Hydraulics Structures

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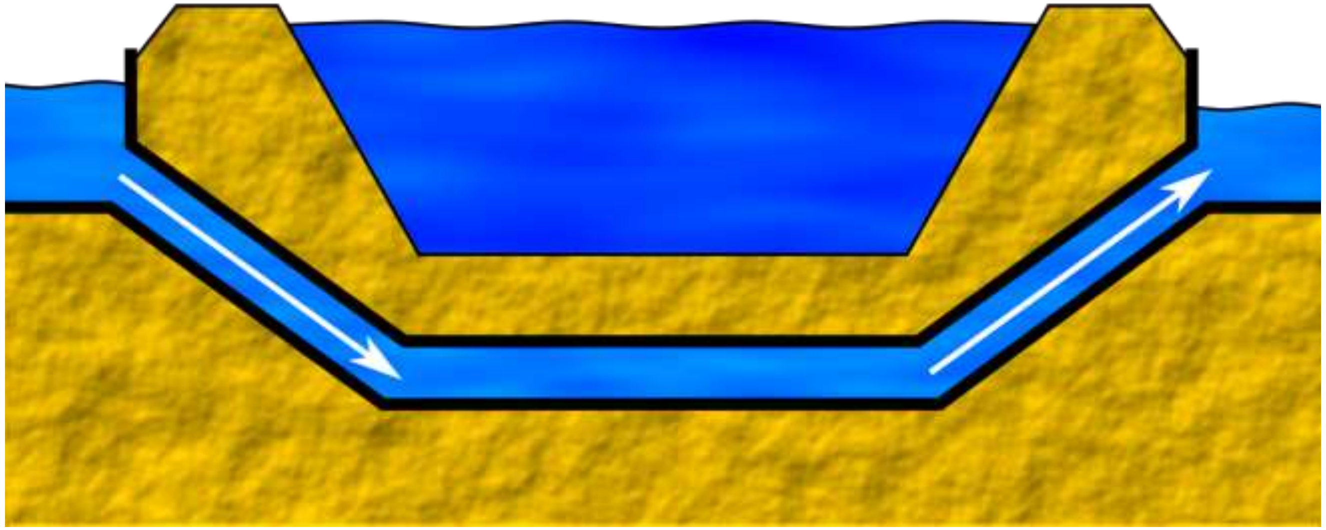
Inverted Siphon

Inverted Siphon is used to convey canal water by gravity under road, railroad, various type of drainage and channels..

A Siphon is closed conduit design to run full under pressure.

A siphon may be circular or rectangular in cross section.



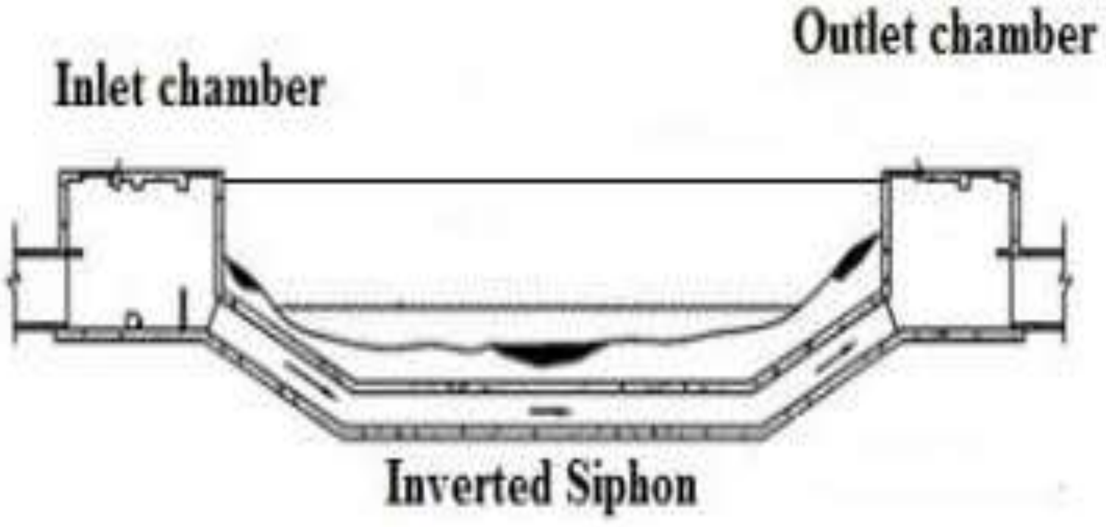
NOTE: If $Q > 2.5\ m^3/sec$ (Use square siphon)

The disadvantages of inverted siphons

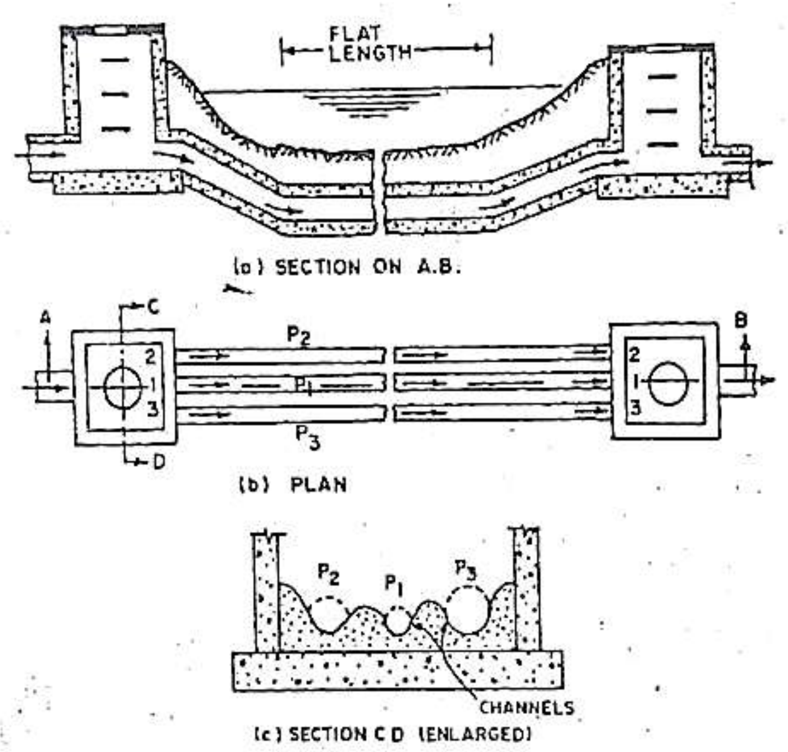
(i) They induce additional head loss to the sewer system which is undesirable in hydraulic performance

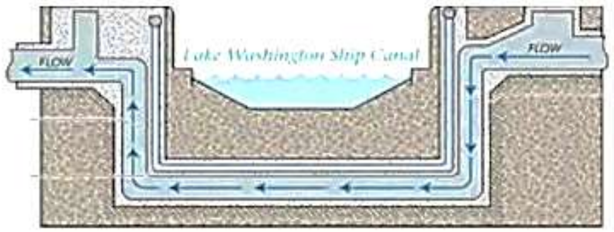
(ii) U-shaped siphons create sediment accumulation problem and previous experience showed that inverted siphons were easily blocked due to siltation

(iii) Maintenance of invert siphons is difficult due to its inaccessibility.



<u>The total head loss (ΔH) in the siphon can be divided into:</u>





- **Head loss of Entry and Exit (h_{f1})**

$$h_{f1} = (K_1 + K_2)\left(\frac{V_s^{\,2}}{2g} - \frac{V_c^{\,2}}{2g}\right)$$

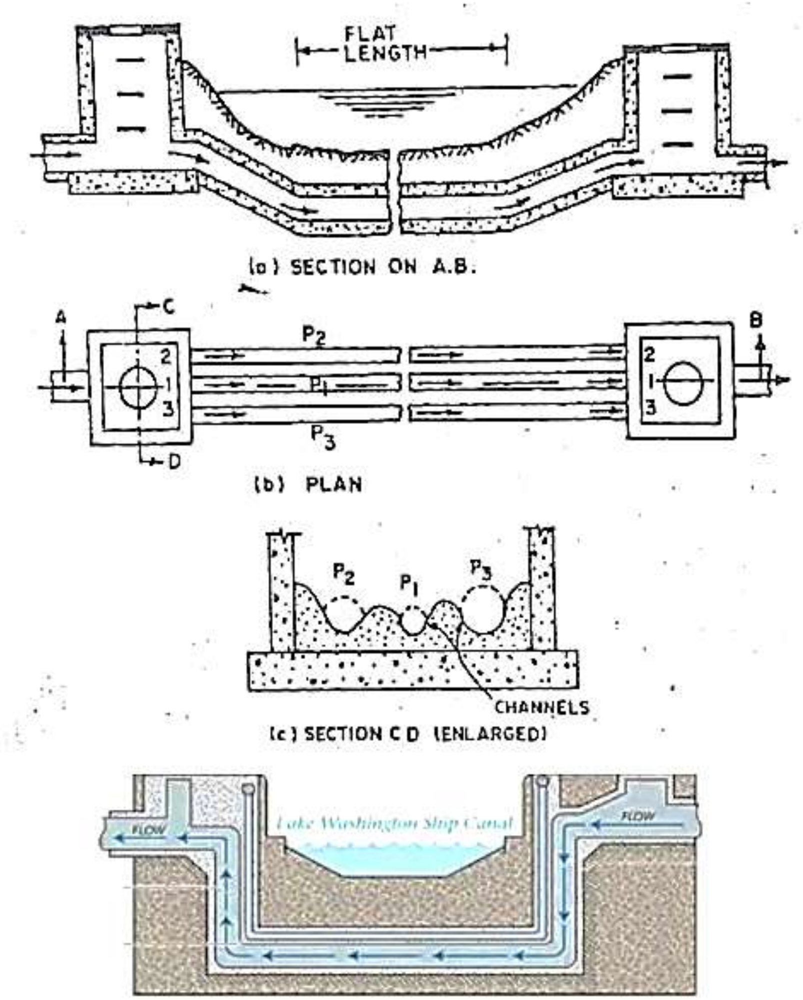
where:

K_1 and K_2 are the cofficient of entery and exit, respectively.

