SEDIMENTATION TANK

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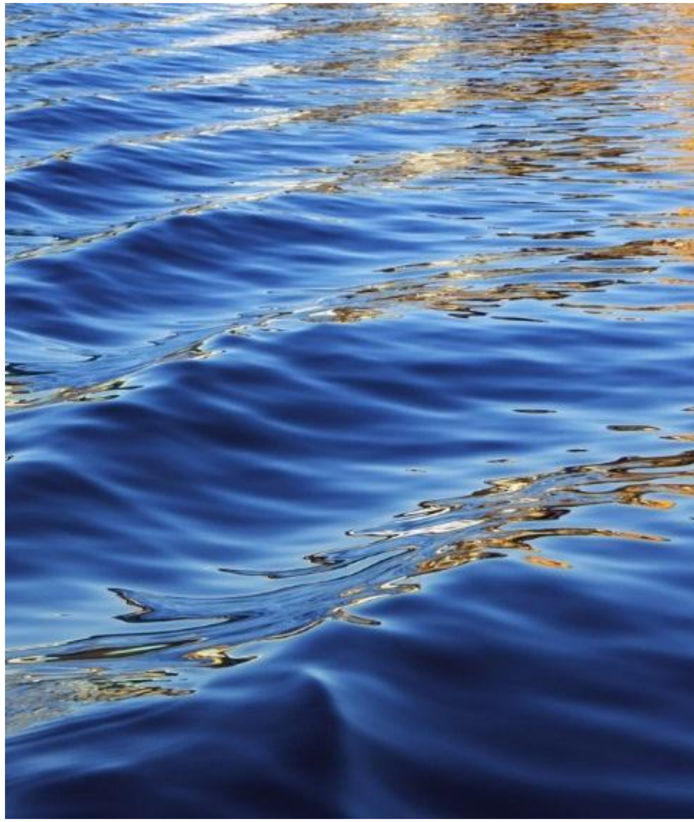

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SEDIMENTATION

- Typical sedimentation tanks used in water treatment are listed in Table 10-1 .

TABLE 10-1
Alternative settling tank configurations

Nomenclature	Configuration or comment
Horizontal flow	Long rectangular tanks
Center feed	Circular, horizontal flow
Peripheral feed	Circular, horizontal flow
Upflow clarifiers	Proprietary
Upflow, solids contact	Recirculation of sludge with sludge blanket, proprietary
High-rate settler modules	Rectangular tank, parallel plates or tubes, proprietary
Ballasted sand	Addition of microsand, proprietary

Adapted from Kawamura, 2000.

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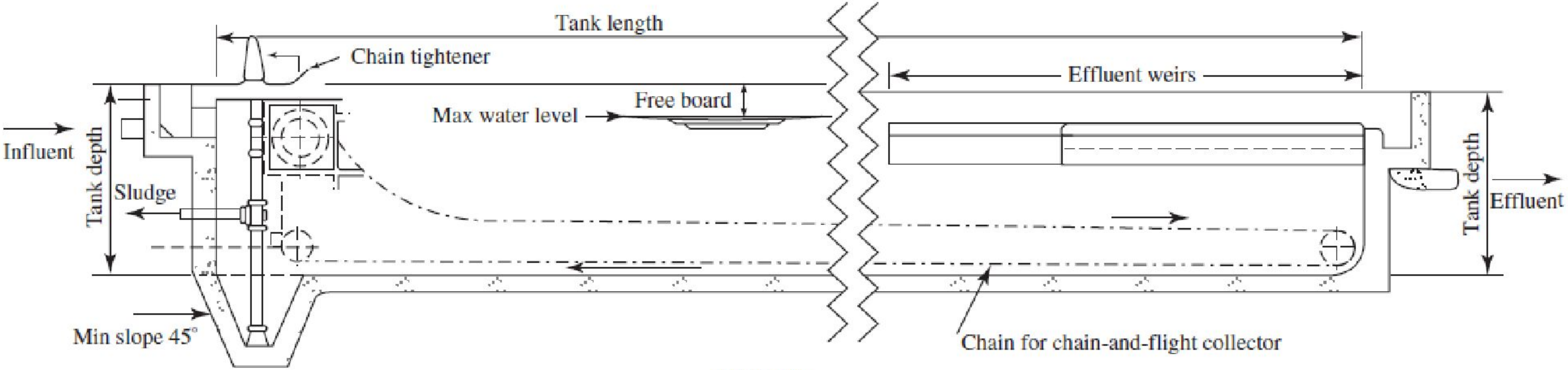
- preference for settling coagulation/flocculation floc is
- (1) a rectangular tank containing high-rate settler modules,
- (2) a long rectangular tank, and
- (3) a high-speed microsand clarifier

