

Design of Municipal Wastewater Treatment Plant (WTP)

Submitted by

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DESIGN OF A WATER TREATMENT

PLANT FOR A FLOW OF 12 MLD

1. CASCADE AERATOR

3) Inlet Shaft :

Assuming water velocity to be 0.75 m/s .

$$\therefore 1.2 \times 12 \text{ MLD} = 1.2 \times \frac{12 \times 10^6 \times 10^{-3}}{24} = 600 \text{ m}^3/\text{h} = 0.166 \text{ m}^3/\text{s}.$$

$$\Rightarrow \text{Area of shaft} = Q/V = \frac{0.166}{0.75} = 0.22 \text{ m}^2.$$

$$\Rightarrow \frac{\pi}{4} d^2 = 0.22 \Rightarrow d = 0.53 \text{ m}$$

$$\therefore \text{Diameter of shaft} = 0.53 \text{ m}.$$

Adopting diameter = 0.6 m or 600 mm .

The shaft's bell mouth dia = 0.8 m .

b) Size & number of steps:

Assuming, space requirement to be $0.03 \text{ m}^3/\text{m}^2\text{h}$.

$$\text{Area of cascade} = 0.03 \times \frac{600}{1.2} = 15 \text{ m}^2.$$

If D_a is the diameter then,

$$15 = \frac{\pi}{4} (D_a^2 - 0.8^2)$$

$$\Rightarrow D_a = \underline{4.44 \text{ m}}.$$

Assuming no. of steps to be 5.

$$\therefore \text{Size of tread} = \frac{4.443 - 0.8}{5 \times 2} = 0.364 \text{ m} \approx \underline{40 \text{ cm}}.$$

Actual size of aerator = $5 \times 2 \times 0.4 + 0.8 = 4.8 \text{ m}$.

Assuming rise of each step = 0.3m

Height of total rise of steps = $0.3 \times 5 = 1.5 \text{ m}$.

3) Size of Collecting launder:

$$\text{Flow in launder} = Q_2 = \frac{1.2 \times 10^3 \times 1.2}{2 \times 24 \times 3600} = 0.0833 \text{ m}^3/\text{s}.$$

Assuming velocity in the launder = 0.8 m/s .

$$\text{Area requirement} = \frac{0.0833}{0.8} = 0.1042 \text{ m}^2.$$

Width of launder = 0.8m (Assumed)

$$\text{Height of water (SWD)} = \frac{0.1042}{0.8} = 0.13 \text{ m}$$

Free board in Launder = 0.2m (assumed)

$$\text{Depth of launder} = 0.13 + 0.2 = 0.33 \\ \text{say } 0.4 \text{ m.}$$

Size of launder = $0.8 \times 0.4 \text{ m}$ (Width \times height)

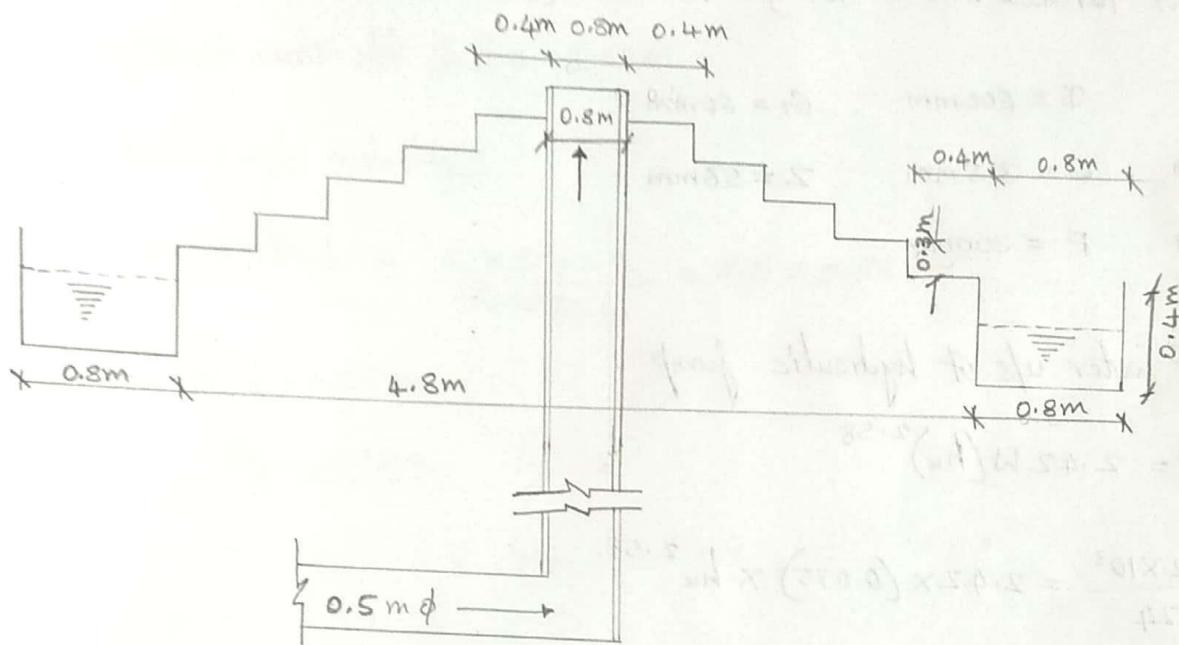
d) Inlet pipe connecting inlet shaft:

$$Q_1 = Q_2 = V_2 A_2$$

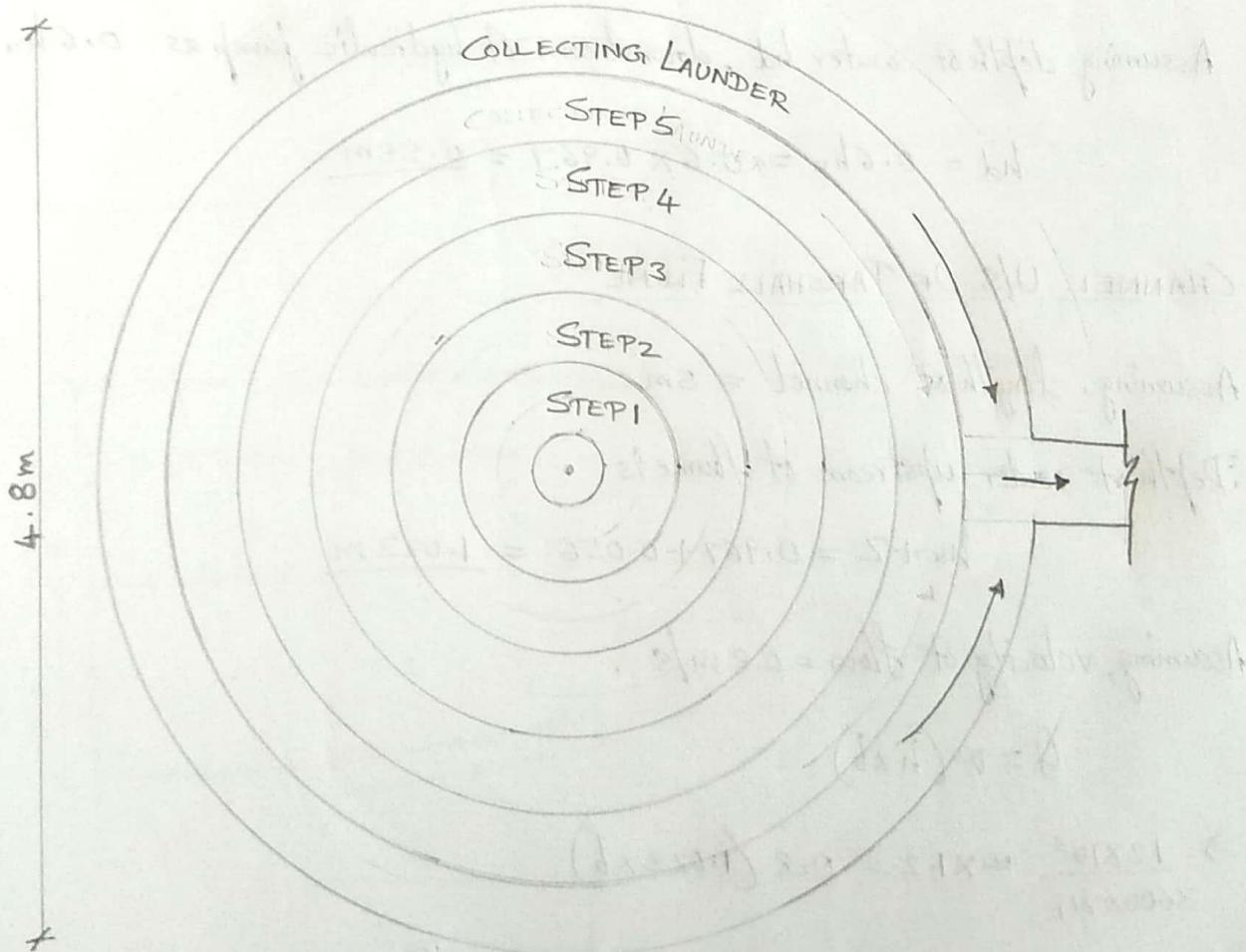
$$\Rightarrow \frac{1.2 \times 1.2 \times 10^3}{3600 \times 24} = 1.2 \times \pi d^2 / 4 \Rightarrow d = 0.42 \text{ m}$$

Say, $0.5 \text{ m} \approx 500 \text{ mm}$.

