การออกแบบระบบผลิตน้ำ

สำหรับน้ำประปาขนาด 5,000 ลูกบาศน์เมตรต่อวัน

โดย นายพรศักดิ์ สมรไกรสรกิจ

2. Design Criteria

Description	Unit	Design Criteria	Design Flow (5000 m^3/day)	Max. Flow (7500 m^3/day)
1. Rapid Mixing				
- Time	sec	1 to 3	2.17	1.45
- G - Value	sec^{-1}	500 to 700	612	1100
- GT			1328	1595
2. Flocculation Basin				
- Type		Baffle Channel	Baffle Channel	Baffle Channel
- No. of Stage	No.	2 - 7	4	4
- Energy Input	sec^{-1}	20 - 60	stage 1 = 60	110
			stage 2 = 35	64
			stage 3 = 20	37
			stage 4 = 15	27
- Detention Time	minute	20 - 40	31	21
3. Sedimentation Basin				
- Type		Rectangular	Rectangular	Rectangular
- Detention Time	hour	1.5 - 4	2.5	1.67
- Surface Loading	m/min	0.02 - 0.06	0.019	0.029
- Water Depth	m.	3.0 - 4.5	3	3
- Mean Velocity	m/min	$\leq$ 1.5	0.129	0.193
- Method of Sludge Drain		Manual	Manual	Manual
- Inlet Diffuser Wall				
Port Velocity	m/sec	0.15 - 0.60	0.165	0.247
Port Spacing	m.	0.40 - 0.70	0.5	0.5
Port Diameter	mm.	100 max	75	75

Description	Unit	Design Criteria	Design Flow (5000 m^3/day)	Max. Flow (7500 m^3/day)
- Effluent Weir Loading	m^3/m./hr.	12 max	8.68	13
4. Filtration Basin				
- Number of Filter Basin	No.	min. 2	3	3
- Filtration rate	m/hr	5 to 7	5.5	8.33
- Filter Flow			Constant Rate	
Control System			Influent Level Control	
- Under Drain System			Pipe Lateral	
- Filter Media				
Type of Media			Sand	
Effective Size	mm.		0.55 - 0.65	
Uniformity Coefficient			1.40 - 1.70	
Depth	mm.		700	
- Back Wash Rate	m./min.	0.60 - 0.70	0.7	
- Surface Wash System				
Type			Fixed Nozzle	
Rate	m./min.	0.12 - 0.16	0.15	
Surface Jet Pressure	m.	15 - 20	15	

1. ข้อมูลพื้นฐาน

1.1 คุณภาพน้ำ

- Turbidity = NTU
- Alkalinity = mg/l as $CaCO_3$
- pH =
- Temperature = ^oC
- Fe = mg/l
- Mn = mg/l
- Hardness = mg/l as $CaCO_3$

1.2 แหล่งน้ำ = Surface Water

1.3 Jar Test

- Alum Dose = mg/l
- Alkalinity = mg/l as $CaCO_3$
- pH =
- Temperature = ^oC

1.4 Design Flow

Design Plant Capacity =	5000	m^3/d
Design Operation Flow =	24	hr

1.5 Type of Water Treatment Plant

- Hydraulic Design System

3. Coagulation Basin Design

3.1 Raw Water Pipe

Design Flow (Q Design) = 5,000 m^3/day

Velocity in Pipe = 1.8 - 2.0 m/s (Kawamura)

Use = 1.8 m/s

∴ Pipe Diameter (D) = $\sqrt{\frac{4Q}{\pi v}}$

= $\sqrt{\frac{4x5,000}{3.14x1.8x3600x24}}$

= 0.2023751 m.

Use Pipe Diameter (D) = 0.2 m.

∴ Acture Velocity = $\frac{Q}{A}$

= 1.8420711 m/s

3.2 Rapid Mixing = Hydraulic Type

Type = Static Mixer

Design Criteria

- Detention Time = 1 - 3 sec
- G - Value = 500 - 700 sec^{-1}
- GT = 350 - 1500

3.3 Calculation

Theory : Rule of Thumb - estimateing the Length of one element is to designated the length as 1.5 - 2.5 times the pipe diameter the base on this criteria,the length of one element is in the range of 3 - 5 ft (Kawamura, page no. 88)

- 2 stage = 2 element

$$Static\ Mixer\ Length = 1.5xDiameter(m)x2(element) - 0.5xDiameter(m)$$

- 3 stage = 3 element

$$Static\ Mixer\ Length = 1.5xDiameter(m.)x3(element) - Diameter(m.)$$

- 4 stage = 4 element

$$Static\ Mixer\ Length = 1.5xDiameter(m.)x4(element) - 1.5xDiameter(m.)$$

- 5 stage = 5 element

$$Static\ Mixer\ Length = 1.5xDiameter(m.)x5(element) - 2.0xDiameter(m.)$$

- 6 stage = 6 element

$$Static\ Mixer\ Length = 1.5xDiameter(m.)x6(element) - 2.5xDiameter(m.)$$

- 7 stage = 7 element

$$Static\ Mixer\ Length = 1.5xDiameter(m.)x7(element) - 3.0xDiameter(m.)$$

- 8 stage = 8 element

$$Static\ Mixer\ Length = 1.5xDiameter(m.)x8(element) - 3.5xDiameter(m.)$$

- 9 stage = 9 element

$$Static\ Mixer\ Length = 1.5xDimerter(m.)x9(element) - 4.0xDiameter(m.)$$

	Try Static Mixer Diameter	=	200	mm.
	Use 3 stage	=	3	element
∴	Static Mixer Length (L)	=	0.7	m.
∴	Acture Velocity	=	$\frac{Q}{A}$	
		=	1.842	m/s
∴	Detention Time (t)	=	0.380007	sec. too less

	Try Static Mixer Diameter	=	250	mm.
	Use 3 stage	=	3	element
∴	Static Mixer Length (L)	=	0.875	m.
∴	Acture Velocity	=	$\frac{Q}{A}$	
		=	1.179	m/s
∴	Detention Time (t)	=	0.7422013	sec.

∴ Bring Acture velocity to Find Head loss from PWA Graph

∴ Head Loss Across Static Mixer = 1 m.

ρ_L = 997.1 kg/m^3 at 25 ^{o}C

μ = 0.000895 kg/m.s (N/m.s) at 25 oC

Theory

$$G = \sqrt{\frac{h_f x g x \rho}{\mu x t}}$$

= 2848.0866 sec^{-1} too hight

Gxt = 2113.8535 too hight

	Try Static Mixer Diameter	=	300	mm.
	Use 2 stage	=	2	element
∴	Static Mixer Length (L)	=	0.75	m.
∴	Acture Velocity	=	$\frac{Q}{A}$	

A

= 0.819 m/s

∴ Detention Time (t) = 0.9160884 sec.

∴ Bring Acture velocity to Find Head loss from PWA Graph

∴ Head Loss Across Static Mixer = 0.25 m.

ρ_L = 997.1 kg/m^3 at 25 ^{o}C

μ = 0.000895 kg/m.s (N/m.s) at 25 oC

Theory

$$G = \sqrt{\frac{h_f x g x \rho}{\mu x t}}$$

= 1727.0052 sec^{-1} too hight

Gxt = 1582.0895 too hight

Try Static Mixer Diameter = 400 mm.

Use 2 stage = 2 element

∴ Static Mixer Length (L) = 1 m.

∴ Acture Velocity = $\frac{Q}{A}$

= 0.461 m/s

∴ Detention Time (t) = 2.1714688 sec.

∴ Bring Acture velocity to Find Head loss from PWA Graph

∴ Head Loss Across Static Mixer = 0.08 m.

ρ_L = 997.1 kg/m^3 at 25 ^{o}C

μ = 0.000895 kg/m.s (N/m.s) at 25 oC

Theory

$$G = \sqrt{\frac{h_f x g x \rho}{\mu x t}}$$

= 634.54224 sec^{-1} OK

Gxt = 1377.8887 OK

3. Coagulation Basin Design

3.1 Raw Water Pipe

Design Flow (Q Design) = 5,000 m^3/day

Velocity in Pipe = 1.8 - 2.0 m/s (Kawamura)

Use = 1.8 m/s

∴ Pipe Diameter (D) = $\sqrt{\frac{4Q}{\pi v}}$

$$= \sqrt{\frac{4x5{,}000}{3.14x1.8x3600x24}}$$

= 0.2023751 m.

Use Pipe Diameter (D) = 0.2 m.

∴ Acture Velocity = $\frac{Q}{A}$

= 1.8420711 m/s

3.2 Rapid Mixing = Hydraulic Type

Type = Static Mixer

Design Criteria

- Detention Time = 1 - 3 sec
- G - Value = 500 - 700 sec^{-1}
- GT = 350 - 1500

3.3 Calculation

Theory : Rule of Thumb - estimateing the Length of one element is to designated the length as 1.5 - 2.5 times the pipe diameter the base on this criteria,the length of one element is in the range of 3 - 5 ft (Kawamura, page no. 88)

- 2 stage = 2 element

$$Static\ Mixer\ Length = 1.5xDiameter(m)x2(element) - 0.5xDiameter(m)$$

- 3 stage = 3 element

$$Static\ Mixer\ Length \quad = \quad 1.5xDiameter(m.)x3(element) \quad - \quad Diameter(m.)$$

- 4 stage = 4 element

$$Static\ Mixer\ Length \quad = \quad 1.5xDiameter(m.)x4(element) \quad - \quad 1.5xDiameter(m.)$$

- 5 stage = 5 element

$$Static\ Mixer\ Length \quad = \quad 1.5xDiameter(m.)x5(element) \quad - \quad 2.0xDiameter(m.)$$

- 6 stage = 6 element

$$Static\ Mixer\ Length \quad = \quad 1.5xDiameter(m.)x6(element) \quad - \quad 2.5xDiameter(m.)$$

- 7 stage = 7 element

$$Static\ Mixer\ Length \quad = \quad 1.5xDiameter(m.)x7(element) \quad - \quad 3.0xDiameter(m.)$$

- 8 stage = 8 element

$$Static\ Mixer\ Length \quad = \quad 1.5xDiameter(m.)x8(element) \quad - \quad 3.5xDiameter(m.)$$

- 9 stage = 9 element

$$Static\ Mixer\ Length \quad = \quad 1.5xDimerter(m.)x9(element) \quad - \quad 4.0xDiameter(m.)$$

Try Static Mixer Diameter = 200 mm.