<u>The total head loss (ΔH) in the siphon can be divided into:</u>

- **Head loss in the two screens (h_{f2})**

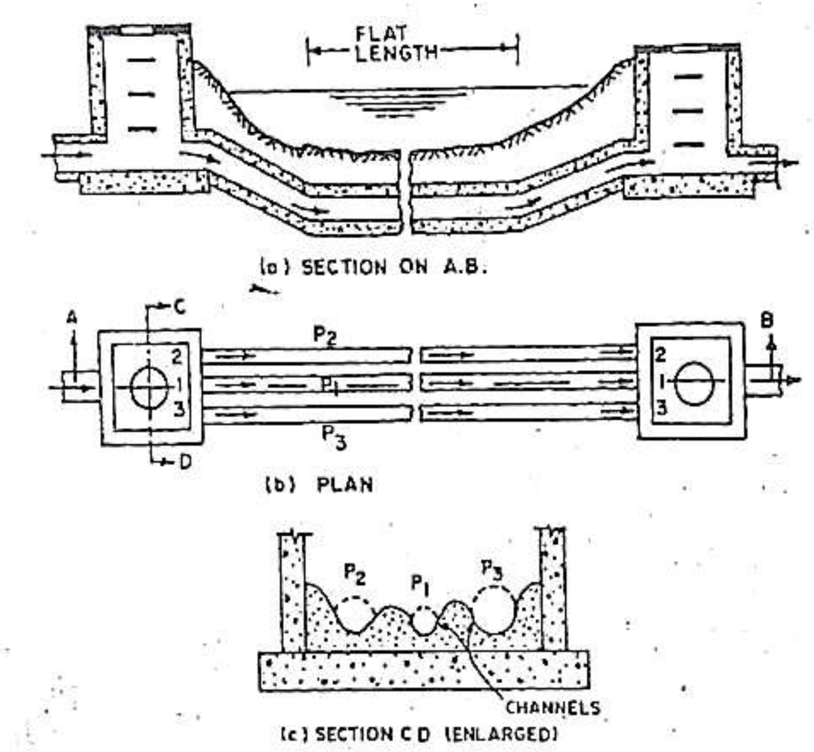
$$h_{f2}=(2 * K_{screen})(\frac{V_c^{2}}{2g})$$

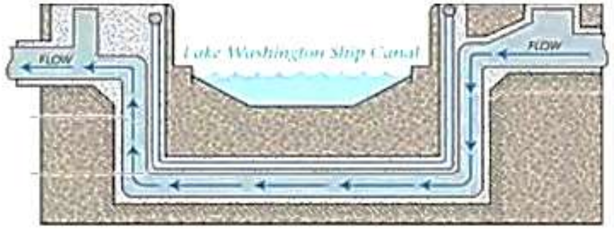


<u>The total head loss (ΔH) in the siphon can be divided into:</u>

- **Head loss in the two elbows (h_{f3})**

$$h_{f3} = (2 * K_{elbow})\left(\frac{{V_S}^2}{2g}\right)$$



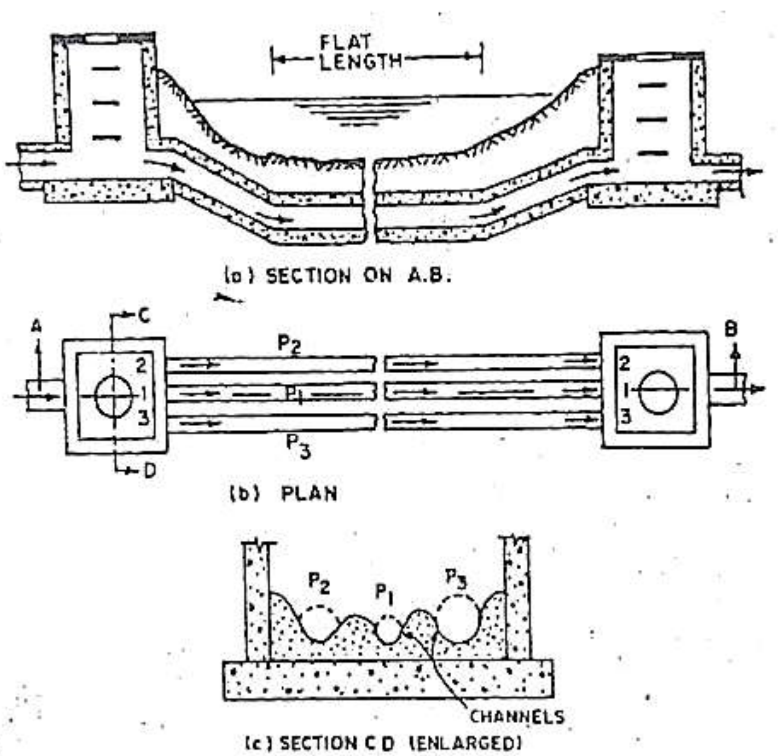


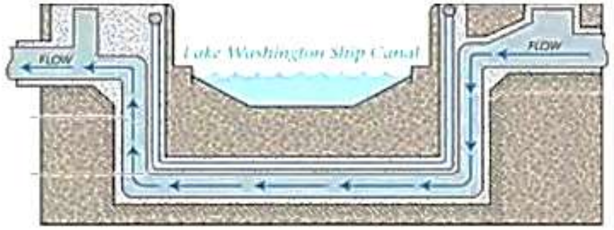
<u>The total head loss (ΔH) in the siphon can be divided into:</u>

- **Head loss due to friction**

$$h_{f4} = \frac{2g\, n^2 L}{(R_{pipe})^{\frac{4}{3}}} \left(\frac{{V_s}^2}{2g}\right)$$

$$\Delta H = h_{f1} + h_{f2} + h_{f3} + h_{f4}$$





Example: Design an inverted siphon required to pass canal discharge under main road with (0.2 m) head loss. The dimensions of canal are:

-Bed width of the canal =1.75 m

-Depth of flow in the canal = 1.5 m

-Side slope of the canal = 1:1

-Velocity of flow in the canal = 0.82 m/sec

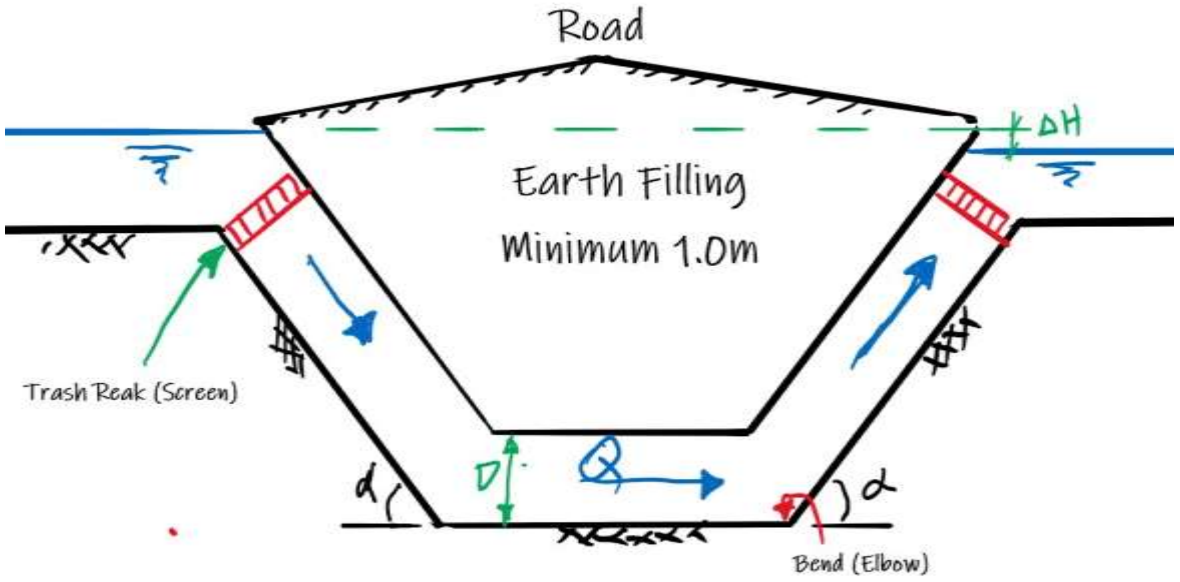
-Safely screens are provided at entry and exit

The inverted siphon has two (22.5^o) elbow at each end.

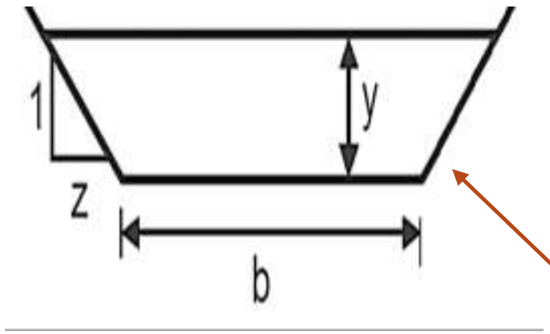
The other site dimensions are given:-

K_1= 0.2, K_2=0.3 , n_{siphon}=0.013, K_{screen}= 0.2, K_{elbow}= 0.05

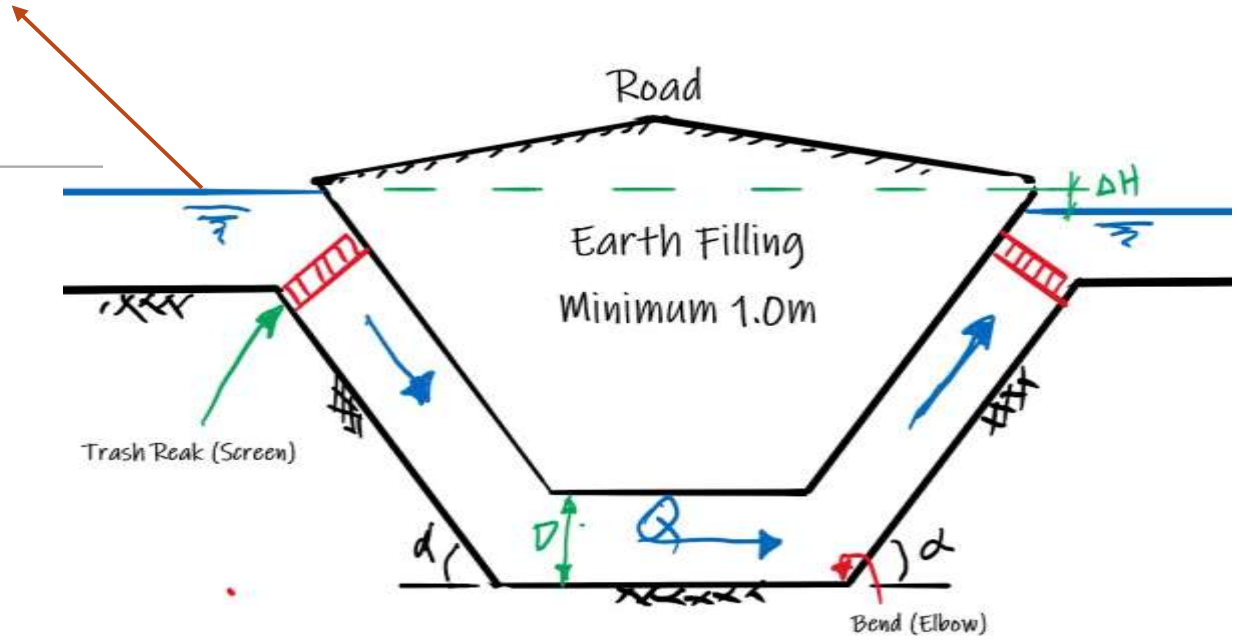
Length of siphon is = 7.5+26.8+7=41.3 m



Solution:



$$Q = VA$$



$$A = By + Zy^2$$

$A=1.75(1.5)+1(1.5)^2=4.875\ m^2$

$Q= 0.82(4.875) = 4\ m^3/sec > 2.5\ m^3/sec$

Use box siphon.