1. CASCADE AERATOR



a) Section of Cascade aerator



b) Plan of Cascade aerator

2. PARSHALL FLUME

Dimensions of Parshall flume for $Q = 12 \text{ MLD}$ (From table)

$$W = 75 \text{ mm} \quad B = 600 \text{ mm} \quad G_1 = 60 \text{ mm}$$

$$A = 460 \text{ mm} \quad C = 315 \text{ mm} \quad Z = 56 \text{ mm}$$

$$D = 391 \text{ mm} \quad F = 300 \text{ mm}$$

Depth of water u/s of hydraulic jump :

$$Q = 2.42 W (h_u)^{2.58}$$

$$\Rightarrow \frac{1.2 \times 12 \times 10^3}{3600 \times 24} = 2.42 \times (0.075) \times h_u^{2.58}$$

$$\Rightarrow h_u = \underline{0.967 \text{ m}}.$$

Assuming depth of water h_d , downstream of hydraulic jump as $0.6 h_u$

$$\therefore h_d = 0.6 h_u = 0.6 \times 0.967 = \underline{0.58 \text{ m}}.$$

3. CHANNEL U/S OF PARSHALL FLUME

Assuming, length of channel = 5m.

Depth of water upstream of flume is .

$$h_u + Z = 0.967 + 0.056 = \underline{1.023 \text{ m}}$$

Assuming, velocity of flow = 0.8 m/s .

$$Q = v (h \times b)$$

$$\Rightarrow \frac{12 \times 10^3}{3600 \times 24} \times 1.2 = 0.8 (1.023 \times b)$$

$$\Rightarrow b = \underline{0.204 \text{ m}}.$$

4. CHANNEL D/S OF PARSHALL FLUME TO DISTRIBUTION CHAMBER

Length of channel = 5m (assumed)

depth of water d/s (h_d) = 0.58m.

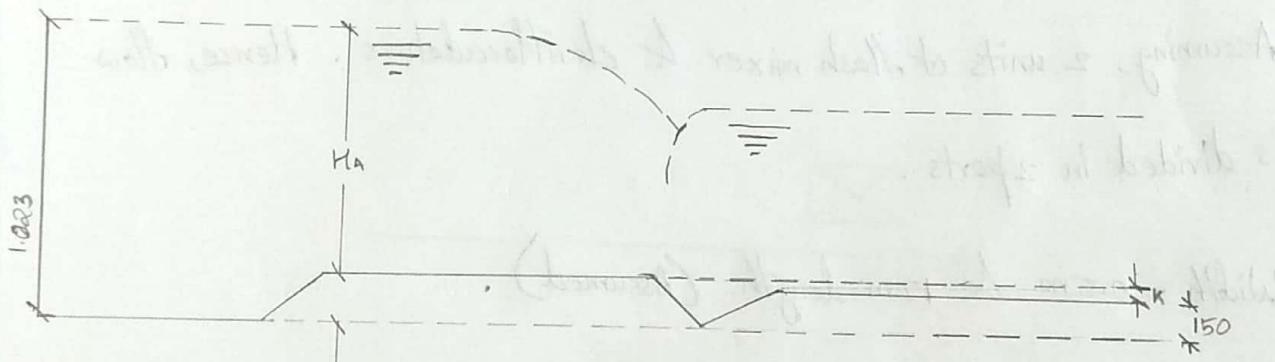
for 0.8 m/s velocity,

$$\delta = v \times h \times b \Rightarrow \frac{12 \times 10^3 \times 1.2}{3600 \times 24} = 0.8 \times 0.58 \times b$$

$$\Rightarrow b = 0.359m$$

Say, 0.36m.

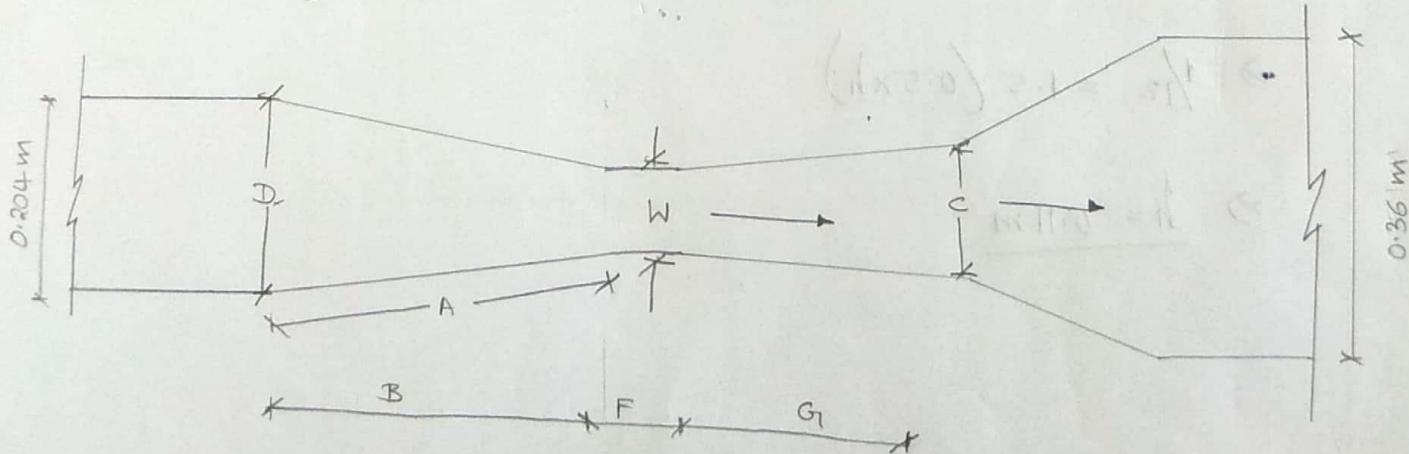
2. PARSHALL FLUME



a) Longitudinal Section

$W = 75\text{mm}$; $B = 600\text{mm}$; $G_1 = 60\text{mm}$; $A = 460\text{mm}$; $C = 315\text{mm}$; $Z = 56\text{mm}$;

$D = 391\text{mm}$; $F = 300\text{mm}$



b) Plan

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5.

DISTRIBUTION CHAMBER

Assuming, 10 seconds detention time.

$$\frac{12 \times 10^3}{3600 \times 24} \times 10 = 1.389 \text{ m}^3 \quad [V = Q \times t]$$

Assuming, SWD = 1 m.

$$\therefore \text{Area} = \underline{1.389 \text{ m}^2}$$

$$\text{Size} = \underline{1.2 \times 1.2 \text{ m}}$$

6. CHANNEL BETWEEN DISTRIBUTION CHAMBER AND FLASH MIXER

Assuming, 2 units of flash mixer & clarifloculators. Hence, flow is divided in 2 parts.

Width = 0.5m & 12m length (Assumed).

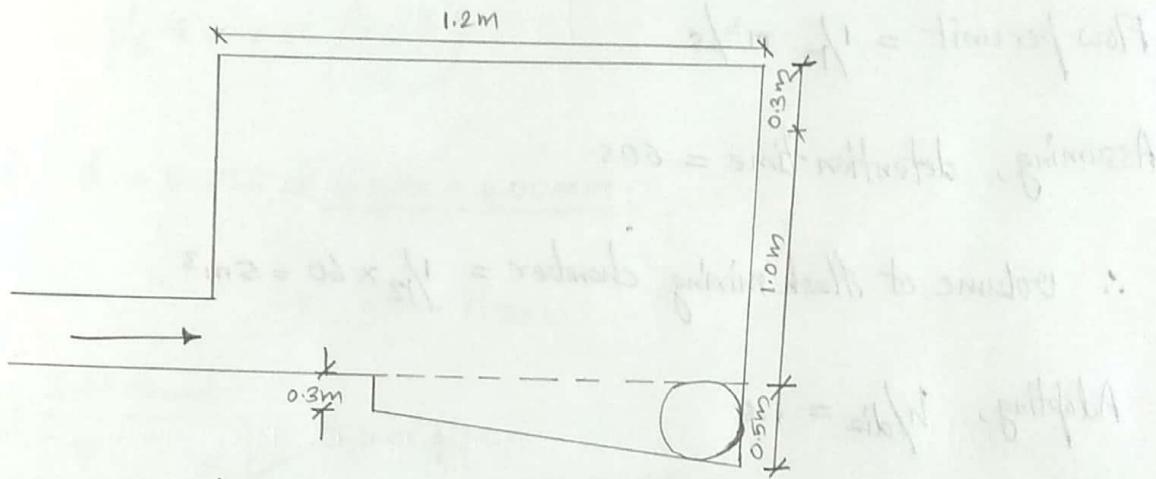
$$\text{Flow per unit} = \frac{1}{6} \times \frac{1}{2} = \frac{1}{12} \text{ m}^3/\text{s}$$

Assuming, $V = 1.5 \text{ m/s}$.

