Islamic University of Gaza -Environmental Engineering Department

Water Treatment

EENV 4331

Lecture 4: Sedimentation

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4. Sedimentation in water Treatment

4.1 Definition of Sedimentation:

It is the process of removing solid particles heavier than water by gravity force.

- **Particles that will settle within a reasonable period of time can be removed using a sedimentation tank (also called clarifiers).**

- **Sedimentation is used in water treatment at the locations indicated in Figures 1 through 4.**

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4.2 Applications of sedimentation in water treatment:

1. Plain settling (or pre-sedimentation) of river surface water .
2. In filtration treatment plants treating surface water to removes flocculated solids. The sedimentation tank comes after the flocculation tank.
3. In Softening treatment plants treating hard water to removes flocculated solids. The sedimentation tank comes after the flocculation tank.
4. In aeration treatment plant removing iron and manganese from ground water

4. Sedimentation in water Treatment

4.3 Geometry of sedimentation tanks:

- Sedimentation tanks are either rectangular or circular tanks.
- Figures 5 to 10 show typical sedimentation tanks used in water treatment.

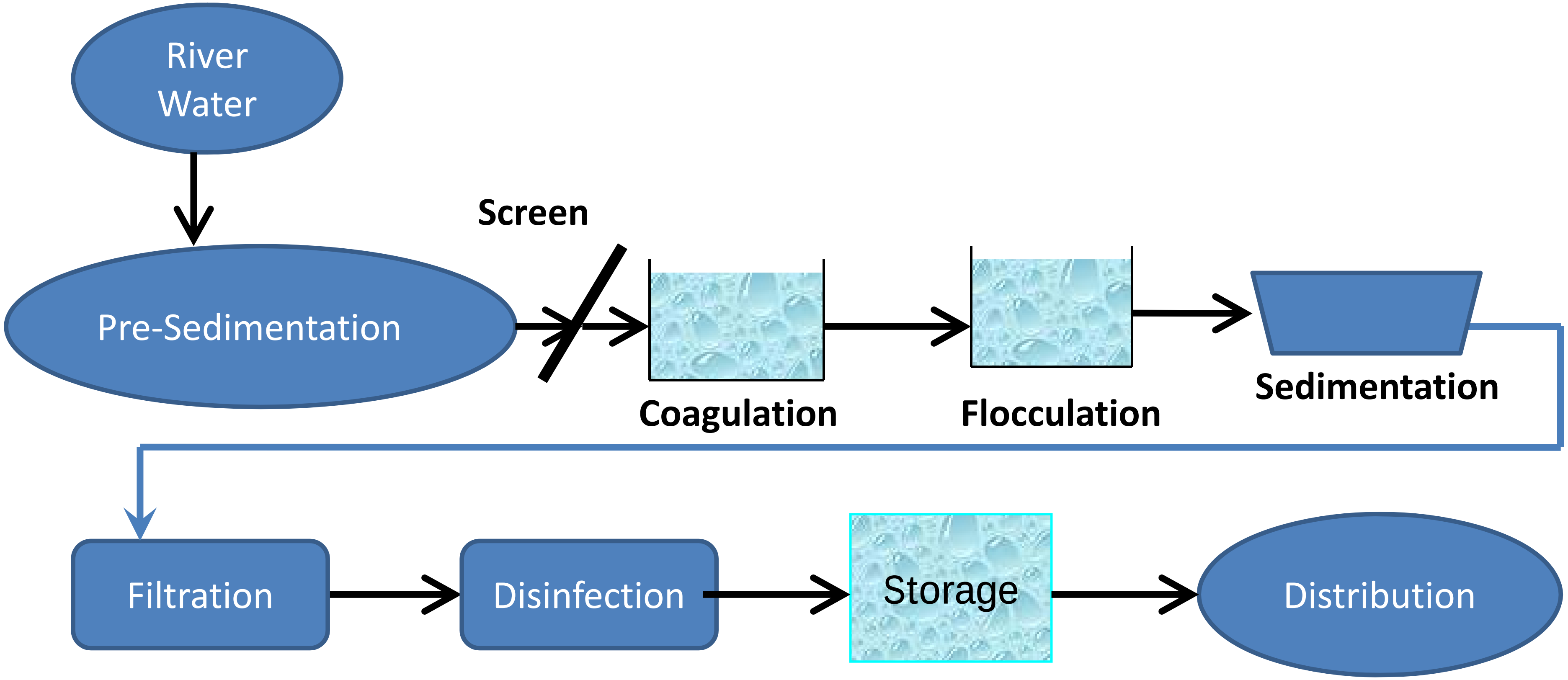

Figure 1: Filtration Treatment Plant (River Water)