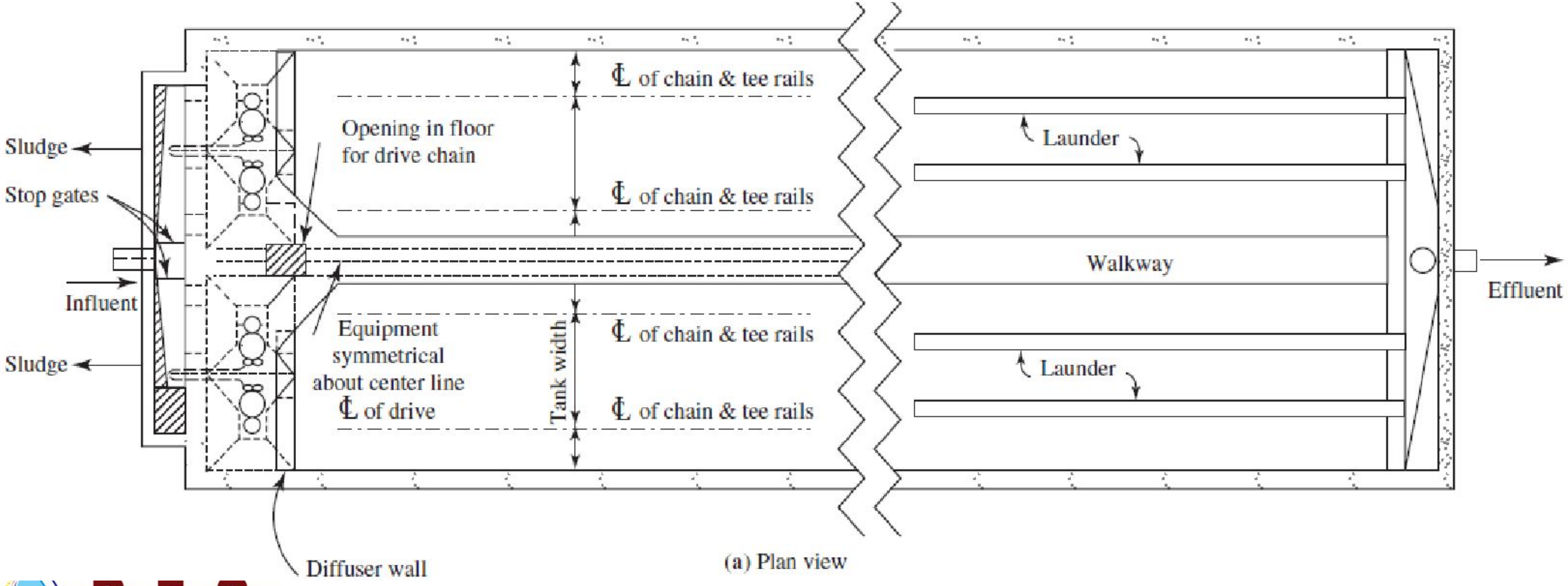
rectangular sedimentation basin

- Current design practice is shifting from rectangular sedimentation basins to high-rate settler modules or, in some cases, dissolved air flotation (DAF).
- The rectangular sedimentation basin been the most frequently design