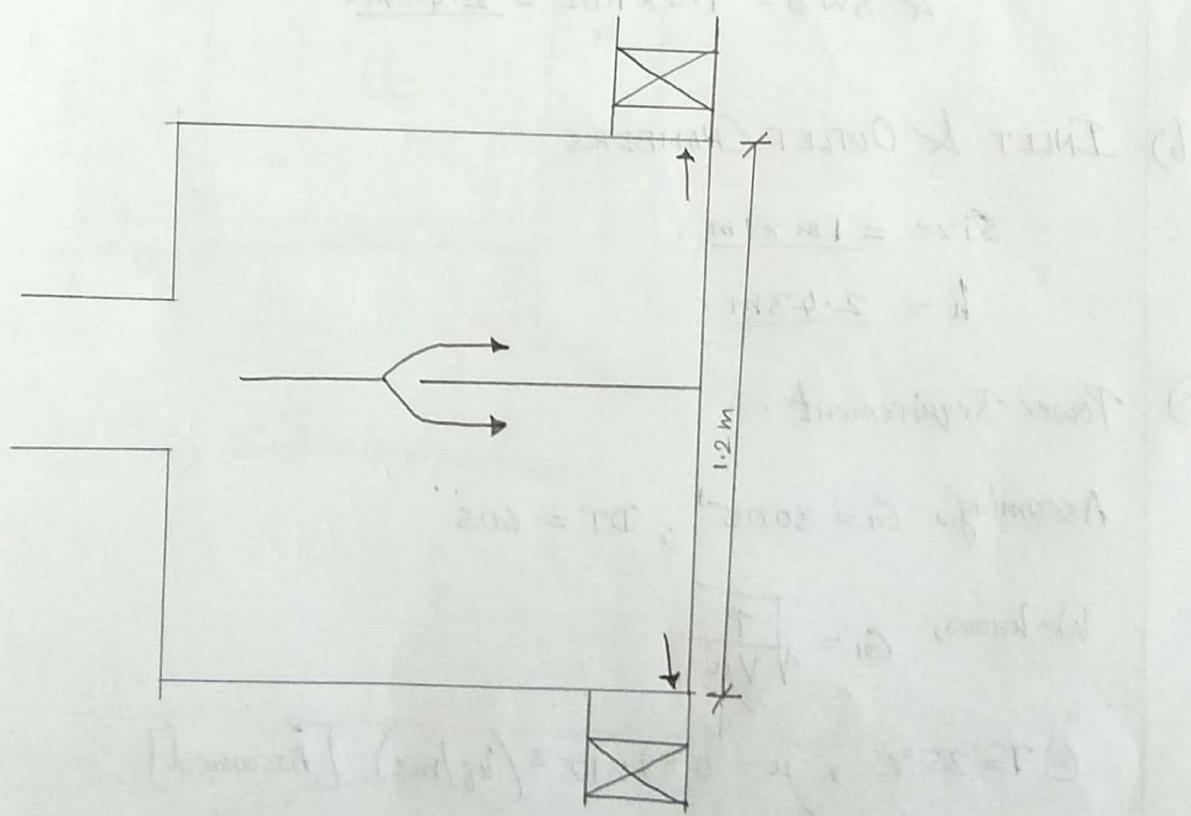
$$\Rightarrow \frac{1}{12} = 1.5 (0.5 \times h)$$

$$\Rightarrow \underline{h = 0.11 \text{ m}}$$

3. DISTRIBUTION CHAMBER



a) Section of distribution chamber



b) Plan of distribution Chamber

FLASH MIXER

a) Size of Chamber:

$$\text{Flow per unit} = \frac{1}{12} \text{ m}^3/\text{s}$$

Assuming, detention time = 60s

$$\therefore \text{Volume of flash mixing chamber} = \frac{1}{12} \times 60 = 5 \text{ m}^3.$$

$$\text{Adopting, } h/d_{12} = 1.5$$

$$\Rightarrow \frac{\pi d^2}{4} \times 1.5d = 5 \Rightarrow d = \underline{1.62 \text{ m}}.$$

$$\& \text{SWD} = 1.5 \times 1.62 = \underline{2.43 \text{ m}}.$$

b) INLET & OUTLET CHAMBERS

$$\text{Size} = \underline{1 \text{ m} \times 1 \text{ m}}.$$

$$h = \underline{2.43 \text{ m}}.$$

c) Power Requirement:

Assuming, $G_i = 300 \text{ s}^{-1}$, $DT = 60 \text{ s}$

$$\text{We know, } G_i = \sqrt{\frac{P}{V\mu}}$$

$$@ T = 25^\circ \text{C}, \mu = 0.89 \times 10^{-3} (\text{kg/ms}) [\text{Assumed}]$$

$$\Rightarrow 300^2 = \frac{P}{5 \times 0.89 \times 10^{-3}}$$

$$\Rightarrow P = \underline{400.5 \text{ watts.}}$$

d) Outlet pipe:

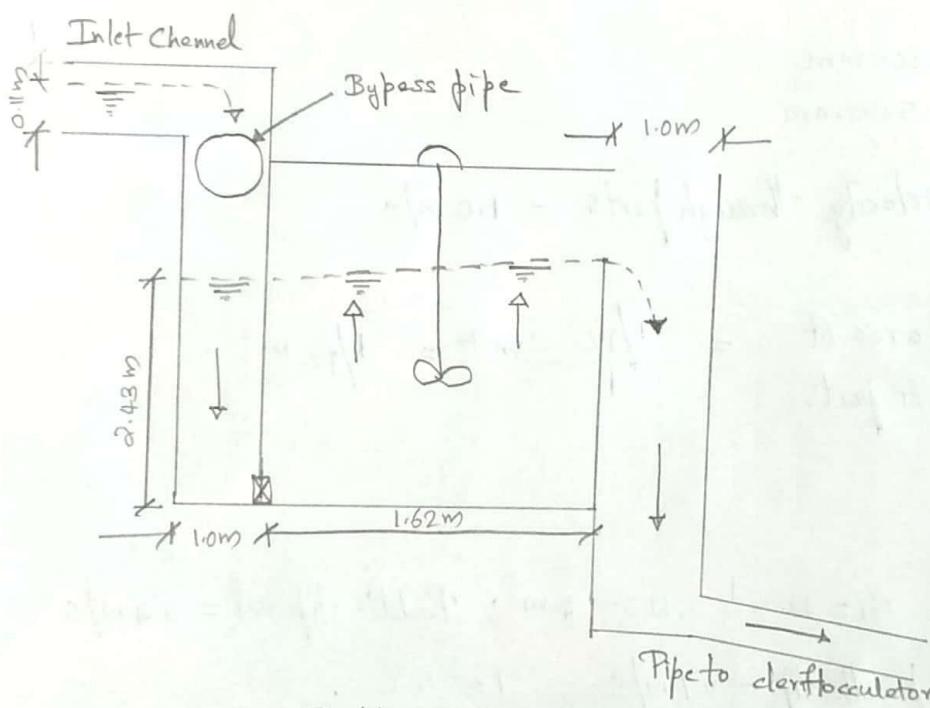
Let velocity in the pipe be 1.5 m/s.

