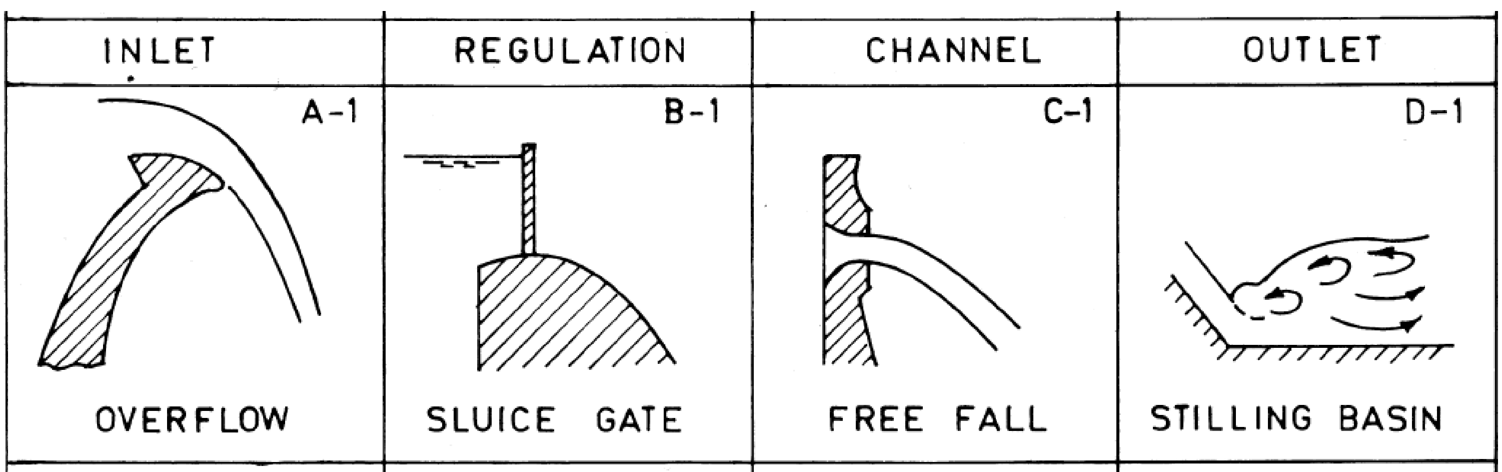
- **Component Parts of a Spillway**

- A spillway generally has the following component parts
    - Entrance channel
    - Control structure
    - Discharge channel (or waterway)
    - Terminal structure (energy dissipator)
    - Exit channel



Hydrologic Consideration

- ✓ The required spillway capacity is usually determined by ***flood routing which is equal to the maximum outflow rate***

- ✓ The following data are required for the flood routing

    - Inflow flood hydrograph

    - Reservoir-capacity curve(indicating the **reservoir storage** at different **reservoir elevations**)

    - Outflow discharge curve(Spillway rating curve)- indicating the **rate of outflow** through spillways at different **reservoir elevations.**

Economic Consideration

- The analysis seeks to identify an ***optimum combined cost of the dam-spillway combination***.

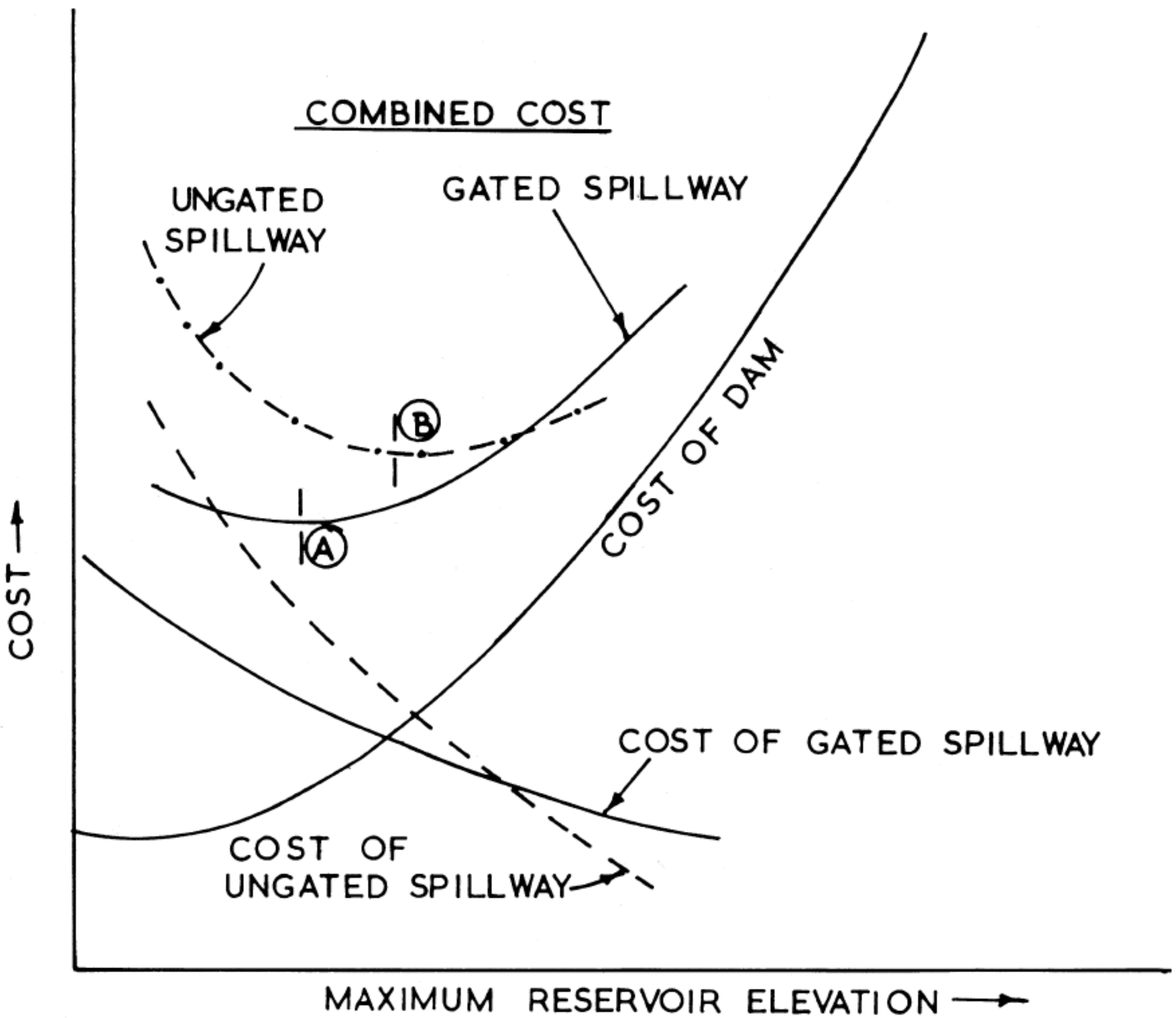


Figure- Comparative costs: spillway-dam combinations.

A:Minimum cost: gated spillway,

B: Minimum cost: ungated spillway (shown in USBR, United States,1960).

Spillway-Hydraulic Design

- **Free Overfall Spillway**

- A free overfall spillway (or a straight drop spillway) is a type of spillway in which the control structure consists of :
  - **a low-height, narrow-crested weir** and the **downstream face is vertical or nearly vertical** so that the water falls freely more or less vertical

- The overflowing water may discharge as a ***free nappe***, as in the case of a ***sharp-crested weir***, or it may be supported along the narrow section of the crest

- The water flowing over the crest drops as a ***free jet clear of the downstream face*** of the ***spillway-suction pressure should be avoided***

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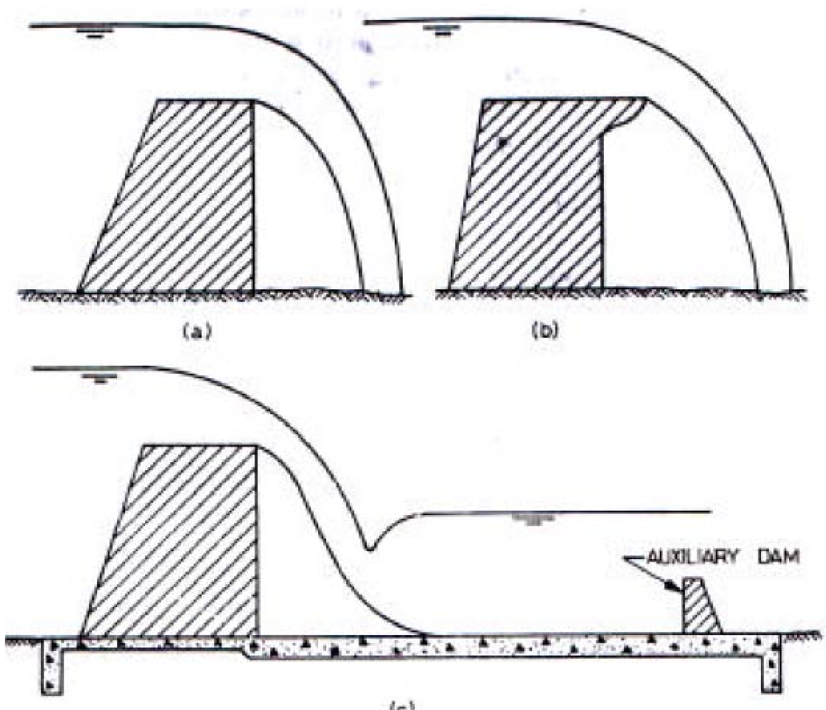
- In order to ***protect the stream bed*** from scouring an ***artificial pool*** is usually constructed by ***excavating a basin in the bed*** and then covering it with a concrete apron-(***Plunge pool construction)***

- If the ***tail water depth is adequate***, a hydraulic jump may form after the jet falls from the crest, which can be used for ***the dissipation of energy***. However, a ***long flat apron*** would be required to contain the hydraulic jump



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- **Ogee (overflow) spillway**

- The ogee or overflow spillway is the most common type of spillway. It has a ***control weir that is ogee or S-shaped***

- The structure divides naturally into three zones: ***the crest***, the ***rear slope***, and ***the toe***

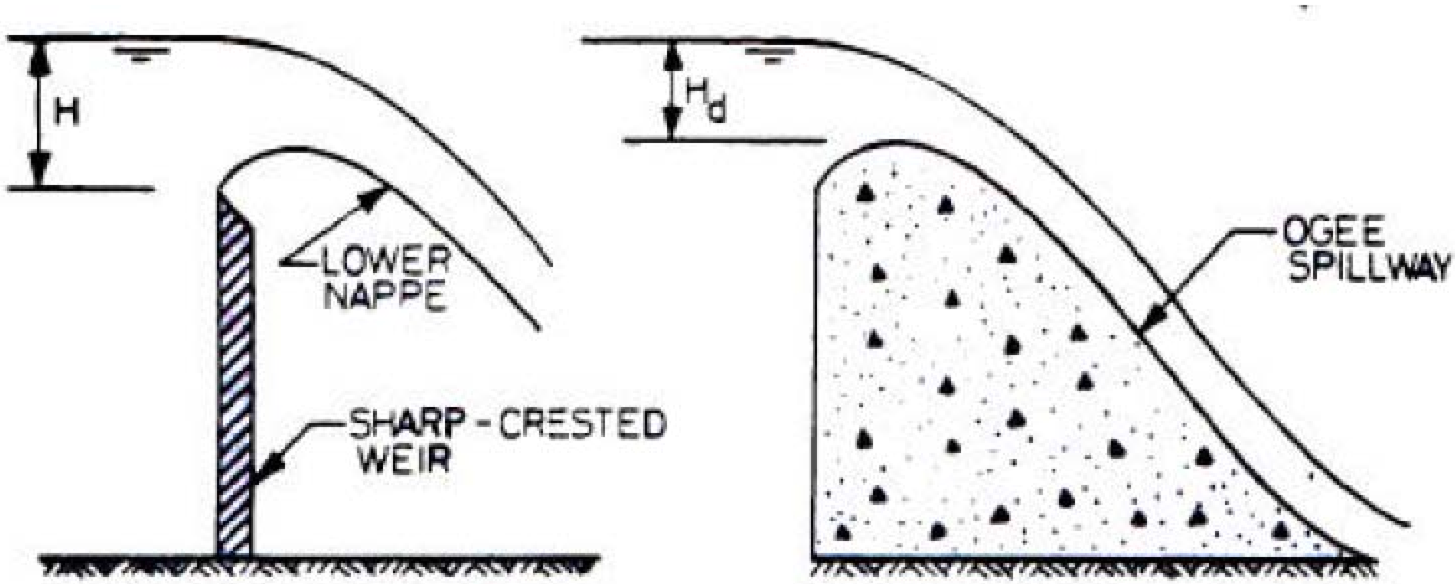
- The ***shape of the crest of the ogee spillway*** is generally made to conform closely to the ***profile of the lower surface of nappe*** (sheet of water) of a ventilated jet issuing from a ***sharp-crested weir***

- An ogee-shaped spillway is an ***improvement upon the free overfall*** spillway(the jet will be guided to glide on a channel)

Contd

- The ***nappe-shaped profile is an ideal profile*** because at the ***design head***, the water flowing over the crest of the spillway always *remains in contact with the surface of the spillway* as it glides over it

- No negative pressure will develop on the spillway surface at design head



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- **Shape of the crest of the overflow spillway(spillway crest profile)**

- Normally the crest is shaped to conform to the ***lower surface of the nappe*** from a fully aerated sharp-crested weir

- The shape of the ogee-shaped spillway depends upon

  - Head over the crest,
  - Height of the spillway above the stream bed or the bed of the entrance channel
  - The inclination of the upstream face of the spillway

- Several standard shapes of the crests of overflow spillways are developed by U.S.B.R. at Waterways Experiment Station(WES)-Shapes are called ***WES standard spillway shapes***