(b) Profile

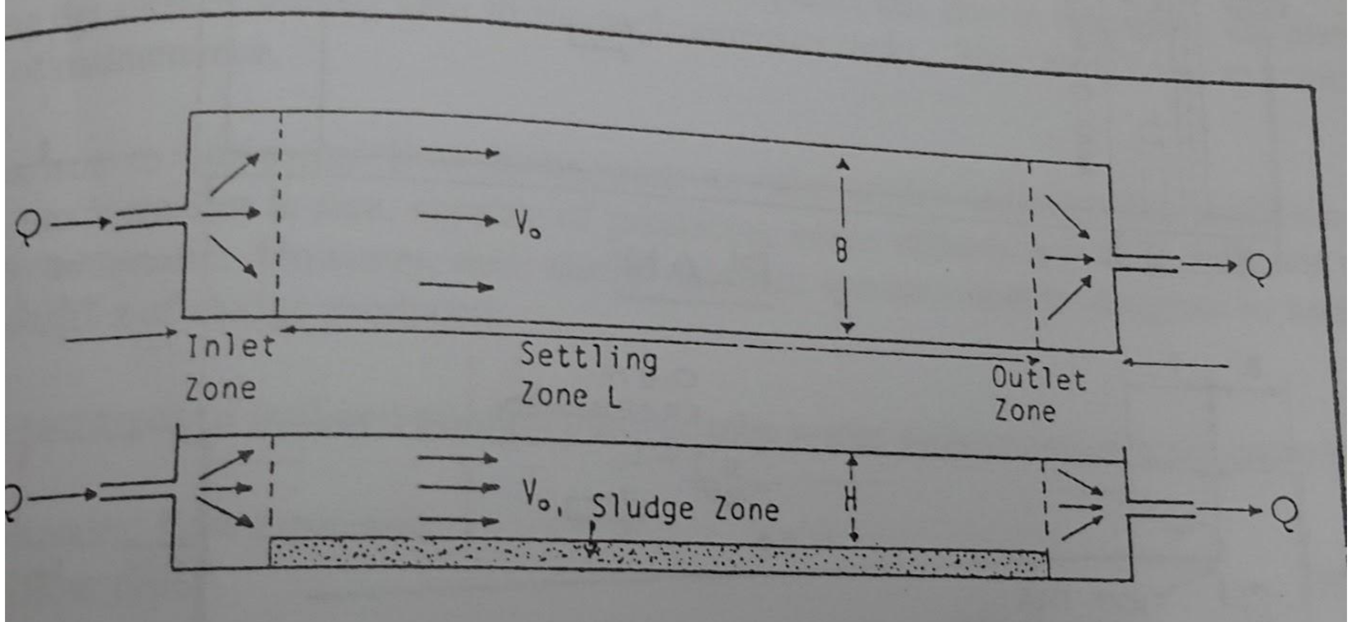
- To provide redundancy, two basins are placed longitudinally with a common wall.



(a) Plan view

SEDIMENTATION BASIN DESIGN-RECTANGULAR BASIN

- 4 zone must be present
- 1. inlet zone
- 2. settling zone
- 3. sludge zone
- 4. outlet zone



(a) Rectangular Horizontal Flow Settling Tank

INLET ZONE

- preferred arrangement is a direct connection between the flocculation basin and the settling tank.
- Disperse influent flow and suspended matter uniformly over the cross section of the basin
- When the flocculated water must be piped to the settling tank, the flow velocity commonly used is in the range of 0.15 to 0.6 m/s.
- This velocity must be reduced and the flow spread evenly over the cross section of the settling tank.
- A diffuser wall is the most effective way to accomplish this.

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SETTLING ZONE

- Overflow rate is the primary design parameter for sizing the sedimentation basin

TABLE 10-2
Typical sedimentation tank overflow rates[a]

Application	Long rectangular and circular, $m^3/d \cdot m^2$	Upflow solids-contact, $m^3/d \cdot m^2$
Alum or iron coagulation		
Turbidity removal	40	50
Color removal	30	35
High algae	20	
Lime softening		
Low magnesium	70	130
High magnesium	57	105

[a]These rates are guides that are applicable at moderate water temperatures—not less than 10°C. For lower temperatures the rates should be reduced.

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- These rates are usually conservative enough that the inlet zone does not have to be added to the length calculated for the settling zone
- In theory the sedimentation basin depth [also called *side water depth* (SWD)] should not be a design parameter because removal efficiency is based on overflow rate.
- However, there is a practical minimum depth required for sludge removal equipment
- Open sedimentation tanks greater than 30 m in length are especially susceptible to wind effects
- For longer tanks, wave breakers (launders or baffles) placed at 30 m intervals are recommended

- The tank depth is usually increased by about 0.6 m to provide *freeboard* to act as a wind barrier.
- Horizontal flow velocities must be controlled to avoid undue turbulence, back mixing, and scour of particles from the sludge.
- Reynolds and Froude numbers can be used to check on turbulence and back mixing.