∴ for 20% overload :-

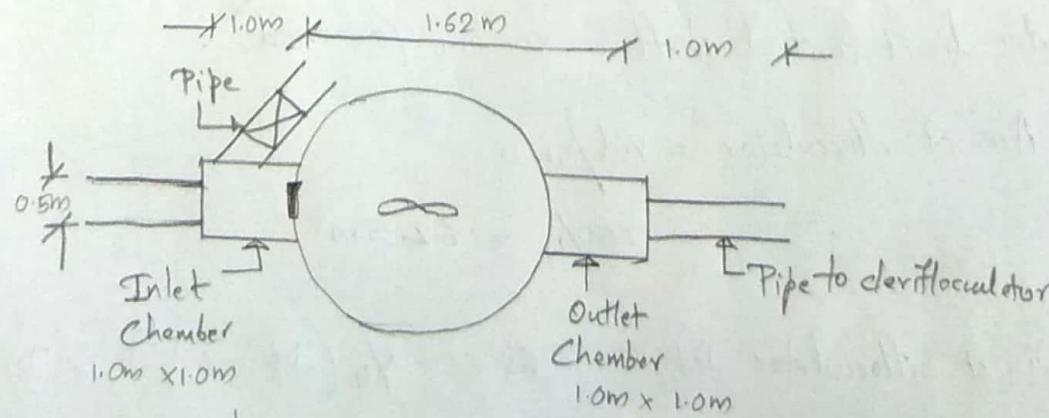
$$\frac{1}{6} * = 1.5 \left(\frac{\pi d^2}{4} \right)$$

$$\Rightarrow d = 0.376 \approx \underline{0.4 \text{ m} = 400 \text{ mm}}$$

4' Flash MIXER



a) Section of flash mixer



b) Plan of flash mixer

8. CLARIFLOCCULATOR

a) Central Shaft :

Assuming, $v = 1.2 \text{ m/s}$

$$\text{Diameter of shaft} = \frac{(4Q)}{(v\pi)}^{1/2} = \frac{(4 \times 1/12)}{(1.2 \times 3.14)}^{1/2} = 0.29 \text{ m}$$

Say, 300mm.

$\therefore \text{ID} = 300 \text{ mm}$

$\text{OD} = 500 \text{ mm}$.

Assuming, velocity through ports = 1.0 m/s.

$$\therefore \text{Total area of opening of ports} = \frac{\pi}{4} \times 1/12^2 \text{ m}^2 = 1/12 \text{ m}^2.$$

b) Flocculator:

$DT = 30 \text{ min}; G_1 = 40 \text{ s}^{-1}; SWD = 4 \text{ m}; \text{Paddle tip vel} = 0.4 \text{ m/s}$

$\text{Water vel @ paddle tip} = 0.1 \text{ m/s}; T = 25^\circ \text{C}$.

Design Calculations :-

$\text{Vol of flocculator} = (1/12 \times 1/12) \times 30 \times 60 = 250 \text{ m}^3$

Outer dia of central shaft = 800mm (assumed).

$$\begin{aligned} \text{Area of flocculator} &= \text{vol}/\text{SWD} \\ &= 250/4 = 62.5 \text{ m}^2. \end{aligned}$$

$\text{Dia of flocculator } D_f \Rightarrow 62.5 = \pi/4 (D_f^2 - 0.8^2) \Rightarrow D_f = 8.956 \text{ m.}$

Power requirement :

$$G_i = \sqrt{\frac{P}{\mu v \rho}} \Rightarrow P = G_i^2 \mu v \rho$$

$$\Rightarrow P = 40^2 \times (0.89 \times 10^{-3}) \times 250 = \underline{356 \text{ watts.}}$$

Also,

$$P = \frac{C_D A_p f (V - v)^3}{2} \quad [\text{for single paddle per arm}]$$

$$\Rightarrow 356 = \frac{1.8 A_p \times 997 (0.4 - 0.1)^3}{2}$$

$$\underline{A_p = 14.694 \text{ m}^2.}$$

Since, there are 2 units;

$$\text{Area of blade per unit} = 14.69 / 2 = 7.34 \text{ m}^2.$$

Assume 3 blades per drive unit & height of each blade = 2m.

$$\text{Width} = \frac{7.347}{2 \times 3} = 1.22 \text{ m.}$$

Let,

3 blades per arm & 4 arm per unit;

each blade of 1.5m length & 0.1m width

$$A_p = 3 \times 4 \times 2 \times \frac{1.5^2}{4} \times 0.1 = \cancel{36 \times 0.1} \quad 4.8 \text{ m}^2$$

$$V = \frac{2\pi r n}{60}$$

$$P = \frac{C_D}{2} \sum_{\text{ap}} \left[\frac{2\pi r n}{60} - 0.25 \times \frac{2\pi r n}{60} \right]^3$$

$$\Rightarrow 356 = \frac{1.8 \times 997}{2} \times 12 \times 0.2 \left[0.75 \times \left(\frac{2\pi n}{60} \right) \right]^3 \times (3^3 + 2^3 + 1^3)$$

$$\Rightarrow n = 2.11 \text{ rpm} \approx 2 \text{ rpm}.$$

$$\begin{aligned}\text{Total area of blades} &= 24 \times 0.3 \times 2 \\ &= 4.8 \text{ m}^2\end{aligned}$$

$$\% \text{ of flocculator} = (8.956 - 0.8) \times 2 = 16.312 \text{ m}^2.$$

$$\frac{\text{Area of blade}}{\text{c/s area of flocculator}} = \frac{16}{68.2} = 23.4 \%$$

$$\text{Bottom slope of flocculator} = \underline{1 \text{ in } 12}.$$

3) Clarifier :

$$D.T = 2.5 \text{ h}; \text{ Surface overflow rate} = 36 \text{ m}^3/\text{m}^2 \cdot \text{d}$$

$$\text{Wier loading} = 300 \text{ m}^3/\text{m.d}; \text{ SWD} = 3 \text{ m}.$$

Design details:-

$$\text{Vol of tank} = \left(\frac{1}{12 \times 1.2} \right) \times 2.5 \times 3600 = 625 \text{ m}^3.$$

$$\text{Area of clarifier} = \frac{625}{3} = 208.33 \text{ m}^2.$$

If 0.2 thickness partition b/w clarifier & flocculator,

$$\text{outer dia of flocculator} = 8.956 + 0.4 = 9.356 \text{ m}.$$

$$208.33 = \pi/4 (D_c^2 - 9.356^2)$$

$$D_c = 18.78 \text{ m}.$$

$$\underline{\text{Say, } 18.8 \text{ m}.}$$

Check for Surface Overflow rate (SOR)!

$$= \frac{Q}{B} = \frac{1}{2} C_d A \sqrt{2g h}$$

$$= \frac{1}{2} C_d A \sqrt{2g h}$$

W.L < permitted value at 300 cm \rightarrow Hence, OK

$$\left(\frac{\theta}{2} \right)$$

For, 90° V notch, the above equation reduces to

$$q = 1.417 h^{5/2}$$

If the total depth of the V-notch is 10cm & water head is 8cm

$$q = 1.417 \times 8^{5/2} = 1.417 \times 32 = 45.34 \text{ m}^3/\text{s}$$

For more uniform flow, spacing of 0.3 m c/c

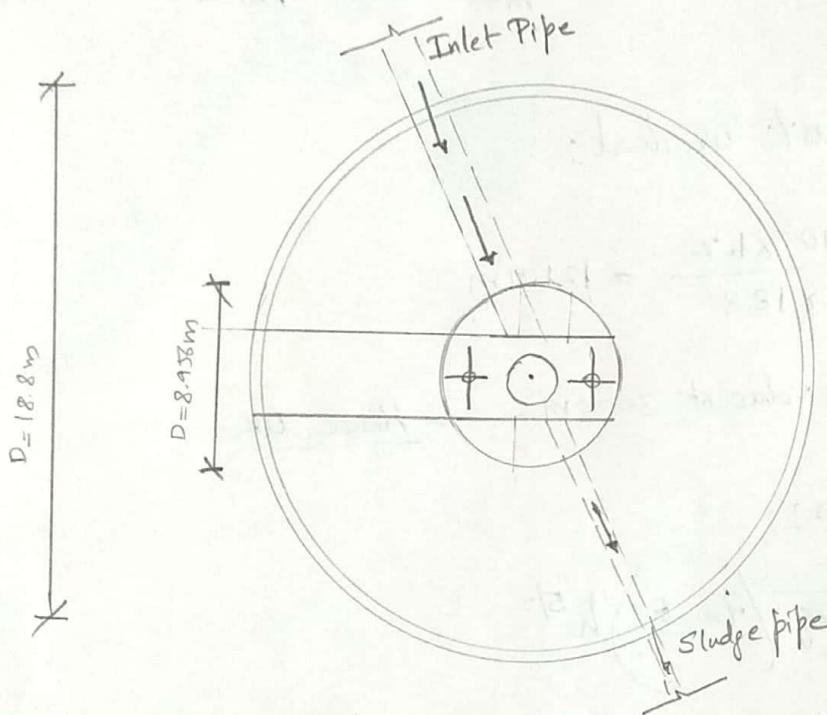
$$\text{no. of notches} = \frac{(18.8 \times \pi)}{0.3} = 19.68$$

d) Peripheral Launder

Let velocity = 0.5 m/s; width = 0.3 m

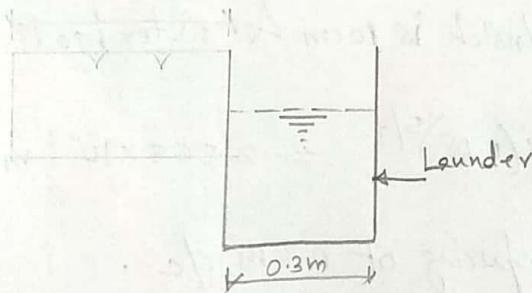
$$(1/2) \times 1/2 = 0.5 \times (0.3 \times h)$$