$$\Delta H = \boxed{h_{f1}} + h_{f2} + h_{f3} + h_{f4}$$

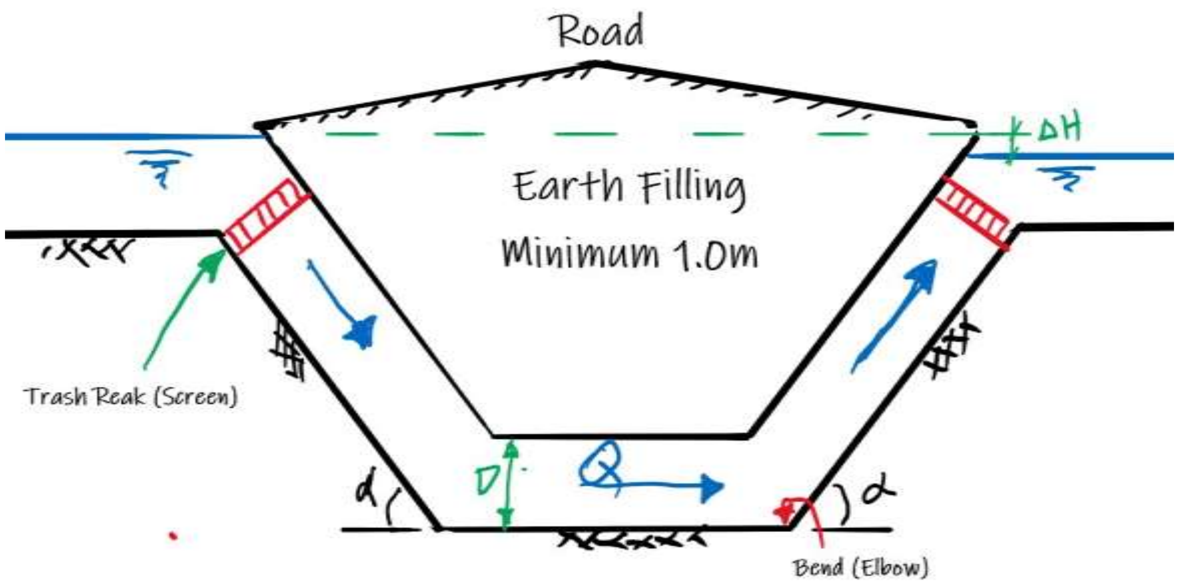
- Head loss of Entry and Exit (h_{f1})

$$h_{f1} = (K_1 + K_2)\left(\frac{{V_s}^2}{2g} - \frac{{V_c}^2}{2g}\right)$$

$$V_s = \frac{Q}{A}$$

$$h_{f1} = (0.2+0.3)\left(\frac{(\frac{4}{D^2})^2 - (0.82)^2}{19.62}\right)$$

$$\boxed{h_{f1} = \frac{0.407}{D^4} - 0.017 \ldots \ldots (1)}$$



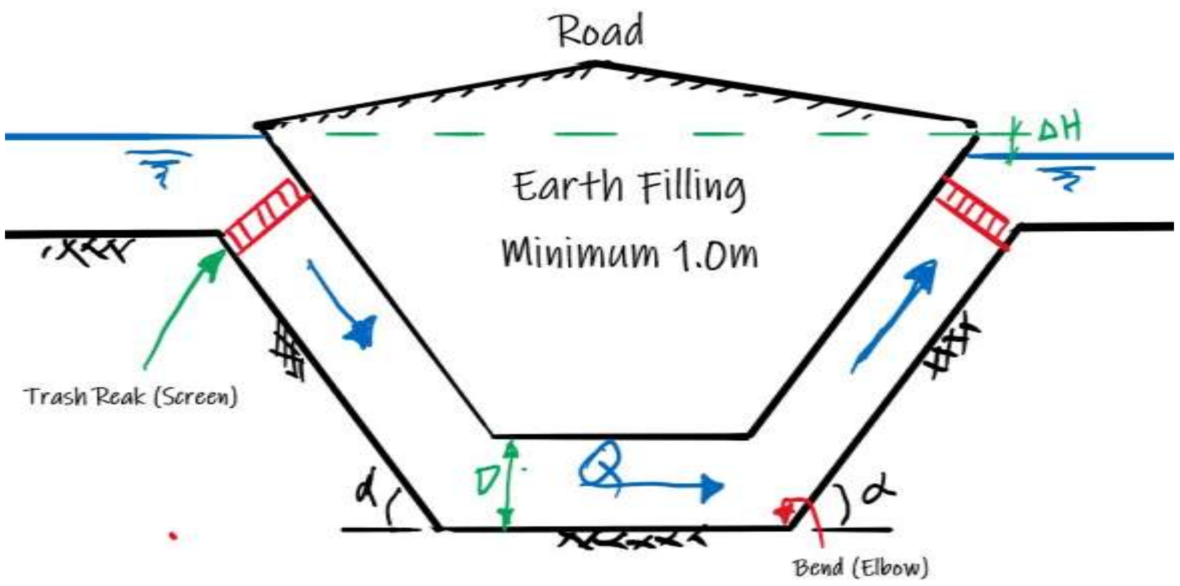
$$\Delta H = h_{f1} + \boxed{h_{f2}} + h_{f3} + h_{f4}$$

- Head loss in the two screens (h_{f2})

$$h_{f2} = (2 * K_{screen})\left(\frac{V_c^{\,2}}{2g}\right)$$

$$= 2 * 0.2 * \frac{0.82^2}{19.62}$$

h_{f2}= 0.0136 m …… (2)



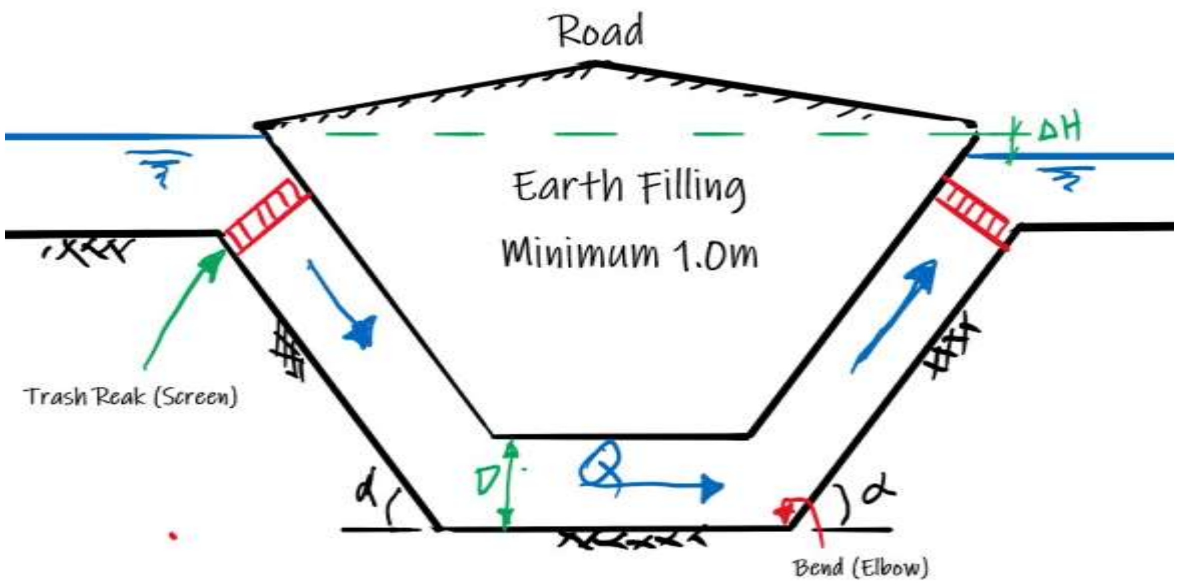
$$\Delta H = h_{f1} + h_{f2} + \boxed{h_{f3}} + h_{f4}$$