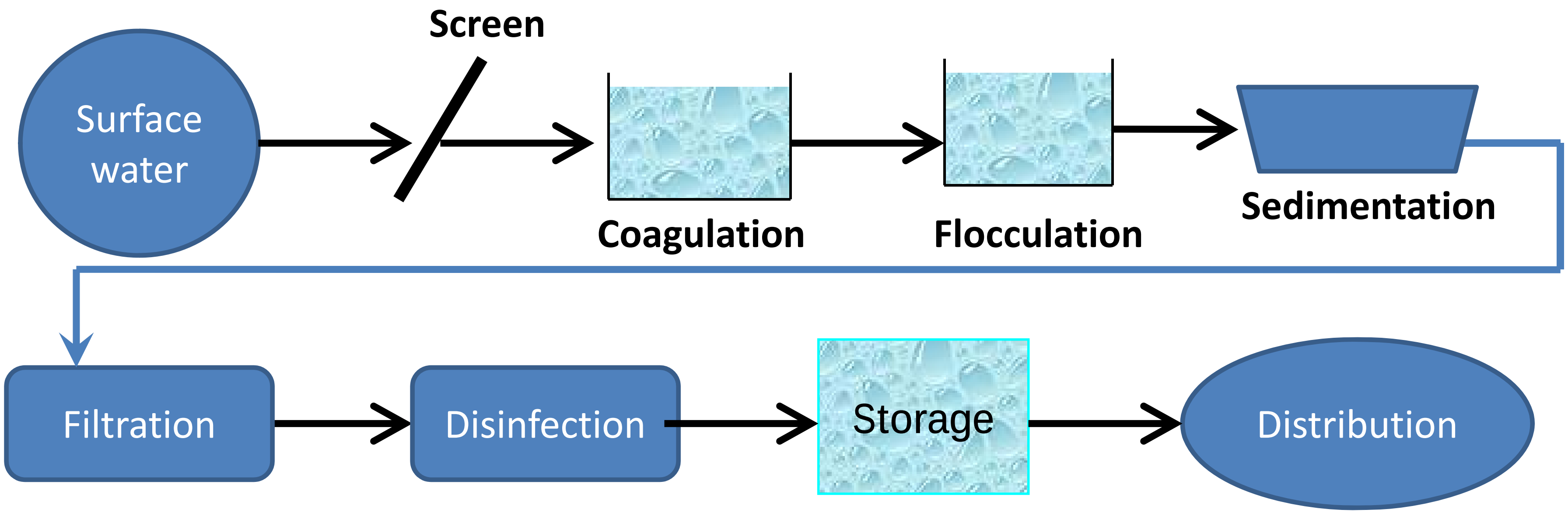

Figure 2 : Filtration Treatment Plant

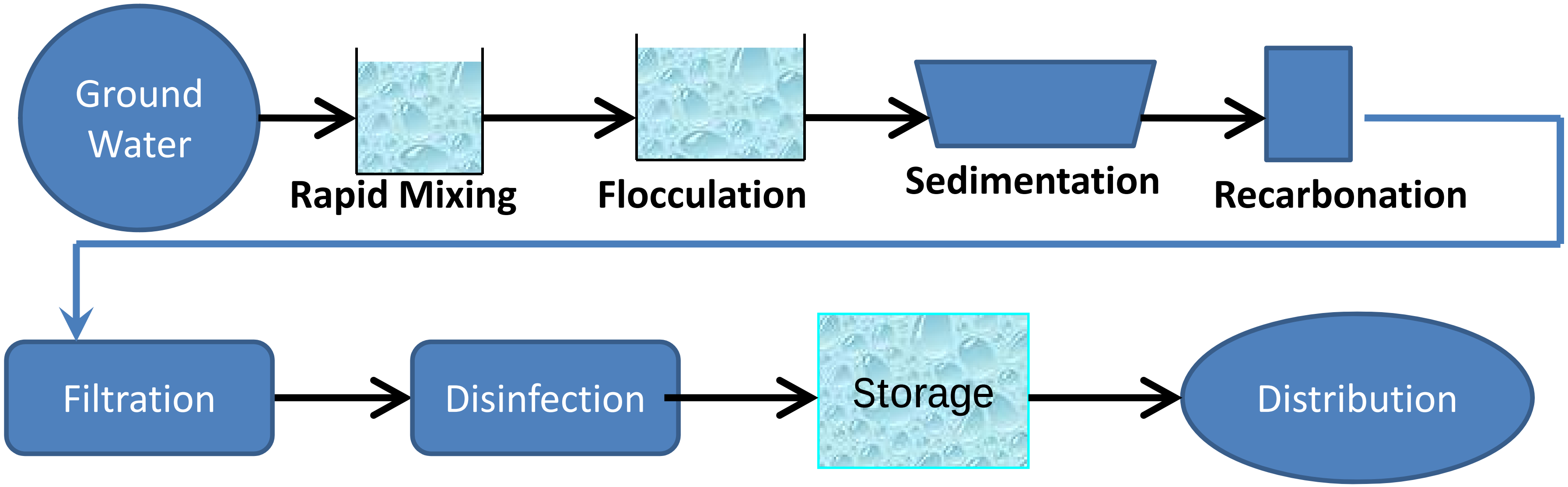

Figure 3: **Softening Treatment Plant Single stage softening**

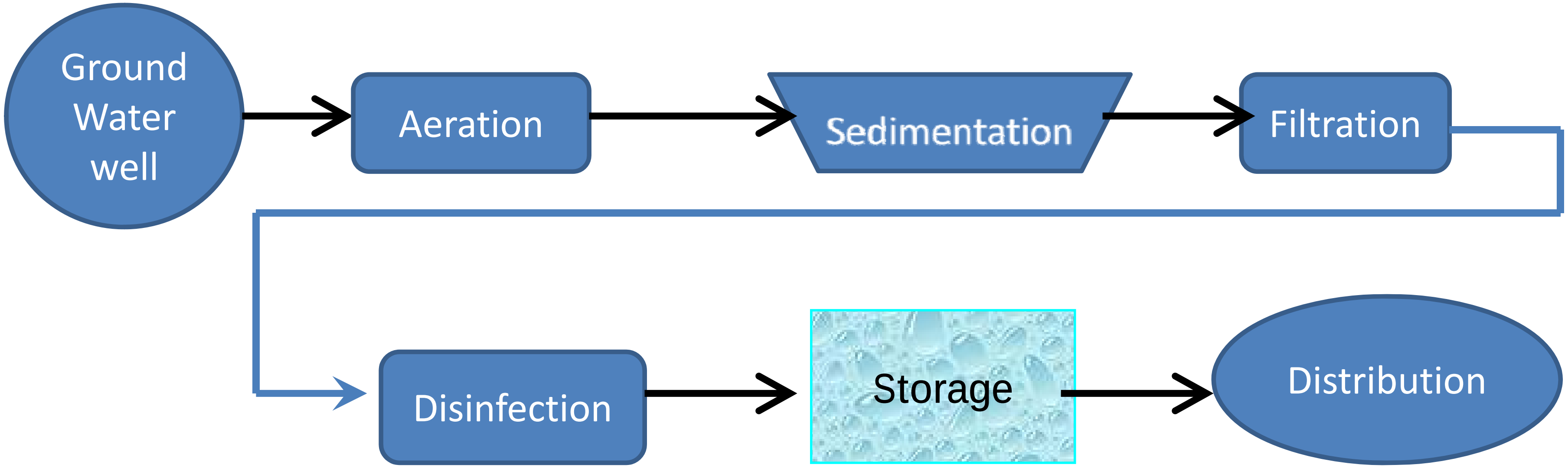

Figure 4 : Aeration Treatment Plant
(iron and manganese removal plant)