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The Reynolds number is determined as:

$$\mathbf{R} = \frac{v_f R_h}{\nu}$$

where $\mathbf{R}$ = Reynolds number, dimensionless
v_f = average horizontal fluid velocity in tank, m/s
R_h = hydraulic radius, m
= A_s/P_w
A_s = cross sectional area, m^2
P_w = wetted perimeter, m
ν = kinematic viscosity, $m^2/s = \mu/\rho$
μ = dynamic viscosity, $Pa \cdot s$
ρ = density of fluid, kg/m^3

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The Froude number is determined as:

$$\mathbf{Fr} = \frac{(v_f)^2}{g\ R_h}$$

where $\mathbf{Fr}$ = Froude number, dimensionless
g = acceleration due to gravity, 9.81 m/s^2

- Recommended values for the settling zone design are **R** < 20,000 and **Fr** > 10^{-5}
- large Reynolds number indicates a high degree of turbulence
- A low Froude number indicates that water flow is not dominated by horizontal flow, and back mixing may occur.

OUTLET ZONE

- The outlet zone is composed of launders running parallel to the length of the tank
- The weirs should cover at least one-third, and preferably up to one-half, the basin length
- The water level in the tank is controlled by the end wall or overflow weirs.

SLUDGE ZONE

- In selecting the depth of the sedimentation tank, an allowance of between 0.6 and 1 m is made for sludge accumulation and sludge removal equipment.
- To facilitate sludge removal, the bottom of the tank is sloped toward a sludge hopper at the head end of the tank
- When mechanical equipment is used, the slope should be at least 1:600

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- Typical design criteria for horizontal-flow rectangular sedimentation basins in larger water treatment plants (40,000 m^3 /d) are summarized in Table 10-4 .
- Some design criteria are quite rigid while others only provide guidance.

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TABLE 10-4
Typical design criteria for horizontal-flow rectangular sedimentation basins

Parameter	Typical range of values	Comment
Inlet zone		
Distance to diffuser wall	2 m	
Diffuser hole diameter	0.10–0.20 m	
Settling zone		
Overflow rate	40–70 $m^3/d \cdot m^2$	See Table 10-2
Side water depth (SWD)	3–5 m	
Length	30 m	Wind constraint
	60 m	Chain-and-flight
	≥80–90 m	Traveling bridge
Width	0.3 m increments	Chain-and-flight
	6 m maximum per train	Chain-and-flight
	24 m maximum = 3 trains per drive	Chain-and-flight
	30 m maximum	Traveling bridge
L:W	4:1 to 6:1	≥6:1 preferred
L:D	15:1	Minimum
Velocity	0.005–0.018 m/s	Horizontal, mean
Reynolds number	< 20,000	
Froude number	$> 10^{-5}$	
Outlet zone		
Launder length	1/3–1/2 length of basin	Evenly spaced
Launder weir loading	140–320 $m^3/d \cdot m$	See Table 10-3
Sludge zone		
Depth	0.6–1 m	Equipment dependent
Slope	1:600	Mechanical cleaning
Sludge collector speed	0.3–0.9 m/min	

Sources: AWWA, 1990; Davis and Cornwell, 2008; Kawamura, 2000; MWH, 2005; Willis, 2005.

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EXAMPLE

- Design the settling tank(s) for the city of Stillwater's water treatment plant expansion using the design overflow rate found in Example 10-3 . The maximum day design flow is 0.5 m 3 /s. Assume a water temperature of 10 C.

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Solution:

a. Find the surface area.

First change the flow rate to compatible units:

$$(0.5 \text{ m}^3/\text{s})(86{,}400 \text{ s/d}) = 43{,}200 \text{ m}^3/\text{d}$$

Using the overflow rate from Example 10-3, the surface area is

$$A_s = \frac{43{,}200 \text{ m}^3/\text{d}}{32.5 \text{ m}^3/\text{d} \cdot \text{m}^2} = 1{,}329.233 \text{ or } 1{,}330 \text{ m}^2$$

b. Select the number of tanks.