Use 3 stage = 3 element

∴ Static Mixer Length (L) = 0.7 m.

∴ Acture Velocity = $\frac{Q}{A}$

= 1.842 m/s

∴ Detention Time (t) = 0.380007 sec.

∴ Check *Renolds Number*($R_{e)}$ = $\frac{D_p \rho_L v_s}{\mu}$ ρ_L = 997.1 kg/m^3 at 25 ^{o}C

μ = 0.000895 kg/m.s (N/m.s) at 25 oC

R_e = 410442.26

Theory

$$f = 0.048 x R_e^{-0.2} \quad if \quad 10^4 < R_e < 10^6$$

$$f = 0.193 x R_e^{-0.35} \quad if \quad 3x10^3 < R_e < 10^4$$

∴ f = 0.003619

Theory

Darcy Formular $h_f = f \frac{L}{D} \frac{v^2}{2g}$

∴ h_f = 0.0021906

Theory

$$G = \sqrt{\frac{h_f x g x \rho}{\mu x t}}$$

= 251.00527 *sec* $^{-1}$ too less

Gxt = 95.383772

Try Static Mixer Diameter = 250 mm.

Use 3 stage = 3 element

∴ Static Mixer Length (L) = 0.875 m.

∴ Acture Velocity = $\frac{Q}{A}$

= 1.179 m/s

∴ Detention Time (t) = 0.7422013 sec.

∴ Check *Renolds Number*(R_{e}) = $\frac{D_p \rho_L v_s}{\mu}$ ρ_L = 997.1 kg/m^3 at 25 ^{o}C

μ = 0.000895 kg/m.s (N/m.s) at 25 oC

R_e = 328353.8

Theory

$$f = 0.048 x R_e^{-0.2} \quad if \quad 10^4 < R_e < 10^6$$

$$f = 0.193 x R_e^{-0.35} \quad if \quad 3x10^3 < R_e < 10^4$$

∴ f = 0.0037842

Theory

Darcy Formular $h_f = f \frac{L}{D} \frac{v^2}{2g}$

∴ h_f = 0.0009382

Theory

$$G = \sqrt{\frac{h_f x g x \rho}{\mu x t}}$$

= 117.54084 *sec*$^{-1}$ too less

Gxt = 87.238961

Try Static Mixer Diameter = 300 mm.

Use 2 stage = 2 element

∴ Static Mixer Length (L) = 0.75 m.

∴ Acture Velocity = $\frac{Q}{A}$

= 0.819 m/s

∴ Detention Time (t) = 0.9160884 sec.

∴ Check *Renolds Number(R_{e})* = $\frac{D_p \rho_L v_s}{\mu}$ ρ_L = 997.1 kg/m^3 at 25 ^{o}C

μ = 0.000895 kg/m.s (N/m.s) at 25 oC

R_e = 273628.17

Theory

$$f = 0.048xR_e^{-0.2} \quad if \quad 10^4 < R_e < 10^6$$

$$f = 0.193xR_e^{-0.35} \quad if \quad 3x10^3 < R_e < 10^4$$

∴ f = 0.0039247

Theory

Darcy Formular $h_f = f\frac{L}{D}\frac{v^2}{2g}$

∴ h_f = 0.0003352

Theory

$$G = \sqrt{\frac{h_f xgx\rho}{\mu xt}}$$

= 63.237189 *sec* $^{-1}$ too less

Gxt = 57.930857

Try Static Mixer Diameter = 400 mm.

Use 3 stage = 3 element

∴ Static Mixer Length (L) = 1.4 m.

∴ Acture Velocity = $\frac{Q}{A}$

= 0.461 m/s

∴ Detention Time (t) = 3.0400564 sec.

∴ Check *Renolds Number*(R_{e}) = $\frac{D_p \rho_L v_s}{\mu}$ ρ_L = 997.1 kg/m^3 at 25 $^\circ$C

μ = 0.000895 kg/m.s (N/m.s) at 25 oC

R_e = 205221.13

Theory

$$f = 0.048xR_e^{-0.2} \quad if \quad 10^4 < R_e < 10^6$$

$$f = 0.193xR_e^{-0.35} \quad if \quad 3x10^3 < R_e < 10^4$$

∴ f = 0.0041572

Theory

Darcy Formular $h_f = f\frac{L}{D}\frac{v^2}{2g}$

∴ h_f = 0.0001573

Theory

$$G = \sqrt{\frac{h_f xgx\rho}{\mu xt}}$$

= 23.778303 *sec* $^{-1}$ too less

Gxt = 72.287381

Try Static Mixer Diameter = 200 mm.

Use 6 stage = 6 element

∴ Static Mixer Length (L) = 1.3 m.

∴ Acture Velocity = $\frac{Q}{A}$

= 1.842 m/s

∴ Detention Time (t) = 0.7057274 sec.

∴ Check *Renolds Number(R $_{e)}$* = $\frac{D_p \rho_L v_s}{\mu}$ ρ_L = 997.1 kg/m^3 at 25 ^{o}C

μ = 0.000895 kg/m.s (N/m.s) at 25 oC

R_e = 410442.26

Theory

$$f = 0.048xR_e^{-0.2} \quad if \quad 10^4 < R_e < 10^6$$

$$f = 0.193xR_e^{-0.35} \quad if \quad 3x10^3 < R_e < 10^4$$

∴ f = 0.003619

Theory

Darcy Formular $h_f = f\frac{L}{D}\frac{v^2}{2g}$

∴ h_f = 0.0040683

Theory

$$G = \sqrt{\frac{h_f xgx\rho}{\mu xt}}$$

= 251.00527 *sec* $^{-1}$ too less

∴ Gxt = 177.14129

Try Static Mixer Diameter = 150 mm.

Use 6 stage = 6 element

∴ Static Mixer Length (L) = 0.975 m.

∴ Acture Velocity = $\frac{Q}{A}$

= 3.275 m/s

∴ Detention Time (t) = 0.2977287 sec.

∴ Check *Renolds Number(R e)* = $\frac{D_p \rho_L v_s}{\mu}$ ρ_L = 997.1 kg/m^3 at 25 $^\circ$C