Figure 5 : Rectangular sedimentation Tank

Figure 6 : Rectangular sedimentation Tank

Figure 7 : Circular sedimentation Tank

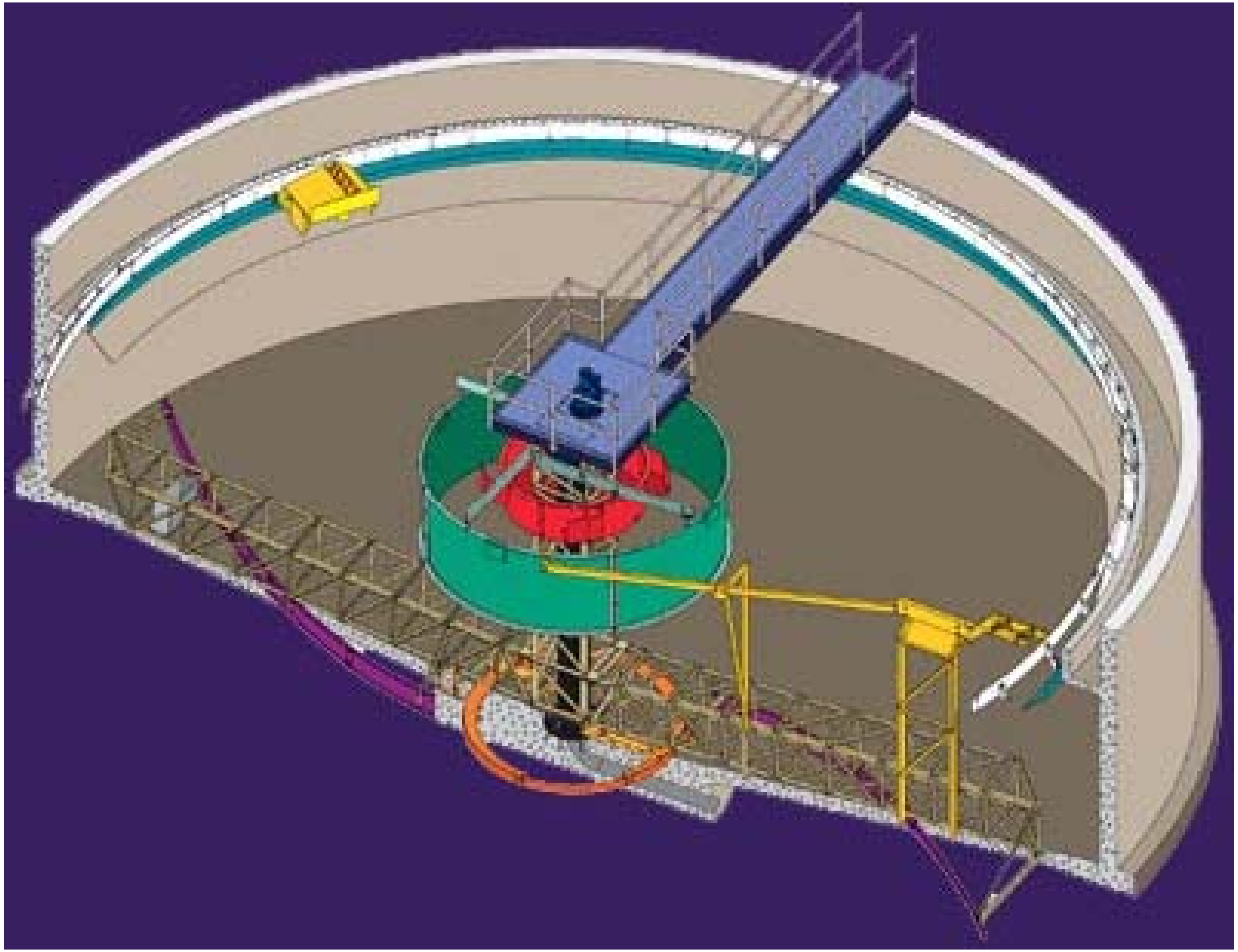

Figure 8 : Circular sedimentation Tank

Figure 9 : Circular sedimentation Tank
Solid contact type

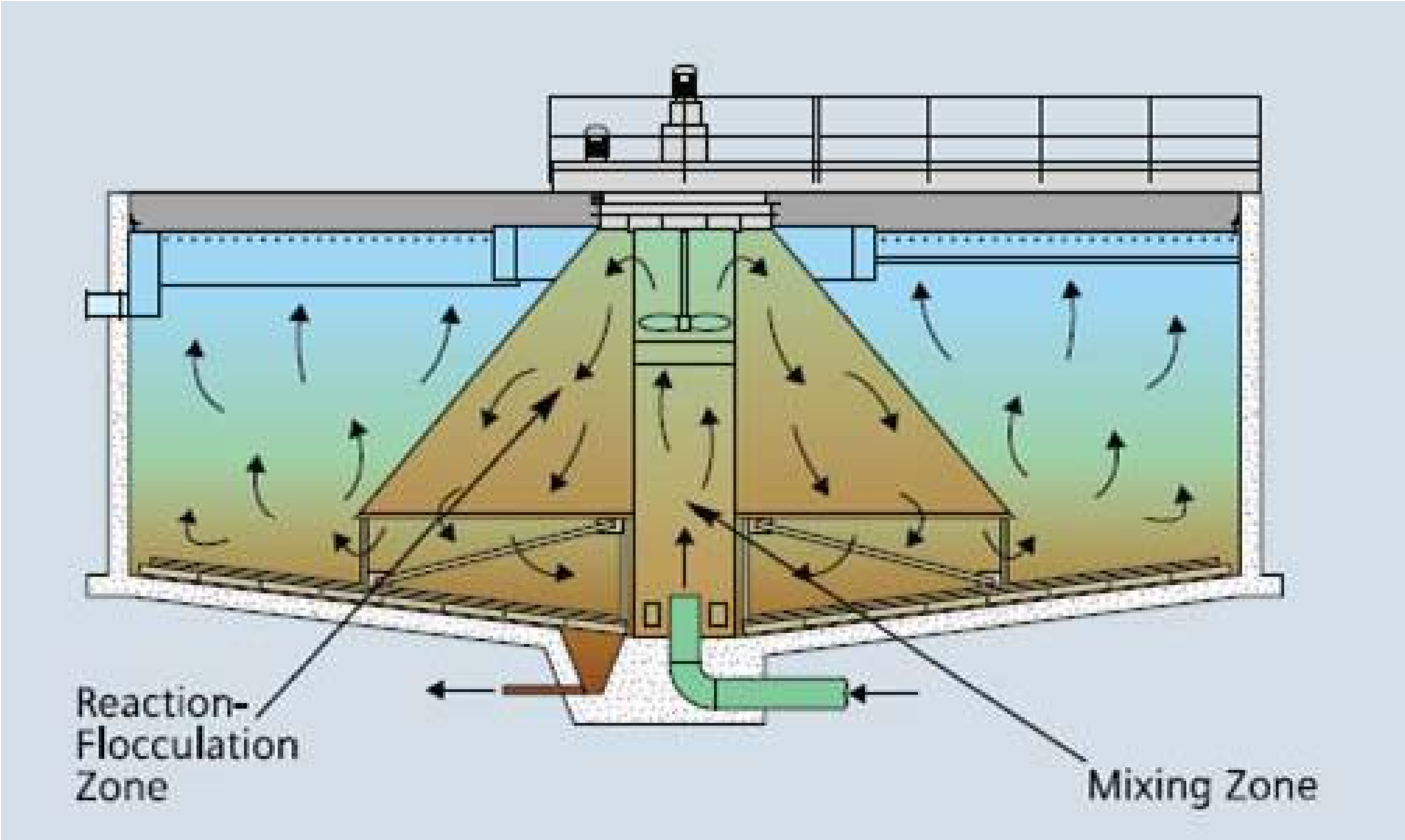

Figure 10 : Circular sedimentation Tank
Solid contact type

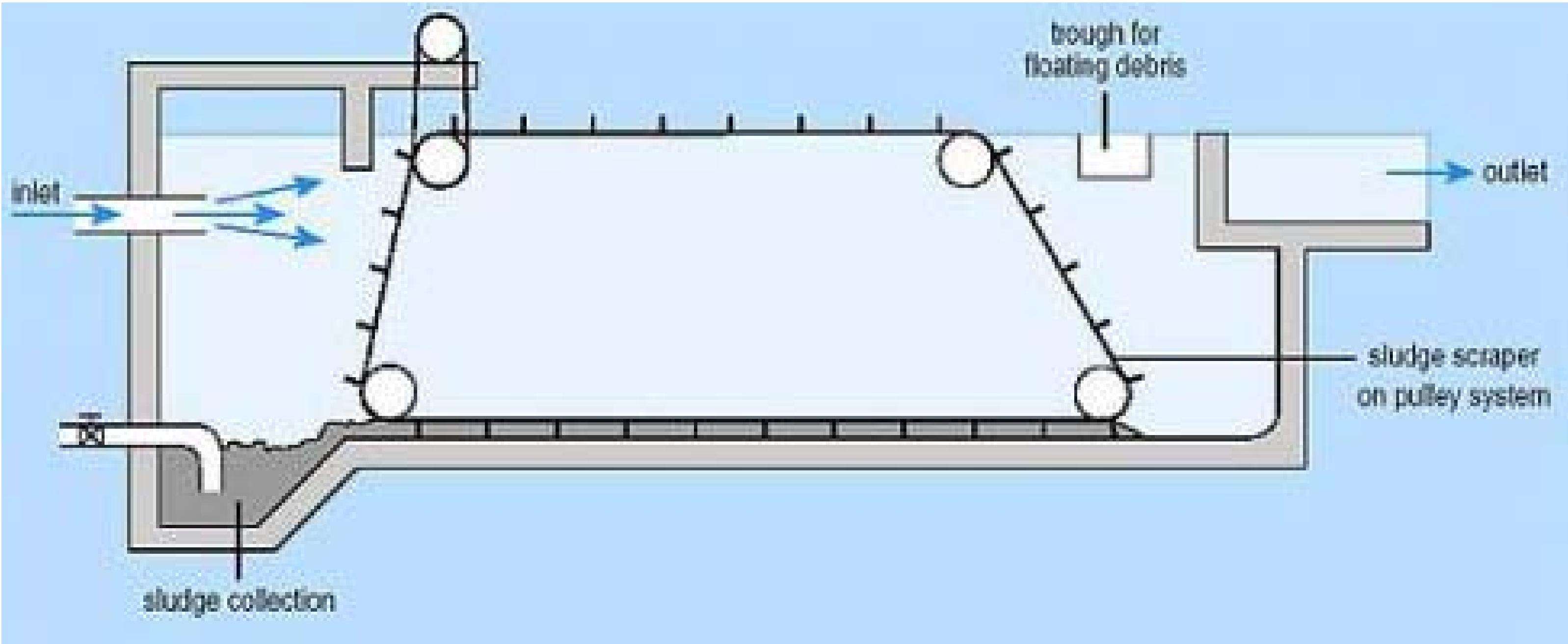

Figure 11 : Rectangular sedimentation Tank sludge collection system

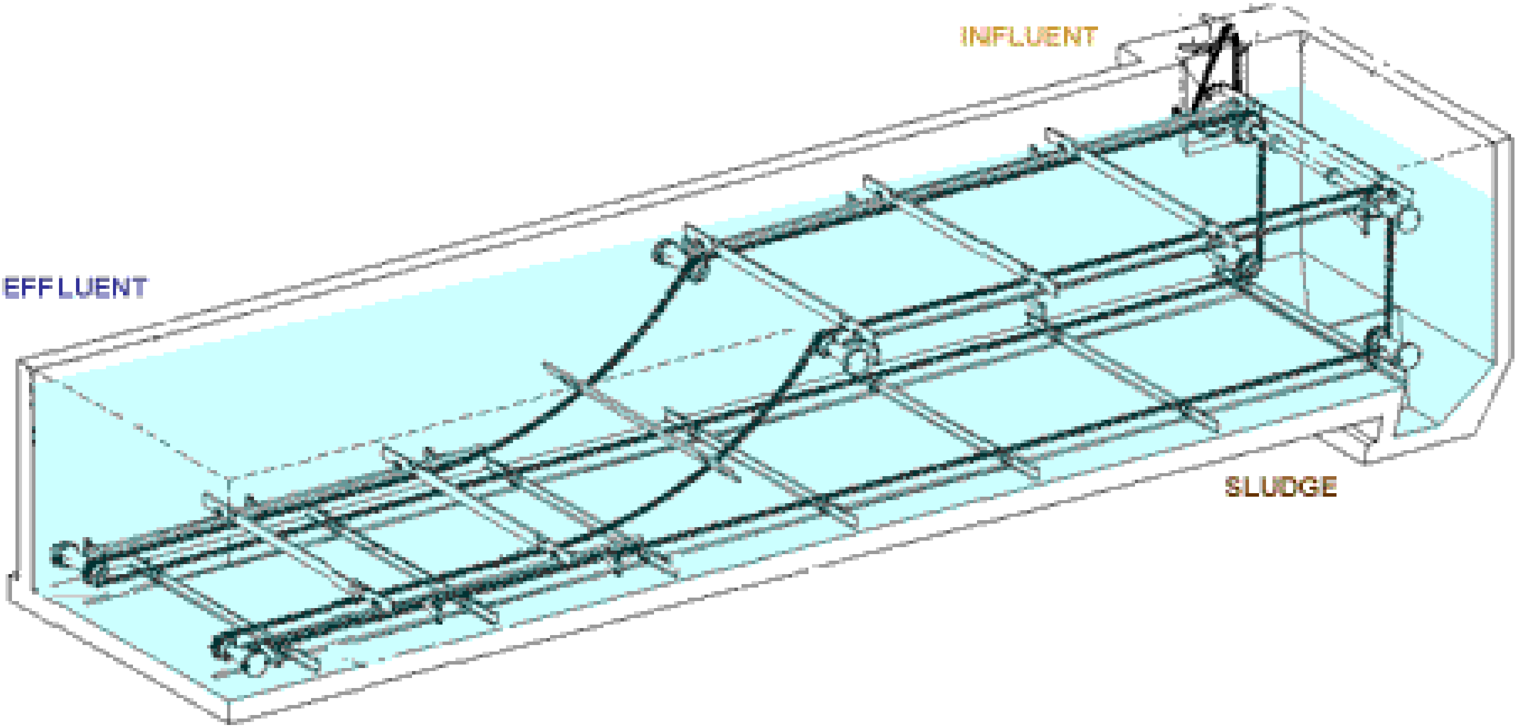

Figure 12 : Rectangular sedimentation Tank sludge collection system