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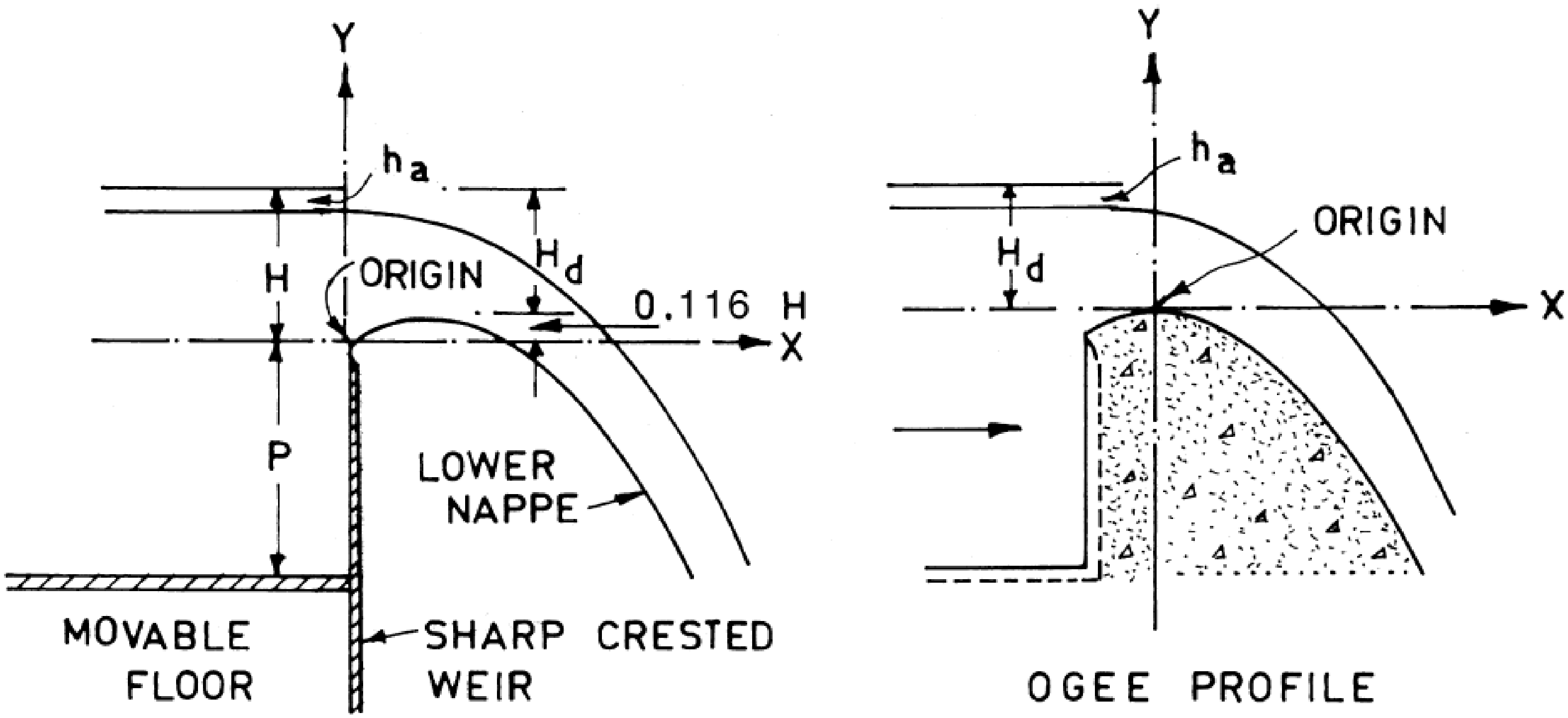
- ***Early crest shapes*** were usually based on a ***simple parabola designed*** to the ***fit the trajectory of the falling nappe*** in the general form

$$y/H = A\,(x/H)^2 + B\,(x/H) + C + D$$



Principle of derivation of crest profile

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- The profiles are defined as they relate to the coordinate axes at the ***apex of the crest***.

- The ***portion upstream of the origin is defined as a compound circular*** arc. The portion downstream is defined by the equation

$$(y/H_d) = -K\,(x/H_d)^n$$ Equation for the D/S profile

where

Hd Design head

K & n are constants whose values depend on the upstream inclination and velocity of approach.

•The shape ***downstream of the crest axis*** further symbolized by the equation for WES standard spillway shapes

$$X^n = K\,H_d^{\,n-1}\,Y$$

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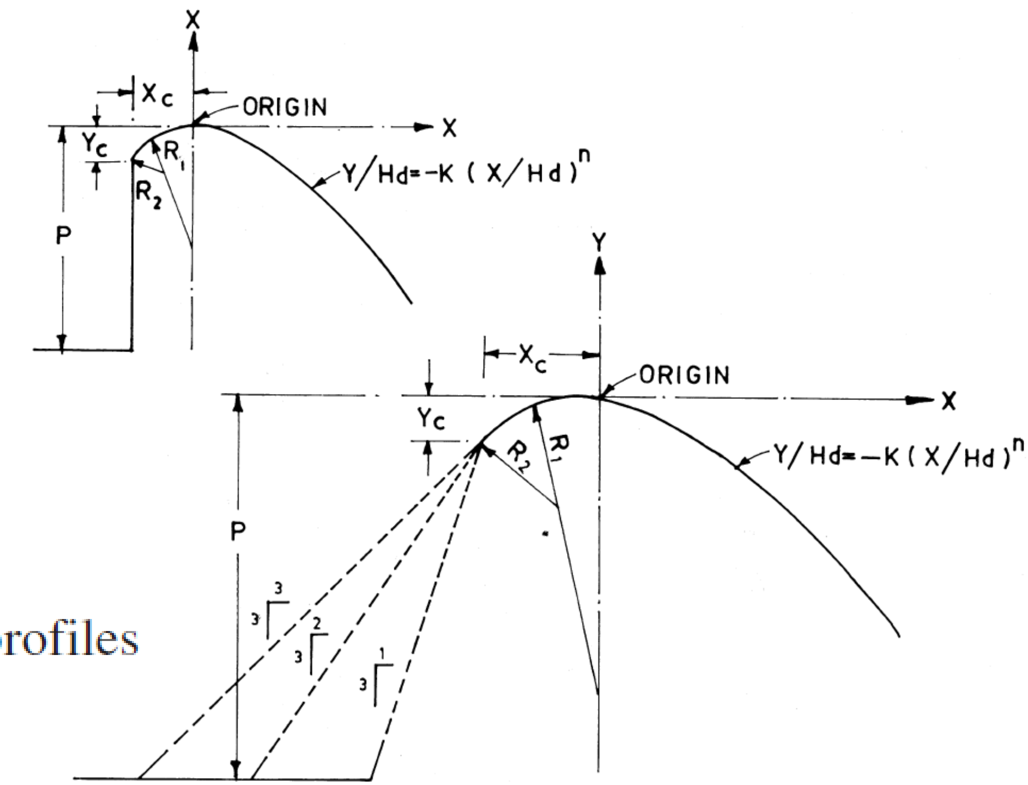
$$X^n = K H_d^{n-1} Y$$

where

- X and Y are coordinates of crest profile with origin at the highest point of the crest.
- Hd design head including velocity head of the approach flow.
- K and n are parameters depending on the slope of the upstream face.



Typical USBR crest profiles

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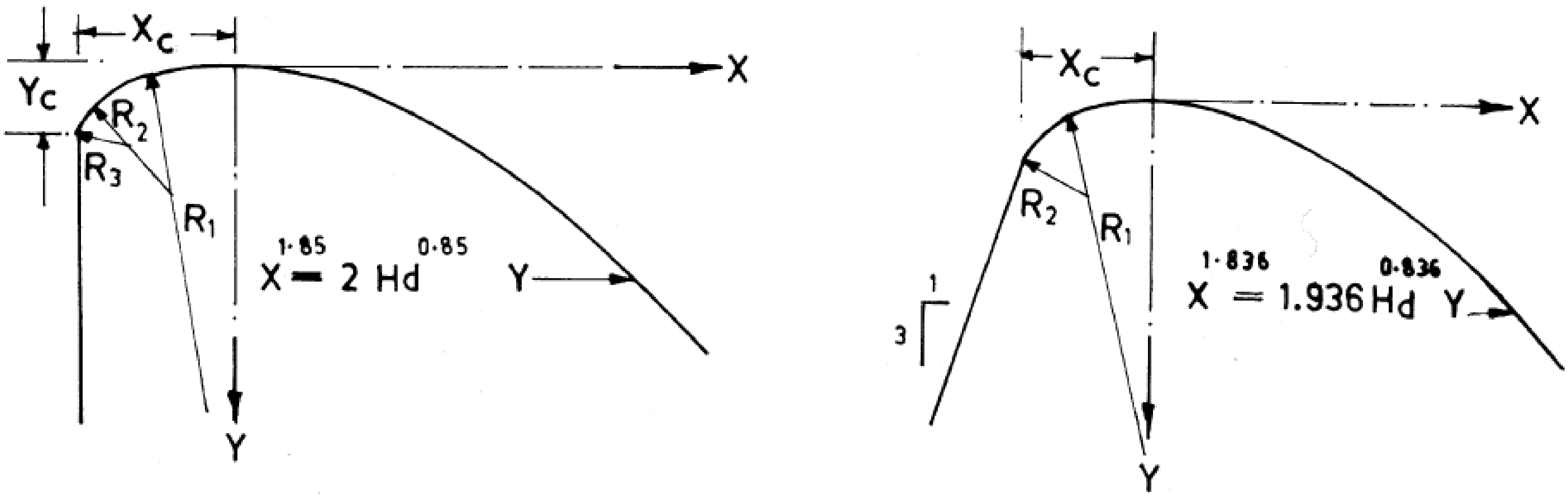
- **Typical WES standard shapes**



$X_c = 0{\cdot}2818\ H_d$; $Y_c = 0{\cdot}136\ H_d$.
$R_1 = 0{\cdot}5\ H_d$; $R_2 = 0{\cdot}2\ H_d$; $R_3 = 0{\cdot}04\ H_d$.

A– VERTICAL UPSTREAM FACE.

$X_c = 0{\cdot}257\ H_d$.
$R_1 = 0{\cdot}68\ H_d$; $R_2 = 0{\cdot}21\ H_d$.

B – 3–ON–1 UPSTREAM FACE.

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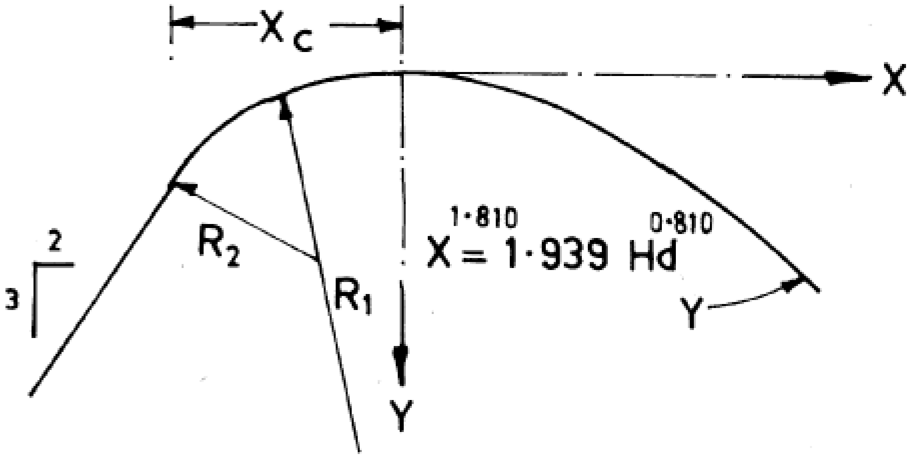
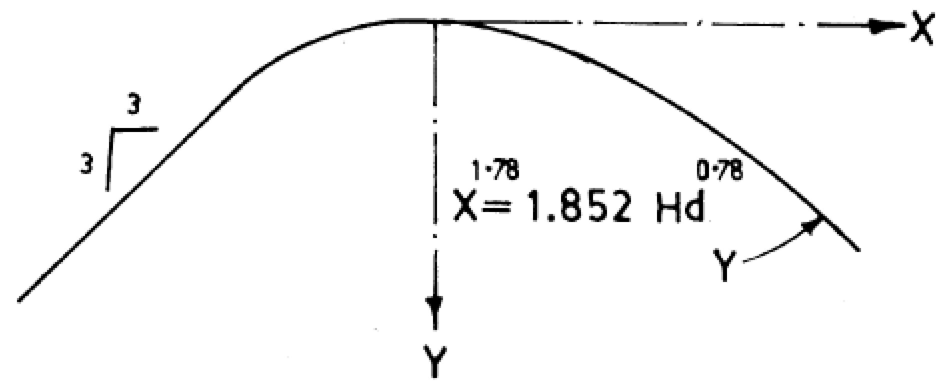


$X_c = 0{\cdot}214\ H_d$

$R_1 = 0{\cdot}48\ H_d$; $R_2 = 0{\cdot}22\ H_d$

C– 3-ON-2 UPSTREAM FACE.



D– 3-ON-3 UPSTREAM FACE

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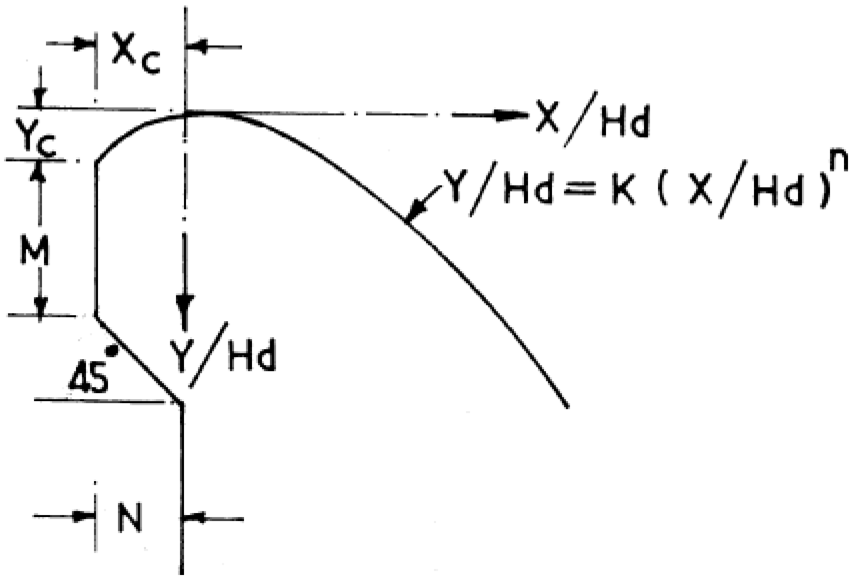
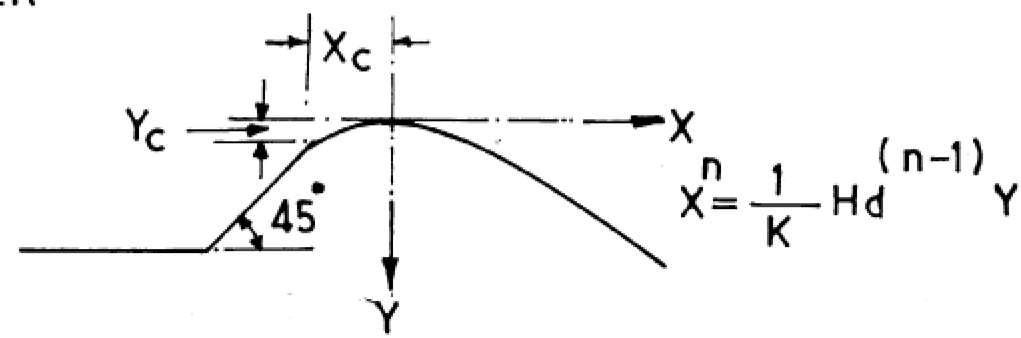