- Head loss in the two elbows (h_{f3})

$$h_{f3} = (2 * K_{elbow})\left(\frac{{V_S}^2}{2g}\right)$$

$$= 2 * 0.05 \, \frac{\left(\frac{4}{D^2}\right)^2}{19.62}$$

$$\boxed{h_{f3} = \frac{0.0815}{D^4} \; \ldots\ldots \; (3)}$$



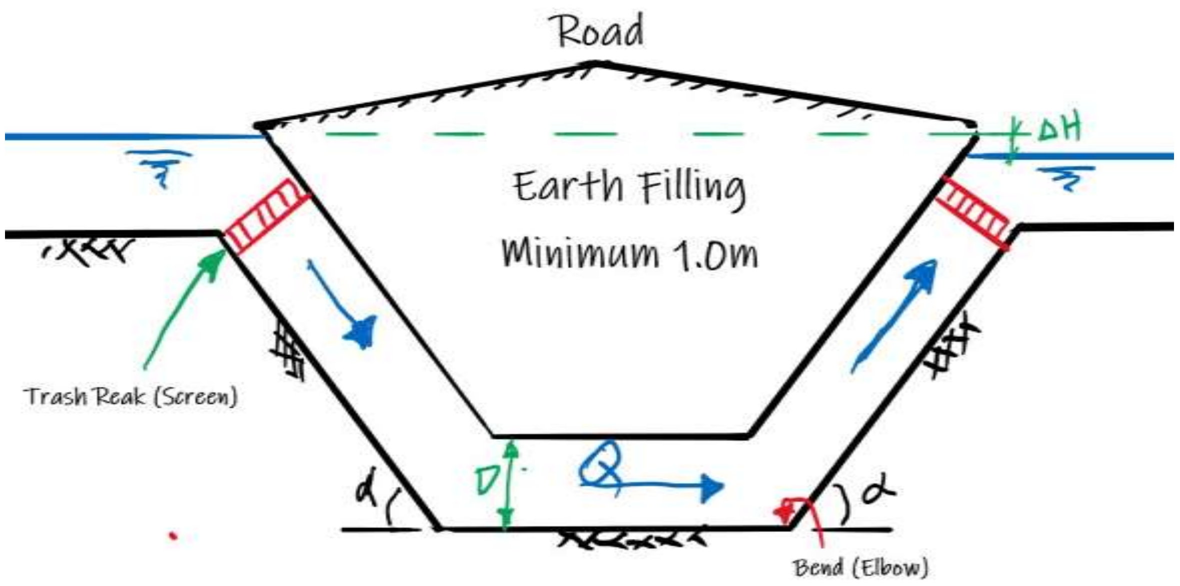
$$\Delta H = h_{f1} + h_{f2} + h_{f3} + \boxed{h_{f4}}$$

- Head loss due to friction

$$h_{f4} = \frac{2g\,n^2 L}{(R_{pipe})^{\frac{4}{3}}} \left(\frac{{V_s}^2}{2g}\right)$$

$$h_{f4} = \frac{19.62\,(0.015)^2(41.3)}{\left(\frac{D}{4}\right)^{\frac{4}{3}}} \left(\frac{\left(\frac{4}{D^2}\right)^2}{19.62}\right)$$

$$\boxed{h_{f4} = \frac{0.709}{D^{5.33}} \;\ldots\ldots\; (4)}$$

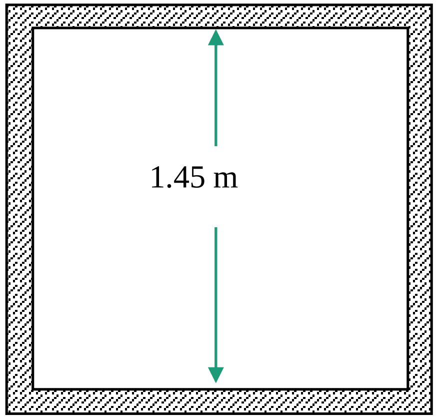


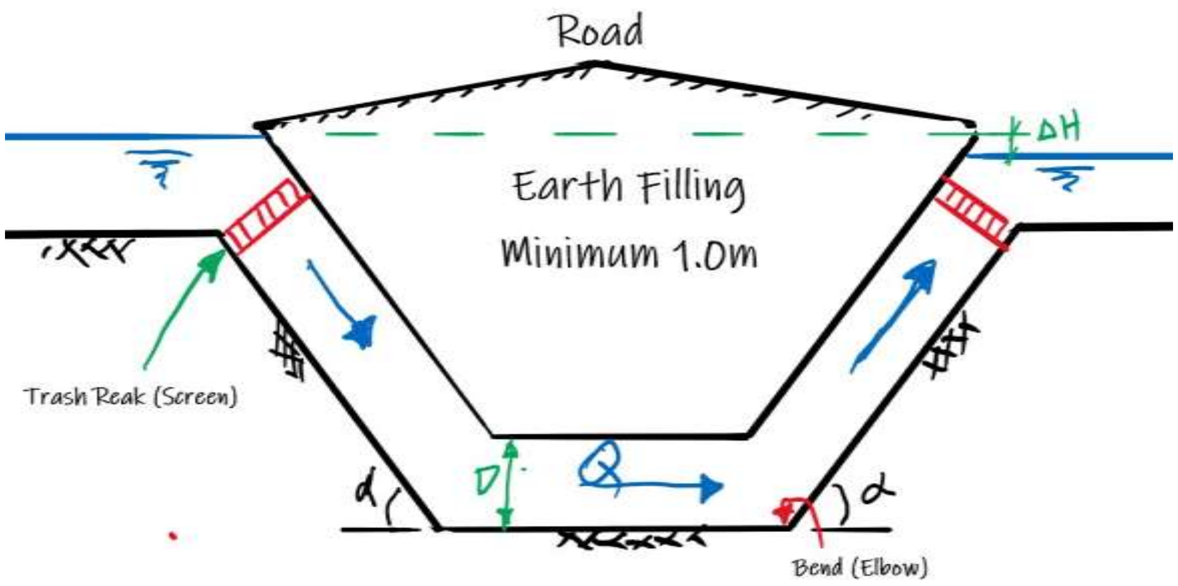
$$\Delta H = h_{f1} + h_{f2} + h_{f3} + h_{f4}$$

$$0.2 = \frac{0.4075}{D^4} - 0.017 + 0.0136 + \frac{0.0815}{D^4} + \frac{0.709}{D^{5.33}}$$

$\boxed{D=1.45\ m}$

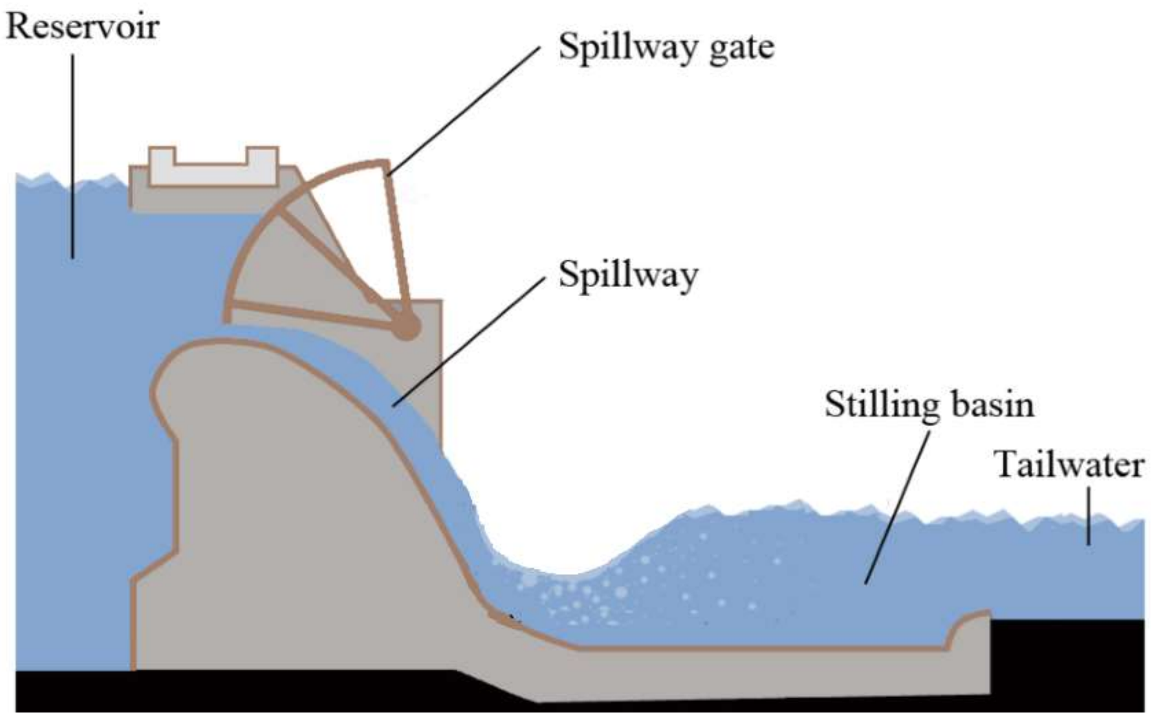
Use box siphon with dimensions (1.45 * 1.45) m





Spillway

A spillway is a structure used to provide the controlled release of water from a dam or levee downstream, typically into the riverbed of the dammed river itself.



Types of spillway

Over-flow Spillway (Ogee Spillway).

Chute Spillway.

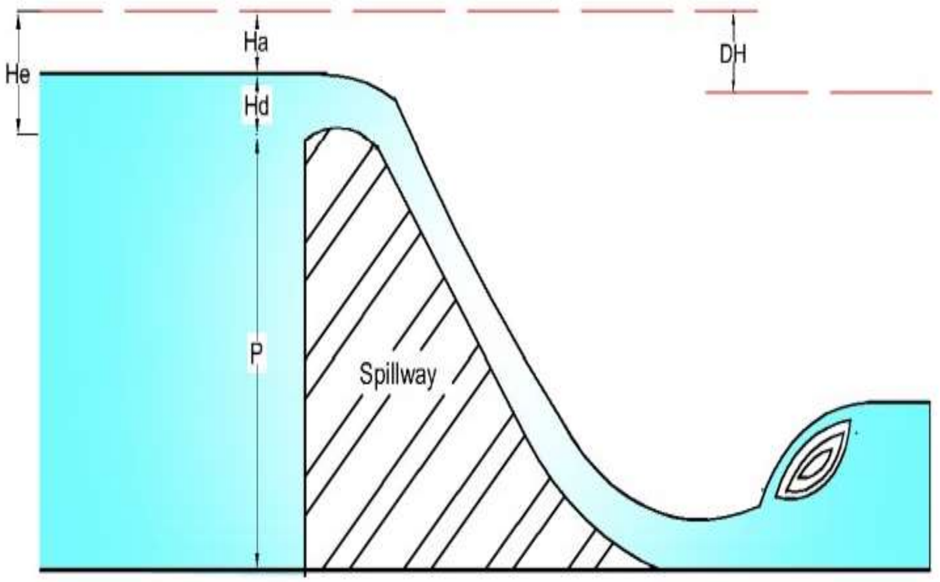
Side channel Spillway.

Shaft Spillway.

Siphon Spillway.

Over-flow Spillway (Ogee Spillway)

Ogee spillway is on overflow portion using to discharge surplus water from the reservoir to the downstream side. Ogee spillway is widely used with concrete arch dams.



