① Initial conc. = 20 mg/L  To remove 60%

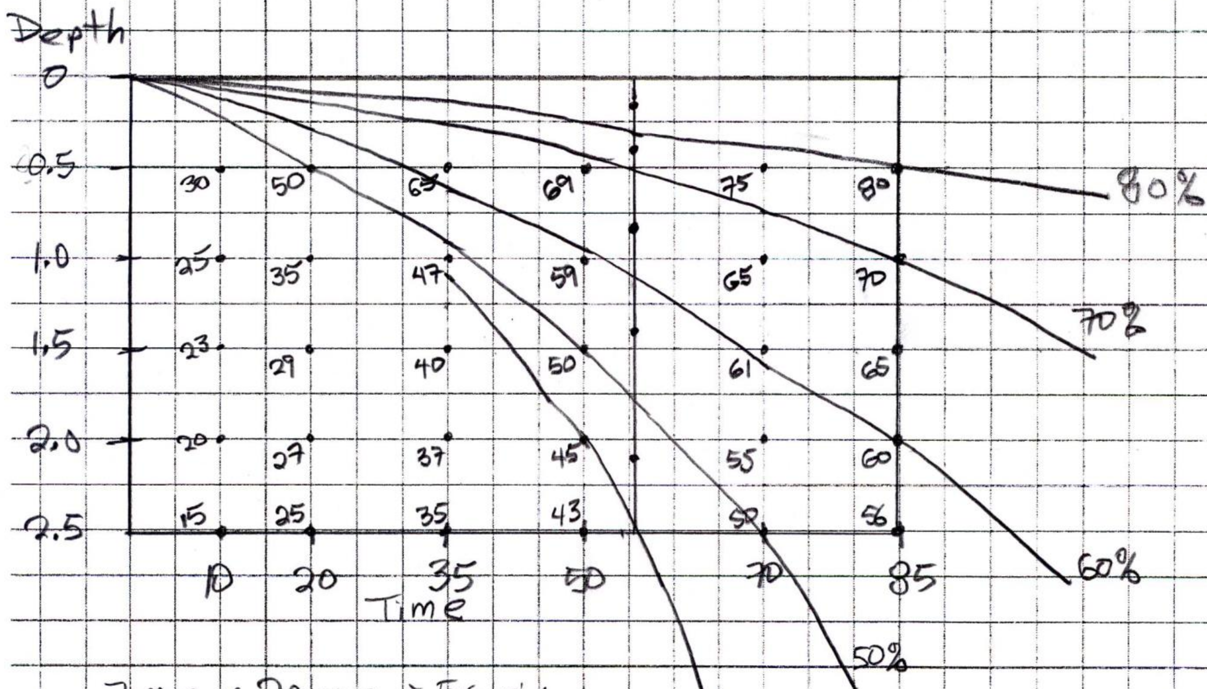
| Depth | Time (min) 10 | | 20 | | 35 | | 50 | | 70 | | 85 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 14 | 30 | 10 | 50 | 7 | 65 | 6.2 | 69 | 5 | 75 | 4 | 80 |
| 1.0 | 15 | 25 | 13 | 35 | 10.6 | 47 | 8.2 | 59 | 7 | 65 | 6 | 70 |
| 1.5 | 15.4 | 23 | 14.2 | 29 | 12 | 40 | 10 | 50 | 7.8 | 61 | 7 | 65 |
| 2.0 | 16 | 20 | 14.6 | 27 | 12.6 | 37 | 11 | 45 | 9 | 55 | 8 | 60 |
| 2.5 | 17 | 15 | 15 | 25 | 13 | 35 | 11.4 | 43 | 10 | 50 | 8.8 | 56 |

Measured concentrations given in mg/L

% removed = $\frac{C_0 - C_i}{C_0}(100\%)$ calculated

For example $\frac{20-17}{20}(100\%) = 15\%$ at 2.5 m depth and at 10 min.

% Removal plotted for depths and times given.




$\frac{7\text{ mm}}{25\text{ mm}} \times 20\text{ min} = 5.6\text{ min}$

50 min + 5.6 min = 55.6 min or time at which 45% removal curve intersects 2.5 m depth line.