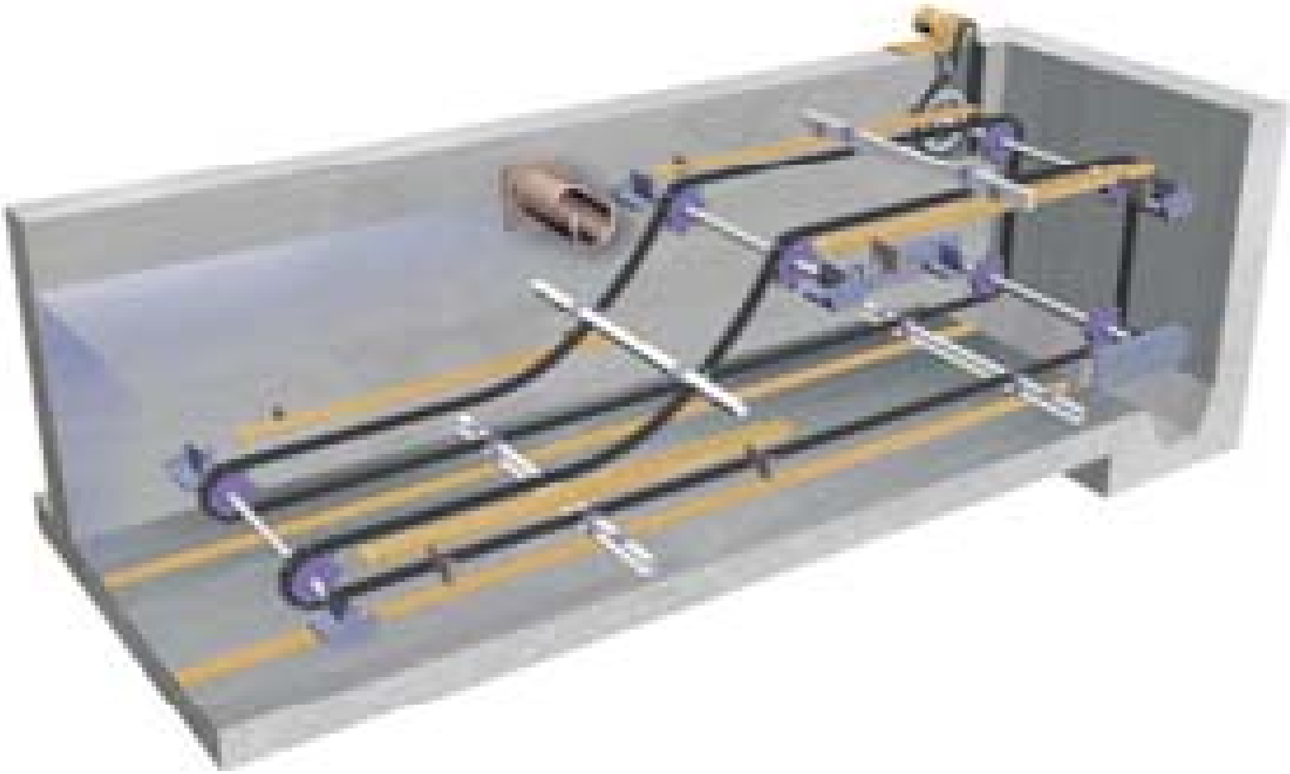

Figure 13 : Rectangular sedimentation Tank sludge collection system

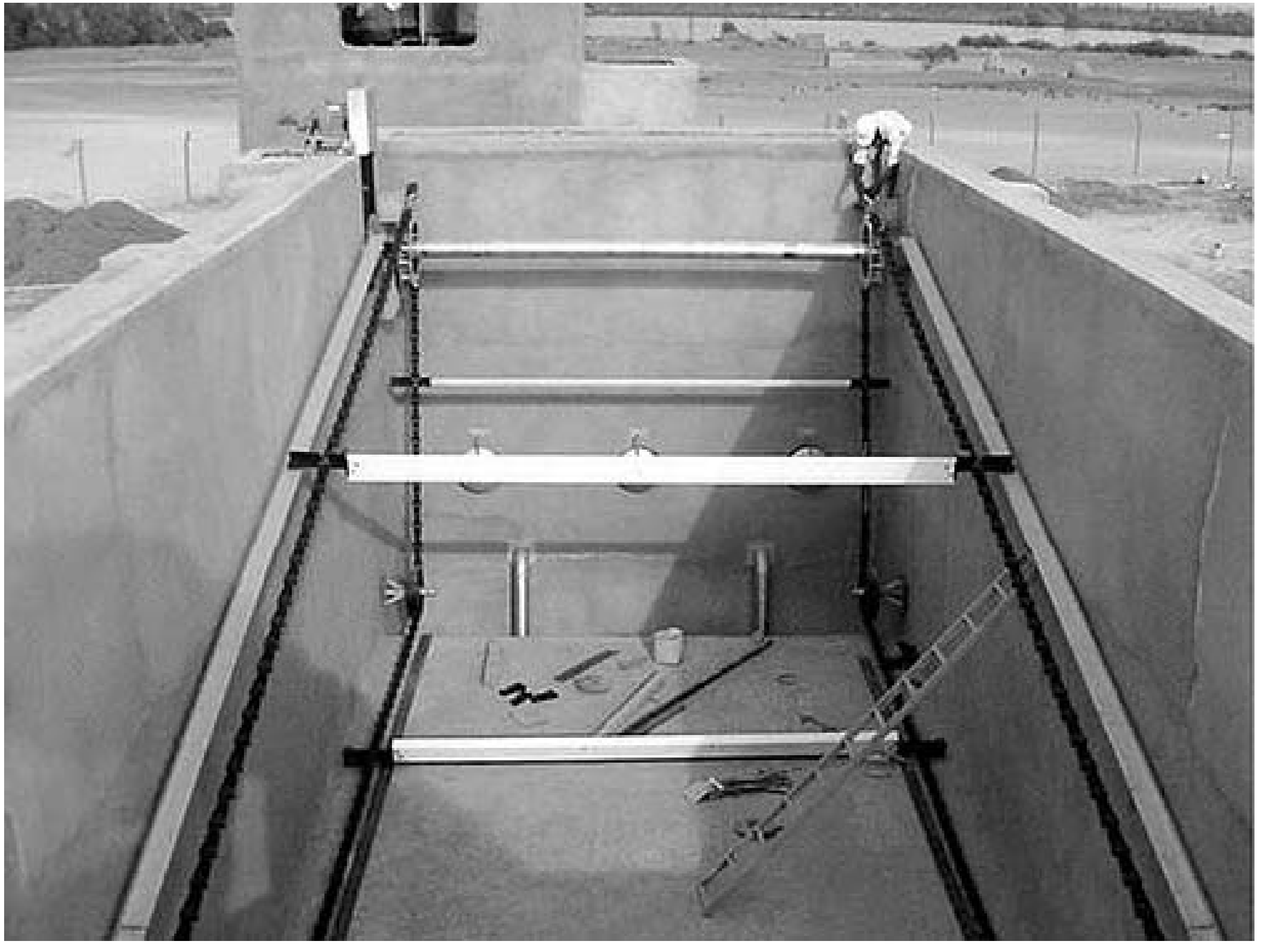

Figure 14 : Rectangular sedimentation Tank sludge collection system

4. Sedimentation in water Treatment

4.3 Theoretical background on Sedimentation

4.3.1 Type of particles :

1) Discrete / individual particle

   - Size, velocity constant during the settling

   - Density 2,000 – 2,200 kg/m^3

2) Flocculent particles

   - Size, velocity fluctuates during the settling

   - Particles flocculate and grow bigger in size

   - Density 1,030 – 1,070 kg/m^3

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4.3.2 Three classes of particles settling :

Type 1

i) Particles settle discretely at a constant velocity

ii) Settle as individual particles and do not flocculate.

iii) E.g. : Sand, grit material

iv) Occurs during :

    i) Pre-sedimentation for sand removal

    ii) Settling of sand during rapid sand filter cleaning

v) Concentration : very low

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Type 2

i) Flocculate during sedimentation

ii) Size constantly changing

iii) Settling velocity is changing

iv) Settling velocity increase with depth and extent of flocculation.

v) Occurs during :

    i) Alum or iron coagulation

vi) Concentration : low

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Type 3 or Zone

i) Settle as mass and form a layer – “blanket

ii) Concentration high (greater than 1000 mg/L)

iii) Distinct clear zone and sludge zone are present.

iv) Occurs during :

    i) Lime-softening sedimentation

    ii) Sludge thickeners in water treatment.