Two tanks is the minimum number. For this flow rate make trial calculations using six tanks.

$$\frac{1{,}330\ \text{m}^2}{6\ \text{tanks}} = 221.66 \text{ or } 222\ \text{m}^2/\text{tank}$$

c. Select a trial width for calculation.

The maximum width for the chain-and-flight sludge collector is 6 m increments. Assume a width of 4 m.

d. Check length-to-width ratio.

$$L = \frac{222\ \text{m}^2/\text{tank}}{4\ \text{m/tank}} = 55.5\ \text{m}$$

$$L/W = \frac{55.5\ \text{m}}{4\ \text{m}} = 13.8 \text{ or } 13.8{:}1$$

This is larger than the ratio of 6:1 and is acceptable.

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e. Select a trial depth.

Because the column depth used to calculate the overflow rate was 2 m, this is a starting point for setting the design depth. An allowance for the sludge depth of 1 m is added to this depth. In addition the tank should be provided with 0.6 m of freeboard. The total depth of the tank is then

$$2 \text{ m} + 1 \text{ m} + 0.6 \text{ m} = 3.6 \text{ m}$$

Side water depth (SWD) = 3.0 m.

If the sludge zone is not counted, the depth of the water is less than the design recommendation of 3 m.

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f. Check the length-to-depth ratios.

$$L/D = \frac{55.5\ \text{m}}{2\ \text{m}} = 27.75 \text{ or } 28:1$$

The L:D ratio is acceptable.

g. Check the velocity and then check the Reynolds and Froude numbers.

$$v_f = \frac{Q}{A} = \frac{0.5\ \text{m}^3/\text{s}}{(6\ \text{tanks})(2\ \text{m depth})(4\ \text{m width})}$$
$$= 0.0104\ \text{m/s}$$

This is within the acceptable range of 0.005 − 0.018 m/s.

$$R_h = \frac{A_x}{P_w} = \frac{(2\ \text{m deep})(4\ \text{m wide})}{2\ \text{m} + 4\text{m} + 2\text{m}} = 1.0\ \text{m}$$

From Appendix A at a temperature of 10°C, the viscosity is $1.307 \times 10^{-6}\ \text{m}^2/\text{s}$ and the Reynolds number is

$$\mathbf{R} = \frac{(0.0104\ \text{m/s})(1.0\ \text{m})}{1.307 \times 10^{-6}\ \text{m}^2/\text{s}} = 7{,}957.15 \text{ or } 8{,}000$$

This is less than 20,000 and is acceptable.

$$\mathbf{Fr} = \frac{(0.0104\ \text{m})^2}{(9.81\ \text{m/s}^2)(1.0\ \text{m})} = 1.1 \times 10^{-5}$$

This is greater than 10^{-5} and is acceptable.

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h. Design the launders.

Provide launders for 1/3 of the tank length

$$L_{\text{Launder}} = \frac{55.5 \text{ m}}{3} = 18.5 \text{ m}$$

Place them at 1 m intervals on center so that there are three in the tank.

i. Check the weir loading rate.

$$WL = \frac{43{,}200 \text{ m}^3/\text{d}}{(6 \text{ tanks})(3 \text{ launders/tank})(18.5 \text{ m/launder})(2 \text{ sides})} = 64.86 \text{ or } 65 \text{ m}^3/\text{d} \cdot \text{m}$$

This is well below the limit of 250 $m^3/d \cdot m$ and is acceptable.

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Summary:

Q_{design} = 43,200 m^3/d = 0.5 m^3/s
Number of tanks = 6
Width of each tank = 4 m
Length of each tank = 55.5 m
L:W = 13.8:1
Depth including sludge = 3.6 m
L:D = 28:1 without sludge depth; 18.5:1 with sludge depth
v_f = 0.0104 m/s
Reynolds number = 8,000
Froude number = 1.1×10^{-5}
Launders = 3 spaced evenly
Launder length = 18.5 m
Weir loading = 65 $m^3/d \cdot m$
Sludge collector = chain-and-flight

The suggested design criteria in Table 10-5 may be used for flow rates less than 40,000 m^3 /d.