μ = 0.000895 kg/m.s (N/m.s) at 25 oC

R_e = 547256.34

Theory

$$f = 0.048 x R_e^{-0.2} \quad if \quad 10^4 < R_e < 10^6$$

$$f = 0.193 x R_e^{-0.35} \quad if \quad 3x10^3 < R_e < 10^4$$

∴ f = 0.0034167

Theory

Darcy Formular $h_f = f \frac{L}{D} \frac{v^2}{2g}$

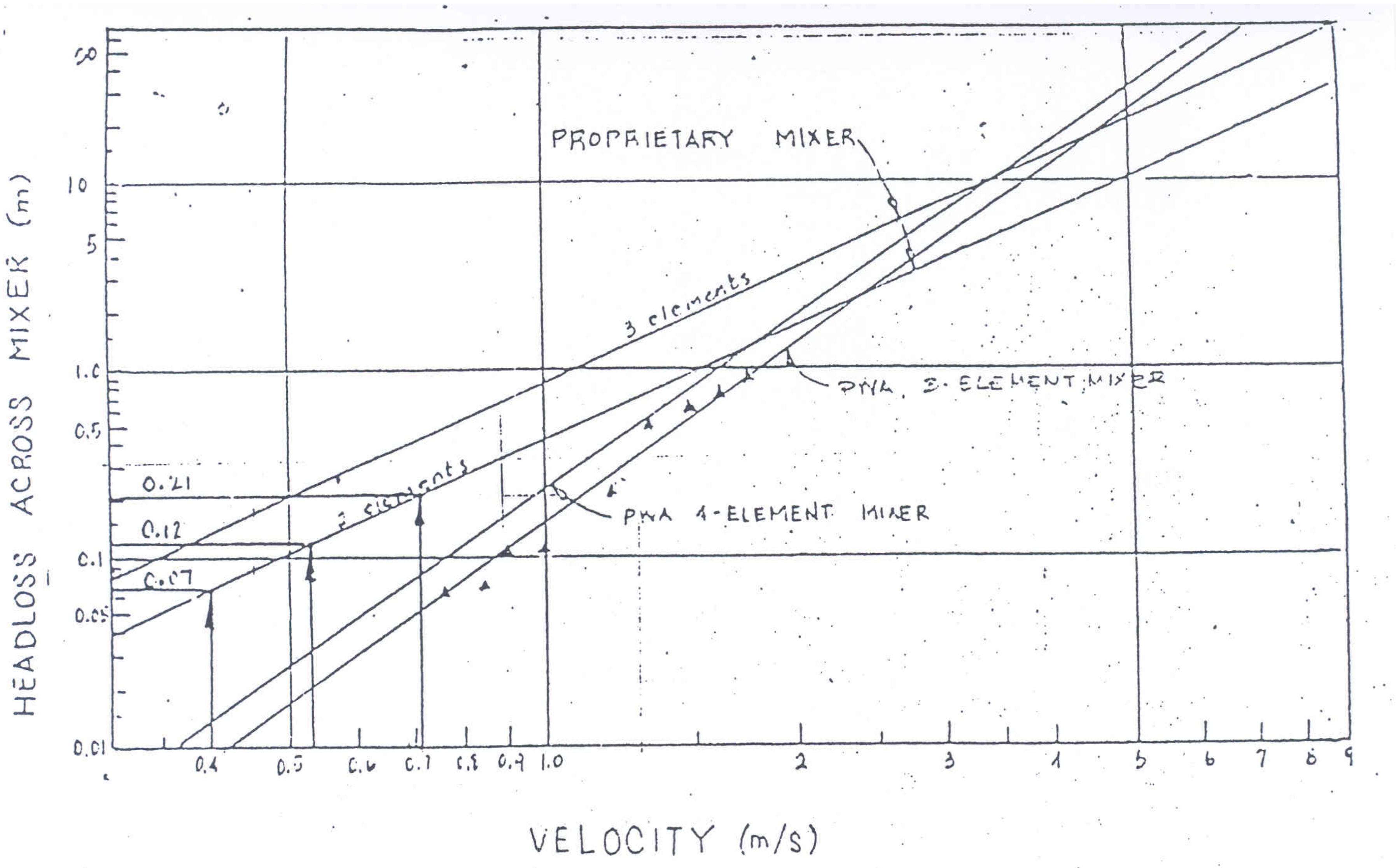
∴ h_f = 0.0121391

Theory

$$G = \sqrt{\frac{h_f x g x \rho}{\mu x t}}$$

= 667.53577 *sec* $^{-1}$

Gxt = 198.74458



PROPRIETARY MIXER
3 elements
2 elements
PWA 2-ELEMENT MIXER
PWA 4-ELEMENT MIXER
HEADLOSS ACROSS MIXER (m)
VELOCITY (m/s)
10
5
1.0
0.5
0.21
0.12
0.1
0.07
0.05
0.01
0.4
0.5
0.6
0.7
0.8
0.9
1.0
2
3
4
5
6
7
8
9

4. Flocculation Basin Design

4.1 Hydraulic Mixing

Type : Round and End Baffle Wall

Design Plant Capacity	:	5000	m^3/day
Design Operation Flow	:	24	hr.

4.2 Design Criteria

- G - Value	=	20 - 60	sec^{-1}
- No. of Stage	=	2 - 7	
- Detention Time	=	20 - 40	minute

4.3 Calculation

No. of Flocculation basin	=	2	Tank
Flow Rate per Tank	=	2500	m^3/day
	=	104.2	m^3/hr
Give Detention Time	=	30	min

Theory

$$(G_{opt})^{2.8} = \frac{44x10^5}{Cxt_d}$$

Where :

C is Optimum Dose Alum	=	30	mg/l
t_d is Detention Time	=	30	min

	G_{opt}	=	20.78	sec^{-1}
Use	G_{opt}	$\approx$	25	sec^{-1}

Give :	No. of Stage	=	4	
	G1 - Value	=	60	sec^{-1}
	G2 - Value	=	35	sec^{-1}

G3 - Value = 20 sec^{-1} (G is reduce 50 %)

G4 - value = 15 sec^{-1}

Water Depth of Flocculation Basin = 2 m.

∴ Flocculation basin Volume = Qxt

= 52.08 m^3

∴ Flocculation Area = 26.04 m^2

Baffle Area 15 % of Flocculation Basin Area

= 3.90625 m^2

∴ Total Area = 29.95 m^2

Give Width of Flocculation Basin = 4.5 m.

∴ Then Length of Flocculation Basin = 6.7 m.

Use = 7.0 m.

Give No. of Baffle at Width = 7.0

Give No. of Baffle at Length = 4.0

Total No. of baffle

∴ - No. of baffle at Width = $Width\,of\ Flocculation\,Ba\sin\ xNo.of\ Baffle$

= 31.50

∴ - No. of baffle at Length = $Length\,of\ Flocculation\,Ba\sin\ xNo.of\ Baffle$

= 28.00

Total No. of baffle = 59.50

Give Width of Concrete = 0.08 m.

∴ Total Area of Baffle = 4.76 m^2

∴ Acture Flocculation Area = 26.74 m^2

∴ Acture Floculation Volume = 53.48 m^3

∴ Acture Detention Time = 31 min

Give No. of Stage = 4

Give No. of Baffle per Stage = 10

Stage 1 $Acture\,Volume\ in\ stage 1 = \dfrac{Acture\ Flocculation\,Volume}{4}$

No. of stage

G1 - Value = 60 sec^{-1}

at Q Design = 104.2 m^3/hr

= 0.028935185 m^3/s

Theory

$$\Delta H = \frac{(G(s^{-1}))^2 x\gamma(m^2/s)xV(m^3)}{g(m/s^2)xQ(m^3/s)}$$

Where : $\gamma = 0.898x10^{-6}\quad m^2/s\quad at\quad 25^oC$

∴ ΔH = 0.15 m.

∴ Head loss in each bend(slit) = 0.015 m.

Theory

$$\Delta H = K\frac{v^2}{2g}$$

Give K = 1.6 (Dr. Kawamura)

∴ v = 0.43 m/s

∴ The required width for each slit in the stage 1 channel is calculate to be

$$Q = Av$$

when $A = width\ for\,each\ slit(m)xwater\,depth(m)$

∴ width of each slit in stage 1 = 0.033 m.

= 33.4811 mm.

Stage 2 $Acture\,Volume\ in\ stage 1 = \dfrac{Acture\ Flocculation\,Volume}{4}$

No. of stage

G2 - Value = 35 sec^{-1}

at Q Design = 104.2 m^3/hr

= 0.028935185 m^3/s

Theory

$$\Delta H = \frac{(G(s^{-1}))^2 x\gamma(m^2/s)xV(m^3)}{g(m/s^2)xQ(m^3/s)}$$

Where : $\gamma = 0.898x10^{-6} \quad m^2/s \quad at \quad 25^oC$

∴ ΔH = 0.05 m.

∴ Head loss in each bend(slit) = 0.005 m.

Theory

$$\Delta H = K\frac{v^2}{2g}$$ Give K = 1.6 (Dr. Kawamura)

∴ v = 0.25 m/s

∴ The required width for each slit in the stage 2 channel is calculate to be

$$Q = Av$$

when $A = width\ for\ each\ slit(m)xwater\ depth(m)$

∴ width of each slit in stage 2 = 0.057 m.

= 57.3961 mm.

Stage 3 $Acture\ Volume\ in\ stage1 = \frac{Acture\ Flocculation\ Volume}{4}$ No. of stage

G3 - Value = 20 sec^{-1}

at Q Design = 104.2 m^3/hr

= 0.028935185 m^3/s

Theory

$$\Delta H = \frac{(G(s^{-1}))^2 x\gamma(m^2/s)xV(m^3)}{g(m/s^2)xQ(m^3/s)}$$

Where : $\gamma = 0.898x10^{-6} \quad m^2/s \quad at \quad 25^oC$

∴ ΔH = 0.02 m.

∴ Head loss in each bend(slit) = 0.002 m.

Theory

$$\Delta H = K\frac{v^2}{}$$

$$\Delta H = K\frac{v^2}{2g}$$ Give K = 1.6 (Dr. Kawamura)

∴ v = 0.14 m/s

∴ The required width for each slit in the stage 3 channel is calculate to be

$$Q = Av$$

when $A = width\ for\ each\ slit(m) x water\ depth(m)$

∴ width of each slit in stage 3 = 0.100 m.

= 100.4432 mm.

Stage 4 $Acture\ Volume\ in\ stage 1 = \frac{Acture\ Flocculation\ Volume}{4}$

No. of stage

G4 - value = 15 sec^{-1}

at Q Design = 104.2 m^3/hr

= 0.028935185 m^3/s

Theory

$$\Delta H = \frac{(G(s^{-1}))^2 x \gamma(m^2/s) x V(m^3)}{g(m/s^2) x Q(m^3/s)}$$

Where :

γ = 0.000000898 m^2/s at 25^o C

∴ ΔH = 0.01 m.

∴ Head loss in each bend(slit) = 0.001 m.

Theory

$$\Delta H = K\frac{v^2}{2g}$$ Give K = 1.6 (Dr. Kawamura)

∴ v = 0.11 m/s

∴ The required width for each slit in the stage 4 channel is calculate to be

$$Q = Av$$

when $A = width\ for\ each\ slit(m) x water\ depth(m)$

∴ width of each slit in stage 4 = 0.134 m.

= 133.9243 mm.