Finding % removed at 55.6 m

Scale: 64 mm = 2.5 m

$$R_{T45} = 45\% + \frac{2.09}{2.50}(50-45) + \frac{1.39}{2.50}(60-50)$$

$$+ \frac{0.820}{2.50}(70-60) + \frac{0.390}{2.50}(80-70)$$

$$+ \frac{0.156}{2.5}(100-80)$$

$$= 45 + 4.18 + 5.56 + 3.28 + 1.56 + 1.25$$

$$= 60.83\%$$

If one is too far off 60% then an additional time needs to be calculated and one would interpolate between the two times to find the time for 60% removal

Detention time ≈ 56 minutes

$$V_o = \frac{H}{t} = \frac{2.5\ m}{56\ min} \times 60 \times 24\ \frac{min}{d}$$

$$= 64.3\ \frac{m}{d}$$

(a) $Q = 25,000\ m^3/d$ Table 7-5 applies.
$V_o = 40\ m^3/d \cdot m^2$
$T = 12°C$

$$A_p = \frac{Q}{V_o} = \frac{25{,}000\ m^3/d}{40\ m^3/d \cdot m^2} = 625\ m^2$$

Try 3 basins $A_p = \frac{625\ m^2}{3} = 208.3\ m^2/\text{basin}$

Use chain-and-flight for sludge removal so W is a multiple of 0.3 m

Try $W = 3.6\ m$

$$L = \frac{625\ m^2}{3\ \text{basins}} \times \frac{1\ \text{basin}}{3.6\ m} = 57.9\ m, \text{ use } 58\ m$$

$L/W = 58/3.6 = 16.1:1 \geq 6:1$ so O.K

Let $SWD = 3.5\ m$ and $D = 2.5\ m$

$L/D = 58/2.5 = 23.2:1 \geq 15:1$ O.K

$$V_{fc} = V_H = \frac{Q}{A_X} = \frac{25{,}000\ m^3/d}{3\ \text{basins}\ (3.6\ m \times 2.5\ m)(60 \times 60 \times 24\ s/d)}$$

$= 0.0107\ m/s$ (OK, 0.005–0.018 m/s)

Check Re ($F_r$ not required for $Q < 40{,}000\ m^3/d$)

$$R_h = \frac{A_X}{P_w} = \frac{(3.6\ m)(2.5\ m)}{2.5\ m + 2.5\ m + 3.6\ m} = \frac{9}{8.6} = 1.05\ m$$

at 12°C $\nu = 0.001236\ m^2/s$

$$Re = \frac{V_H R_h}{\nu} = \frac{(0.0107\ m/s)(1.05\ m)}{0.001236} = 9.09 \text{ OK} < 20{,}000$$

Let launders be 1/3 basin length and 2 per basin

$58/3 = 19.3$ m; use 19 m.

$$WL = \frac{25{,}000 \text{ m}^3/\text{d}}{(3 \text{ basins})(2 \text{ launders/basin})(19 \text{ m})(2 \text{ sides/launder})}$$

$$= 109.64 \text{ m}^3/\text{d}\cdot\text{m}, \text{ OK, } \leq 250 \text{ m}^3/\text{d}\cdot\text{m}$$

$$Q_{design} = V_o A_p = \frac{40 \text{ m}^3}{\text{d}\cdot\text{m}^2}(58.0 \text{ m})(3.6 \text{ m})(3 \text{ basins})$$

$$= 25{,}056 \text{ m}^3/\text{d}$$

Summary:
- 3 basins
- L = 58 m; W = 3.6 m; D = 2.5 m
- SWD = 3.5 m
- Sludge zone depth = 1.0 m
- L:D = 58:2.5 = 23.2:1
- $V_f$ = 0.0107 m/s
- Re = 9.09
- 2 launders / basin
- WL = 110 $m^3$/d·m
- Chain-and-flight sludge removal.

3) $Q = 25{,}000\ m^3/d$
$T = 12^\circ C$
settler tubes at 60° with horizontal
with hydraulic diameter = 0.05 m
floc has excellent settling characteristics

Let $V_0 = 150\ m^3/d \cdot m^2$ because of settling capacity of floc ($V_0 = 60 - 180\ m^3/d \cdot m^2$)

$$A_p = \frac{Q}{V_0} = \frac{25{,}000\ m^3/d}{150 m^3/d \cdot m^2} = 167\ m^2$$

Try 2 basins $\frac{167 m^2}{2} = 83.5 m^2 = A_p$ / basin.

$$Q = 25{,}000\ \frac{m^3}{d} \times \frac{d}{86{,}400 s} = 0.289\ m^3/s$$

Try $W = 3.6$ m (multiple of 0.3 m)

$$L_{settlers} = \frac{83.5\ m^2}{3.6\ m} = 23.2\ m$$

$$L_{basin} = \frac{23.2 m}{0.75} = 30.9\ m \rightarrow \text{use } 31\ m.$$

Sludge zone depth = 2.0 m (Fig. 7-14)

Settler height = 1.4 m (0.5 - 2.0 m range)

Top settler to top launder = 1.0 m (0.6 - 1.0 m range)

SWD = 2.0 m + 1.4 m + 1.0 m = 4.4 m

Total D with freeboard = 4.5 m + 0.6 m = 5.0 m

Use D, not SWD to find approach velocity, $V_H$

$V_H = \frac{Q}{A_x} = \frac{0.289\ m^3/s}{(2\ \text{basins})(2.4\ m)(3.6\ m)} = 0.01672\ m/s \not\leq 0.01\ m/s$ not O.K.