The **Discharge Formula** of ogee spillway is: -

$$Q = C * \ L_e * H_e^{\frac{3}{2}}$$

where: -

$Q: Discharge.$

$L_e: Effective\ length\ of\ Spillway.$

$C: Coefficient\ of\ discharge.$

$H_e: Total\ head\ over\ the\ crest.$

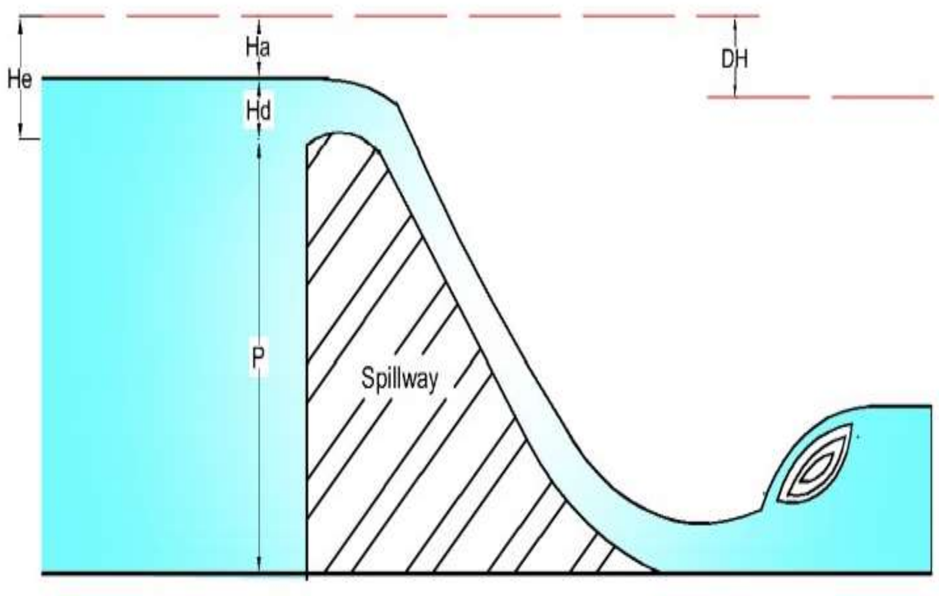
H_e: *Total head over the crest.*

$$H_e = H_d + H_a$$

H_a: *Approach velocity head.*

$$H_a = \frac{{V_a}^2}{2g}$$

$$V_a = \frac{Q}{(P + H_d) * L}$$



Note … For high spillway, the approach velocity is small and $\mathbf{H_a}$ it can be neglected.

$H_a \approx 0 \rightarrow H_e = H_d$ ……. $\frac{P}{H_d} > 1.33$, then it is high spillway.

$$L_e = L - 2(K_p * n + K_a) * H_e$$

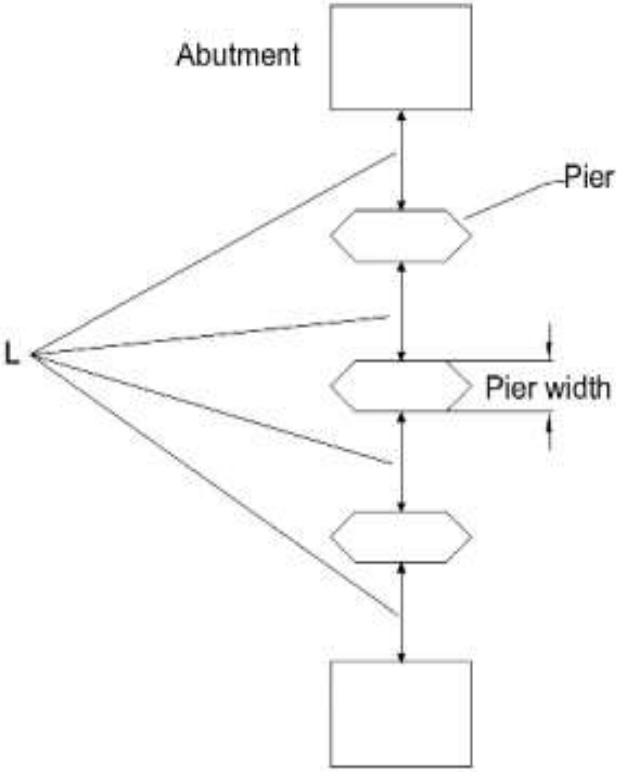
Where:-

L: *Net length of the crest.*

n: *Number of piers.*

K_p: *Pier contraction coefficient .*

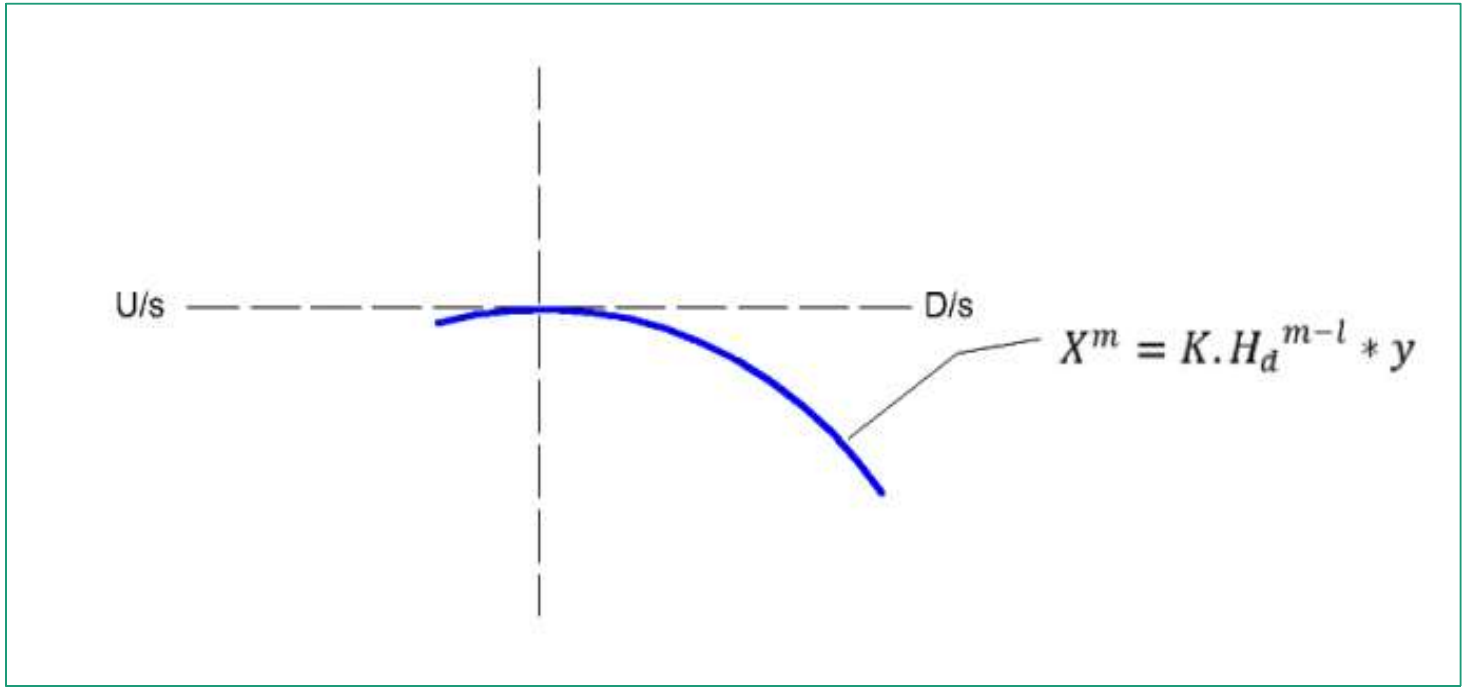
K_a: *Abutment pier contraction coefficient .*



<u>Equation of the crest of Ogee Spillway: -</u>

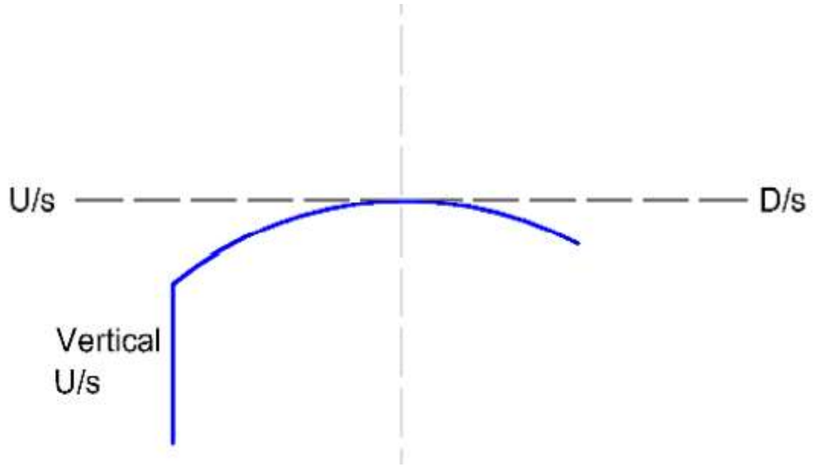
The general equation of the (D/s) **crest shape** of ogee spillway is: -

$$X^m = K * H_d^{m-1} * y$$



For spillway having a vertical (U/S) face, the (D/S) crest shape is given by the following equation: -

$$X^{1.85} = 2 * H_d^{0.85} * y$$



For spillway having sloping (U/S) face, the coefficient (K) and (m) are given by the following: -

Shape of U/s face	k	m
Vertical	2	1.85
3(V):1(H)	1.925	1.836
3:2	1.939	1.81
3:3	1.873	1.776

The U/S curve of the crest is defined by the following equation: -

$$y = \frac{0.724 * (x + 0.27\,H_d^{\,1.85})}{H_d^{\,0.85}} + 1.26H_d - 0.4315H_d^{\,0.375} * (x + 0.27\,H_d^{\,0.625})$$