E– CREST WITH OFFSET AND RISER



F – LOW OGEE CREST

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Case I	Low Ogee Crests: $P=5m$, $H_d=10m$, $P/H_d=0.5$											
U/S Face	USBR				WES (Original)				WES (Elliptical)			
	X_c	Y_c	K	n	X_c	Y_c	K	n	X_c	Y_c	K	n
Vertical	2.595	0.968	0.511	1.835		not defined			2.683	1.572	0.488	1.85
1:3	2.465	0.836	0.511	1.815		not defined			2.633	1.271	0.488	1.85
2:3	2.282	0.628	0.51	1.764		not defined			2.498	1.0	0.488	1.85
3:3	2.139	0.463	0.51	1.748	2.135	0.445	0.524	1.748	2.314	0.777	0.488	1.85
Case II	High Overflow Spillways: $P=40m$, $Hd=10m$, $P/Hd=4$											
Vertical	2.817	1.242	0.5	1.868	2.818	1.36	0.5	1.85	2.800	1.64	0.5	1.85
1:3	2.474	0.91	0.5	1.848	2.57	0.875	0.516	1.836	2.748	1.326	0.5	1.85
2:3	2.161	0.667	0.53	1.795	2.14	0.75	0.516	1.810	2.608	1.043	0.5	1.85
3:3	2.019	0.454	0.54	1.776	2.0	0.454	0.54	1.776	2.416	0.811	0.5	1.85

Comparison of Spillway Crest Profiles

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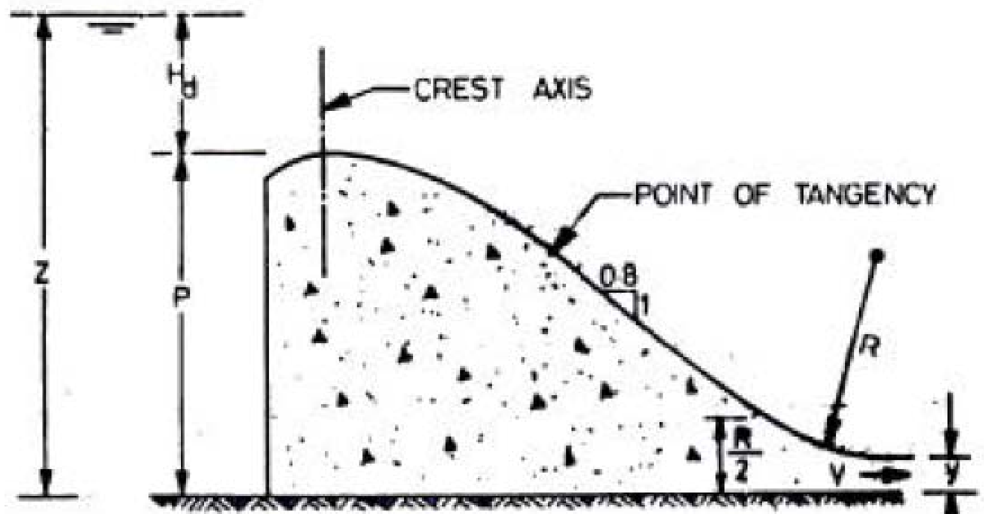
- The ***curved profile of the crest section*** is continued till it meets ***tangentially the straight sloping surface*** of the downstream face of the overflow dam

- At the ***end of the sloping surface of the spillway***, a curved circular surface, called ***bucket**, is* provided to create a ***smooth transition of flow from the spillway*** surface to the river ***downstream of the outlet*** channel



•The **bucket** is also useful for the **dissipation of energy** and prevention of scour

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- The **radius R of the bucket** can be approximately obtained from the relation

$$R = (10)^a$$

$$a = (V + 6.4H_d + 4.88)/(3.6H_d + 19.52)$$

Where
V: is the velocity of flow at the toe of spillway (m/s)
Hd: is the design head

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•The velocity of flow *V may be approximately determined from the relation*

$$V = \sqrt{2g(Z + H_a - y)}$$

Where

Z: is the total fall from the upstream water level to the floor level at the d/s toe,

Ha: is the head due to velocity of approach,
y :is the depth of flow at toe and
g: is the acceleration due to gravity.

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•Generally, a radius of about one-fourth of the spillway height is found to be satisfactory.

$$R = P / 4$$

where

P: is the height of spillway crest above the bed

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▪ Upstream profile of the crest

(a) Vertical upstream face

- The ***upstream profile of the crest*** should be ***tangential to the vertical face*** and should have zero slope at the crest axis

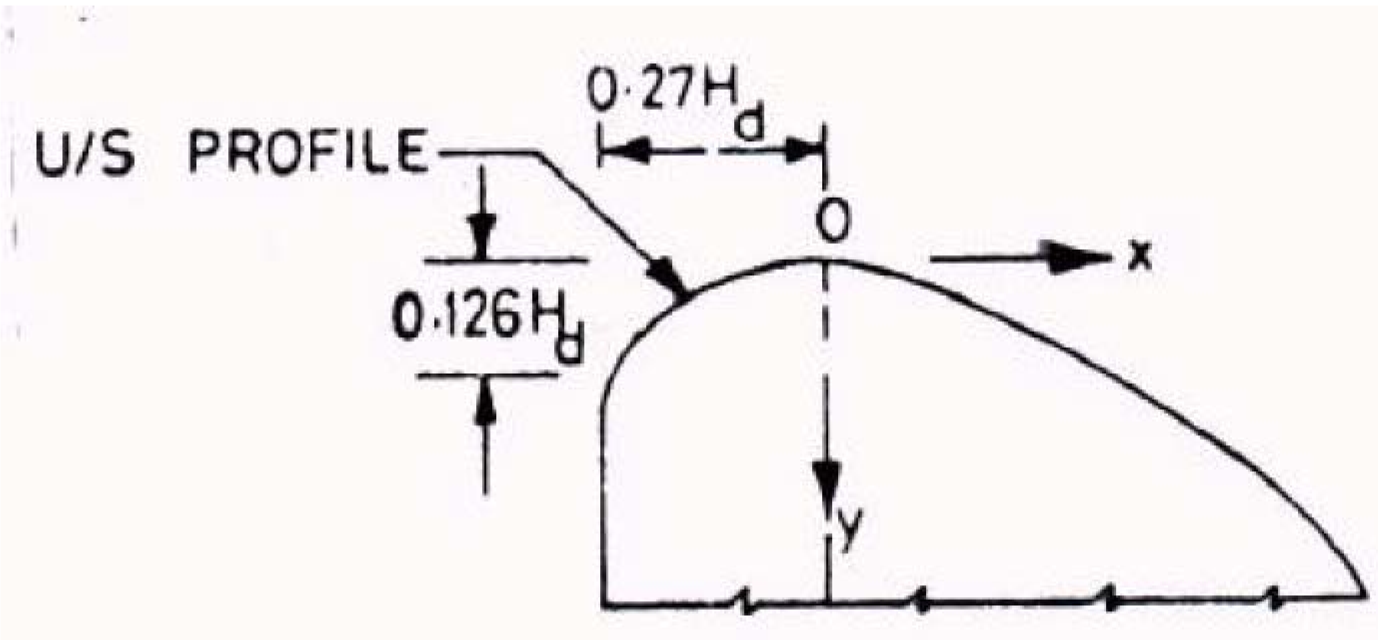
- The upstream profile should conform to the following equation with usual notations

$$y = \frac{0.724(x + 0.270H_d)^{1.85}}{(H_d)^{0.85}} + 0.126H_d - 0.4315(H_d)^{0.375}(x + 0.270H_d)^{0.625}$$

- It may be noted that the values of x are negative according to the chosen axes of coordinates

Contd

- It may be noted that the values of *x are negative according to the chosen axes of coordinates*
- The ***maximum absolute value of x is 0.270 Hd****, for which the value of y is equal to 0126 Hd when the* ***u/s face is vertical***



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b) Sloping upstream face

- The ***coordinates of the upstream profile*** in the case of ***sloping upstream face*** can be determined from Table
- Slopes of 1:3, 2:3 and 3:3(H:V). For intermediate slopes the values may be interpolated

Values of *y/Hd for the u/s profile*

x/H_d	*Slope 1:3*	*Slope 2:3*	*Slope 3:3*	*Vertical*
0.000	0.0000	0.0000	0.0000	0.0000
-0.020	0.0004	0.0004	0.0004	0.0004
-0.040	0.0016	0.0016	0.0016	0.0016
-0.060	0.0037	0.0036	0.0036	0.0038
-0.080	0.0067	0.0066	0.0065	0.0068
-0.100	0.0106	0.0104	0.0103	0.0108
-0.120	0.0156	0.0153	0.0150	0.0158
-0.160	0.0291	0.0283	0.0275	0.0296
-0.170	0.0330	0.0365	0.0313	0.0339
-0.180	0.0376	-	0.0354	0.0386
-0.190	0.0425	0.0412	0.0399	0.0437
-0.200	0.0480	0.0554	0.0450	0.0494
-0.210	0.0550	-	-	0.0556
-0.220	0.0650	-	-	0.0624
-0.230	0.0800	-	-	0.0701
-0.240	-	-	-	0.0787
-0.250	-	-	-	0.0889
-0.260	-	-	-	0.1016
-0.270	-	-	-	0.1260

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- **Discharge Characteristics**

- Choosing as an example the ***rectangular weir without side contraction***, the basic equation of the discharge is as follows

$$Q = \frac{2}{3}\sqrt{2g}\, b\left[\left(h_u + \frac{V_a^2}{2g}\right)^{3/2} \right]$$

where

Q	**= discharge in m^3/s.**
g	**= gravitational acceleration m/s^2**
h_u	**= water depth above the crest of weir level in m.**
b	**= length of weir crest in m.**
V_a	**= approach velocity in m/s.**

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- No allowance was made for ***the local losses of energy***, therefore, the result need to be multiplied by an ***experimental factor***, which is smaller than the unity and is generally **called the discharge coefficient (Cd),**

- **For smaller velocities the value of** $\left(\frac{V_a^2}{2g}\right)^{3/2}$ **can be neglected**

$$Q = \frac{2}{3} C_d \sqrt{2g}\, b\, h_u^{3/2}$$

The value of $\frac{2}{3} C_d \sqrt{2g}$ = C is sometimes called the overfall coefficient, and the expression is written as:

$Q = C\, b\, h_u^{3/2}$.

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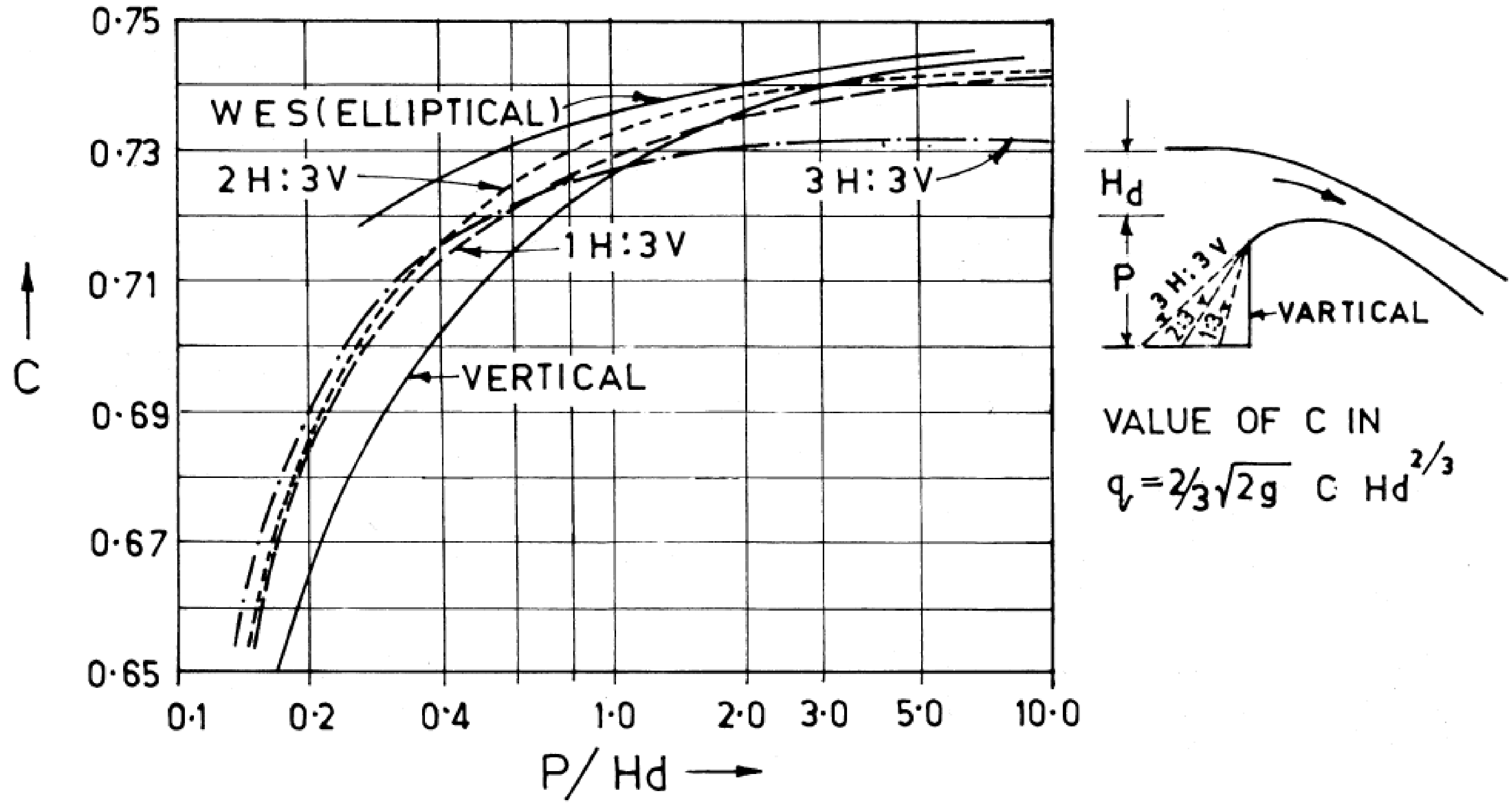
- It is important to mention, that **while Cd is a dimension less value**, the **value of C always has a dimension**, and is generally given in units of m ½ /s