TABLE 10-5
Typical design criteria for small to medium horizontal-flow rectangular sedimentation basins

Parameter	Typical range of values	Comment
Number of tanks	1 + 1 spare	< 10,000 m^3/d
	≥2	≥20,000 m^3/d
Inlet zone		
Distance to diffuser wall	4% of length	up to 2 m
Diffuser hole diameter	0.10–0.20 m	
Settling zone		
Overflow rate	20 $m^3/d \cdot m^2$	< 10,000 m^3/d
	40 $m^3/d \cdot m^2$	>10,000 m^3/d
Side water depth (SWD)	3–5 m	
Length	30 m	Wind constraint
	60 m	Chain-and-flight
Width	0.3 m increments	Chain-and-flight
	6 m maximum per train	Chain-and-flight
L:W	minimum of 4:1	≥6:1 preferred
L:D	15:1	Minimum
Velocity	0.005–0.018 m/s	Horizontal, mean
Reynolds number	< 20,000	
Outlet zone		
Launder length	1/3–1/2 length of basin	Evenly spaced
Launder weir loading	≤ 250 $m^3/d \cdot m$ of launder	
Sludge zone		
Depth	0.6–1 m	Equipment dependent
Slope	1:600	Mechanical cleaning
Sludge collector speed	0.3–0.9 m/min	

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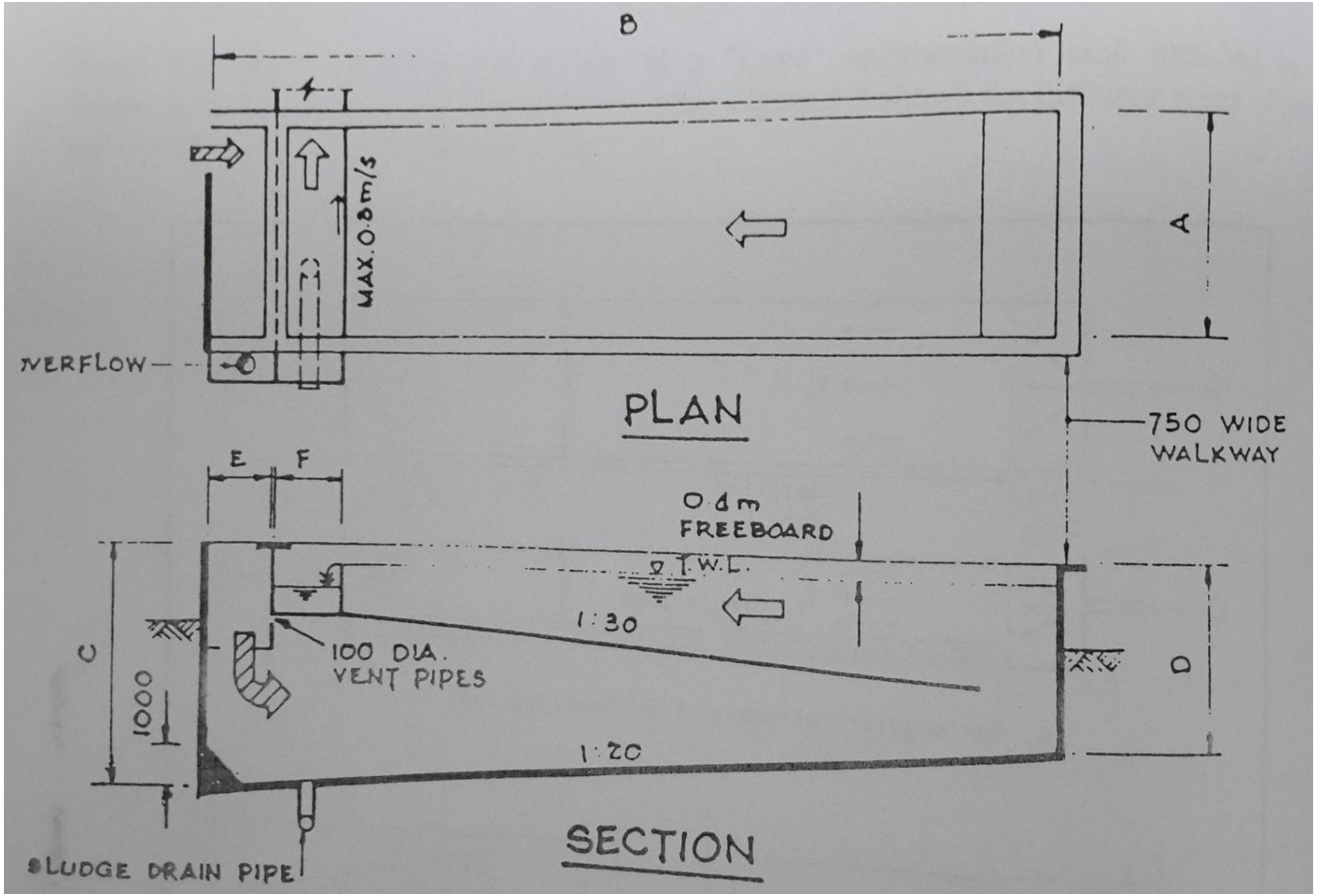
"LOVO TANK"