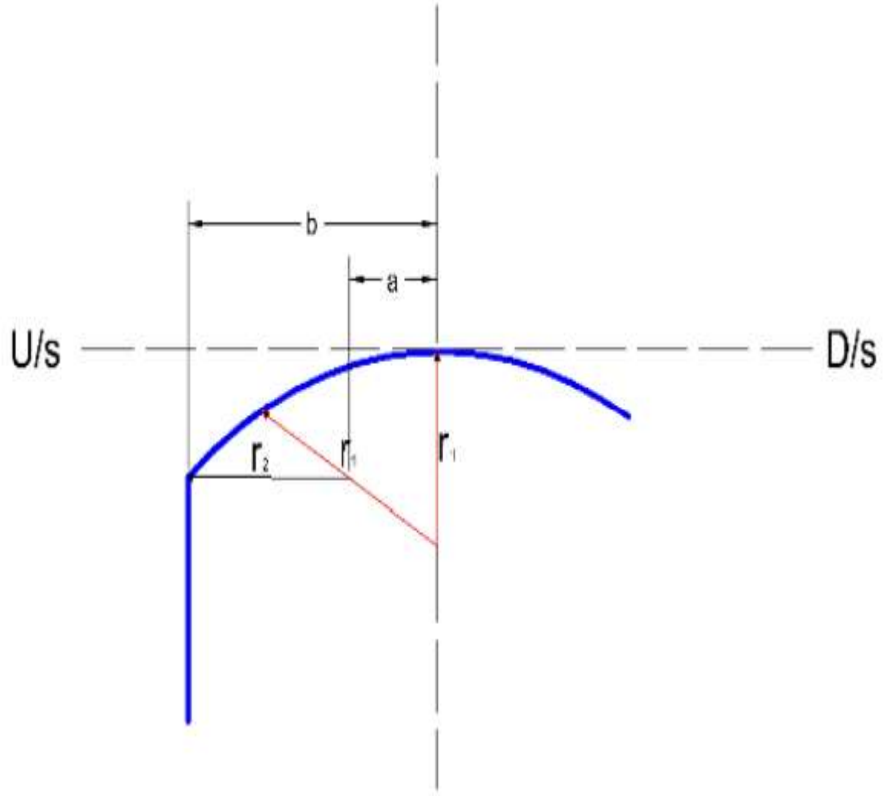
Or it can be determined graphically as following:-

$a = 0.175\,H_d$

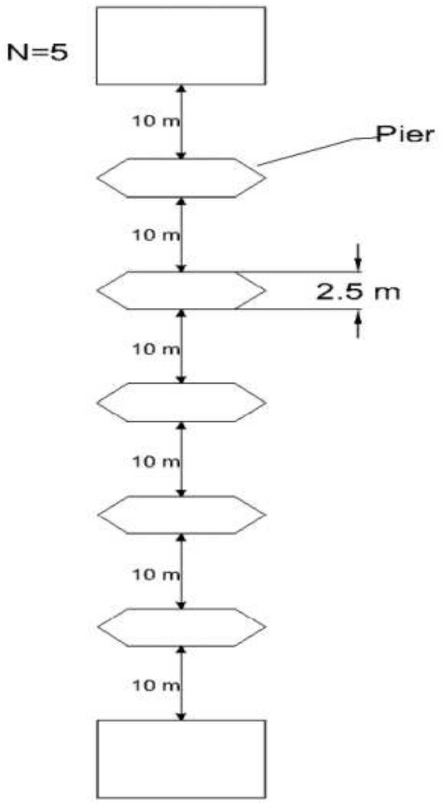
$b = 0.282\,H_d$

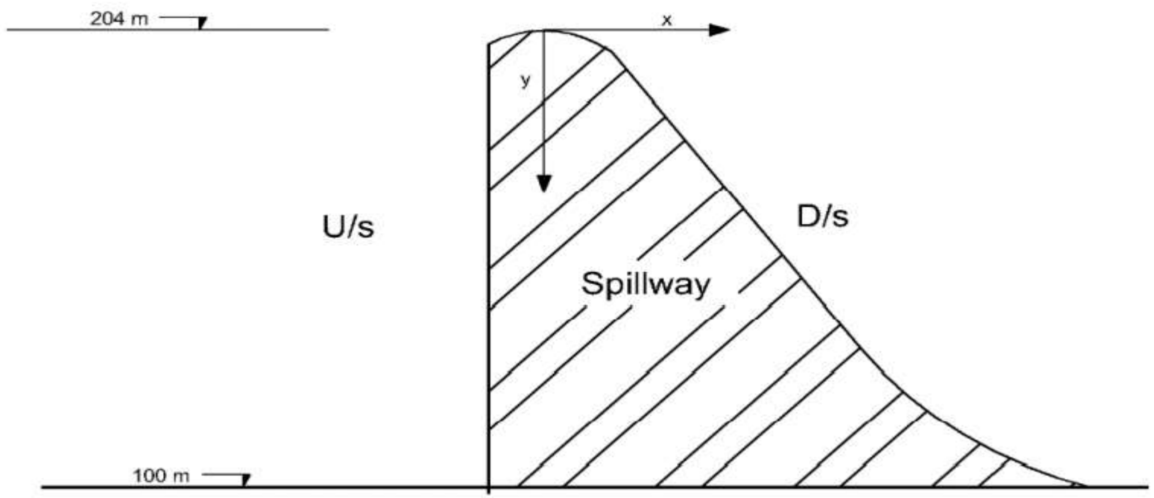
$r_1 = 0.5\,H_d$

$r_2 = 0.2\,H_d$



Example: Design downstream crest curve of ogee spillway for concrete gravity dam having downstream face sloping of (0.7:1). The design discharge for the spillway is 8000 m^3/sec. The height of spillway crest is kept at level 204 m and the upstream face is vertical. The average riverbed level at the site is 100 m. The spillway length crest consists of 6 spans having clear width of 10 m each. The thickness of each pier is 2.5, K_p=0.01, Ka=0.1, C=2.2.





Solution

$$X^m = K.H_d{}^{m-l} * y$$

Use vertical face:-

$$X^{1.85} = 2H_d{}^{0.85} * y$$

$$Q = C * L_e * H_e{}^{\frac{3}{2}}$$

$$L_e = L - 2\left(K_p * n + K_a\right) * H_e$$

$$L_e = (6 * 10) - 2(0.01 * 5 + 0.1) * H_e$$

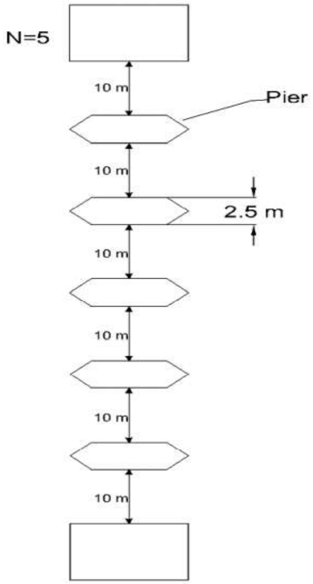
$$L_e = 60 - 0.3H_e - - - - - - - - - - - -(1)$$

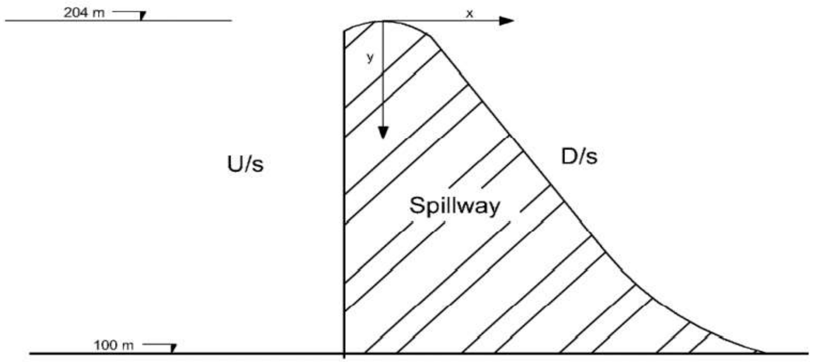
$$8000 = 2.2(60 - 0.3H_e) * H_e{}^{\frac{3}{2}}$$

$$H_e = 16.3\ m$$

$$If\ \frac{P}{H_d} > 1.33 \quad High\ spillway\ , H_a = 0$$

$$P = 204 - 100 = 104\ m$$





$$Assume\ Hd = He = 16.3$$

$$\frac{104}{16.3} > 1.33$$

$$\therefore The\ spillway\ is\ high\ and\ we\ can\ neglected\ H_a, H_a = zero$$

$$\therefore\ Hd = He = 16.3$$

$$X^{1.85} = 2(16.3)^{0.85} * y$$

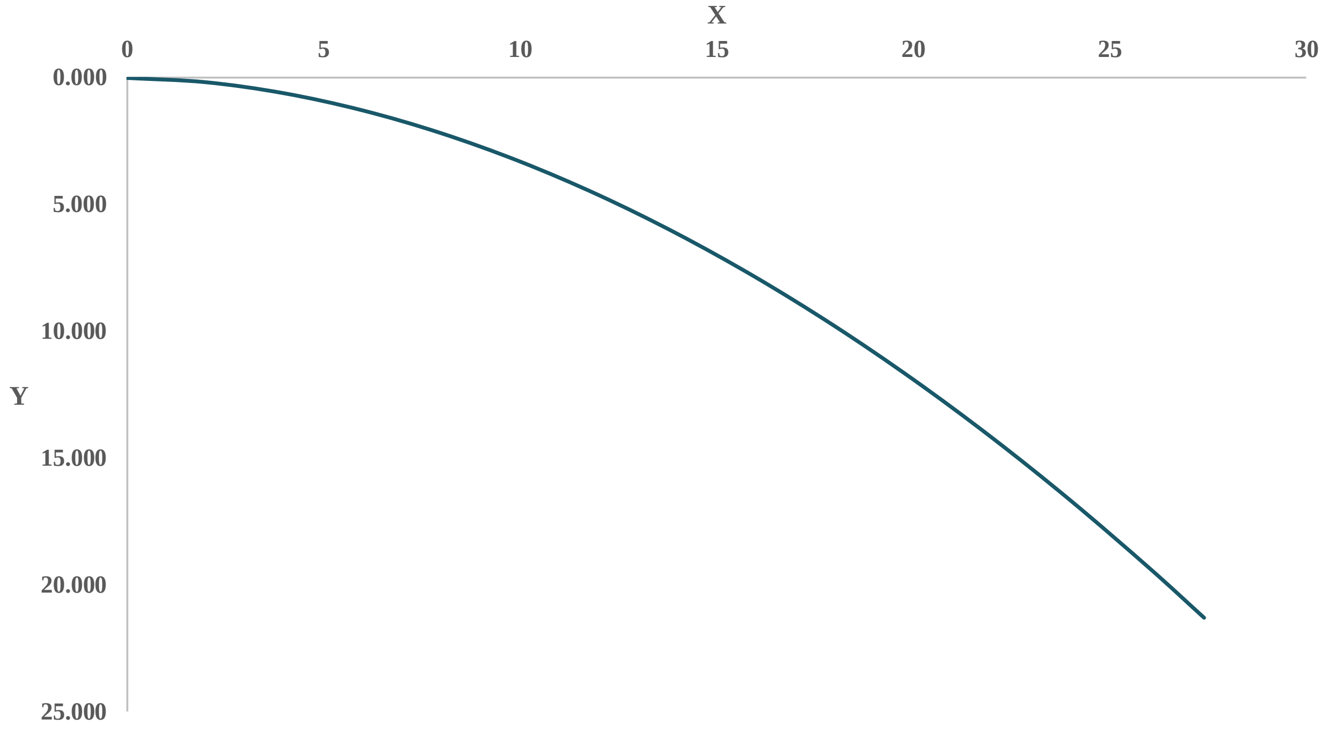
$$y = \frac{X^{1.85}}{21.448}$$

$$\frac{dy}{dx} = \frac{1.85\, X^{0.85}}{21.448}$$

$$\frac{1}{0.7} = \frac{1.85X^{0.85}}{21.448}$$

$$x = 27.4$$

X	0	2	4	6	8	10	12	14
Y	0	0.168	0.606	1.283	2.184	3.301	4.625	6.151
X	16	18	20	22	24	26	27.4	
Y	7.875	9.792	11.899	14.194	16.673	19.334	21.304	