Increase settler height to 2.0 m
and D to 3.0 m so SWD ≤ 5.0 m

$V_H = \frac{Q}{A_x} = 0.01672\ m/s \left(\frac{2.4\ m}{3.0\ m}\right) = 0.0134\ m/s$ better but still not O.K.

Before trying more basins or a greater W
test $V_{fc}$

$V_{fc} = \frac{Q}{A \sin\theta} = \frac{0.289\ m^3/s}{(167\ m^2)(\sin 60°)} = 0.00208\ m/s$ low because

$V_{fc}$ preferred range = 0.0025 – 0.0033 m/s

We can let $V_o = 180\ m^3/d \cdot m^2$ because of the excellent settling characteristics.

$A_p = \frac{Q}{V_o} = \frac{25{,}000\ m^3/d}{180\ m^3/(d \cdot m^2)} = 139\ m^2$

$V_{fc} = \frac{0.289\ m^3/s}{(139\ m^2)(\sin 60°)} = 0.00240\ m/s$ this is better and will be considered acceptable.

Let $V_H = 0.01\ m/s = \frac{0.289\ m^3/s}{(2\ \text{basins})(3.0\ m)(W)}$ ; $W = 4.82$

Width of W = 4.80 m gives $V_H = 0.01003\ m/s$ which is considered acceptable and rounds off to 0.01 m/s

4.80 m is a multiple of 0.3 m

$A_p = 139\ m^2$

For 2 basins $\frac{A_p}{\text{basin}} = \frac{139\ m^2}{2} = 69.5\ m^2$

$L_{\text{settlers}} = \frac{69.5}{4.80\ m} = 14.5\ m$

$L_{\text{basin}} = \frac{14.5\ m}{0.75\ m} = 19.\dot{3};$ say $19.4\ m$

At $12°C$ $\nu = 1.236 \times 10^{-6}\ m^2/s$

Hydraulic diameter of tubes $= 0.05\ m$

$R_h = \frac{A_x}{P_w} = \frac{\pi r^2}{2\pi r} = \frac{r}{2} = \frac{0.025\ m}{2} = 0.0125\ m$

$Re = \frac{V_{fc} R_h}{\nu} = \frac{(0.0024\ m/s)(0.0125\ m)}{1.236 \times 10^{-6}\ m^2/s} = 24.3 < 50$ O.K.

$Fr = \frac{V_{fc}^2}{g R_h} = \frac{(0.0024\ m/s)(0.0024\ m/s)}{(9.81\ m/s^2)(0.0125\ m)} = 4.69 \times 10^{-5}$
$> 10^{-5}$ OK

$L_{\text{launder}} = L_{\text{settler}} = 14.5\ m$ Try 2/basin equally spaced

$WL = \frac{25{,}000\ m^3/d}{(2\ \text{basins})(2\ \frac{\text{launders}}{\text{basin}})(14.5\ m)(2\ \text{sides})} = 215.5\ \frac{m^3}{d \cdot m^2}$

$< 300\ m^3/d \cdot m^2 \rightarrow$ O.K.

Summary: 2 basins

$W = 4.80$ m

$L = 19.4$ m

$L_{settlers} = 14.5$ m

SWD = 5.0 m

Total D = 5.0 m + 0.6 freeboard

$V_H = 0.01$ m/s

$V_{fc} = 0.0024$ m/s

Re = 24.3

$Fr = 4.69 \times 10^{-5}$

$L_{launders} = 14.5$ m

2 launders/basin equally spaced

$Q_{design} = 25{,}000 \frac{m^3}{day} = A_p V_0 = (14.5\,m)(4.80\,m)(180$

$= A_p V_0 = (14.5\,m)(4.80\,m)(180\,m^3/d \cdot m^2)(2\text{ basins})$

$= 25{,}056 \frac{m^3}{day}$ (check)

Showing $V_H$ calculation:

$$V_H = \frac{0.289\,m^3/s}{(2\text{ basins})(3.0\,m)(4.80\,m)} = 0.0100\text{ m/s}$$

(3.0 m = D, 4.80 m = W)

For redundancy 3 basins in total are necessary