5. CLARIFLOCULATOR

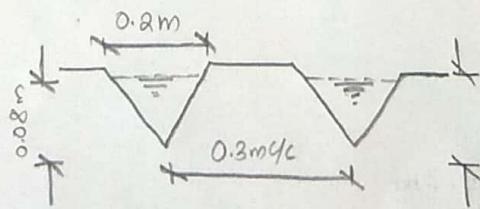


a) Plan of clarifloculator

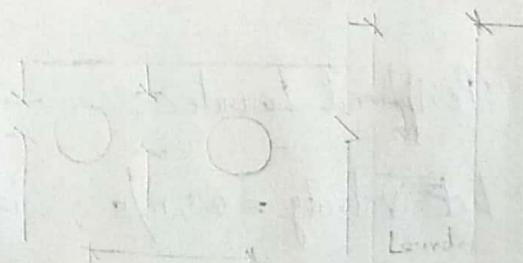
b) Plan of trough & launder



c) Sections of V notches



d) Section of surface



9 RAPID GRAVITY FILTERS

Data:

Flow = 12 MLD

Rate of filtration = $5 \text{ m}^3/\text{m}^2\text{h}$.

No. of beds = 1

Design Details

Flow per bed = 12 MLD = $500 \text{ m}^3/\text{h}$

Area of 1 bed = $\frac{500}{5} = 100 \text{ m}^2$

provide size of bed = $12 \times 9 \text{ m}^2$

Ratio of L/W = $12/9 = 1.33$

This is in range of 1.11 to 1.66; hence O.K.

a) Sand

provide depth of sand = 75 cm

effective size = 0.5 mm

uniformity coefficient = 1.5

d_{10} size = 0.50 mm

d_{60} size = 0.75 mm

b) Gravel

Depth of gravel = 0.45 m

size of gravel at top = 2 to 5 mm

size of gravel at bottom = 50 mm

c) Depth of water

Depth of water above sand surface = 2 m

Free board = 0.5 m

Total depth of filter box = $0.75 + 0.45 + 2 + 0.5 = 3.7 \text{ m}$

d) Under drain system

Provide 2 sections per filter bed

Hence provide 2 units of under drain systems per bed.

$$\text{Area of filter per section} = 12 \times 4.5 \\ = 54 \text{ m}^2$$

$$\text{Under drain sections orifice area required} = 0.3\% \text{ of filter area} \\ = \frac{0.3}{100} \times 54 = 0.162 \text{ m}^2$$

$$\text{Lateral area} = 2 \times \text{orifice area} \\ = 2 \times 0.162 = 0.324 \text{ m}^2$$

$$\text{Manifold area} = 1.5 \times \text{lateral area} \\ = 1.5 \times 0.324 = 0.486 \text{ m}^2$$

$$\frac{\pi}{4} d_m^2 = 0.486 \\ \Rightarrow d_m = 0.786 \text{ m}; \text{ say } d_m = 800 \text{ mm}$$

Diameter of lateral = 80mm (assumed)

$$\text{Area of lateral} = \frac{\pi}{4} \times 0.08^2 = 5.0265 \times 10^{-3} \text{ m}^2$$

$$\text{No. of laterals} = \frac{0.324}{5.0265 \times 10^{-3}} = 64.45$$

say 66

so provide 33 no. of laterals on either side of manifold.

If dia. of orifice is 12mm;

$$\text{Area of each orifice} = \frac{\pi}{4} \times 0.012^2 \\ = 1.13 \times 10^{-4} \text{ m}^2$$

$$\therefore \text{No. of orifices per lateral} = \frac{0.162}{66 \times (1.13 \times 10^{-4})} = 21.72$$

say 22

∴ size of pit for 800mm dia manifold will be 0.9m (width) \times 0.9m (ht.)

$$\text{Length of each lateral} = \frac{4.5 - 0.8}{2} = 1.85 \text{ m}$$

$$\frac{\text{Length of lateral}}{\text{Dia of lateral}} = \frac{1.85}{0.08} = 23.125 < 60; \text{ Hence; ok.}$$

If twin orifices are provided per cross sections of the lateral at an angle of 30° to vertical then 17

$$\text{Spacing of orifices} = \frac{1.85}{11} = 0.168 \\ \approx 170 \text{ mm c/c}$$

Thus; Size of manifold = 800 mm dia.

$$\text{Spacing of laterals} = \frac{12}{33} = 0.36 \text{ m} \\ = 360 \text{ mm c/c}$$

To summarise

No. of laterals on either side = 33

Size of laterals = 80 mm

Size of manifold = 800 mm

Size of orifices = 12 mm

No. of orifices per lateral = 22

Spacing of twin orifices per c/s = 170 mm c/c

Size of pt for manifold of 800mm dia. = $0.9 \text{ m} \times 0.9 \text{ m}$.

e). Back Washing of filter

Rate of back wash = $600 \text{ L/m}^2 \cdot \text{min}$.

Rate of air wash = $750 \text{ L/m}^2 \cdot \text{min}$. @ 0.35 kg/cm^2 pressure

f). Wash Water Troughs and Central Bullet

Assume back wash water rate as $600 \text{ L/m}^2 \cdot \text{min}$

$$\begin{aligned} \text{Back wash water required per bed} &= 600 \times 12 \times 9 \\ &= 64,800 \text{ L/min} \\ &= 1.08 \text{ m}^3/\text{s} \end{aligned}$$

Design of Troughs

No. of troughs on either side of gullet = 6 (assumed)

Total no. of troughs = 12

$$\therefore \text{flow per trough} = \frac{108}{12} \text{ m}^3/\text{s} = 0.09 \text{ m}^3/\text{s}$$

Assume flat bottom trough with zero slope and free fall.

Hence; $q = 1.376 b h_o^{3/2}$

Assume width of trough as 0.3 m

$$h_o = \left[\frac{0.09}{1.376 \times 0.3} \right]^{2/3} = 0.362 \text{ m}$$

say 0.4 m

Add free board = 0.15 m

Depth of trough = 0.55 m

clear spacing between troughs = $\frac{12 - 6 \times 0.3}{6} = 1.7$

This is less than 2m; hence O.K.

The bottom of the trough will be 100mm above 50% expanded sand.

\therefore The trough bottom height above unexpanded sand bed

$$= 750 \times 0.5 + 100$$

$$= 475 \text{ mm or } 0.475 \text{ m}$$

Design of Gullet.

Assume flat bottom gullet with zero slope and free fall.

Assume width of gullet = 0.6 m.

$$q = 1.376 b h_o^{3/2}$$

$$h_o = \left[\frac{1.08}{1.376 \times 0.6} \right]^{2/3} = 1.196 \text{ m}$$

But adopt $h_o = 1.2 \text{ m}$. Add free board as 0.3m.

\therefore Total depth of gullet below trough bottom is 1.5 m.

Air Scouring

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$$\begin{aligned}\text{Air flow rate per section} &= 150 \text{ L} \times 54 / \text{min} \\ &= 40,500 \text{ L/min} \\ &= 40.5 \text{ m}^3/\text{min}.\end{aligned}$$

$$\begin{aligned}\therefore \text{Air flow rate per bed} &= 40.5 \times 2 \\ &= \underline{81 \text{ m}^3/\text{min}} @ 0.35 \text{ kg/cm}^2 \text{ pressure}.\end{aligned}$$

$$\text{No. of air blowers} = 2 \quad (1 \text{ working} + 1 \text{ standby})$$

Capacity of blowers for washing both sections at a time;

$$= 81 \times 1.5 \text{ for } 50\% \text{ overload}$$

$$= 121.5 \text{ say } \underline{125 \text{ m}^3/\text{min.}} @ 0.35 \text{ kg/cm}^2 \text{ pressure.}$$

New size of filter bed:

Provide gullet depth upto filter bottom.

$$\begin{aligned}\text{Width of each bed} &= 4.5 + 4.5 + 0.8 \\ &= 9.8 \text{ m} \quad (\text{Assuming } 0.1 \text{ m thickness gullet})\end{aligned}$$

$$\therefore \text{size of each bed} = \underline{12 \text{ m} \times 9.8 \text{ m}}$$

g) Wash Water Tank.