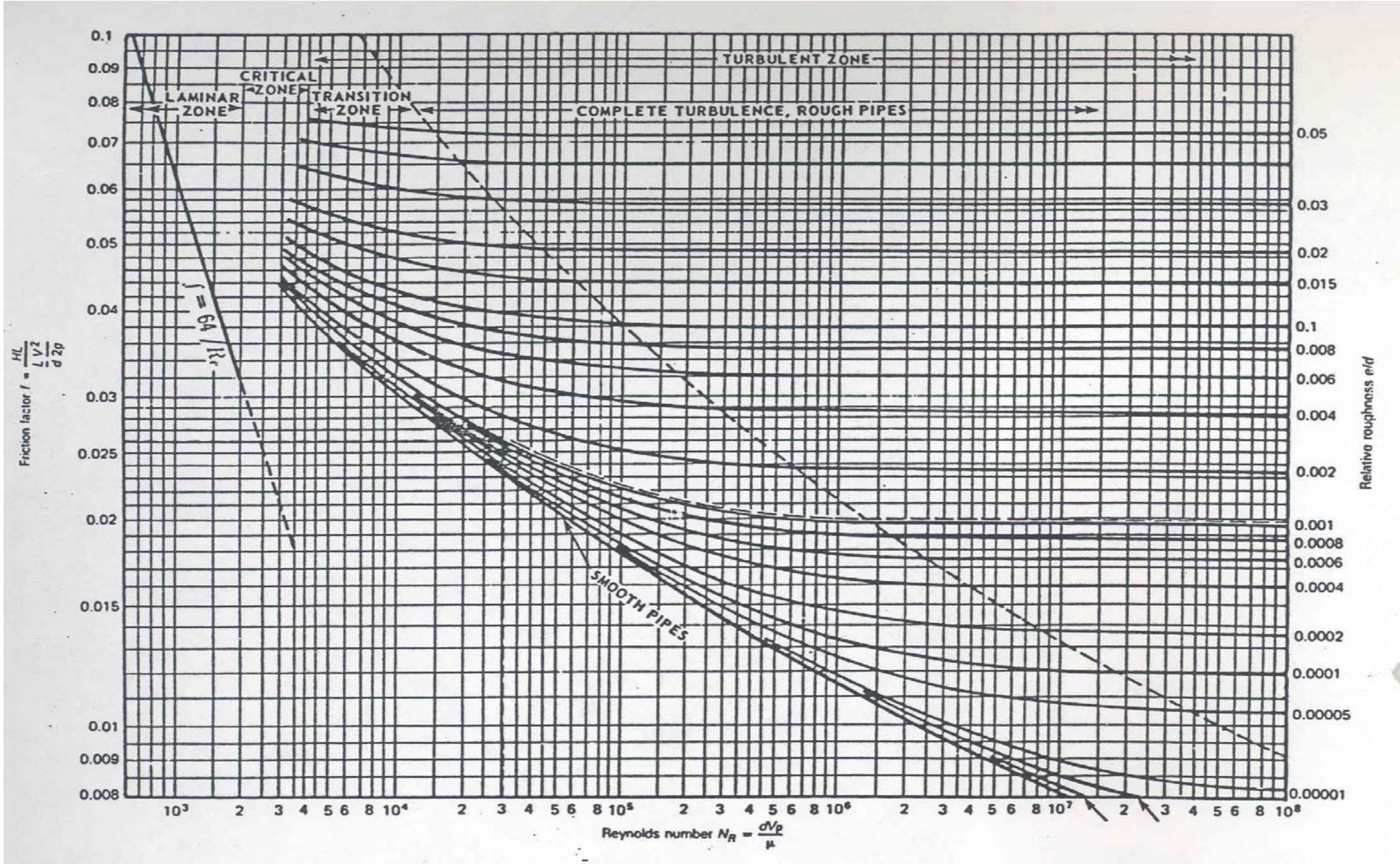
CHECK $G_{average} = \dfrac{G_1 + G_2 + G_3 + G_4}{4}$

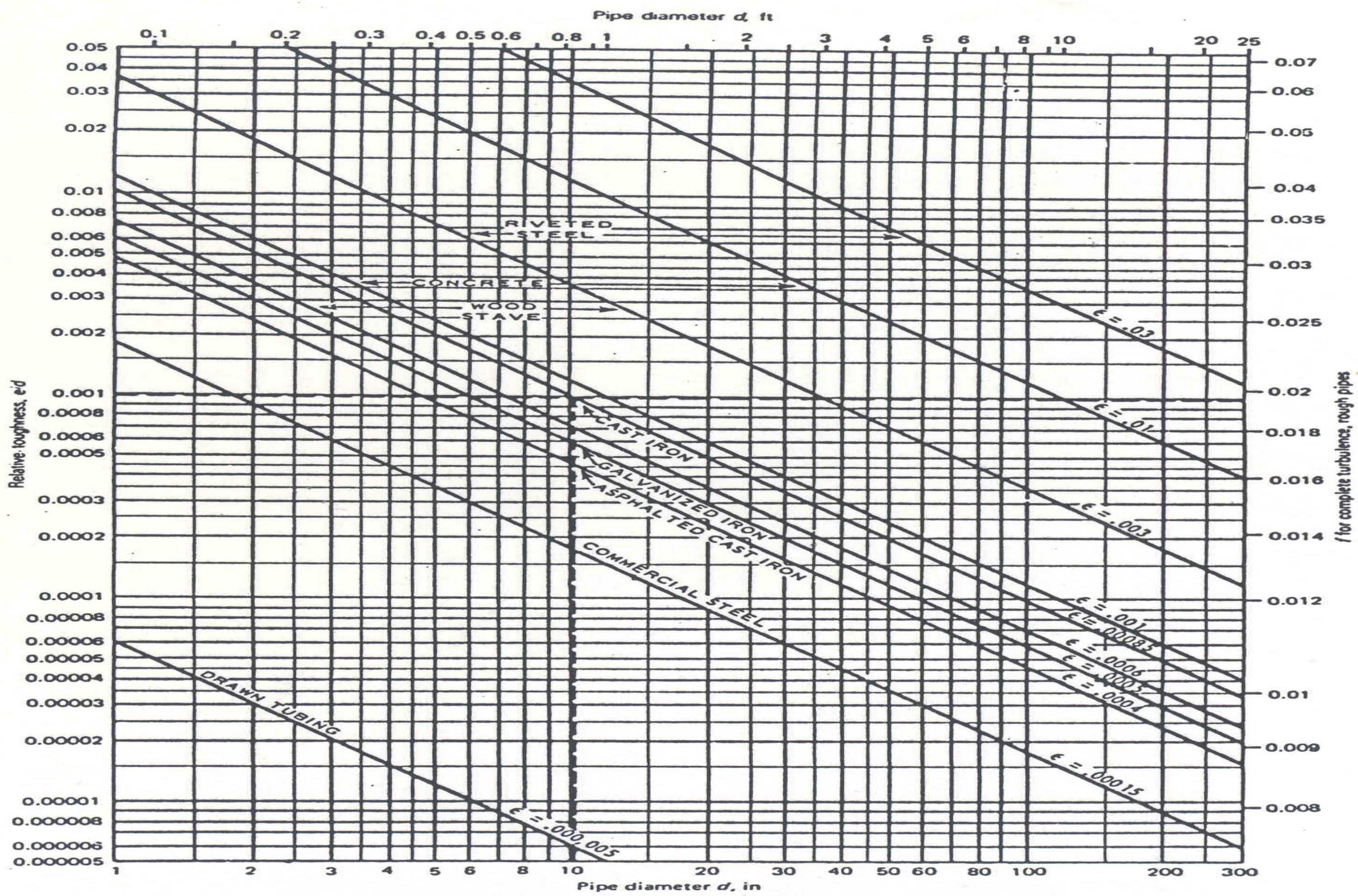
$= 32.5 \quad sec^{-1}$

$G_{average} x t = 60{,}069$ OK.

Design Criteria $1x10^4 < Gxt < 1x10^5 \quad (Kawamura)$

$1x10^4 < Gxt < 15x10^4 \quad (Qasim)$


TURBULENT ZONE
CRITICAL ZONE
LAMINAR ZONE
TRANSITION ZONE
COMPLETE TURBULENCE, ROUGH PIPES
SMOOTH PIPES
Friction factor f = HL / (L/d V²/2g)
Relative roughness e/d
Reynolds number N_R = dVρ/μ
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.025
0.02
0.015
0.01
0.009
0.008
0.05
0.03
0.02
0.015
0.1
0.008
0.006
0.004
0.002
0.001
0.0008
0.0006
0.0004
0.0002
0.0001
0.00005
0.00001
10³ 2 3 4 5 6 8 10⁴ 2 3 4 5 6 8 10⁵ 2 3 4 5 6 8 10⁶ 2 3 4 5 6 8 10⁷ 2 3 4 5 6 8 10⁸


Pipe diameter d, ft
0.1
0.2
0.3
0.4 0.5 0.6
0.8 1
2
3
4 5 6
8 10
20 25
0.05
0.04
0.03
0.02
0.01
0.008
0.006
0.005
0.004
0.003
0.002
0.001
0.0008
0.0006
0.0005
0.0003
0.0002
0.0001
0.00008
0.00006
0.00005
0.00004
0.00003
0.00002
0.00001
0.000008
0.000006
0.000005
Relative roughness, e/d
0.07
0.06
0.05
0.04
0.035
0.03
0.025
0.02
0.018
0.016
0.014
0.012
0.01
0.009
0.008
f for complete turbulence, rough pipes
RIVETED STEEL
CONCRETE
WOOD STAVE
CAST IRON
GALVANIZED IRON
ASPHALTED CAST IRON
COMMERCIAL STEEL
DRAWN TUBING
ε = .03
ε = .01
ε = .003
ε = .001
ε = .00085
ε = .0006
ε = .0005
ε = .0004
ε = .00015
ε = .000 005
1
2
3
4
5
6
8
10
20
30
40
50 60
80 100
200
300
Pipe diameter d, in

5. Sedimentation Basin Design

5.1 Design Criteria (Dr.Kawamura)

5.1.1 Rectangular Basin (Horizontal Flow)

Surface Loading	=	0.83 - 2.5	m/hr
Water Depth	=	3 - 5	m.
Detention Time	=	1.5 - 3.0	hr.
Width/Length	=	> 1/5	
Weir loading	=	< 11	m^3/m.hr.

5.1.2 Upflow type (Radial-Upflow type)

Circular or square in shape

Surface Loading	=	1.3 - 1.9	m/hr
Water Depth	=	3 - 5	m.
Settling Time	=	1 - 3	hr.
Weir loading	=	7	m^3/m.hr.