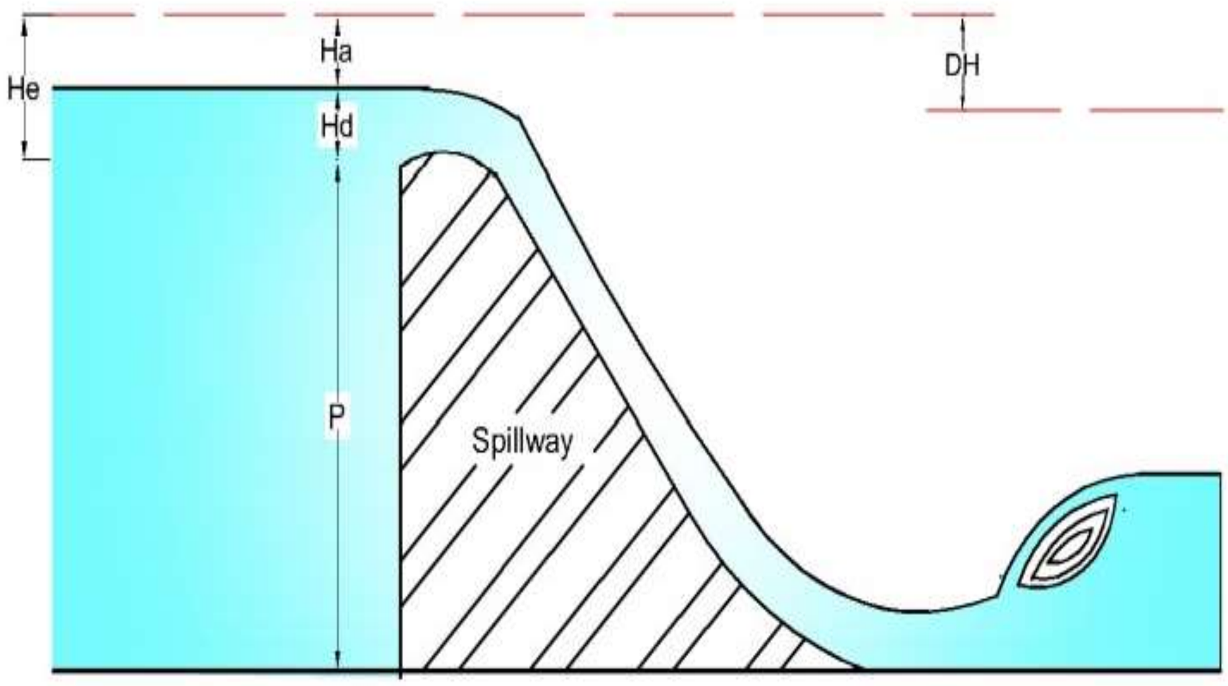


Example: A hydraulic jump occurred at the end of ogee spillway. For this jump, $Fr_1=11$. The crest of this spillway consists 6 spans having clear width of 10 m for each. The thickness of each pier is 2m. The downstream sloping of the spillway is 0.8:1 and the upstream face is vertical. $K_p=0.01$, $K_a=0.1$, $C=2.2$, $H_d=H_e=4.5$ m

1) Find the crest height of this spillway (P).

2) Find the D/s crest coordinates of the spillway.

3) Find the dissipated energy in the jump.



Solution

$$1) E_0 = E_1 = E_2 + \Delta E$$

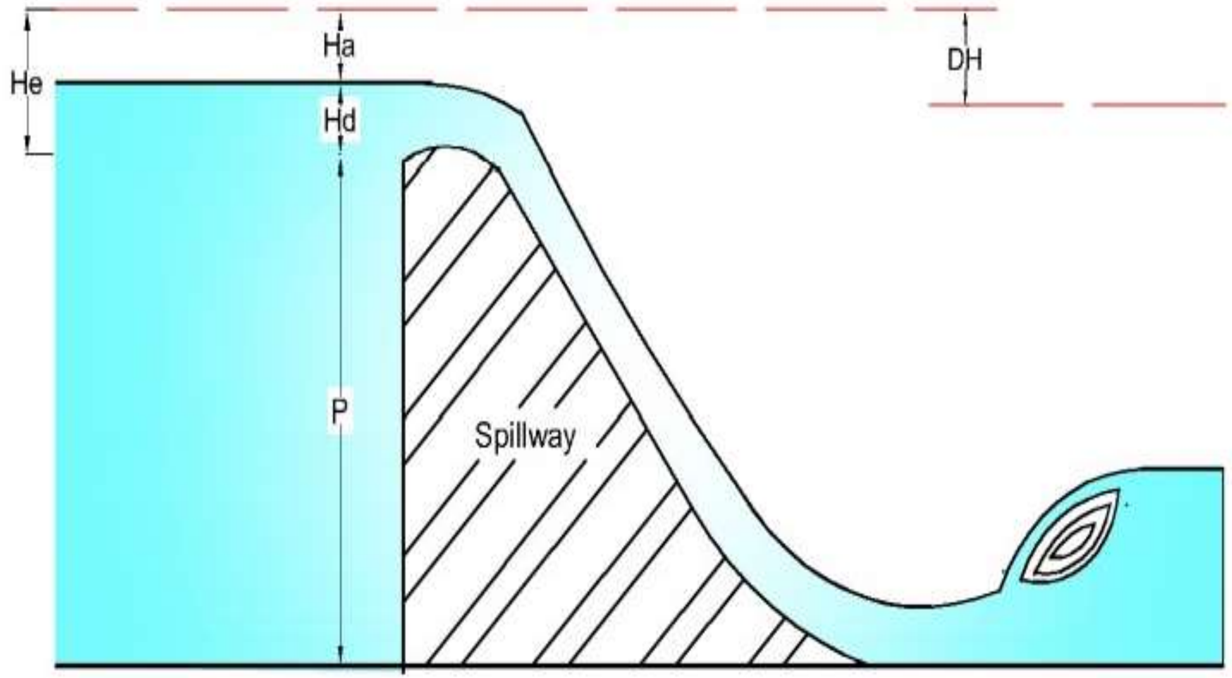
$$\frac{{v_0}^2}{2g} \approx 0$$

$$E_0 = y_0 = H_d + P$$

$$E_1 = y_1 + \frac{{v_1}^2}{2g}$$

$$H_d + P = y_1 + \frac{{v_1}^2}{2g}$$

$$F_{r1} = \frac{v_1}{\sqrt{g y_1}}$$



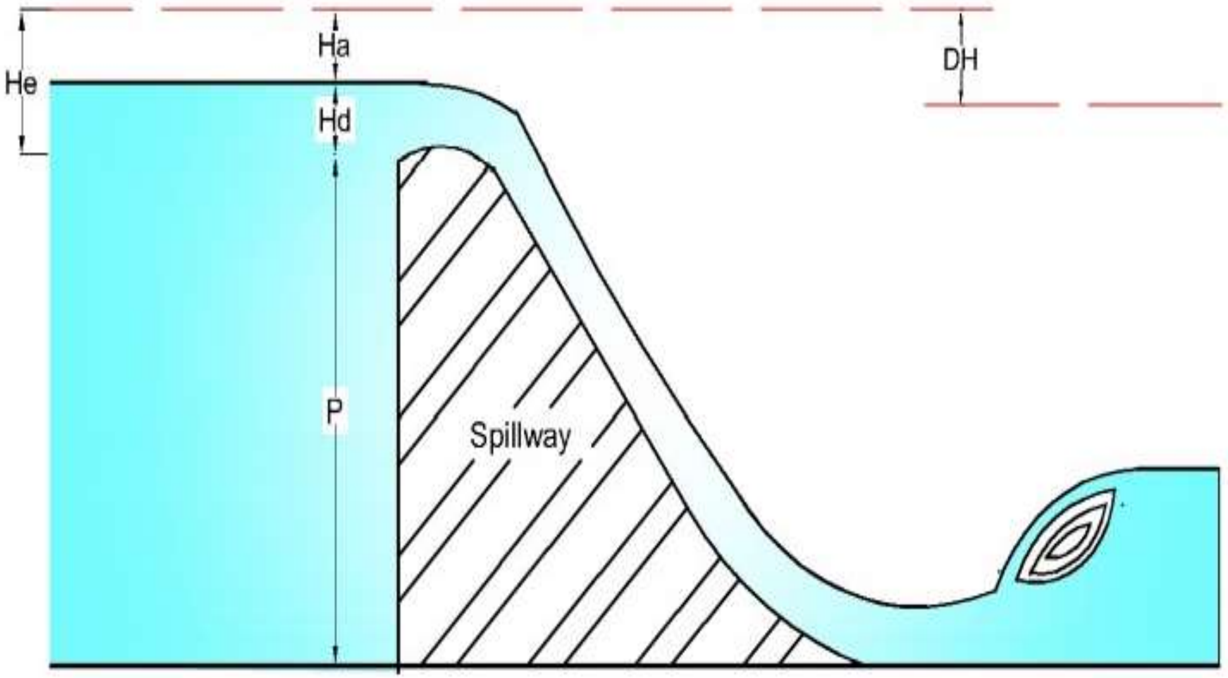
$$Q = C * L_e * H_e^{\frac{3}{2}}$$

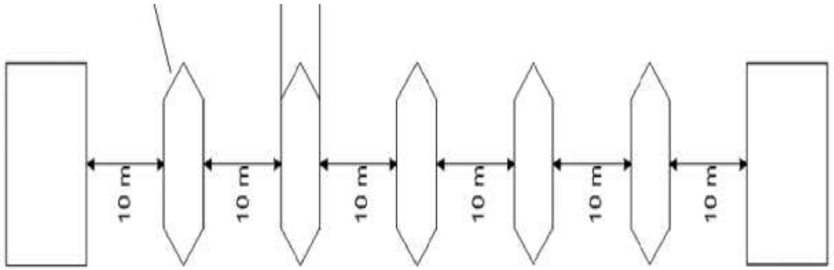
$$L_e = L - 2(K_p * n + K_a) * H_e$$

$$L_e = (6 * 10) - 2(0.01 * 5 + 0.1) * 4.5 = 58.65\, m$$

$$Q = 2.2 * 58.65 * (4.5)^{\frac{3}{2}}$$

$$Q = 1231.7\, m^3/sec$$





$$v_1 = \frac{Q}{A_1}$$

$$v_1 = \frac{1231.7}{(y_1(60 + 5 * 2)} = \frac{1231.7}{(70y_1)} = \frac{17.6}{y_1}$$