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- The discharge characteristics of the standard spillway can also be derived from the characteristics of the sharp crested weir

$$Q = CL_e\left(H + H_v\right)^{3/2}$$

Where:

Q- discharge
C- Coefficient which depends on u/s and d/s flow condition
L_e- effective crest length
H- head on the crest
H_v- approach velocity head

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- Where ***crest priers and abutments*** are shaped to cause side contractions of the overflow, ***the effective length, L_e,*** will be less than the *net length of the crest*

$$L_e = L' - 2(NK_p + K_a)(H + H_V)$$

Where: *L'*- net length of the crest
N- Number of piers
K_p- piers contraction coefficient
K_a- abutment contraction coefficient

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Pier condition	**K_p**
Square nosed pier with corners rounded on a radius equal to about 0.1 of the pier thickness	0.02
Rounded nosed piers	0.01
Pointed nose piers	0

Abutment condition	**Ka**
Square abutments with head wall at 90^o to direction of flow	0.20
Rounded abutments with head wall at 90^o to the direction flow	0.10
Rounded abutments with head wall placed at not more than 45^o to the direction of flow	0

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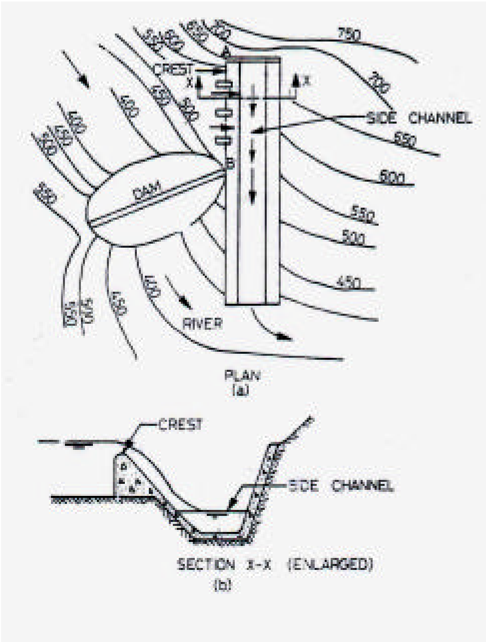
- **Side channel spillway**

- The ***crest of the control weir*** is placed along the side of the discharge channel. The ***crest is approximately parallel*** to the ***side channel*** at the entrance

- The side channel spillway is usually ***constructed in a narrow canyon*** where ***sufficient space is not available*** for an overflow spillway.



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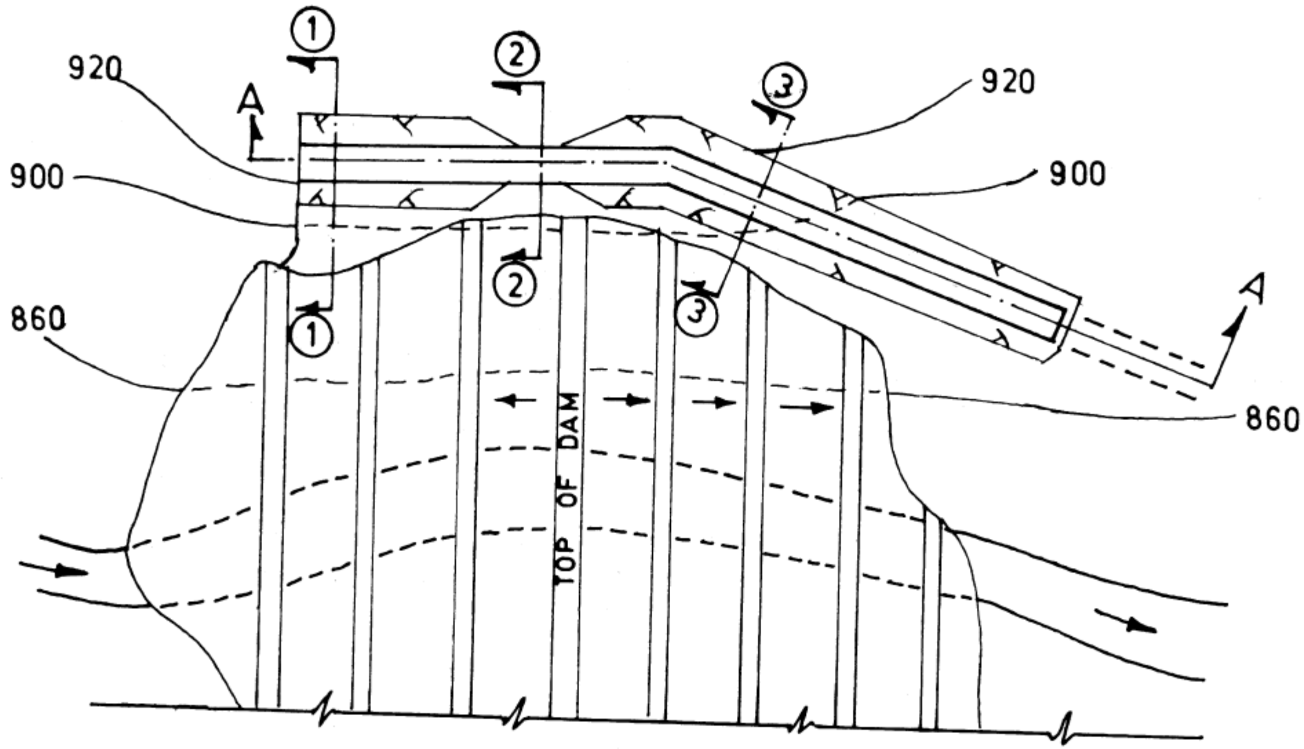

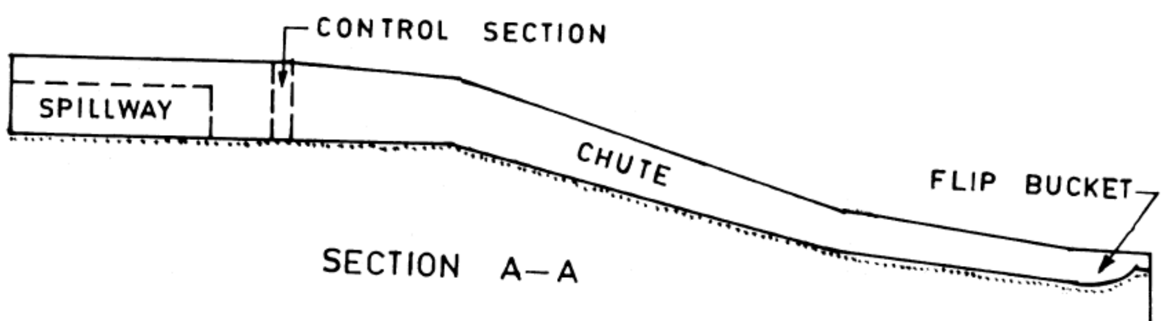

SECTION A—A

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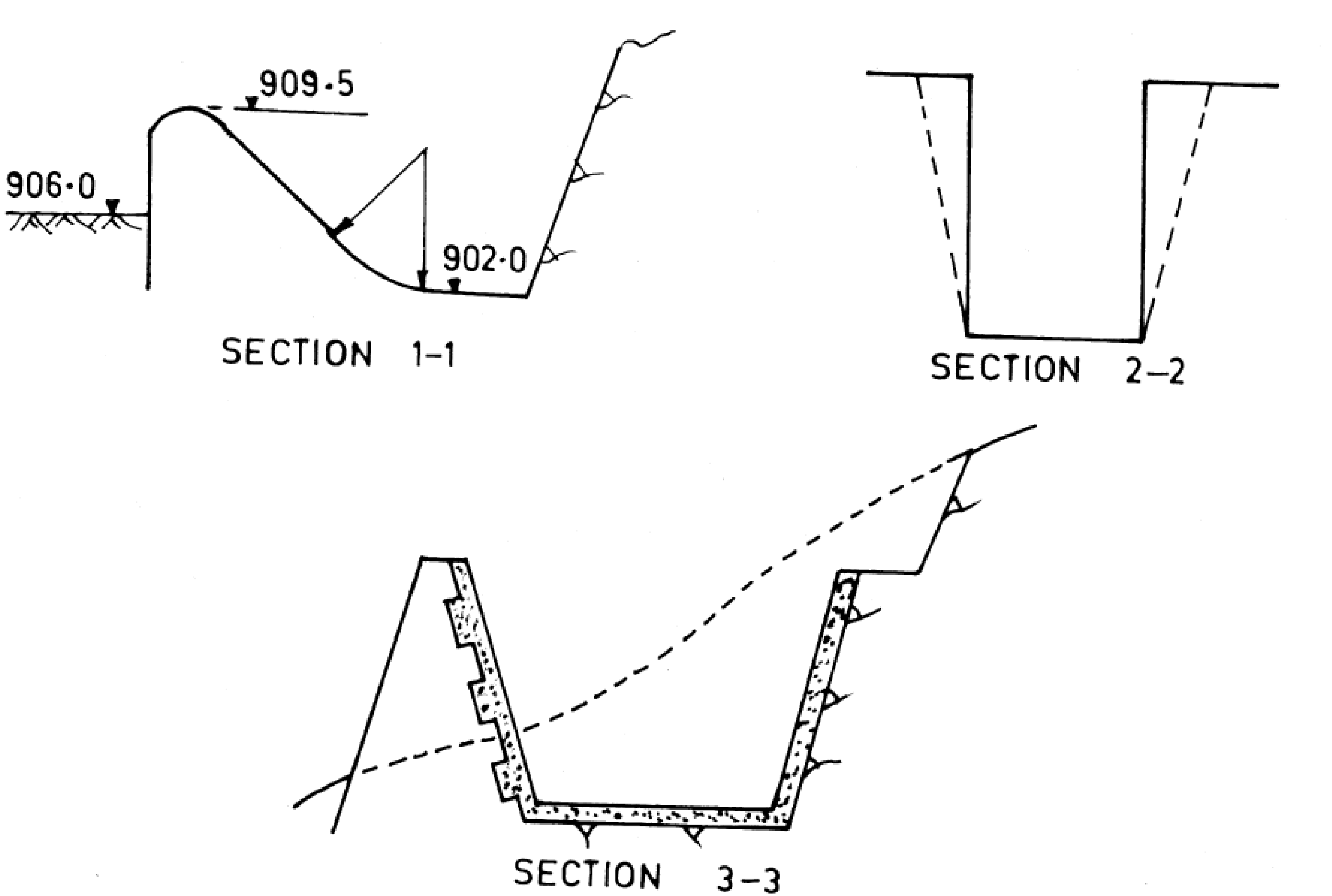

Typical layout of a side channel spillway

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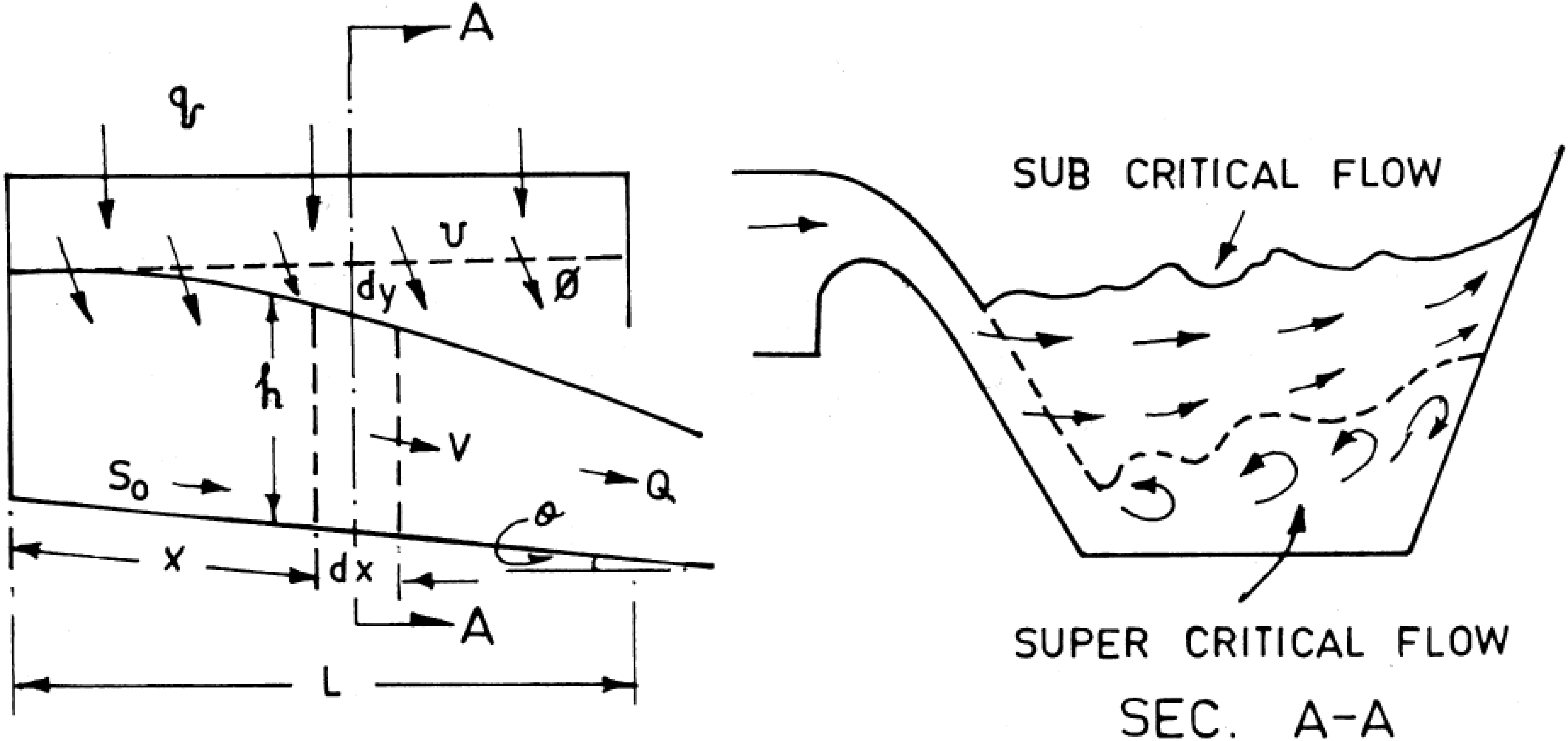
✓ **Analysis of flow in a trough**



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•Referring the figure the ***differential equation of the flow profile*** ignoring channel friction is given by

$$\frac{dy}{dx} = \frac{1}{g}\left(V\frac{dV}{dx} + \frac{V^2}{x}\right)..$$

where

dy = Fall in the water surface along the channel length dx
V = Average velocity at the cross-section under consideration
x = Distance measured along the channel from upstream end

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✓Since the ***discharge increases linearly with the distance***, the ***velocity can also be assumed to vary with x*** in some arbitrary manner

$$V = a\,x^n$$

from which

$$\frac{dV}{dx} = nax^{n-1} = \frac{nV}{x}$$

$$\frac{dy}{dx} = \frac{1}{g}\left(V\frac{dV}{dx} + \frac{V^2}{x}\right)..$$

$$y = \frac{a^2(n+1)}{g(2n)}x^{2n}$$

$$y = \left(\frac{n+1}{n}\right)\left(\frac{V^2}{2g}\right)$$

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- The constants ***a and n are arbitrary*** and may be selected in such a way as to ***produce a profile that will most economically*** conform to the site conditions.