5.1.3 Reactor Clarifiers

Flocculation Time	=	approx 20	min
Settling Time	=	1 - 2	hr.
Surface Loading	=	2 - 3	m/hr
Weir loading	=	7.3 - 15	m^3/m.hr.
Upflow Velocity	=	< 50	mm./min.

5.1.4 Sludge Blanket Clarifier

Flocculation Time	=	approx 20	min
Settling Time	=	1 - 2	hr.
Surface Loading	=	2 - 3	m/hr
Weir loading	=	7.3 - 15	m^3/m.hr.
Upflow Velocity	=	< 10	mm./min.

Slurry circulation rate	= up to 3 - 5 times the raw water inflow rate	

5.2 Calculation

Type : Horizontal rectangular Tank

Design Plant Capacity	:	5000	m^3/day
Design Operation Flow	:	24	hr.

Design Criteria for Horizontal Rectangular Tank

5.2.1 Inlet and Outlet of the Basin

Headloss through the ports	=	0.3 - 0.9	mm.	
The Size of Ports in Diameter	=	0.075 - 0.20	m.	
The Ports spacing approx	=	0.25 - 0.5	m.	
Velocity through Diffuser wal	=	0.15 - 0.60	m/s	(Prof. Munsin)
Weir Loading rate	=	6 - 11	m^3/hr.m	(Prof. Munsin)

5.2.2 Horizontal rectangular Tank Design (Dr.Kawamura)

Minimum number of tank	=	2		
Water Depth	=	3 - 4.5	m.	
Mean Flow Velocity	=	0.3 - 1.7	m/min	
	=	0.15 - 0.91	m/min	(Prof. Munsin)
Surface Loading	=	0.02 - 0.06	m/min	(Prof. Munsin)
	=	1.4 - 3.4	m/hr	
Detention Time	=	1.5 - 4	hr.	
	=	2 - 4	hr.	
Length/Width Ratio (L/W)	=	Minimum of 4:1		
Water Depth/Length Ratio	=	Minimum of 1:15		
Sludge Collector Speed				
For the Collection path	=	0.3 - 0.9	m/min	
For the Return	=	1.5 - 3.0	m/min	

Design Plant Capacity	=	5000	m^3/day
Number of Sedimentation	=	2	Tank
∴ Flow rate per Basin	=	2500	m^3/day

5.3 Inlet Zone

Inlet Diffusion Wall

Darcy - Weisbach Formular

$$h_f = f \frac{L}{D} \frac{v^2}{2g}$$

Relationship with G

$$G^2 = \frac{fv^3 \rho}{2gD\mu}$$

Where :

G = $Mean\ velocity\ gradient(s^{-1})$

f = $Friction\ Factor$

v = $velocity\ passthrough\ orifice(m/s)$

D = $Diameter\ of\ Orifice(m)$

ρ = $Mass\ Density\ of\ Water\ (kg/m^3$ = 997.1 kg/m^2 at 25 oC

μ = $absolute\ viscosity(kg/m.s)$ = 0.000895 kg/m.s (N/m.s) at 25 oC

Give G = 10 1/sec (Design Criteria G = 10 - 75 s^{-1})

Orifice made from concrete : ε = 1.22 mm.

Give Diameter of Orifice = 100 mm. ∴ Area = 0.007854 m^2

ε/D = 0.0122

find f Give from Reynolds number

Give Reynolds number(R) = 17,000

From Moody Diagram

then f = 0.042

∴ v = 0.161 m/sec

(PWA . Criteria 0.15 - 0.20 m/sec)

Check Renold Number (R)

R = vD/ν or $\frac{D_p \delta_L v_s}{\mu}$ $\gamma = \frac{\mu}{\delta}$

17,957 **O.K.**

∴ Total Area of Pores = Q/v m^2

0.35888 m^2

46 pores

Theory Headloss = $\frac{1}{2g} x \left(\frac{v}{C} \right)^2$

Give C for Orifice = 0.65

∴ Headloss = 0.0031 m.

5.4 Horizontal Rectangular Basin

Design Plant Capacity	=	5000	m^3/day	
Number of Sedimentation	=	2	Tank	
Flow rate per Basin	=	2500	m^3/day	
Give Water Depth	=	3	m.	
Give Surface Loading	=	1.9	m/hr.	
	=	0.031667	m/min	(Design Criteria : 0.02 - 0.06 m/min)

∴ The Required total surface Area = $\dfrac{Q(m^3/\min)}{Surface\ Loading\,(m/\min)}$ m^2

= 54.82 m^2

	Give Tank Width	=	4.5	m.	(Because Flocculation basin Width : 4.5 m)
∴	Tank Length	=	12.18	m.	
	Give Detention Time	=	3	hr.	
∴	Tank Volume	=	Qxt		
		=	312.50	m^3	
∴	Acture Tank Length	=	23.15	m.	
	Use Acture Tank length	≈	24	m.	
∴	Width : Length	=	1 : 5.14		(Design Criteria > Minimum 1:5) OK.
∴	Acture Surface Loading	=	1.00	m/hr.	
		=	0.0167	m/min.	(PWA. Design Criteria : 0.02 - 0.06 m/min)

5.5 Outlet Zone

Give Weir Loading = 12 m^3/hr.m.

Weir Length = 8.68 m.

Give Outlet Zone Width = 2.5 m.

Theory

Launder Size (d) = $Q^{0.4}$ m.

Use 2 Launder per Basin

$$= \left(\frac{2500}{24x3600x2}\right)^{0.4}$$

∴ d = 0.18 m.

Use d = 0.25 m.

Check Weir Length (L)

Theory $$L = \frac{0.2Q}{Hv_s}$$

where :

L = Combined weir length (m)

Q = Flow rate (m^3/day) = 2500 m^3/day

H = Depth of Tank (m) = 3 m

v_s = Settling velocity (m/day)

Give v_s = 0.04812 m/min = 69.2928 m/day

$$L = \frac{0.2x2500(m^3/day)}{3(m)x69.3(m/day)}$$

∴ Weir Length (L) = 2.41 m.

Use weir length = 2.5 m.

∴ Weir length/Basin = 10 m.

Check Launder Depth

Theory $$W = \left(\frac{Q(m^3/s)}{1.4B(m)}\right)^{2/3}$$

where :

W = Launder Depth (m.)

Q = Total flow rate of discharge (m^3/sec)

B = inside width of the Launder (m.)

W = 0.19 m.

Use W = 0.3 m.

Use V-noych weir 90 degree

Theory Discharge of water over V-notch weir

$$Q = \frac{8}{15} C_d \sqrt{2g} \tan\frac{\theta}{2} H^{5/2}$$

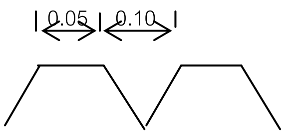
where :

Q = Overflow Discharge (m^3/s)

C_d = Discharge Coefficient = 0.584

θ = V - notch angle 90 degree

H = Heigh of flow (m.)



Give 1 V-notch weir have length = 0.15 m.

∴ Total V-notch weir = 67

Flow rate per V-notch weir = 1.56 m^3/hr

$H^{5/2}$ = 0.000194

∴ H = 0.033 m.

6. Fiter Tank Design

Design Criteria (Dr. Kawamura)

6.1 Number of Fliter = minimum 2

Theory

$$N = 1.2Q^{0.5}$$

Where :

N = Total number of filters

Q = Maximum plant flow rate in (mgd)

6.2 Size of Filter

6.2.1 Ordinary gravity filters

- Width of Filter cell	= 3 - 6	m.
- Length to width ratio	= 2 : 1 to 4 : 1	
- Area of Filter cell	= 25 - 100	m^2
- Depth of the filter	= 3.2 - 6	m.

6.2.2 Self-backwash filters

- Depth of the filter	= 3 - 6	m.
- Length to width ratio	= 2 : 1 to 4 : 1	
- Area of Filter cell	= 25 - 80	m^2
- Depth of the filter	= 5.5 - 7.5	m.

6.3 Filter Bed

Type of Medium and Depth

L/d_e > 1000 for ordinary monosand and media bed

6.4 Filtration Rate

Filter rate = 15 - 20 $m^3/hr/m^2$

6.5 Headloss across the filter

- Total Headloss across each filter (for ordinary gravity filter) = 2.7 - 4.5 m.
- Net Headloss available for filtration (for ordinary gravity filter) = 1.8 - 3.6 m.

6.6 Filter washing

- Ordinary rapid sand bed = 0.6 - 0.74 m/min
- Ordinary dual media bed = 0.74 - 0.9 m/min

6.7 Surface Wash Rate : Fix nozzle type

- Flow rate = 0.12 - 0.16 m/min
- Pressure = 55 - 83 KPa

6.8 Filter Media

6.8.1 Medium Sand for rapid sand filter

- Filter rate = 7.0 - 7.5 m/hr.
- Effective Size = 0.45 - 0.65 mm.
- U.C. = 1.4 - 1.7
- Depth = 0.6 - 0.75 m.
- S.G. = 2.63

6.8.2 Multimedia filter

- High rate filtration 10 - 30 m/hr.

Sand

- Effective Size = 0.45 - 0.65 mm.
- U.C. = 1.4 - 1.7
- Depth = 0.3 m.

Anthacite Coal

- Effective Size = 0.90 - 1.4 mm.
- S.G. = 1.5 - 1.6
- Depth = 0.45 m.

6.9 Underdrain

6.9.1 Normal backwash filters

- Pipe lateral
  - Headloss at ordinary backwash rate = 0.9 - 1.5 m.
  - Ordinary size (diameter) = 6 - 10 mm.
  - Lateral spacing = 12 inch
  - Orifices are spaced 3 - 4 in. apart and 45^{o} down-angle from the horizontal on both sides of the lateral
  - Maximum lateral length of 20 ft

- Precast concrete laterals
  - Headloss at ordinary backwash rate
  - Orific size (diameter) = 8 - 10 mm.
  - 12 in lateral spacing
  - 3 in. orifice spacing on eather side of the lateral
  - Maximum lateral length of 16 ft.