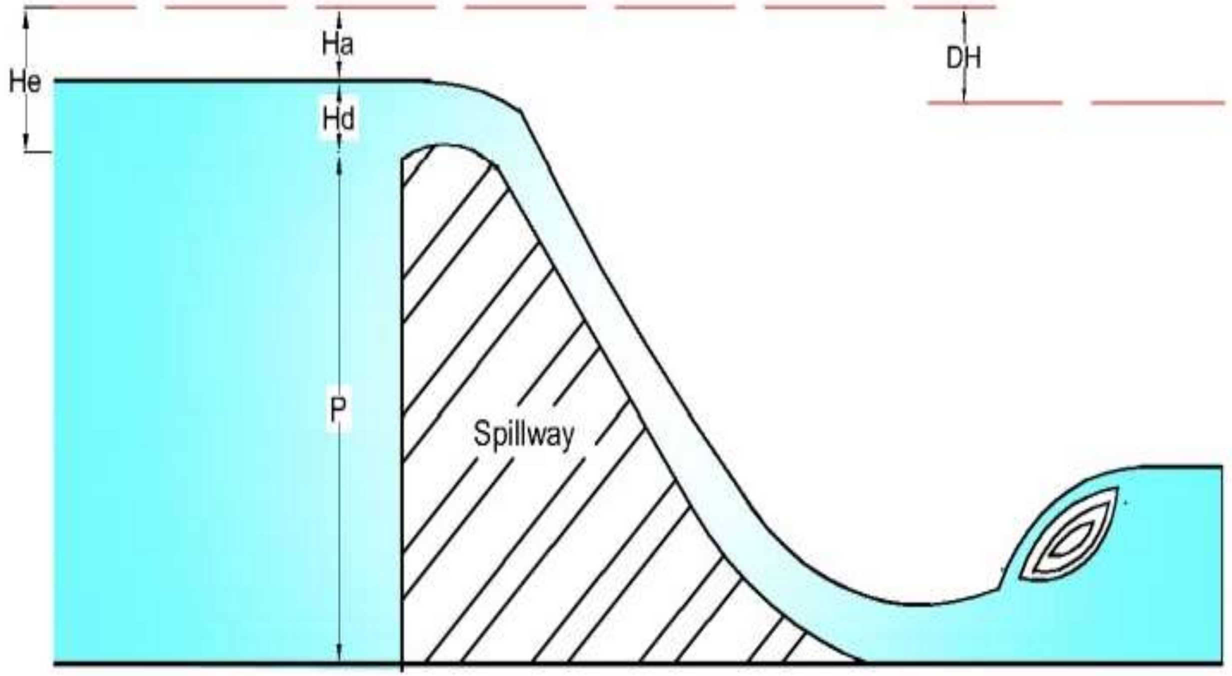
$$11 = \frac{\frac{17.6}{y_1}}{\sqrt{9.81y_1}}$$

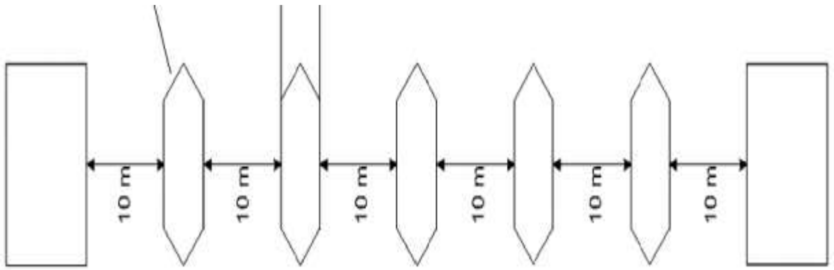
$$y_1 = 0.638$$

$$v_1 = \frac{17.59}{0.638} = 27.5 \ \ m/sec$$

$$4.5 + P = 0.638 + \frac{(27.5)^2}{19.62}$$

$$P = 34.68 \, m$$





X	0	2	4	6	6.4
Y	0	0.502	1.810	3.832	4.318

2) $X^{1.85} = 2H_d{}^{0.85} * y$

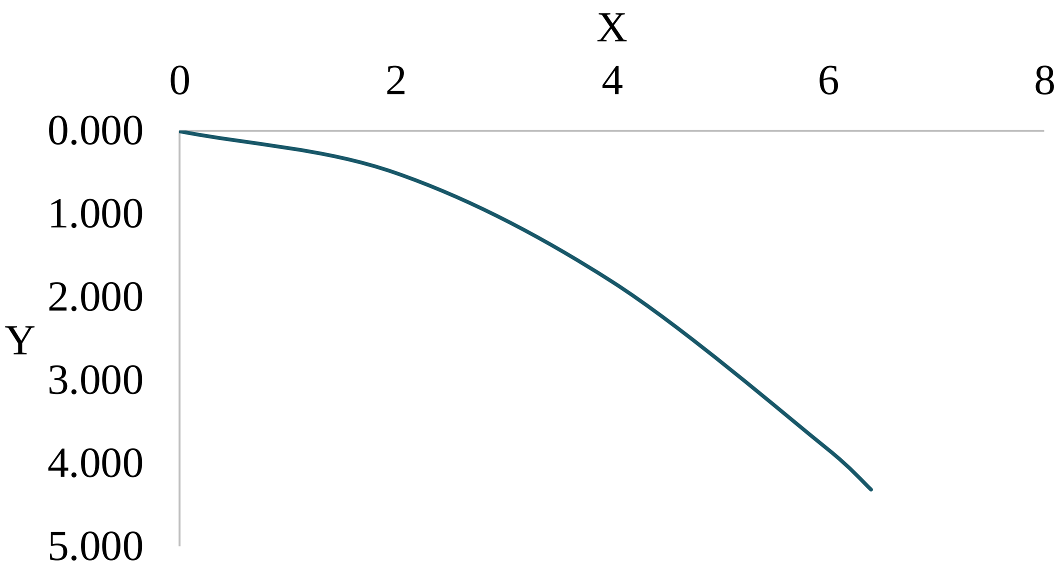
$$X^{1.85} = 2(4.5)^{0.85} * y$$

$$y = \frac{X^{1.85}}{7.18}$$

$$\frac{dy}{dx} = \frac{1.85\ X^{0.85}}{7.18}$$

$$\frac{1}{0.8} = \frac{1.85X^{0.85}}{7.18}$$

$$x = 6.4$$



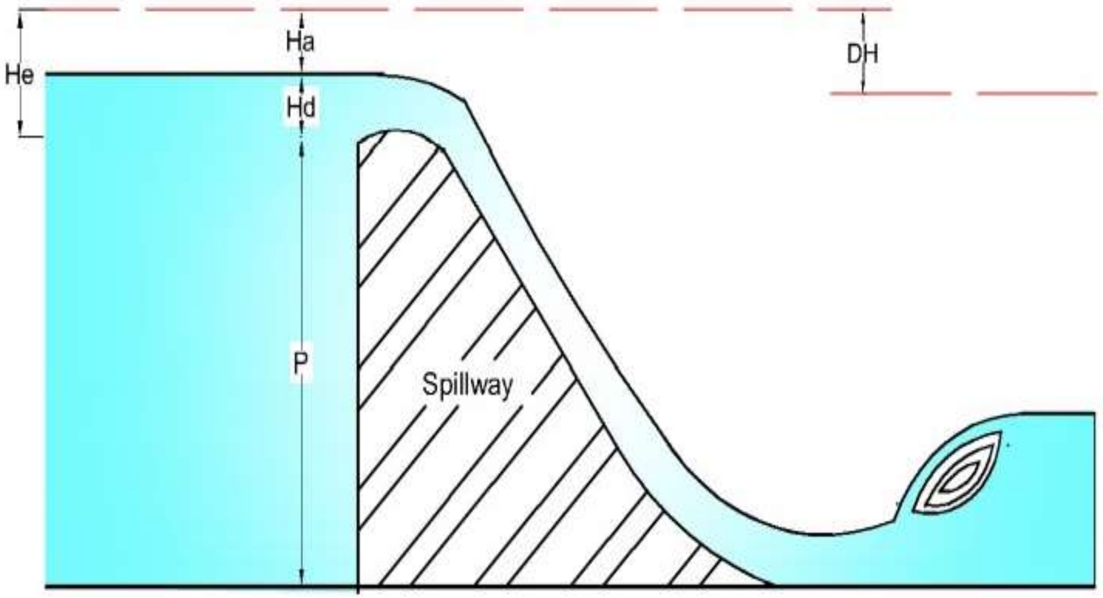
3)

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

$$\frac{y_2}{y_1} = \frac{1}{2}\left[\sqrt{1 + 8{Fr_1}^2} - 1\right] \quad , \quad \frac{y_2}{0.638} = \frac{1}{2}\left[\sqrt{1 + 8(11)^2} - 1\right]$$

$$y_2 = 9.6\ m$$

$$\Delta E = \frac{(9.6 - 0.638)^3}{4(0.638)(9.6)} = 29.3\ m$$



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