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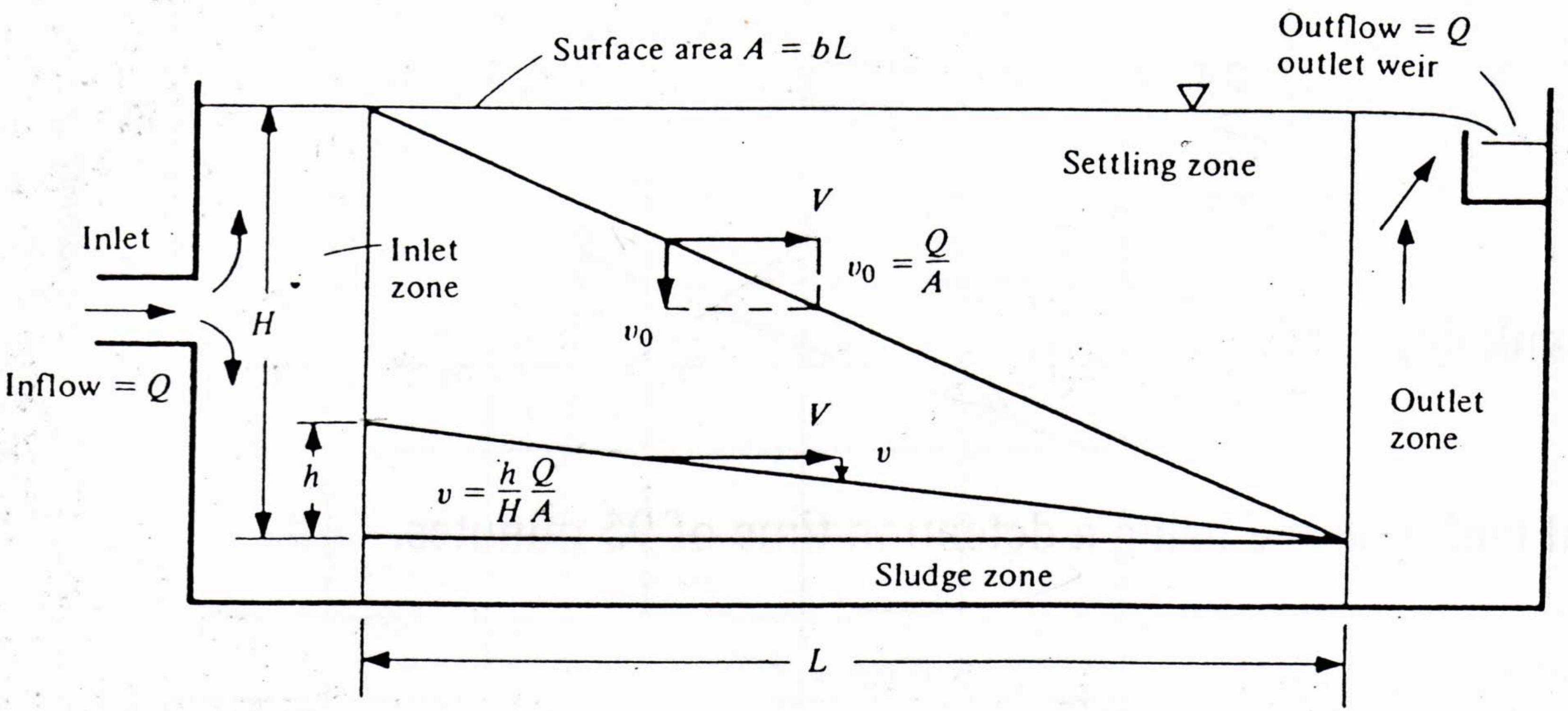
4.4 Sedimentation theory



An ideal rectangular sedimentation tank illustrating the settling of discrete particles.

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- Settling velocity (v_s) must be determined to assure good sedimentation tank design.
- Overflow rate (v_o) must be set at some value LESS THAN or EQUAL to V_s

$$v_s = \frac{H}{t}$$

$$v_s = \frac{H}{t} = \frac{H}{\left[\frac{V}{Q}\right]} = \frac{HQ}{l * W * H} = \frac{Q}{A_s}$$

But → $$v_0 = \frac{Q}{A_s}$$

So → $$v_0 = v_s$$

Where

Q = flow rate (m^3/h)

A_s = surface area (m^2)

H = depth of water, m

W = tank width, m

L = tank length, m

t = detention time, hr

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4.5 Design of Sedimentation tanks

4.5.1 Plain Sedimentation:

Particles settle separately:

$$\boxed{V_s = \sqrt{\frac{4g(\rho_s - \rho)d}{3C_D\rho}}}$$

V_s = settling velocity
D = particle diameter
ρ = water density
ρ_s = particle density
C_D = drag coefficients

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4.5.1 Plain Sedimentation:

Drag coefficient is calculated as:

$R_e < 1$, Laminar Flow →

$$C_D = \frac{24}{R}$$

$1 < R_e < 10^4$, Transitional Flow →

$$C_D = \frac{24}{R} + \frac{3}{\sqrt{R}} + 0.34$$

$R_e > 10^4$, Turbulent Flow →

$$C_D = 0.40$$

Where R = Reynolds number

$$R = \frac{\rho V_s D}{\mu}$$

μ = dyna ty , N.s/m^2

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4.5 Design of Sedimentation tanks

4.5.1 Plain Sedimentation:

At laminar flow, settling velocity equation is simplified to Stocks law:

$$\boxed{v_s = \frac{g(\rho_s - \rho)D^2}{18\mu}}$$

V_s = settling velocity
D = particle diameter
ρ = water density
ρ_s = particle density
C_D = drag coefficients

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Example 4.1 :

Find the settling velocity (v_s) for sand particles with a diameter of 0.020mm.
ρ = 2650 kg/m^3, μ= 1.002X10^{-3} N.s/m^2 at 20 ^{0}C,β = 0.05 , f=0.03. what is vs for particles with D = 0.5 mm?

Solution:

Assume first the flow is laminar and check for Reynolds number:

$$v_s = \frac{9.80(2650-1000)(0.02*10^{-3})^2}{18*1.002*10^{-3}} = 3.59X10^{-4}\,m/s$$

$$R = \frac{\rho V_s D}{\mu} = \frac{1000*3.58*10^{-4}*0.20*10^{-3}}{1.002*10^{-3}} = 0.00715$$

R<1 , so its laminar flow

For particles with D = 0.5mm:

$$v_s = \frac{9.81(2650-1000)(0.5*10^{-3})^2}{18*1.002*10^{-3}} = 0.22m/s$$

$$R = \frac{\rho V_s D}{\mu} = \frac{1000*0.22*0.50*10^{-3}}{1.002*10^{-3}} = 110$$

R>1 , so its transitional flow

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so

$$\boxed{C_D = \frac{24}{110} + \frac{3}{\sqrt{110}} + 0.34 = 0.84}$$

$$\boxed{v_s = \sqrt{\frac{4*9.81(2650-1000)0.5*10^{-3}}{3*110*1000}} = 0.11\, m/s}$$

Solve again for R_e : $\boxed{R_e = 55}$ R>1 , so its transitional flow O.K

Solve again fir C_D : $\boxed{C_D = 1.18}$

Solve again for v_s : $\boxed{v_s = 0.10 m/s}$

$$\boxed{Take \;\; v_0 = v_s = 3.59 * 10^{-4} \; m/s = 31 \; m/d = 31 \; m^3/m^2.d}$$

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4.5 Design tanks

4.5.1 Plain Sedimentation:

Example 4.2:

Design pre-sedimentation tanks to be used to remove grit and sand from a river water that is used to produce 20000 m^3/d drinking water .Use the overflow rate and horizontal velocities calculated in example 4.1. Use two tanks.