6.9.2 Self - backwash type of filter

- Headloss at design backwash rate : 0.15 - 0.3 m.

Gravel Support Bed

Layer Number	Size	Depth of Size
1	20 - 40 mm.	100 - 150
2	12 - 20 mm.	75 mm.
3	6 - 12 mm.	75 mm.
4	3 - 6 mm.	75 mm.
5	1.7 - 3 mm.	75 mm.

6.9.3 Basic Hydraulic

	Ordinary Filter (m/s)	Self-backwash filter (m/s)
1. Influent channel	0.6	0.6
2. Influent valve	0.91	1.52
3. Effluent Channel	1.52	0.6
4. Effluent Valve	1.52	0.6
5. Backwash main	3.05	0.91
6. Backwash valve	2.4	1.52
7. Surface wash line	2.4	2.4
8. Wash-waste main	2.4	2.4
9. Wash-waste valve	2.4	2.4
10. Inlet to filter underdrain lateral	1.37	1.37

6.10 Filtration Design

Filtration type : Single Filter Media

Backwash by : Elevation Tank and Surface wash

- Q design = 5000 m^3/day

Theory

$$N = 1.2Q^{0.5}$$ (Dr.Kawamura,210 page)

Where :

N = Total Number of filters

Q = Maximum plant flow rate in mgd

∴ N = 1.37922 Use 3 Tanks

Give Hydraulic Loading = 7 m^3/hr/m^2

∴ Surface Area of Filter Tank = 29.76 m^2

∴ Area per Tank = 9.92 m^2

∴ Use Tank area = 4.45 x 2.23 (Length to width ratio 2 : 1 to 4 : 1)

Use Acture Tank Area ≈ 5 x 2.5 m^2

∴ Acture tank Area = 12.5 m^2

∴ Flow per Tank = 1667 m^3/day

1. Inlet Pipe Design

- Give velocity = 0.6 m/s (JWWA)

$$Q = Av$$

$$D = \sqrt{\frac{4Q(m^3/s)}{\pi v}}$$

D = 0.20238 m.

∴ Use inlet pipe diameter (D) = 0.2 m.

Acture Velocity $= \dfrac{Q(m^3/s)}{A(m^2)}$

$\therefore$ Acture Velocity = 0.61434 m/s

Headloss

- Give Pipe length (L) = 2.5 m.

- Friction Loss

Theory

Hazen - William Equation

$$Q(m^3/s) = 0.278CD_{(m)}^{2.63}S^{0.54}$$

$$\therefore \quad S = \left(\frac{Q(m^3/s)}{0.278CD_{(m)}^{2.63}}\right)^{1/0.54} = \left(\frac{3.597Q(m^3/s)}{CD_{(m)}^{2.63}}\right)^{1.85}$$

From Slope of Energy grade Line (S) = $\dfrac{h_L}{L}$

$$\therefore \quad h_L = SxL$$

$$\therefore \quad h_L = \left(\frac{3.597Q(m^3/s)}{CD_{(m)}^{2.63}}\right)^{1.85} xL$$

New Pipe use C = 120

$\therefore$ h_L = 0.00644 m

- Miner Loss K - Value

1 - Inlet	=	0.5	(velocity head)
1 - Outlet	=	1	(velocity head)
1 - Gate Valve	=	0.2	
Total	=	1.7	

∴ Miner Loss = $\frac{Kv^2}{2g}$

Miner Loss = 0.0327 m

∴ Total Headloss = Friction Loss + Miner Loss

= 0.03914 m

2. Filter Media

Sand

- Effective Size = 0.45 - 0.65 mm. ≈ 0.55 mm.
- Uniformity Coefficient = 1.40 - 1.70
- Sand Fliter Depth (L) = 0.65 m
- L/d_e = 1182 more than 1000 OK.

Gravel Support Bed

Layer		Size (mm.)	Depth of Layer (mm)
Upper	1	1.7 - 3.0	150
	2	3 - 6	75
	3	6 - 1 2	75
	4	12 - 20	75
Lower	5	20 - 40	75

Underdrain design

- Type : Pipe lateral
- Velocity in lateral pipe = 1.37 m/s
- Lateral spacing = 0.08 - 0.20 m (Mahidol University)

use = 0.2 m
- Orifice diameter = 6.38 - 12.7 mm. (Mahidol University)

use = 7 mm

- Orifice area/crossection area of filter tank

= 0.0015 - 0.005

- Orifice area/pipe area = 0.25 - 0.5
- Number of lateral = 25 (give lateral spacing 0.2 m. Length Tank)
- Flow rate = $Velocity\ \ rate\ in\ lateral\ \ pipe(m/s)xSurface\ \ Area\,(m^2)$

∴ Surface area of Pipe lateral = 0.00056 m^2

- Flow per Lateral = 3 m^3/hr
- **Pipe Lateral Diameter** = $\sqrt{\dfrac{4Q\,(m^3/s)}{\pi v\,(m/s)}}$ m

= 0.02679 m

∴ Use Pipe Lateral Diameter(D ≈ 27 mm

- Total Orifice area/ filter area = 0.35 % (Design Criteria : 0.2 - 1.5 %)

∴ Total Orofice Area = 0.04375 m^2

- Give Number of Orifice = N

∴ $$Nx\frac{\pi D(m)^2}{4} = Total\ Orifice\ \ Area(m^2)$$

∴ N = 1137

- Number of Orifice / Lateral = 45.5 pores

∴ - Orifice Spacing = 0.05498 m

Use Orifice Spacing = 0.05 m

3. Clear Water Pipe in Filter tank

3.1 Clear water pipe in Filter tank (Lateral pipe)

- Velocity = 1 m/s (JWWA)
- Flow per tank = 1667 m^3/day

  = 69.4 m^3/hr
- Pipe Diameter (D)

$$Q = Av$$

$$D = \sqrt{\frac{4Q(m^3/s)}{\pi v}}$$

= 0.157 m

- Use pipe diameter = 200 mm.

∴ Lateral Pipe length = 2.5 m.

3.2 Clear water pipe in Filter tank (Maniflow)

- Pipe Diameter (D)

$$Q = Av$$

$$D = \sqrt{\frac{4Q(m^3/s)}{\pi v}}$$

= 0.2715 m

∴ Use ≈ 300 mm.

4. Backwash Pipe

- Backwash rate = 0.7 m/min (Design Criteria 0.6 - 0.7 m/min)

$$Q = Av$$

- Flow rate = 525 m^3/hr
- Velocity = 2 m/s (JWWA)
- Pipe Diameter

$$D = \sqrt{\frac{4Q(m^3/s)}{\pi v}}$$

= 0.3048 m

∴ Use pipe diameter = 300 mm.

5. Lateral Backwash pipe

- Flow rate = 525 m^3/hr
- Velocity = 2 m/s (JWWA)
- Pipe Diameter

$$D = \sqrt{\frac{4Q(m^3/s)}{\pi v}}$$

= 0.3048 m

∴ Use pipe diameter = 300 mm.

6. Collecter Backwash Pipe

- Flow per tank = 69.4 m^3/hr
- Velocity = 3 m/s (JWWA criteria 2.5 - 6.0 m/s)
- Pipe Diameter $D = \sqrt{\frac{4Q(m^3/s)}{\pi v}}$

= 0.091 m

∴ Use pipe diameter = 100 mm.

7. Surface wash Pipe

- Surface wash rate = 0.15 m/min (Design Criteria 0.12 - 0.16 m/min)
- Flow rate $Q = Av$

= 112.5 m^3/hr

Use Flow rate = 115 m^3/hr

- Surface jet pressure = 15 - 20 m. (Design criteria)

(headloss)

Use = 15 m

Theory

$$h = \frac{1}{2g} x \left(\frac{v}{c}\right)^2$$

∴ Velocity = 11.151 m/s

-Give Orifice Diameter = 5 mm.

- Orifice Area = $\frac{\pi D^2}{4}$

= 1.9635E-05 m^2

- Flow per orifice = 0.0002 m^3/s

- Number of Orofice = $\frac{Q_{total}}{Q_{orifice}}$

= 146 holes

- Use 2 Pipe lateral

∴ Number of Orifice per lateral = 73.0 holes

∴ Orifice spacing = 0.0658 m (Tank Length = 5 m)

(minus length from Wall tank = 0.1 m.

2 side = 0.2 m)

- Try orifice Diameter = 6 mm.

∴ Orifice area = 2.82743E-05 m^2

- Flow per orifice = 0.0003 m^3/s

∴ Number of Orifice per lateral = 101.3198 holes

- Use 2 Pipe lateral

∴ Number of Orifice per lateral = 50.65992 holes

∴ Orifice spacing = 0.1 m

-Surface wash pipe Diameter

Main Pipe

Velocity = 2.4 m/s (Dr.Kawamura)

Pipe Diameter

$$D = \sqrt{\frac{4Q(m^3/s)}{\pi v}}$$

Use Pipe Diameter = 0.1302 m

∴ Use Pipe Diameter = 150 mm.

Lateral = 2 pipe

Velocity = 2.4 m/s (Dr.Kawamura)

Pipe Diameter

$$D = \sqrt{\frac{4Q(m^3/s)}{\pi v}}$$

Use Pipe Diameter = 0.092 m.

∴ Use Pipe Diameter = 100 mm.