- It can be seen that when n = 1/2, the profile will be linear, concave downward for n >1/2 and concave upward for n <1/2

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•A procedure without imposing any relationship between the ***average velocity V and distance x*** has been suggested by **USBR (1977),** as

$$\Delta y = \frac{Q_1}{g}\frac{(v_1 + v_2)}{(Q_1 + Q_2)}\left[(v_2 - v_1) + \frac{v_2(Q_2 - Q_1)}{Q_1}\right]$$

➢which can be applied to calculate the ***water surface profile in a step-by-step manner***.

➢Q1 and V1 and Q2 and V2 are the ***discharge and velocity*** at the beginning and end of a small distance Δx.

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- The ***effect of channel friction and uneven velocity distribution*** can be introduced considering that A= Q/V (at respective locations) $h_f = S_f \;\; .dx$ and $x = \; S_0.dx$

$$\frac{dy}{dx} = \frac{S_0 - S_f - 2\alpha Qq / gA^2}{1 - \alpha Q^2 / gA^2 D} \quad \Leftrightarrow \quad \frac{dy}{dx} = \frac{S_0 - S_f - 2Qq / gA^2}{1 - F^2}$$

$$F^2 = Q^2B/gA^2$$

where

$S_0 =$ Bed slope

$S_f =$ Friction slope

$\alpha =$ Energy correction coefficient

$A =$ Cross-sectional area

$D =$ Hydraulic depth A/B, where $B =$ water surface width

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Location of critical flow section X_c in an uncontrolled channel is given by

$$X_c = \frac{8q^2}{g\,B^2\left(S_0 - \frac{gP}{C^2 B}\right)}$$

where

P = Wetted perimeter

C = Chezy coefficient

- This can be solved by a trial method, in conjunction with the relationship for the critical depth, for a given channel section

- If **Xc < L**, the total length of the channel, it would mean that the ***flow upstream of the critical flow section would be sub-critical*** and downstream of it will be supercritical

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- **Siphon spillway**

- A siphon spillways operates on the principle of siphonic action. There are basically two types of siphon spillways
  - Hood or Saddle siphon (as shown in Figure 1)
  - Volute siphon(as shown in Figure 2)

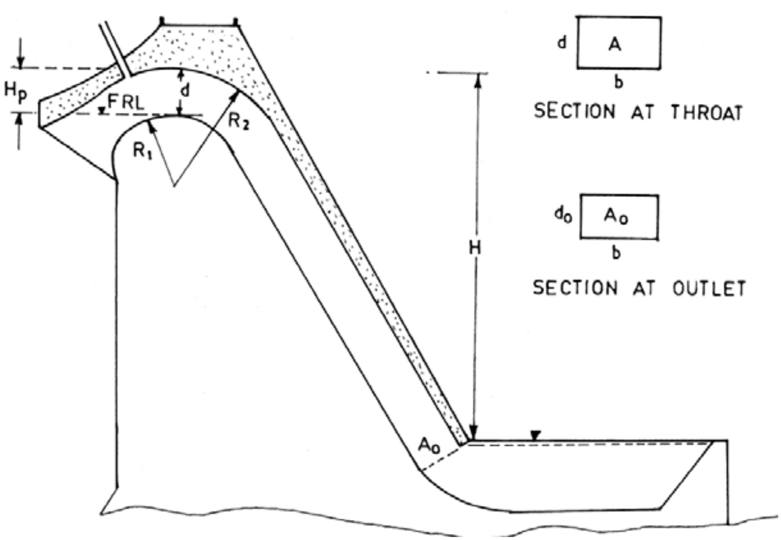


Figure 1 Typical saddle siphon

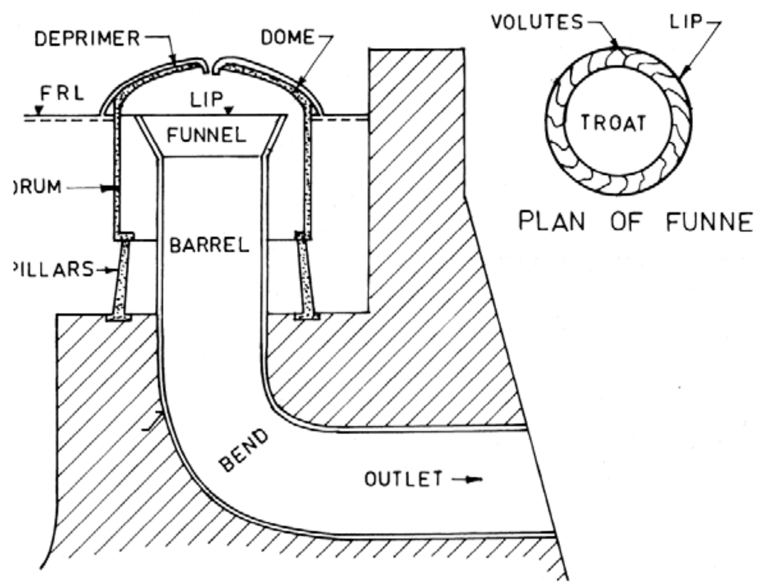


Figure 2 Typical siphon volute

Contd

- All necessary precautions must be taken to ensure that ***the vacuum is maintained*** and that it does not become so excessive as to cause ***cavitation***

- The ***maximum negative pressure*** at the spillway crest is theoretically **10 m of water** at sea level

- Allowing for the **vapor pressure of water**, **loss due to turbulence**, etc., the **maximum net effective head** is rarely more than about **7.5 m**

This corresponds to a velocity of $\sqrt{2 \times 9.81 \times 7.5} \approx 12 m/s.$

⬇

Which means that the initial velocity in any siphon cannot exceed about 12 m/s at the inlet

Contd

Hydraulic Design Consideration

- The following characteristics are relevant in the hydraulic design of siphon spillways:
  - Discharging capacity
  - Priming depth
  - Regulating flow
  - Effect of waves in the reservoir
  - Cavitation
  - Vibration

Contd

- **Discharging Capacity**

- The flow in the throat section of a saddle siphon can be idealised as a **free vortex**, so that

$$R = V_1 R_1 = V_2 R_2 = \text{constant}$$

where

V = Velocity of flow

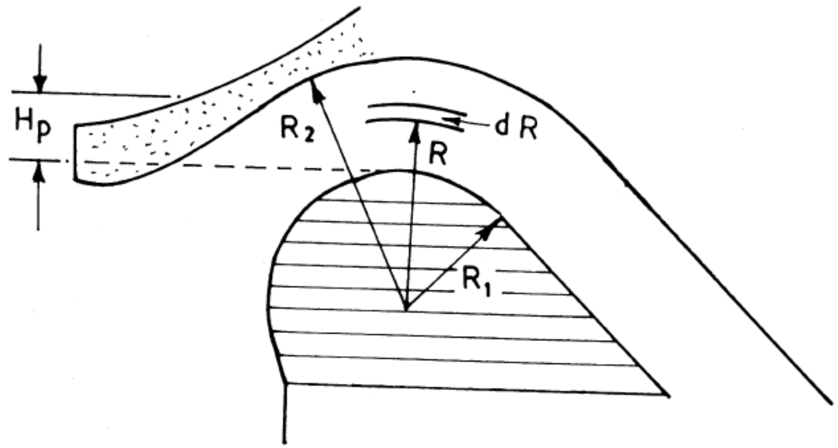
R = Radius

Subscript 1 refers to quantities at the crest and subscript 2 refers to the crown of the siphon.

$$V = V_1 \frac{R_1}{R}$$

Contd

Referring to Figure 1, discharge through an elemental area dA formed by a strip dR and throat width b is



$$Q_A = V_1 \frac{R_1}{R} dA = V_1 \frac{R_1}{R} b\, dR$$

and hence

$$Q = \int_{R_1}^{R_2} V_1 \frac{R_1}{R} b\, dR = V_1 R_1 b \int_{R_1}^{R_2} \frac{dR}{R} = V_1 R_1 b \left[1\mathrm{n} \frac{R_2}{R_1} \right]$$

Contd

Since, the maximum value of V_1 is 12 m/s,

$$Q_{max} = 12\, R_1\, b\left[\ln\frac{R_2}{R_1}\right]$$

and the average velocity will be

$$V_a = \frac{Q}{A} = \frac{12 R_1 b}{(R_2 - R_1)b}\left[\ln\frac{R_2}{R_1}\right] = \frac{12 R_1}{(R_2 - R_1)}\left[\ln\frac{R_2}{R_1}\right]$$

✓This ***velocity should be the same at all sections along the siphon*** barrel unless there is expansion or contraction of the section

Contd

✓when the ***siphon is running full***, the velocity is given by the total head H

$$V = \mu\sqrt{2g\,H}$$

Total head H (from reservoir level up to the tail water level)

μ = siphon-coefficient accounting for various losses such as inlet, friction, bend, etc.

If the siphon barrel is of constant cross section without constriction or expansion,

$$\mu = \frac{1}{\sqrt{k}} = \frac{1}{\sqrt{(1+k_i+k_f+k_b+\ldots)}}$$

Where k_i etc. are loss coefficients for inlet, friction, bend and outlet.

Contd

When the outlet section is constricted, the exit velocity V_0 is given by

$$H = \frac{V_0^2}{2g} + \frac{V_a^2}{2g}(k_i + k_f + k_b + ..)$$

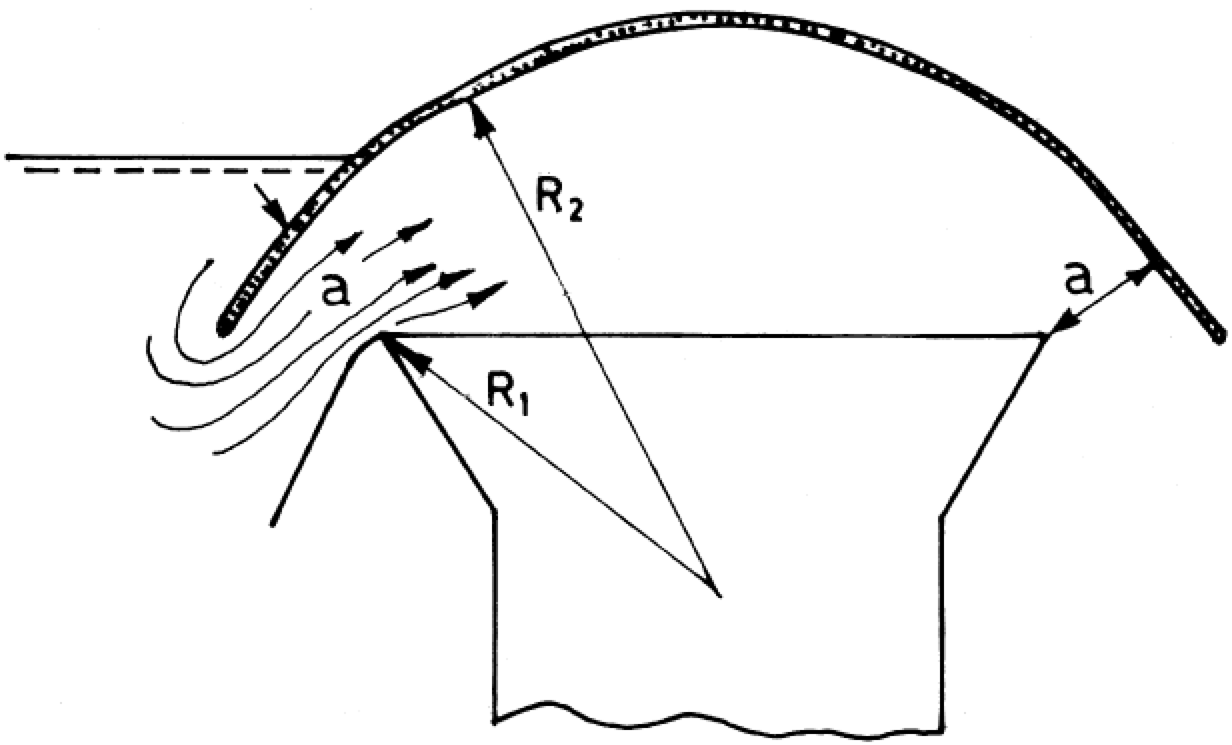
Energy Equation(Enterance and Exit)

✓The **required outlet area Ao** can then be calculated from Vo

$$A_0 = \frac{Q}{V_0} = \frac{AV_a}{V_0} = \frac{A}{\sqrt{\frac{2gH}{V_a^2} - (k_i + k_f + k_b + ...)}}$$

Contd

✓The discharge in ***the volute siphon*** can also be calculated in the same way by assuming that the ***flow entering the funnel at the lip takes a circular path***



Calculation of discharge in a volute siphon.