- Modification of rectangular horizontal flow sedimentation tank
- Incorporating an intermediate slanting slab spanning the whole width of the tank
- Thus dividing it into a top and a bottom compartment.



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Design criteria for "LOVO" sedimentation tank

- Surface loading @ overflow rate should not exceed 1.5 $m^3/m^2/hr$
- Detention time must not be less than 2 hrs
- L:W is between 2:1 and 4:1
- Depth between 3 to 5 m
- A certain quantity of sludge acculumation (10 to 15 % of tank capacity) should be allowed for in computing the capacity of the tank.
- Inlet velocity should be in the region of 0.1 m/sec and outlet weir loading should be about $8m^3/hr/m$

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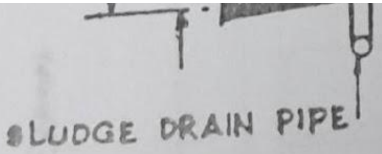

SECTION

ALL DIMENSIONS ARE INTERNAL

TYPE	FLOW m^3/h	A	B	C	D	E	F	GROSS VOLUME m^3	NET VOLUME m^3	RETENTION h	GROSS AREA	RISE RATE m/h
1	0 - 50	3200	12,800	3700	3060	450	500	112	102	2.04	41	1.22
2	51 - 70	3900	15,600	3580	2800	450	600	156	142	2.03	61	1.15
3	71 - 90	4500	18,000	3610	2710	450	600	202	184	2.04	81	1.11
4	91 - 110	5000	20,000	3650	2650	800	700	249	227	2.06	100	1.10
5	111 - 130	5300	21,200	3800	2740	800	700	293	267	2.05	112	1.16
6	131 - 150	5500	22,000	4020	2920	800	800	340	310	2.07	121	1.24
7	151 - 200	6000	24,000	4380	3180	800	900	449	409	2.05	144	1.39
8	201 - 250	6500	26,000	4640	3340	800	1000	562	512	2.05	169	1.48
9	251 - 300	7100	28,400	4710	3290	800	1100	672	612	2.04	202	1.49
10	301 - 350	7700	31,000	4850	3300	800	1200	814	744	2.13	239	1.47
11	351 - 400	8200	32,800	5020	3380	1250	1200	952	872	2.18	269	1.49
12	401 - 450	8800	35,200	5250	3490	1250	1300	1149	1059	2.35	310	1.45
13	451 - 500	9100	36,400	5400	3580	1250	1400	1266	1166	2.33	331	1.51
14	501 - 550	9600	38,400	5600	3600	1250	1500	1464	1354	2.46	369	1.49
15	551 - 600	10,000	40,000	3770	3770	1250	1500	1642	1522	2.54	400	1.50

DESIGN CRITERIA			
	B : A	=	4.1 NOMINAL
	NET VOLUME	=	GROSS VOLUME - 10% SLUDGE ALLOWANCE
	RETENTION	=	NET VOLUME / FLOW = MIN. 2 h
	RISE RATE	=	MAX. 1.5 m/h
	WATER VELOCITY IN TANK	=	MAS. 0.02 m/s
	TANK DRAIN DOWN TIME	=	MAX. 1h
	SLUDGE ALLOWANCE	=	12 MIN. RETENTION AT MAX. FLOW.

TABLE 9.2 - 'LOVO' SEDIMENTATION TANKS