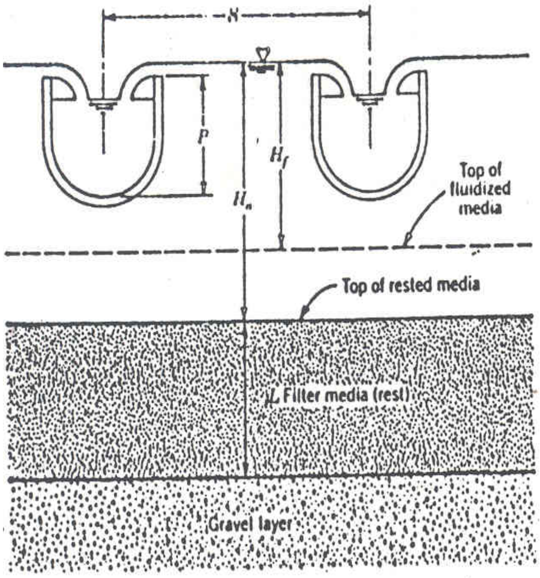


FIGURE 21-35. Height and spacing of wash troughs.

higher upflow velocity when flow gets above the trough bottom elevation and the U-shaped troughs allow for thinner walls because of a higher moment of inertia and greater structural integrity. The bottom of the wash trough should not be flat because froth and suspended matter is often trapped under the trough bottom and may never be washed out.

In either case, the troughs should be large enough to carry the maximum expected wash rate with 5–10 cm free-fall into the trough at the upper end. They should also provide a free-fall to the main collection outlet gullet at the lower end. The bottom of the trough may be either horizontal or sloping.

The required cross-sectional area of the wash trough for a given design flow can be quickly estimated from Figure 21-36. For troughs that have level inverts and rectangular cross section, required trough height can be computed by the following formula:

$W + B/2 + \text{free board}$ $2/3$

$$\text{Minimum trough height} = \left(\frac{Q}{1.4B}\right)^{2/3} + \text{free board}$$

$\therefore W + B/2 = \left(\frac{Q}{1.4B}\right)^{2/3} + F$

where Q is the total flow rate of discharge (m^3/sec), B is the inside width of the trough (m), and, freeboard should be a minimum of 50 mm (2 in.).

Filter Underdrains

Filter underdrainage systems differ primarily due to the different filter-washing systems and filter types

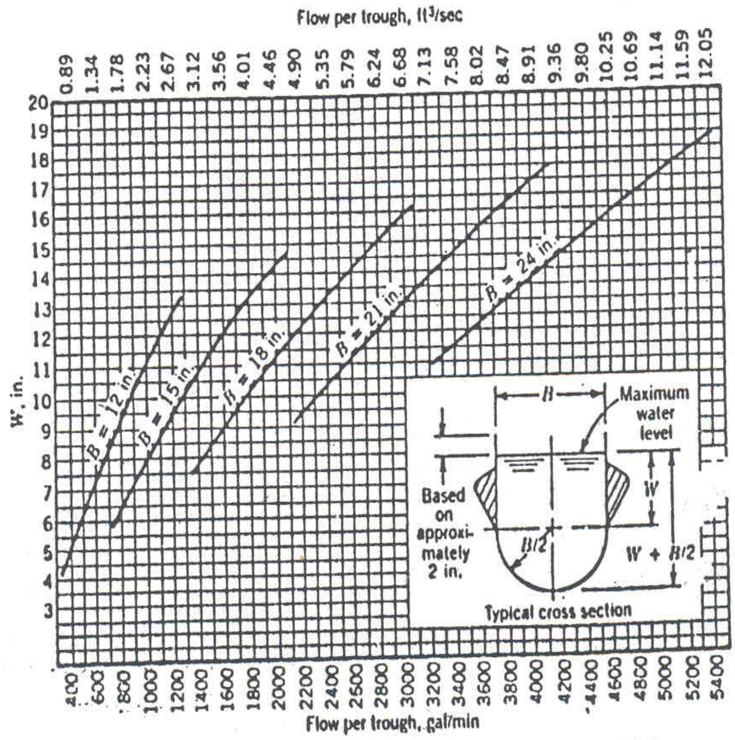


FIGURE 21-36. Wash-trough sizing diagram. (Courtesy of Leopold Co.)

Minimum trough height

$= W + B/2 + \text{free board}$

$= \left(\frac{Q}{1.4B}\right)^{2/3} + \text{free board}$

$$\boxed{\therefore W + \frac{B}{2} = \left(\frac{Q}{1.4B}\right)^{2/3}}$$

8. Water Through Design

Theory

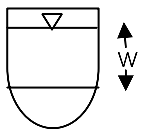
$$\text{Minimum trough height} = \left(\frac{Q(m^3/s)}{1.4B(m)}\right)^{2/3} + \text{free board}$$ ' 1

$$\text{Minimum trough height} = W + \frac{B}{2} + \text{free board}$$ *Equation 2*

∴ *Equation* ' = *Equation 2*

$$\therefore \quad W + \frac{B}{2} = \left(\frac{Q(m^3/s)}{1.4B(m)}\right)^{2/3}$$

Where :



W = water depth inside of the trough from base line (m)

B = inside width of the trough (m)

Q = total flow rate of discharge per trough (m^3/s)

Design Criteria backwash water and air = 0.25 - 0.7 m^3/m^2.min use 0.7 m^3/m^2.min

$$\text{backwash rate} = \frac{Q(m^3/s)}{\text{Surface area}(m^2)}$$

∴ Q = 0.14583 m^3/s

Use 2 trough per Filter tank

∴ total flow rate of discharge per trough = 0.072917 m^3/s

Give Free board = 0.051 m. (free board should be a minimum of 50 mm.)

Give inside width of the trough = 0.4 m.

∴ Minimum trough height(P) = 0.307897 m.

= 30.78971 cm.

≈ 31 cm.

From Sand Layer Depth (L) = 650 mm. = 0.65 m.

Theory $$0.75L + P < H_o < L + P$$

$$0.7954 < H_o < 0.957897$$

Use H_o = 0.88 m

Theory $$1.5H_o < S < 2H_o$$

$$1.31497 < S < 1.753294$$

Use S = 1.53 m

Hydraulic Design

1. Head loss (Run)
    - 1.1 Head loss Sand
    - 1.2 Head loss Gravel
    - 1.3 Head loss Underdrain
    - 1.4 Head loss at outlet piping

2. Head loss (Backwash)
    - 2.1 Head loss Sand
    - 2.2 Head loss Gravel
    - 2.3 Head loss Underdrain
    - 2.4 Head loss piping from Elevation Tank

3. Head loss from Surface wash

- Calculation later from Layout and find out Hydraulic grade line and Surface & Backwash pipe

9. Chlorination Design

Design Criteria (Dr. Kawamura)

Dosage	:	1 - 5 mg/l (2.5 mg/l average)
Number of chlorine feeder	:	Minimum of two : one stanby is required
Residual Chlorine	:	Over 0.5 mg/l (Higher Level)
Contact time	:	Over 30 min (longer)
pH	:	6 - 7
Chlorine solution tank	:	Enough to produce a 1 day supply
Chlorine stock	:	Minimum of 15 days storage
Safety features	:	Eye wash, shower, gas masks

Design

Use liquid chlorine concentration 1 % prepare from stock liquid chlorine 50 % feed to main pipe before Elevation tank. Keep Contact time = 30 min (minimum)

1. Chlorine Feeder

Q - Design = 5000 m^3/d

= 208.3 m^3/hr

Assume Chlorine demand of water = 1 mg/l

For residual chlorine about 0.5 - 1 mg/l

Use chlorine dosage 1.5 - 2 mg/l

Required chlorine = 208.3 x(1.5 to 2 mg/l)

= 312.5 to 416.7 g/hr

Meaning of liquid chlorine 1 % is chlorine = 10 g/l (1 L of water = 1000 g)

Chorine feeder rate = 31.25 to 41.67 L/hr

$\therefore$ Use Chlorine feeder rate = 35 to 40 L/hr

2. Dilution stock liquid chlorine solution 50 % to 1 % liquid chlorine solution

Assume stock liquid chlorine solution 50 % one plastic equal = 20 liters

Theory $N_1 x V_1 = N_2 x V_2$

Where :

N = Chlorine concentration (%)

V = Volume of Liquid (liters)

Give N_1 = 50 %

V_1 = 20 liters

N_2 = 1 %

V_2 = ? liters

50 % x 20 = 1% x V_2

∴ V_2 = 1000 liters

Use mixing tank volume = 1000 liters made from plastic

Fill stock Liquid Chlorine = 20 liters in mixing tank and fill water until limited 1000 liters

3. Period of Mixing

Maximum chlorine feeder rate = 40 Liters/hr

Required Liquid Chlorine = 960

= 960 Liters/day

So period of mixing = Every Day

4. Liquid Clorine 50 % Stock

Use storage time = 30 days (1 month)

Required Liquid Chlorine = 1 %

= 28800 Liters per month

Required Liquid Chlorine = 50 %

= 576 Liters per month

∴ Stock Liquid Chlorine = 28.8 Plastic Tank per Month

∴ For Order per Month say = 29 Plastic Tank

10. Surface Wash and Backwash System

- Use water from Elevation tank
- Water Level in Elevation tank = 22 - 25 m.
- From Site Pant : Pipe length = 35 m.