Contd

$$Q = C_d . a . \frac{V_1 R_1 \log e \frac{R_2}{R_1}}{R_2 - R_1}$$

where

C_d = Coefficient of discharge ≈ 0.7

a = Area of the annular space

If the area at the outlet section is A_o and H is the operating head available,

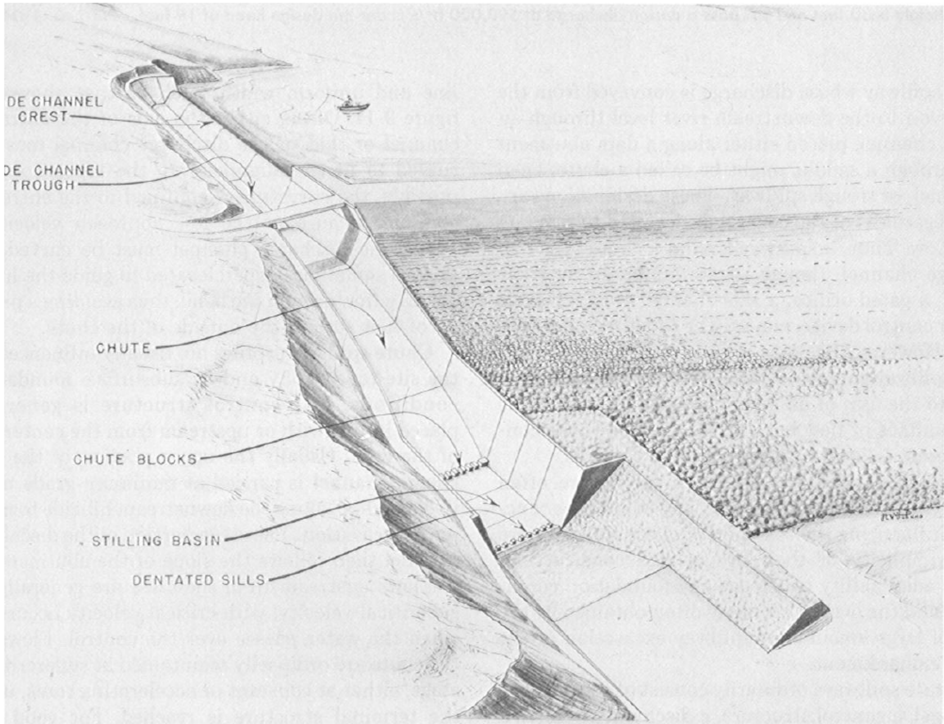
$$Q = C_d . A_o \sqrt{2g\,H}$$

Cd may be **assumed to be 0.70**, however, model observations have shown this to be as **high as 0.85**

Contd

- **Chute spillway**

- A chute spillway (or trough spillway or open channel spillway) ***consists of a steep sloped open channel called a chute or trough***, which carries the water passing over the crest of spillway to the river downstream



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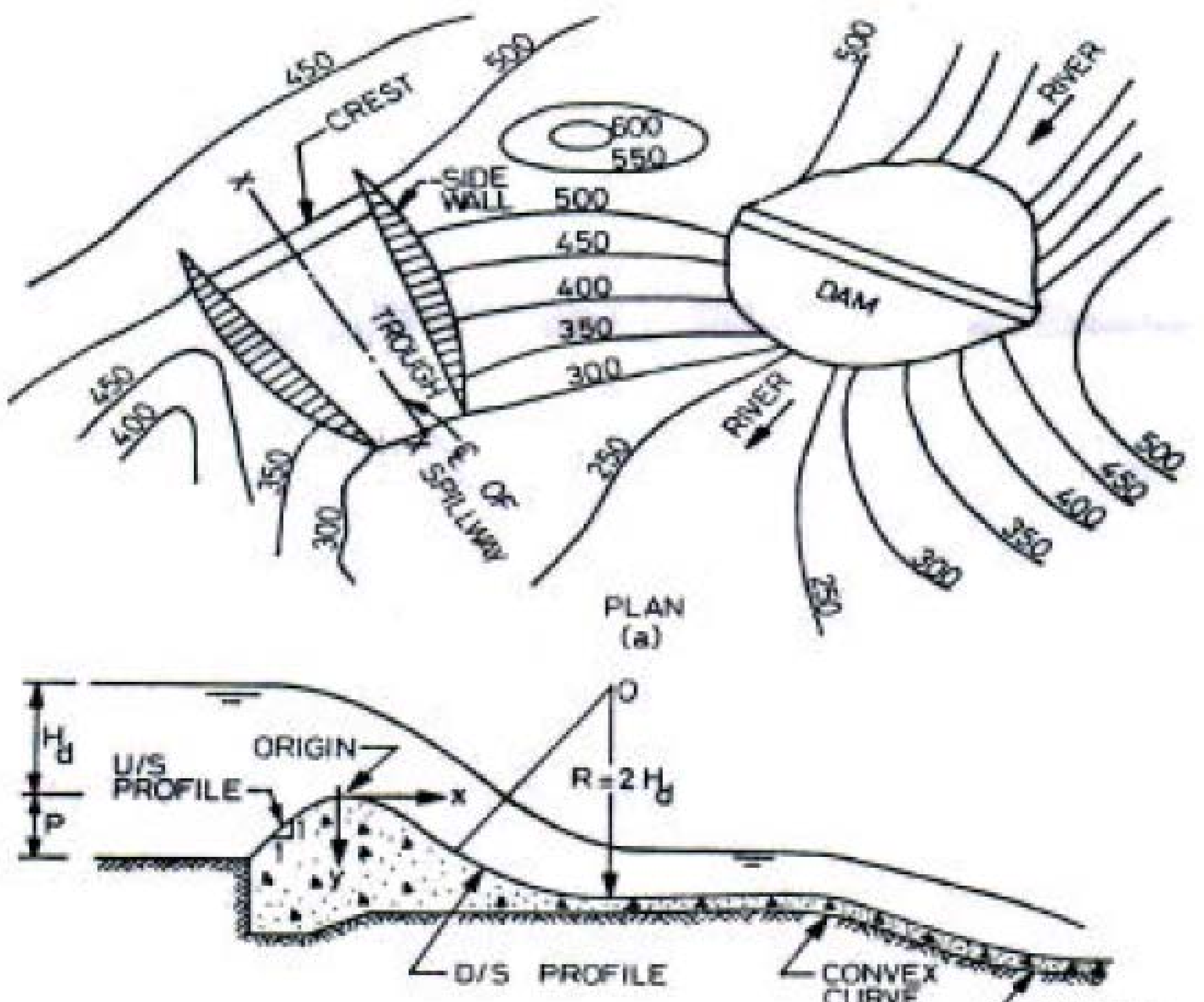
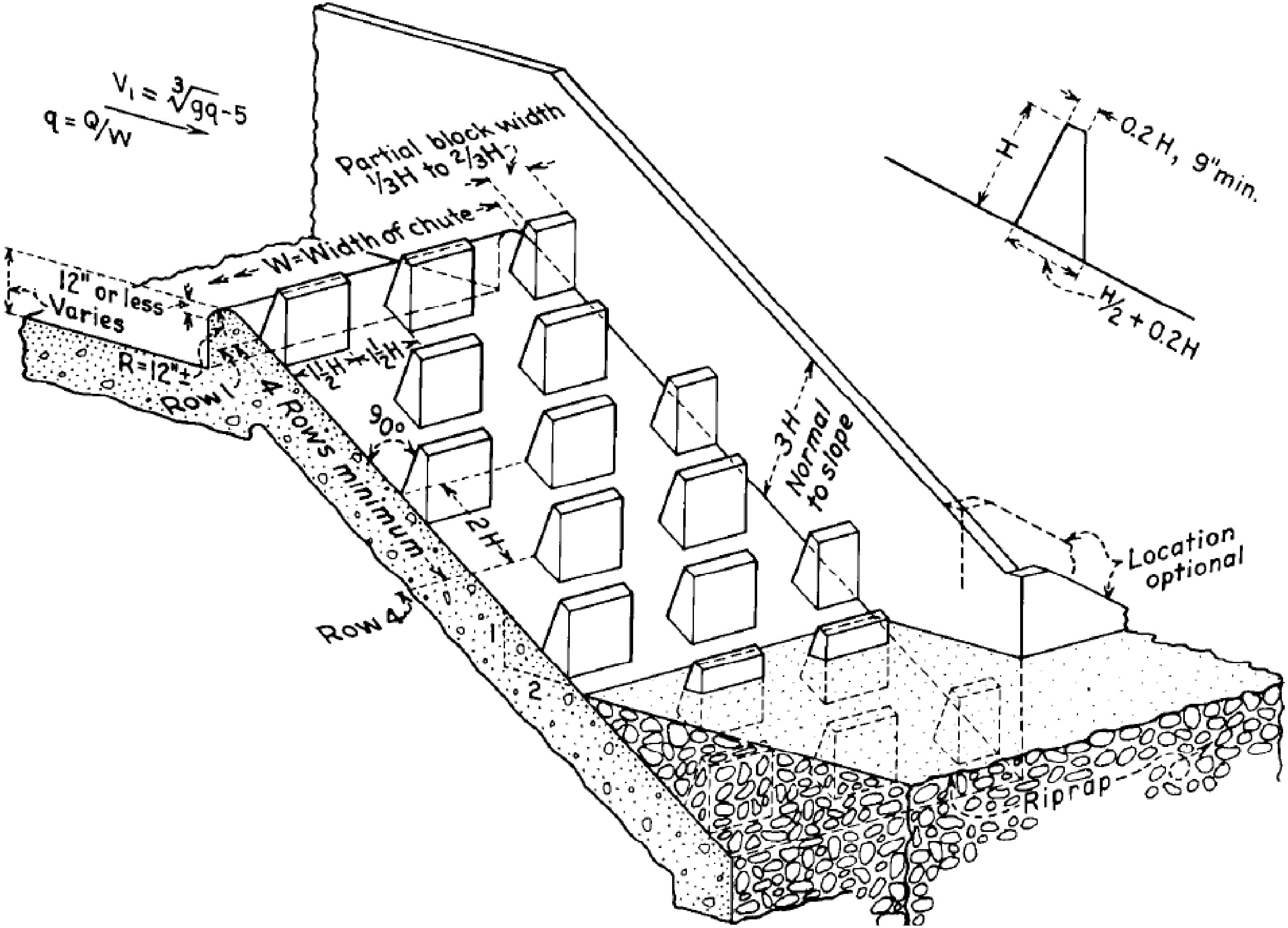


SECTION X-X ALONG CENTRE LINE OF SPILLWAY (ENLARGED SCALE)

Contd

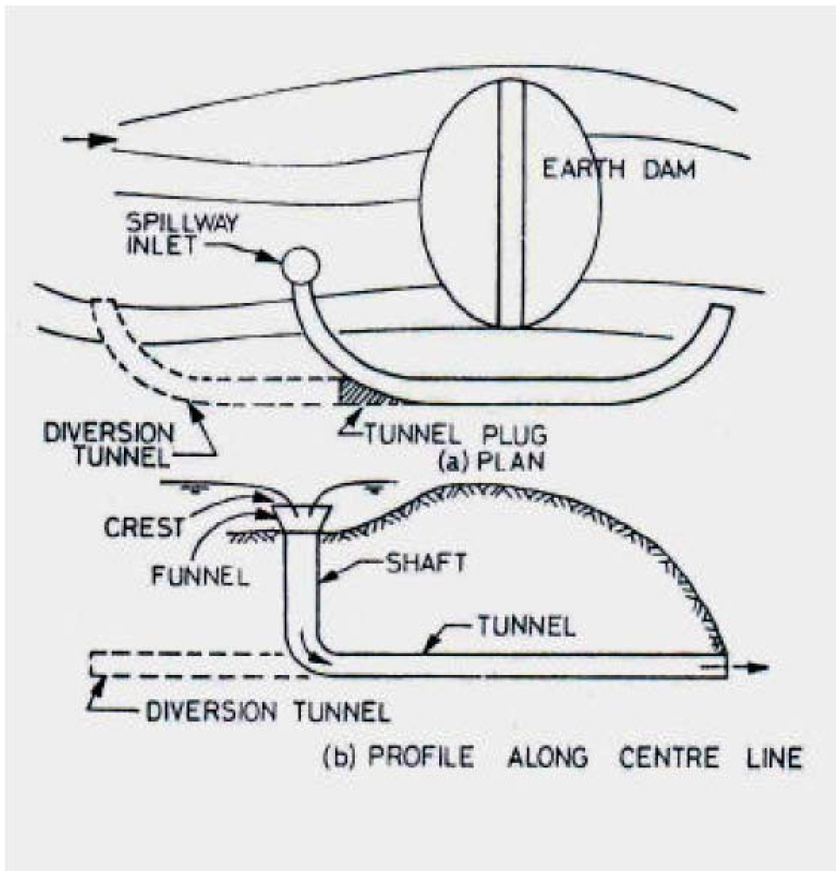


Basic proportions of a baffled chute spillway.

Contd

- **Shaft spillway**

✓A ***shaft (or morning glory) spillway*** consists of a ***large vertical funnel***, with its ***top surface at the crest level of the spillway*** and its lower end connected to a vertical (or nearly vertical) shaft.



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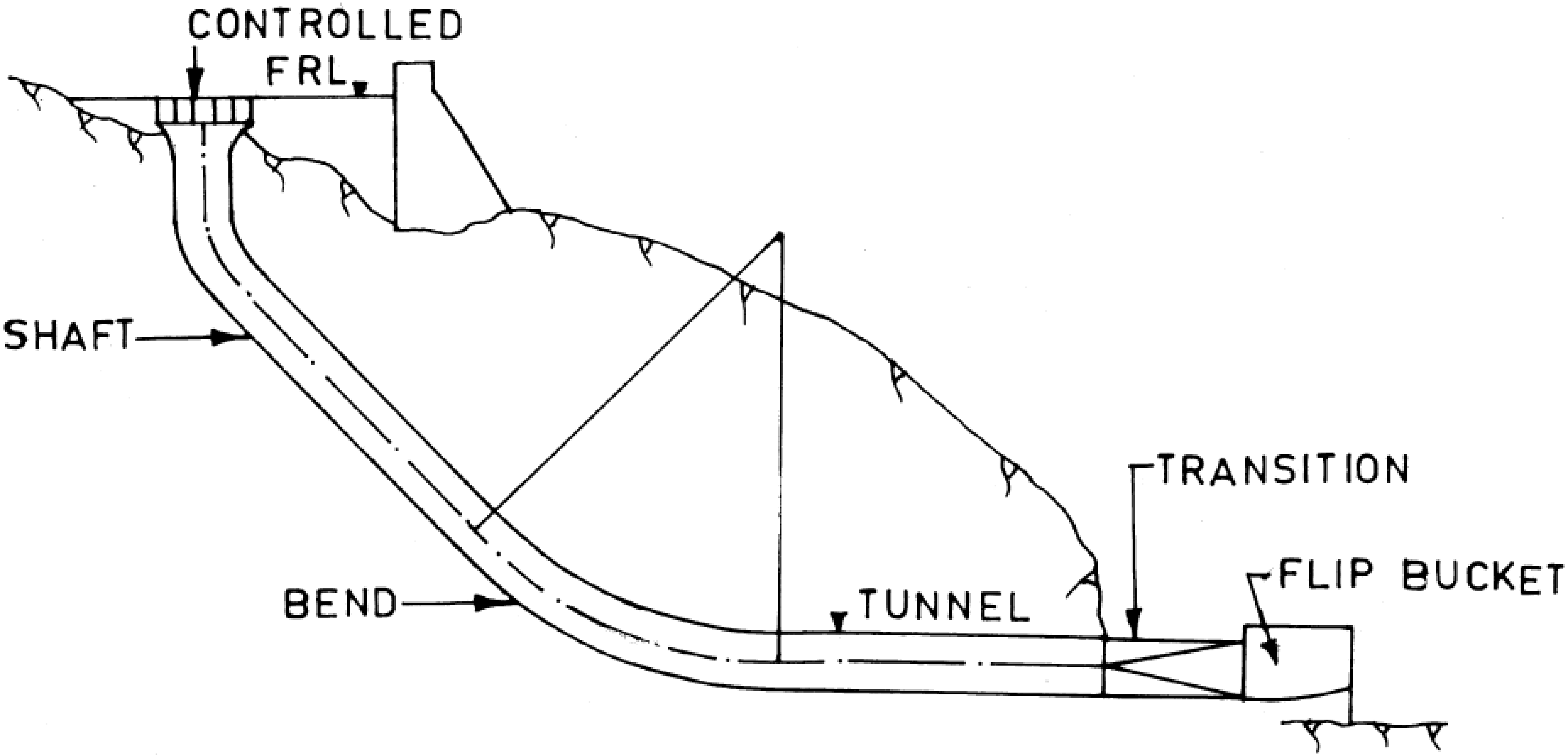
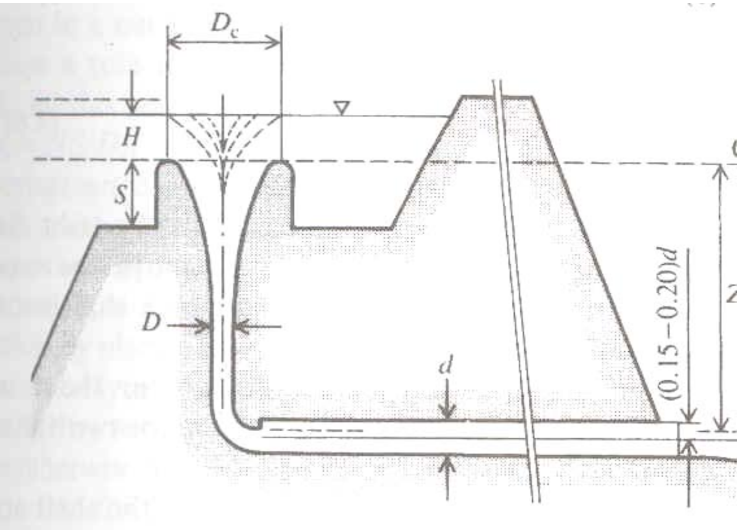