Vol. of water required for 10 min. back wash of filter bed

$$\begin{aligned}&= 64,800 \text{ L} \times 10 \\ &= 648,000 \text{ L} \\ &= 648 \text{ m}^3\end{aligned}$$

for 10% extra quantity;

$$= 648 \times 1.1 = 712.8 \text{ m}^3$$

provide water depth as 4m.

$$\therefore \text{Area required} = 178.2 \text{ m}^2$$

provide length of 30m; width = 5.94m.

provide inner dimensions of 30m x 6m

²⁰
b). Wash Water Pumps

Since there's only one bed; to be back washed is 24 hrs; the wash water tank has to be filled up in 24 hrs. time.

$$\text{Rate of pumping} = \frac{64,800 \text{ L} \times 10}{24 \times 3600} = 7.5 \text{ L/s}$$
$$= 7.5 \times 10^{-3} \text{ m}^3/\text{s}$$

Assume 7m head (range 6m to 8m) and add 10% other losses.

∴ Actual height of tank bottom w.r.t underdrain-

$$= 7 + 0.7 = 7.7$$

Say 8m.

Assume suction head & SWD as 4m each.

Static head for pump = Suction head + ht. of tank + SWD + free board.

$$= 4 + 8 + 4 + 0.5 = 16.5 \text{ m.}$$

Assume length of delivery pipe = 25m ; dia = 100 mm

frictional losses ; $h_f = 0.499 \text{ m.}$

∴ total head $16.5 + 0.499 = 16.99 \text{ m}$

Say 17m.

$$\text{pump BHP} = \frac{7.5 \times 10^{-3} \times 997 \times 17}{75 \times 0.7 \times 0.9}$$

$$= 2.69$$

Say 15

provide two pumps (one as stand by) each of 15 BHP.

i) Filter water inlet channel

$$Q = \frac{12 \times 10^3 \times 1.2}{24 \times 3600} = \frac{1}{6} \text{ m}^3/\text{s}$$

Let velocity in the channel be 1m/s & width be 0.5 m

$$\frac{1}{6} = 1.0 \times (0.5 \times h)$$

$$h = 0.333$$

Provide free board = 0.3m

$$\therefore h = 0.633 \text{ m}$$

Say 7m

j) Inlet pipe for each filter bed

Inlet flow per bed, $Q = \frac{1}{6} \text{ m}^3/\text{s}$ (with 20% overload)

For a velocity of flow = 1.0 m/s;

$$\frac{1}{6} = 1.0 \pi \times \frac{d^2}{4}$$

$$\underline{d = 460 \text{ mm}}$$

k) Filter water outlet pipe per section of filter bed

outflow per section = $\frac{1}{12} \text{ m}^3/\text{s}$ (with 20% overload)

For a velocity of flow = 1.2 m/s;

$$\frac{1}{12} = 1.2 \times \pi \frac{d^2}{4}$$

$$\underline{d = 0.297 \text{ m}}$$

Say 300 mm

l) Pulse water outlet channel

outflow total = $\frac{1}{6} \text{ m}^3/\text{s}$ (with 20% overload)

22 Let width of channel be 1m and velocity of flow be = 1 m/s

$$\frac{V}{g} = 1.0 \times (1.0 \times h)$$

\therefore SWD in channel = 0.166 m

Provide free board of 0.3m;

$$\begin{aligned}\text{Total depth of channel} &= 0.166 + 0.3 \\ &= 0.466\end{aligned}$$

Say ~ 0.5m

(a). Filter wash water inlet pipe from OHT

$$\text{Wash water required} = 1.08 \text{ m}^3/\text{s}$$

$$\begin{aligned}\text{for } 20\% \text{ overload; } Q &= 1.08 \times 1.2 \\ &= 1.296 \text{ m}^3/\text{s}\end{aligned}$$

For a flow velocity of 3 m/s;

$$1.296 = 3 \times \pi \times \frac{d^2}{4}$$

$$\text{Wash water pipe dia.} = d$$

$$d = 0.742 \text{ m}$$

\therefore Adopt 750 mm dia. pipe.

(b). Filter wash water inlet pipe per section of filter.

$$Q = \frac{1.296}{2} = 0.648 \text{ m}^3/\text{s}$$

$$0.648 = 3 \times \pi \times \frac{d^2}{4}$$

$$d = 0.524 \text{ m}$$

\therefore Adopt 550mm dia. pipe.

o) Filter Backwash water storage lagoon.

$$\text{Back wash water from the bed} = \frac{600 \times 12 \times 9}{10^3} \text{ m}^3/\text{d} \times 10 \text{ min}$$

$$= 648 \text{ m}^3/\text{d}$$

provide 3 days detention time in the storage lagoon;

$$\therefore \text{vol. of tank} = 648 \times 3 = 1944 \text{ m}^3$$

If SWD = 3.5 m; area of lagoon = 555.43 m^2

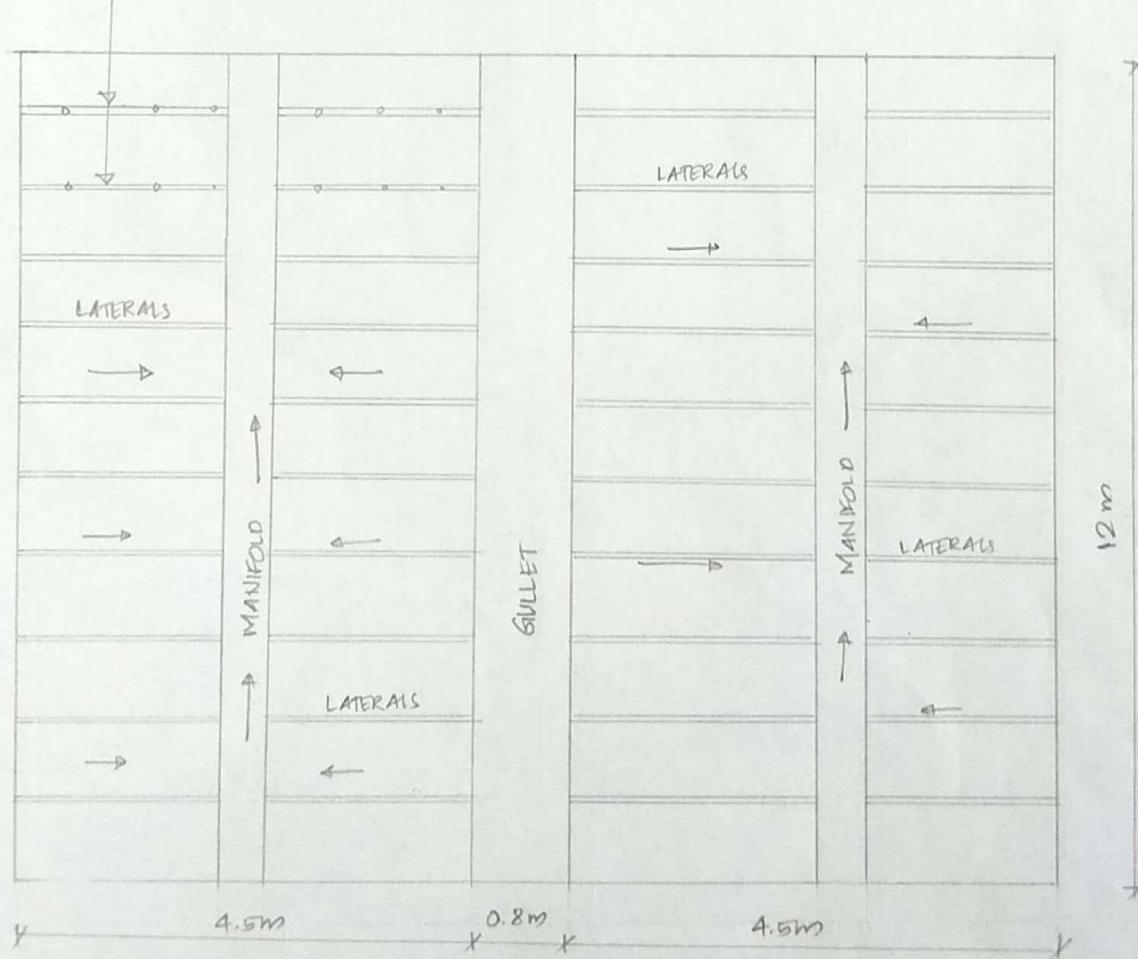
provide lagoon size $30\text{m} \times 20\text{m} \times 3.5\text{m}$

The side bank of the lagoon will have a slope of 1:2.