Backwash System

Use Pressure for Backwash

- Head loss due to water flowing through a sand bed fluidized

Theory

$$\frac{h_L}{L} = (1-e)(S_g - 1)$$

Where :

h_L = head loss through the media bed during backwash. (m)

e = porosity of the clean stratified bed at rest. (not fluidiz = 0.4

L = depth of the stratified bed at rest. (m) = 0.65 m

S_g = specific gravity of the media. = 2.65

Calculation

h_L = 0.6 m

- Head loss through the supporting gravel bed fluidzed

จาก $H/L = (150\nu V/g)[(1-\varepsilon)^2/\varepsilon^2](1/\omega)^2\,\Sigma(xi/di^2) + (1.75V^2/g)(1-\varepsilon/\varepsilon^2)(1/\omega)\,\Sigma(xi/di)$

ν	=	0.9629	mm^2/s
V(Backwash rate)	=	11.67	mm/s
ε	=	0.4	
ω	=	0.8	

Layer	Size (mm)	di	Depth (mm)	xi	xi/di	xi/di^2
1	1.7 - 3	2.26	150	0.3333	0.1476	0.0654
2	3 - 6	4.24	75	0.1667	0.0393	0.0093
3	6 - 12	8.49	75	0.1667	0.0196	0.0023
4	12 - 20	15.49	75	0.1667	0.0108	0.0007
5	20 - 40	28.28	75	0.1667	0.0059	0.0002
			450	1.0000	0.2232	0.0778

From H/L = 0.0995

H = 0.0448 m.

- Backwash trough height

Give Fluidized Bed Expand = 25 %

∴ Media Depth(Fluidized) = 0.65 + 0.1625

= 0.8125 m

∴ Expanded sand depth = 0.8125 - Sand Fliter Depth

= 0.1625 m

∴ Backwash trough height = $Expanded\ Sand\ Depth + trough\ height + 6\,in$

(Munsin Tuntuvate)

= 0.6227971

∴ Head loss for Backwash system =

$$Headloss\ in\ sand\ bed\ \ fluidized + gravel\ bed\ \ fluidized + sand\ depth + backwash\ trough$$

= 1.9611 m

11. Headloss in Piping System

Give backwash rate = 0.7 m/min (Design criteria = 0.6 - 0.7 m/min)

Acture tank Area = 12.5 m^2

∴ Backwash flow rate = $A(m^2)xv(m/hr)$

= 525 m^3/hr

Give Main Pipe Diameter = 300 mm

= 0.3 m

∴ Acture velocity = 2.0642 m/s

11.1 Friction Loss (h_L) at Main Pipe

Theory Hazen-William Equation

$$Q(m^3/s) = 0.278CD_{(m)}^{2.63}S^{0.54}$$

$$h_L = SxL$$

$$\therefore \quad h_L = \left(\frac{3.597Q(m^3/s)}{CD_{(m)}^{2.63}}\right)^{1.85} xL(m)$$

Give New Pipe C = 120

Pipe Diameter = 0.3 m

Pipe Length = 35 m

∴ h_L = 0.5288 m too Low

Try Main Pipe Diameter = 250 mm

= 0.25 m

∴ Velocity = 2.9724 m/s

∴ h_L = 1.2839 m OK

11.2 Velocity Miner HeadLoss K

11.2.1.accessory

1 - Inlet	=	1
3 - 90^{o} Bend	=	2.25
Total	=	3.25

Theory

$$\text{Headloss} = K\frac{v^2}{2g}$$

Headloss = 1.464 m

11.2.3. Velocity headloss in Main pipe

1. Pipe Diameter	=	0.3	m
2. Velocity	=	2.0642	m/s
3. K	=	2.2	
Headloss	=	0.4778	m

11.3 Headloss at lateral

Flow per Lateral = 21 m^3/hr

Theory Hazen-William Equation

$$h_L = \left(\frac{3.597Q(m^3/s)}{CD_{(m)}^{2.63}}\right)^{1.85} xL(m)$$

Pipe Diameter = 0.0268 m

∴ Headloss = 12.472 m

11.4 Headloss at Orifice

Flow per Orifice	=	0.061	m^3/hr
- Orifice diameter	=	7	mm
Velocity	=	0.4411	m/s

Theory Headloss = $\frac{1}{2g} x \left(\frac{v}{C}\right)^2$

Give C for Orifice = 0.65

∴ Headloss = 0.0235 m

∴ Total Headloss = 16.409 m

- Sand Depth = 0.65 m
- Gravel Depth = 0.45 m
- Sand Expansion = 0.16 m
- Trough Height = 0.31 m

∴ Trough Height From Base Line = 1.57 m

∴ Total Dynamic Head = 17.98 m

- Water Level in Elevation tank = 22 - 25 m. Choose = 22 m.

∴ Different Head Loss = 4.02 m.

11.5 Use Orifice Plate

Theory Headloss = $\frac{1}{2g} x \left(\frac{v}{C}\right)^2$

Give C for Orifice = 0.65

∴ Velocity (v) = 5.58 m/s

Theory Pipe Diameter

$$D = \sqrt{\frac{4Q(m^3/s)}{\pi v}}$$

∴ Pipe Diameter = 0.182 m.

= 182 mm.

12. Headloss and Hydraulic Profile

Q_{design} = 5000 m^3/d

Q_{max} = $1.5Q_{design}$

= 7500 m^3/d

- Headloss at static Mixer

  at Q design = 0.08 m.

- Headloss at Flocculation

  for 1st Stage

  at Q design = 0.15 m.

  for 2nd Stage

  at Q design = 0.05 m.

  for 3rd Stage

  at Q design = 0.02 m.

  for 4th Stage

  at Q design = 0.01 m.

- Headloss at Diffuser wall (Inlet Zone Sedimentation)

  at Q design = 0.0031 m.

- Headloss Over V-notch weinr (Outlet Zone Sedimentation)

  at Q design = 0.0328 m.

- Headloss Inlet Pipe (Filtration)

at Q design = 0.0391 m.

- Head loss pass through clean filter media (Filtration)

จาก H/L = $(5\nu V/g)[(1-\varepsilon)^2/\varepsilon^3](6/\omega)^2\Sigma(xi/di^2)$

ν = 0.9629 mm^2/s

V = 1.94 mm/s

ε = 0.4

ω = 0.8

ชั้นทรายสูง = 0.65 m.

H/L = 1.00

H = 0.65 m.

- Headloss Through Gravel (Filtration)

จาก H/L = $(150\nu V/g)[(1-\varepsilon)^2/\varepsilon^2](1/\omega)^2\ \Sigma(xi/di^2) + (1.75V^2/g)(1-\varepsilon/\varepsilon^2)(1/\omega)\ \Sigma(xi/di)$

ν = 0.9629 mm^2/s

V = 1.94 mm/s

ε = 0.4

ω = 0.8

Layer	Size (mm)	di	Depth (mm)	xi	xi/di	xi/di^2
1	1.7 - 3	2.26	150	0.3333	0.1476	0.0654
2	3 - 6	4.24	75	0.1667	0.0393	0.0093
3	6 - 12	8.49	75	0.1667	0.0196	0.0023
4	12 - 20	15.49	75	0.1667	0.0108	0.0007
5	20 - 40	28.28	75	0.1667	0.0059	0.0002
			450	1.0000	0.2232	0.0778

From H/L = 0.0076

H = 0.0034 m.

∴ Total Head loss across the filter Media at Q_{design}

= Head loss pass through clean filter media (Filtration) + Headloss Through Gravel (Filtration)

= 0.652 m.

- Head loss for underdrain

1. Head loss at orifice

Total Number of filters	=	3	Tanks
- Q design	=	5000	m^3/day
∴ Flow rate per Tank	=	1667	m^3/day
1 Tank have Number of lateral	=	25	
∴ Flow rate per lateral	=	66.67	m^3/day
1 lateral have Number of orifice	=	45.47	pores
∴ Flow rate per orifice	=	1.466	m^3/day
	=	0.061	m^3/hr

Theory

$$Q = Av$$

∴ Velocity pass through orifice

= 0.441 m/s

∴ Head loss at orifice

Theory

$$Q = C_d A\sqrt{2gh_L} \qquad (1)$$

$$Q = Av \qquad (2)$$

$$\therefore \quad Av = C_d A\sqrt{2gh_L} \qquad (3)$$

$$\left(\frac{v}{C_d}\right)^2 = 2gh_L$$

$$\therefore \quad h_L = \frac{1}{2g}\left(\frac{v}{C_d}\right)^2 \qquad (4)$$

$$2g\left(C_d\right)$$

C_d Orifice = 0.61

∴ Head loss at orifice = 0.027 m.

2. Head loss at Lateral

Flow rate per lateral = 66.67 m^3/day

= 2.778 m^3/hr

Theory

$$Q = Av$$

∴ Velocity pass through lateral

= 1.37 m/s

Minor loss = $K\dfrac{v^2}{2g}$

K outlet = 1

∴ Minor loss = 0.096 m.

Theory

$$h_L = \left(\frac{3.597Q(m^3/s)}{CD_{(m)}^{2.63}}\right)^{1.85} xL$$

New Pipe C = 120

h_L = 0.296 m.

∴ Total Head loss at Q_{design} = h_L + Minor loss

= 0.391 m.

- Head loss at delivery Pipe (Lateral Clear water Pipe in Filtration Tank)

Theory

$$Q = Av$$

- Flow per tank = 69.44 m^3/hr
- Use pipe diameter = 0.2 m.

∴ Velocity pass through lateral clear water pipe

= 0.614 m/s

- Miner Loss		K - Value	
1 - Inlet	=	0.5	(velocity head)
1 - Outlet	=	1	(velocity head)
1 - Gate Valve	=	0.2	
90^{o} bend	=	0.9	
Tee	=	1.8	
Total	=	4.4	

Theory Miner Loss = $\frac{Kv^2}{2g}$

= 0.085 m.

- Head loss at delivery Pipe (Maniflow Clear water Pipe in Filtration Tank)

Give Pipe Length = 20 m.

Theory

$$h_L = \left(\frac{3.597Q(m^3/s)}{CD_{(m)}^{2.63}} \right)^{1.85} xL$$

New Pipe C = 120

h_L = 0.089 m.