Elements of a shaft spillway.

Contd



- The free overfall the discharge is given by:

$$Q = \frac{2}{3} C_d \pi D_c \sqrt{2g} H^{3/2}$$

- ✓The drowned (submerged) regime, the discharge is given by

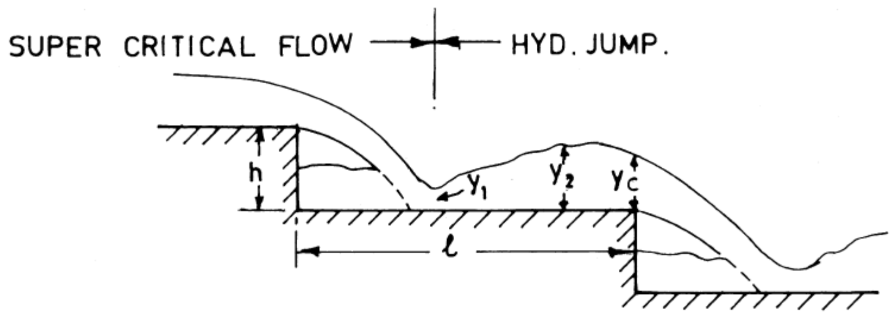
$$Q = \frac{1}{4} C_{d1} \pi D^2 [2g(H + Z)]^{1/2}$$

Contd

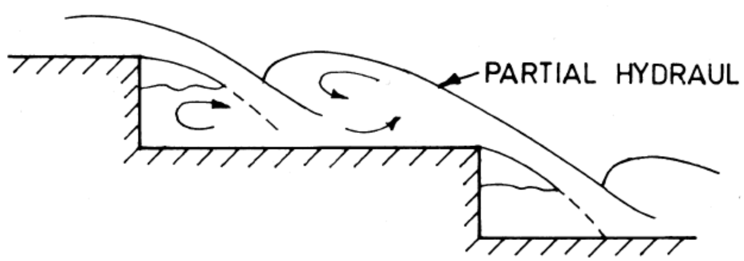
- **Stepped Spillways(Cascaded spillway)**

✓It is ideally suited for ***very high dams*** in which the energy cannot be ***dissipated by a hydraulic jump or a bucket***

Stepped Spillways

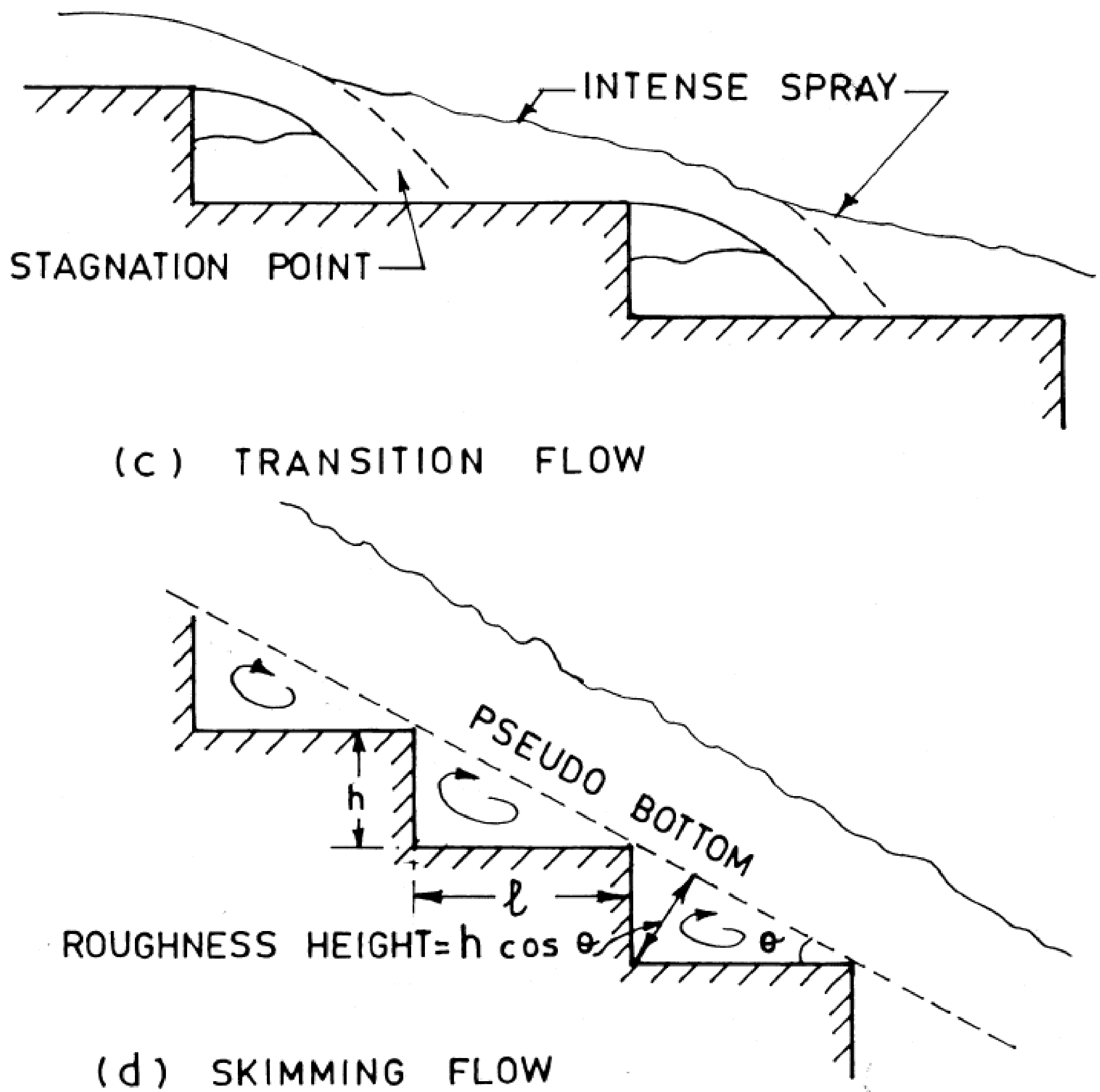


(a) NAPPE FLOW WITH FULLY DEVELOPED HYDRAULIC JUMP



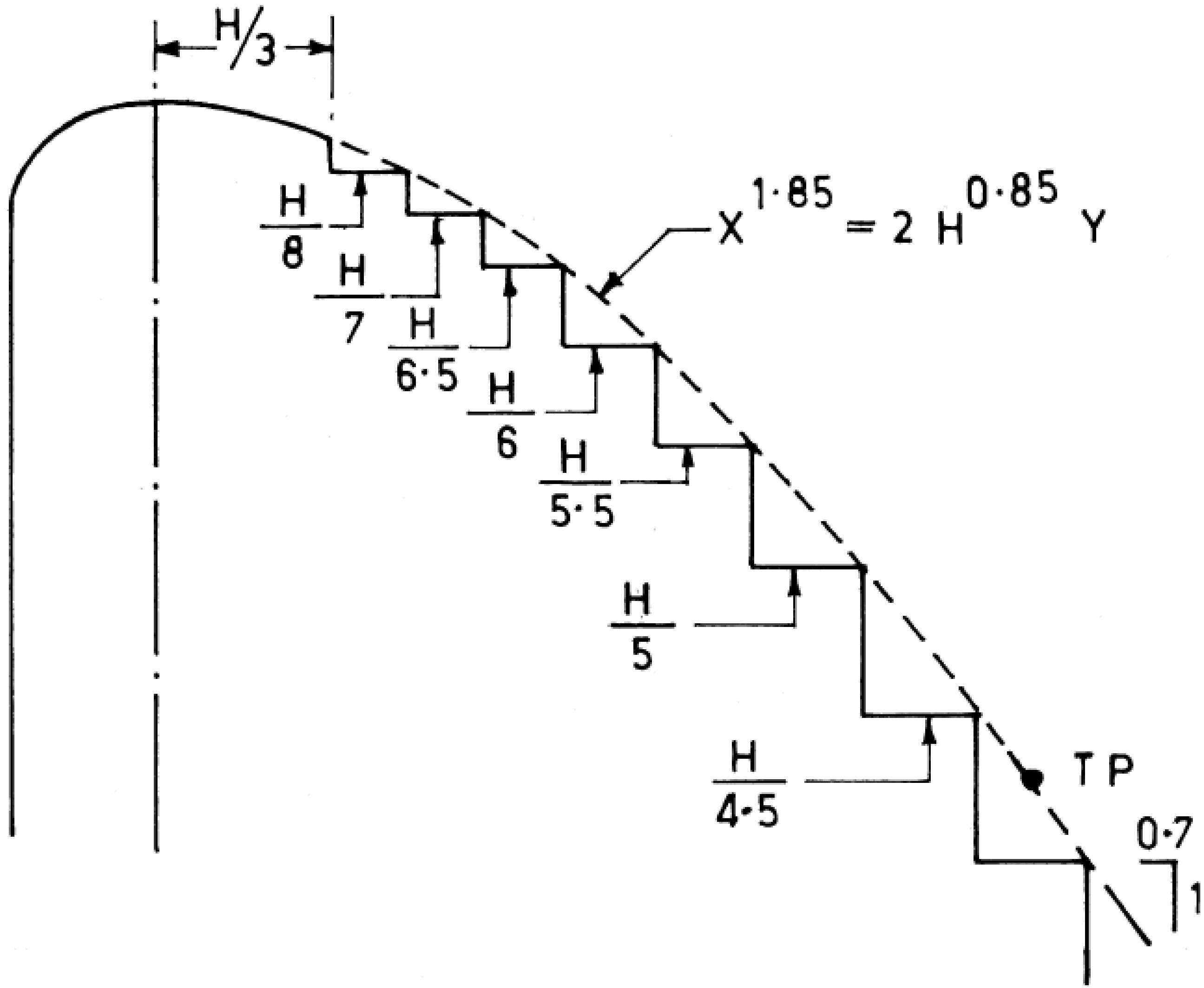
(b) NAPPE FLOW WITH PARTIAL HYDRAULIC JUMP.

Contd



Flow regimes on stepped spillways.