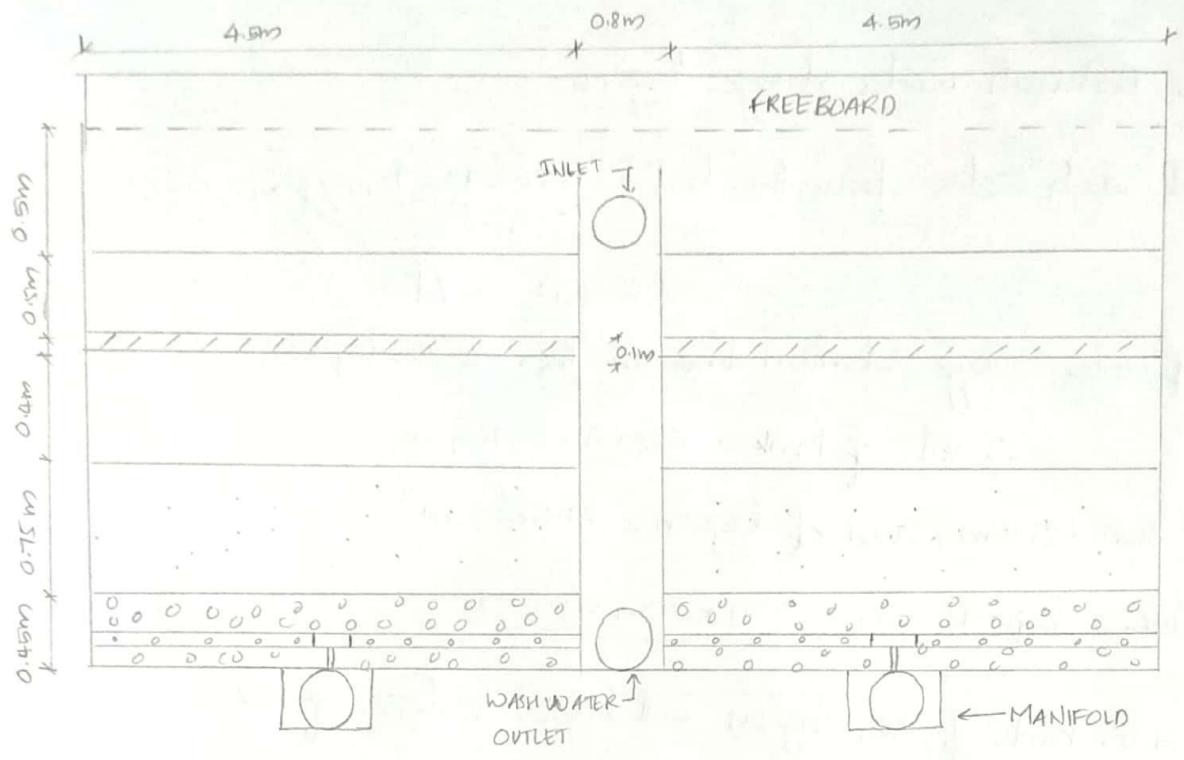
6. RAPID SAND FILTER

33 Laterals on each side of manifold
of $80\text{mm} \phi$ and

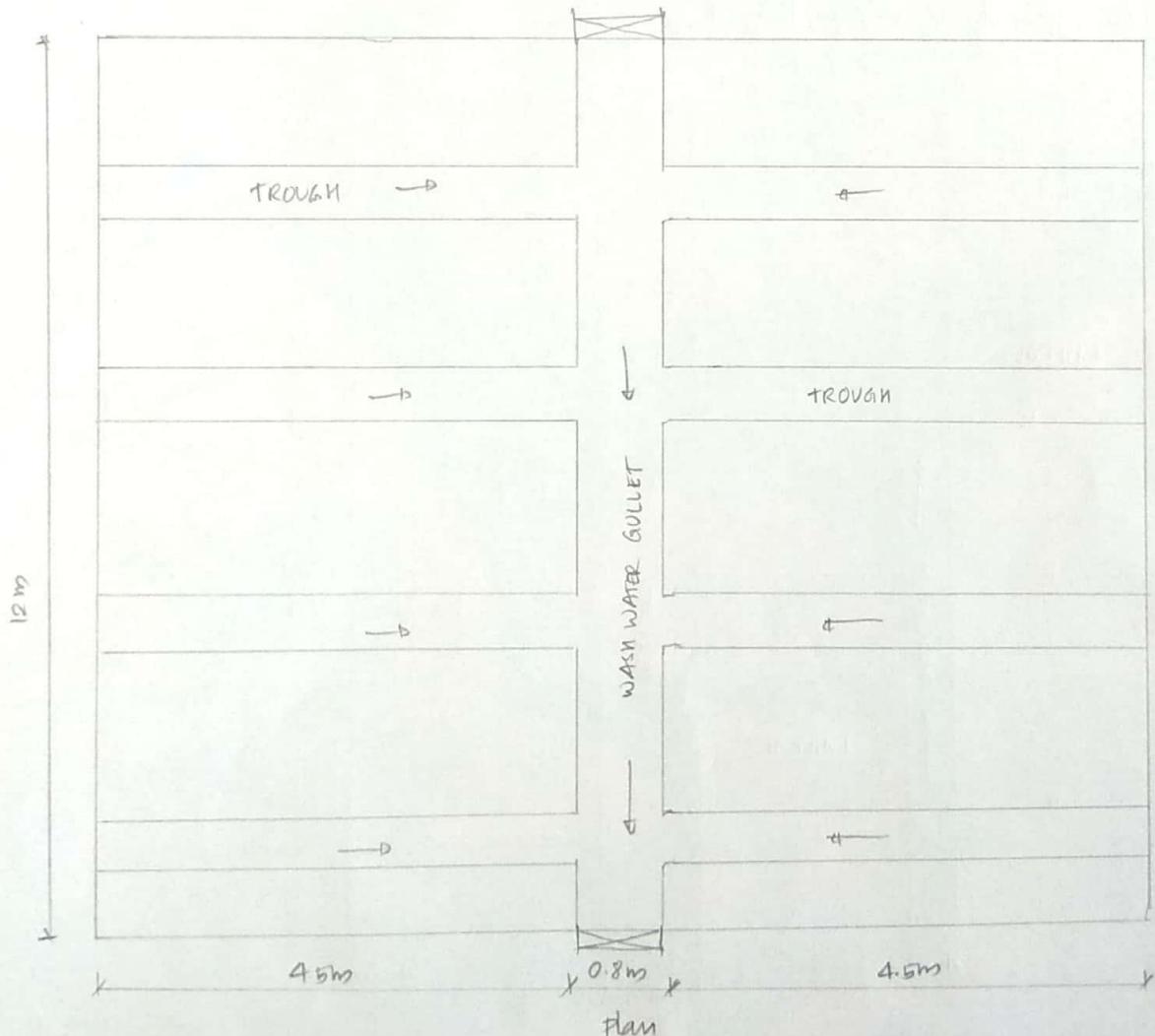
22 orifices of $12\text{mm} \phi$ per lateral



a). Plan of underdrain system



Elevation (c/s)



b) plan & c/s of RSF

10) CLARIFIER SLUDGE STORAGE LAGOON

Sludge wasted from clarifier = 3% of total vol. of water

$$\therefore \text{vol. of sludge produced per day} = 12 \times 10^3 \times \frac{3}{100} = 360 \text{ m}^3/\text{d}$$

provide 2 days detention time;

$$\therefore \text{vol. of lagoon} = 360 \times 2 = 720 \text{ m}^3.$$

If sub of lagoon = 3m, then

$$\text{Area of lagoon} = 240 \text{ m}^2$$

provide lagoon of size $16\text{m} \times 15\text{m} \times 3\text{m}$.

11) SLUDGE DRYING BEDS

Assuming vol. of sludge = 20% of inflow to the lagoon.

$$\therefore \text{vol. of settled sludge} = \frac{720 \times 0.2}{2} = 72 \text{ m}^3/\text{d}$$

Let the dewatering, drying & removal cycle be of 6 days & depth of application of sludge = 0.3m.

$$\text{plan area} = \frac{72 \times 6}{0.3} = 1440 \text{ m}^2$$

Area of each bed = 144 m^2 (provide 10 no. of beds)

of size $12\text{m} \times 12\text{m}$.

provide: sand depth = 0.3m.

E.S of sand = 0.5 - 0.75 mm.

Depth of gravel = 0.3m

Size of gravel = 3 to 6mm

Bottom slope of bed = 1:1.

outlet pipe from each bed = 200 mm dia.