Contd



Crest profile and transition

Contd

- **Spillway Crest Gates**

✓The following ***factors influence the decision*** whether a spillway should be gated or ungated:

- Safety of the dam
- Cost economics
- Operational problems
- Downstream conditions
- Special considerations

Contd

✓From the standpoint of ***operation***, the ***spillway crest gates can be divided into four*** groups:

- Mechanical
- Semi-mechanical
- Automatic type fusible
- Automatic type restoring

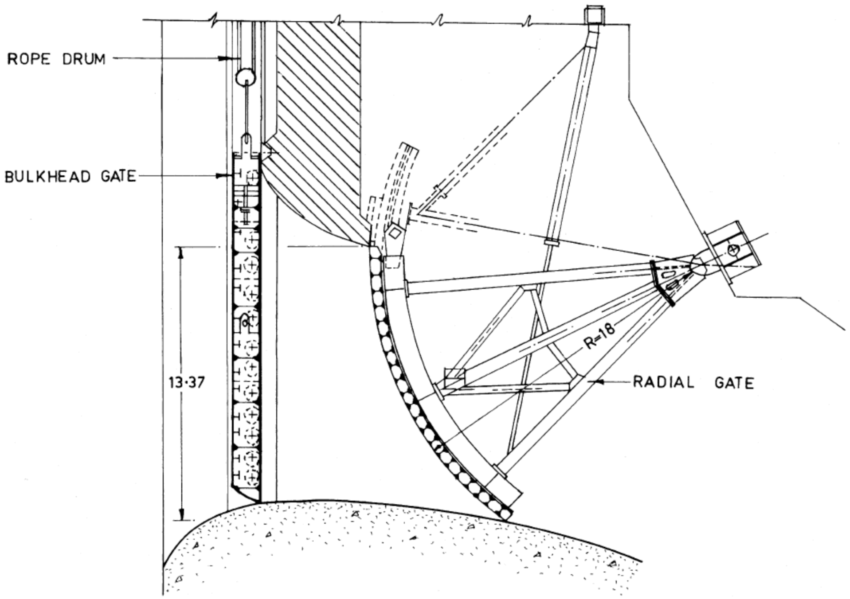
Contd

Type of Spillway	Ungated	Gated			
Features	Conventional raising	Mechanical	Semi-mechanical	Fusible	Fully automatic
Cost	X	X	T	T	T
Environment	O	O	T	T	T
Maintenance	T	X	X	O	O
Retain Storage after large floods	T	T	O	X	T
Time to Construct	X	O	O	T	T
Reliability	T	X	O	T	T
No Operator or External Power	T	X	X	T	T
Emergency Draw-down-Large Releases	X	T	T	X	T

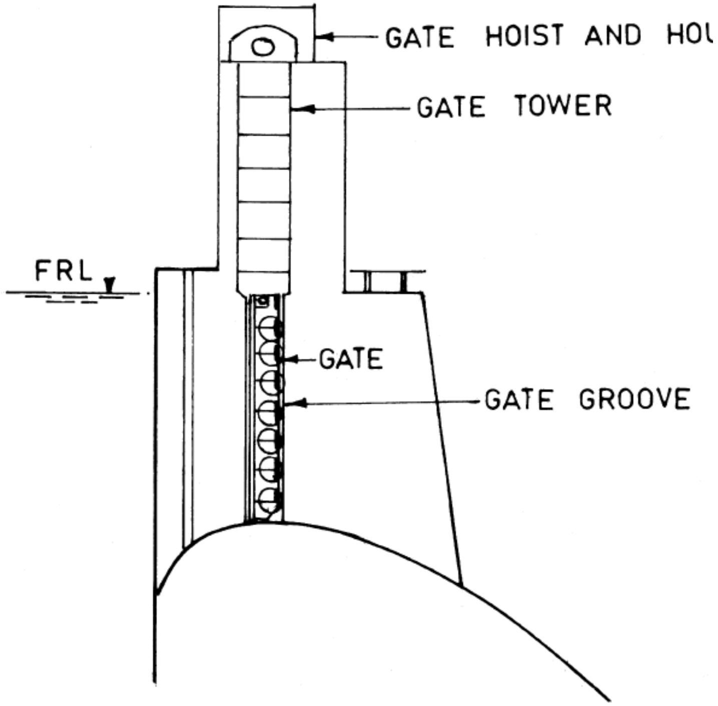
X: Disadvantage, O: Possible advantage, and T: Advantage

Contd

✓The common types of mechanical gates include **radial, vertical lift, and flap gates**

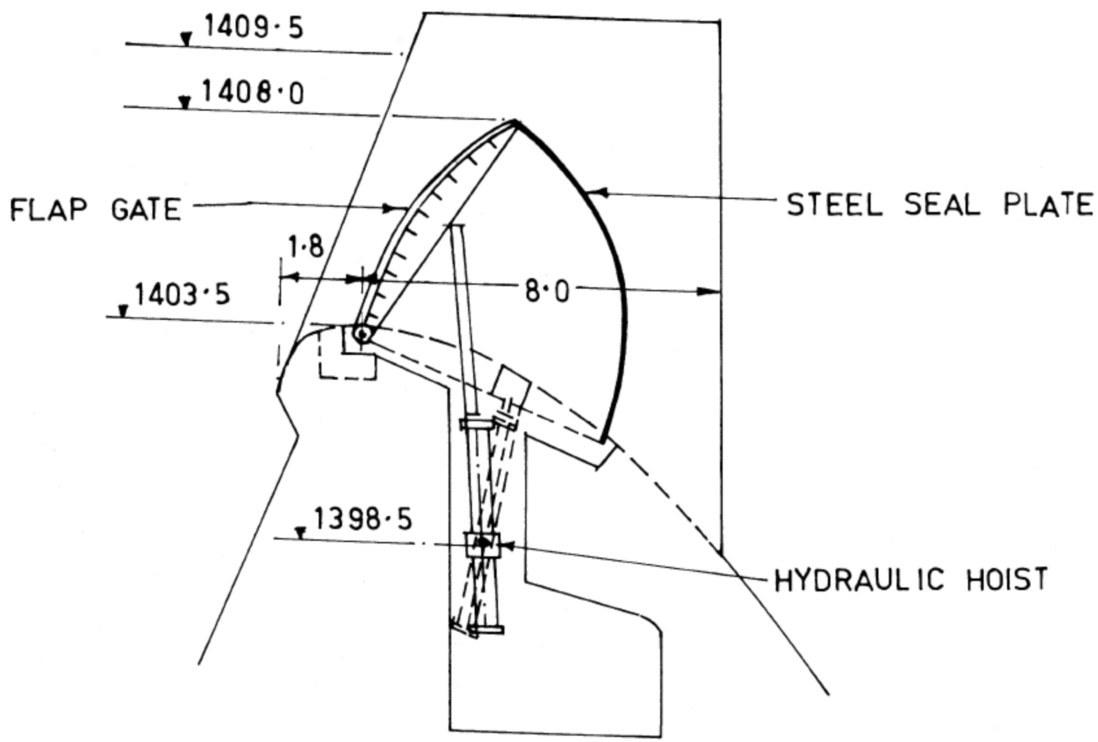


radial gate.



Vertical lift gate

Contd



flap gate.

Contd

- **Spillway Crest Gates**

✓Various types of gates have been evolved to control the flow of water over the spillway when the reservoir is full.

I. Flashboards
   i.Temporary
   ii.permanent
   i.Stop logs & needles
   ii.Rectangular lift gates
   iii.Radial (Tainter) gates
   iv.drum gates
   v.Rolling (roller) gate
   vi.Tilting (Flap) gate

Contd

- **Stilling Basin**

✓ A channel structure of mild slope whose purpose is to ***confine all or part of the hydraulic jump*** or other energy reducing action and ***dissipate some of the high kinetic energy of the flow***

✓The ***stilling basin is designed to insure that the jump occurs*** always at such a location that the ***flow velocities*** entering the erodible downstream channel are ***incapable of causing harmful scour***.

Contd

•***Hydraulic jump characteristics*** relevant to its application to the energy dissipation are:

✓Classification of jump

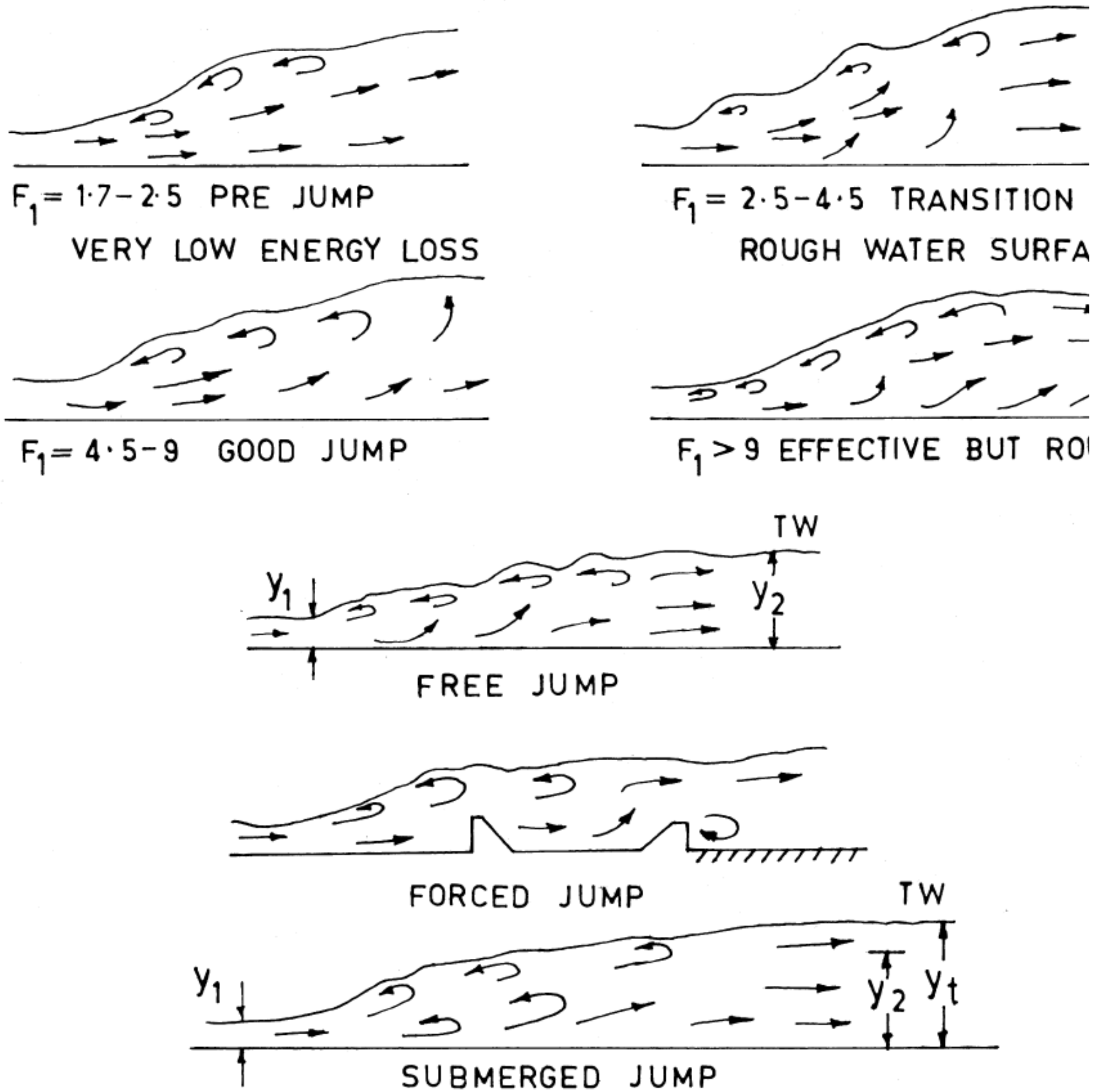
✓Length, including length of the roller

✓Conjugate depth and energy loss

✓Turbulence characteristics

✓Air entrainment by hydraulic jump

Contd



Classification of hydraulic jump.

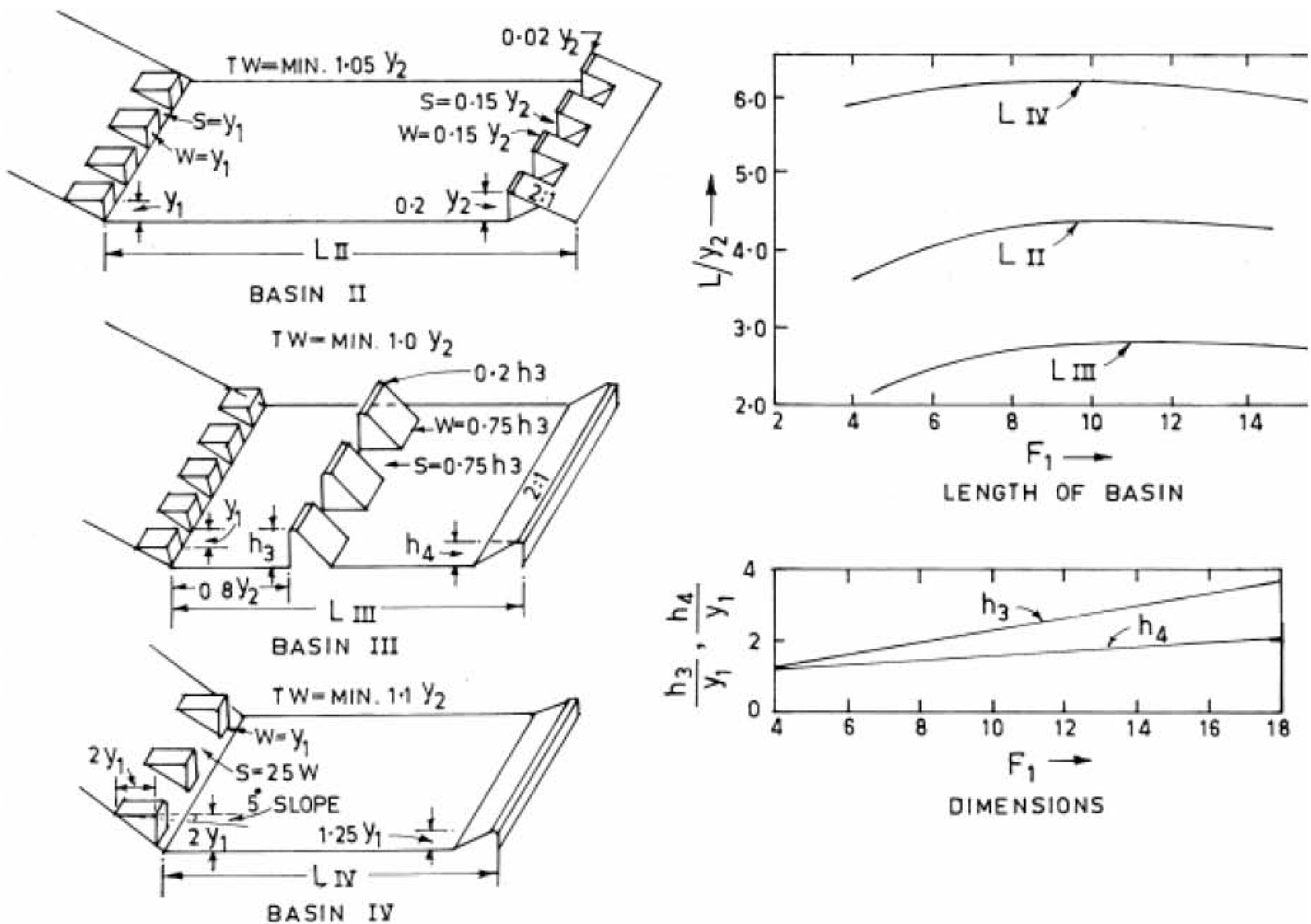
Contd

Hydraulic jump equation
$$\frac{y_2}{y_1} = \frac{1}{2}(\sqrt{8F_1^{\,2}+1}-1)$$

Jump head loss equation:
$$\frac{\Delta E_j}{y_1} = \frac{(\frac{y_2}{y_1}-1)^3}{4y_2/y_1} = \frac{(\sqrt{8F_1^{\,2}+1}-3)^3}{16(\sqrt{8F_1^{\,2}+1}-1}$$

Energy dissipation efficiency
$$\frac{\Delta E_j}{E_1} = \frac{\Delta E_j/y_1}{E_1/y_1} = \frac{(\sqrt{8F_1^{\,2}+1}-3)^3}{8(\sqrt{8F_1^{\,2}+1}-1)(2+F_1^{\,2}}$$

Jump height:
$$\frac{y_2-y_1}{y_1} = \frac{1}{2}\sqrt{8F_1^{\,2}+1}-\frac{3}{2}$$



USBR stilling Basins II, III, and IV.

- END

- THANKS