12) PURE WATER SUMP

Let detention time = 1 hour.

$$\therefore \text{vol. of sump} = \frac{12 \times 10^3}{24} = 500 \text{ m}^3$$

provide SWD of sump = 3 m.

$$\text{Area of sump} = \frac{500}{3} = 166.67 \text{ m}^2$$

Say $13\text{m} \times 13\text{m}$.

13) CHLORINATION UNITS

a. chlorinators

Total flow = 12 MLD.

Dose of chlorine = 2 mg/L.

$$\text{Chlorine requirement} = \frac{12 \times 10^3 \times 2}{10^3} = 24 \text{ kg/d.}$$

b. Emergency chlorination.

provide no. of tanks = 2.

capacity of each tank = 12 h.

Assume 25% is available chlorine; the bleaching powder required per day

$$= 24 \times 4 = 96 \text{ kg/d}$$

or 48 kg for 12 h.

Assume 10% strength of solution;

$$\begin{aligned} \text{vol. of solution tank} &= 48 \times 10 = 480 \text{ L} \\ &= 0.48 \text{ m}^3 \end{aligned}$$

Size of tank = $0.1 \times 0.1 \times 1 \text{ m}$.

provide free board = 0.3 m.

Actual size of the tank = $0.7 \text{ m} \times 0.7 \text{ m} \times 1.3 \text{ m}$.

c). chlorine room and chlorine tonner room.

chlorine requirement for 7 days;

$$= 24 \text{ kg/d} \times 7 = 168 \text{ kg.}$$

∴ 1 tonne of 200kg will be installed and 1 tonne will be as stand by.

14. ALUM REQUIREMENT

Let avg. alum dose be:

10mg/L = Monsoon season.

30mg/L = Winter season.

10mg/L = Summer season.

Assuming 75% purity;

$$\text{alum requirement} = \frac{12 \times 10^6 \times 70}{10^6 \times 0.75} = 1120 \text{ kg/d}$$

(for worst season)

∴ Alum requirement for 90 days storage

$$= 1120 \times 90$$

$$= 100,800 \text{ kg.}$$

a. Alum solution tanks.

provide 2 tanks (1 tank as stand by) for 1120kg/d capacity.

b. Preparation of solutions

Assuming strength of solution = 5% & purity = 75%.

$$\text{From Table Q3.1; Requirement} = \frac{52.70}{0.75} = 70.27 \text{ g.}$$

$$\text{Quantity of water} = \frac{1120 \text{ kg} \times 10^3}{70.27 \text{ g/L}} = 15.938 \text{ m}^3$$

provide SWD = 3m.

Adopt tank size of $3 \times 2 \times 3 \text{ m}$

Provide free board of 0.3 m.

Actual size of tank = $3 \times 2 \times 3.3$ m.

Alum requirement for 7 days = $1120 \times 7 = 7840$ kg.

c) Alum and TCA storage space.

i) Space for alum.

for 10 days + 7 days (temporary storage);

$$\begin{aligned} \text{alum requirement} &= 1,00,800 + 7840 \\ &= 1,08,640 \text{ kg.} \end{aligned}$$

Assume 1m³ of alum weighs 1400 kg;

$$\text{vol.} = \frac{108640}{1400} = \underline{63.9 \text{ m}^3}$$

ii) Space for TCA

TCA required for 7 days storage;

$$= 96 \times 7 = 672 \text{ kg}$$

Assume 1m³ of TCA weighs 1400 kg;

$$\text{vol.} = \frac{672}{1400} = 0.48 \text{ m}^3$$

iii) Total volume of chemicals.

$$\text{vol.} = 63.9 + 0.48 = 64.38 \text{ m}^3$$

Assume 20% extra;

$$\begin{aligned} \text{vol. of chemicals} &= 64.38 \times 1.2 \\ &= 77.256 \text{ m}^3 \end{aligned}$$

If 4 m is height of building, and 3 m is height of stacking;

$$\text{area requirement} = 25.752 \text{ m}^2$$

15. CHEMICAL HOUSE

a). Overall building can be of RCC framed structure with brick panels in two floors.

b). Ground floor:

(i). space for chemical storage.

(ii). space for laboratory.

(iii). space for toilet.

(iv). M.C.C. Room.

(v). space for office.

c). First floor.

(i). space for 2 alum solution tanks.

(ii). space for 2 TCA solution tanks.

(iii). space for chain pulley block.

d). Height of building.

Ground floor — 4m (normally)

First floor — 5m (normally)

16. FILTER HOUSE AND ANNEX

(i). A block of 1 filter bed, having 2 sections, the size of each section is $12\text{m} \times 4.5\text{m}$ with 0.8 m outer width of gullet. Thus size of one bed is $12\text{m} \times 9.8\text{m}$.

(ii). An annex building will have ground and first floor.

17. CALCULATIONS FOR HEAD LOSSES IN VARIOUS UNITS:

Velocities (Max, limits, m/s)

(a). filter piping	=	1 m/s
filter inlet	=	1 m/s
filter outlet	=	1.2 m/s
filter upwash	=	3.0 m/s
filter waste water	=	3.0 m/s
Air inlet	=	0.6 m/min

(b). Other systems

collecting channel in cascade aerator	=	1 m/s
channel from aerator to flash mixer	=	1.5 m/s
flash mixer to flocculator (pipe)	=	0.8 to 1.8 m/s
clariflocculator launder	=	0.6 m/s
filter feed channel	=	0.9 m/s
Pure water channel	=	1.5 m/s

Formulas used:

Hydraulic Gradient for channels :

$$S = \left[\frac{Q \cdot n \cdot (B+2D)^{2/3}}{(B \cdot D)} \right]^2$$

Hydraulic Gradient for pipes :

$$S = \left[\frac{3.5875 \cdot Q}{C \cdot D^{0.63}} \right]^{1.852}$$

Details of head losses in various channels for 120% of average flow.

S.No.	channel Description	Flow (m ³ /s)	velocity (m/s)	channel width, B (m)	Liquid depth, D (m)	Hydraulic gradient's (m/m) [#]	length of channel, L (m)	Headloss * $h_f = L \times S \times 1.1$
1.	Collecting launder of cascade aerator	1/2	0.8	0.8	0.13	1.36×10^{-4}	8.8	1.319×10^{-3}
2.	Aeration launders to plume	1/6	0.8	0.204	1.023	3.68×10^{-4}	5	2.04×10^{-3}
3.	Plume to distribution launder	1/6	0.8	0.36	0.58	2.18×10^{-4}	5	2.10199×10^{-3}
4.	Distribution launders to plume	1/2	1.5	0.5	0.11	2.9×10^{-4}	12	3.828×10^{-3}
5.	Peripheral launders of clarifier	1/24	0.5	0.3	0.277	3.99×10^{-5}	30	1.32×10^{-3}
6.	channel between launders & filter inlet channel including filter feed channel	1/26	1.0	0.5	0.333	2.41×10^{-4}	55	0.044
7.	Pure water channel.	1/6	1.0	0.166	2.89×10^{-4}	45	0.014	

* 10% extra head loss is considered to cover minor losses.

Assumed n = 0.014

Details of head losses in various pipes for 10% of average flow.

S. No.	Pipe location	Flow (m^3/s)	value of c	velocity of flow (cm/s)	Dia. of pipe - D (m)	Hydraulic gradient, S (m/m)	length, L (m)	head loss $hf = L \times S \times 1.1$ (m) *
1.	Inlet pipe from flash mixer to clarifier outlet	$\frac{1}{6}$	100	1.5	0.4	6.62×10^{-3}	30	0.218
2.	central shaft of clarifier	$\frac{1}{12}$	100	1.2	0.3	7.44×10^{-3}	5	0.04
3.	filter inlet	$\frac{1}{6}$	100	1.0	0.46	3.35×10^{-3}	0.5	1.842×10^{-3}
4.	filter outlet upto weir chamber per section	$\frac{1}{12}$	100	1.2	0.3	7.44×10^{-3}	5	0.0409
5.	filter outlet from chamber to pure water	$\frac{1}{6}$	100	1.0	0.45	3.73×10^{-3}	1.0	4.101×10^{-3}
6.	Pure water pipe	$\frac{1}{6}$	100	1.0	0.45	3.73×10^{-3}	20	0.082
7.	Wash water pipe from wash water tank.	1.296	100	3.0	0.75	0.0138×10^{-3}	50	0.759 0.299
8.	Wash water inlet pipe per section.	0.648	100	3.0	0.65	0.0143 0.0065	4	0.076
9.	Wash water outlet per bed	1.296	100	3.0	0.75	0.0138	54	0.821
10.	Rising main to wash water tank.	1.5×10^{-3}	100	-	0.10	0.0181	25	0.499

* providing 10% extra considering minor losses