Solution:

$$\boxed{Take\ v_0 = v_s = 31\, m^3/m^2.d} \longrightarrow \boxed{v_0 = \frac{Q}{A_s} = \frac{Q}{w * l}}$$

*Flow/tank = (Q/2)= 20000/2 = 10000 m^3/dh

As = 10000/31 = 322.5 m^2

•Select Width to length ratio 1:4

•A = W* 4W = 322.5 m2 $\longrightarrow$ W= 8.98 m , L = 35.92 (take W= 9 m, L= 36 m)

•Assume detention time = 3 hrs

H = $t*V_0$ = (3*31)/24= 3.88 m ≈ 3.90 m

•V_h = Q/(W*H) = 10000/(24*60*9*3.9) = 0.198 m/min

•Take weir loading rate = 250 m^3/m.d:

$L_{weir} = Q/W_{load}$ = 10000/250 = 40 m , Use suspended troughs inside the tank.

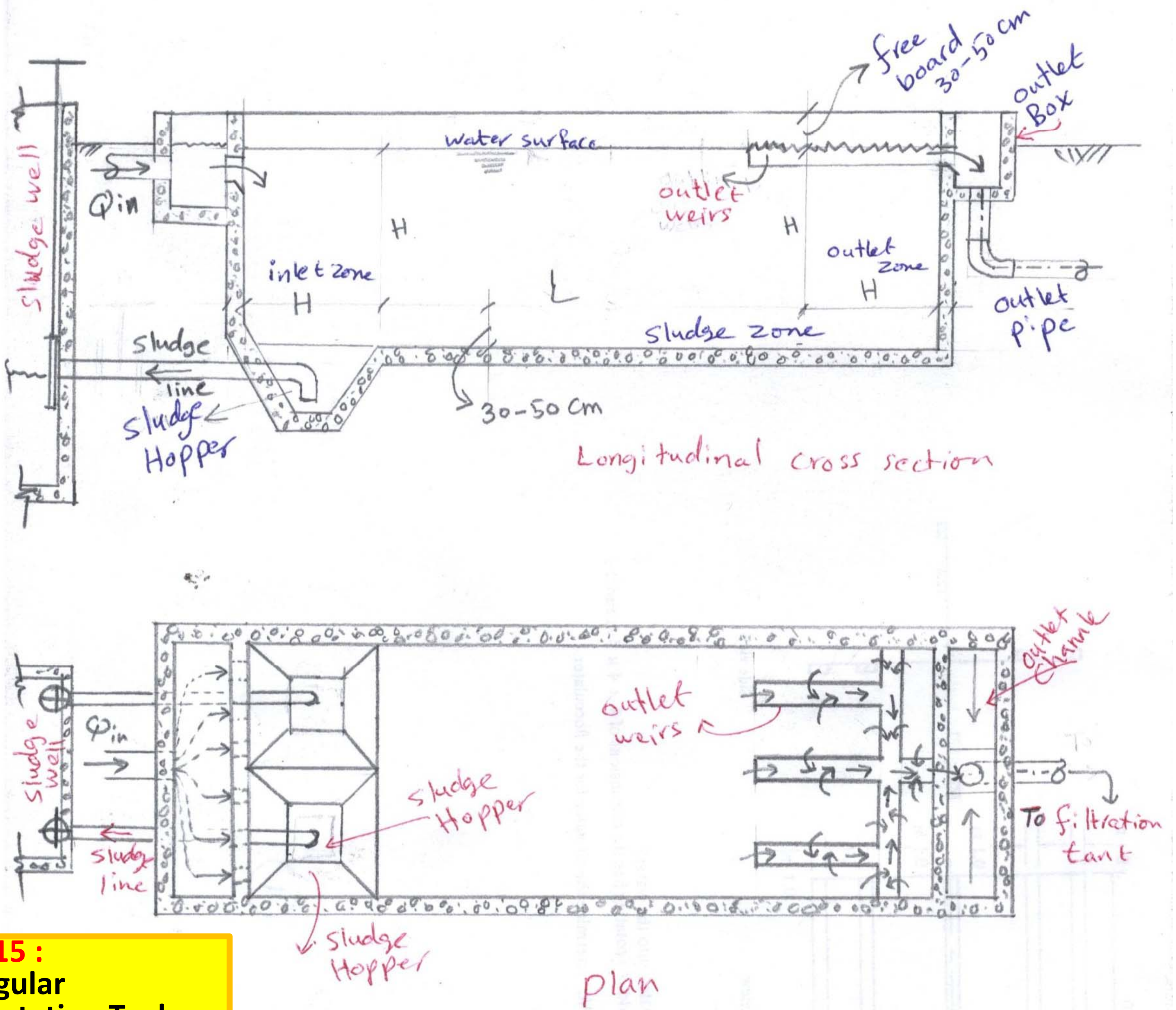

Figure 15 :
Rectangular sedimentation Tank

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Example 4.3:

Repeat example 4.3 using circular tank.

Note: the maximum tank diameter is 40 m

Solution:

$$\boxed{Take\ v_0 = v_s = 31\, m^3/m^2.d} \rightarrow \boxed{v_0 = \frac{Q}{A_s}}$$

*Flow/tank = (Q/2)= 20000/2 = 10000 m^3/d

As = 10000/31 = 322.5 m^2

•$A_s = \pi D^2/4$= 322.5 m2 D = 20.27 m ≈20.30 m < 40 m

•Assume detention time = 3 hrs

H = $t*V_0$ = (3*31)/24= 3.88 m ≈ 3.90 m

Check horizontal velocity at the beginning and end of settling zones:

•$V_h = Q/(\pi D_{in} H)$ = 10000/(24*60*3.14*3.9*3.9) = 0.145 m/min (End of inlet zone)

•$V_h = Q/(\pi D_{out} H)$ = 10000/(24*60*3.14*24*3.9) = 0.024 m/min (beginning of outlet zone)

•Take weir loading rate = 250 $m^3/m.d$:

$L_{weir} = Q/W_{load}$ = 10000/250 = 40 m , Use suspended troughs inside the tank.

Available Length = $\pi D_{total} = \pi(2H + D)$ =3.14*(2*3.9+20.30) = 88.23 m > 40 m O.K

Available W_{load} = Q/L = 10000/88.23 = 113.34 $m^3/m^2.d$ < 250 $m^3/m.d$ O.K

H= side wall height (tank depth)
D_{in}= H
D_{out} =H+D
D_{total}= 3H+D
D= diameter calculated from
the Over flow rate

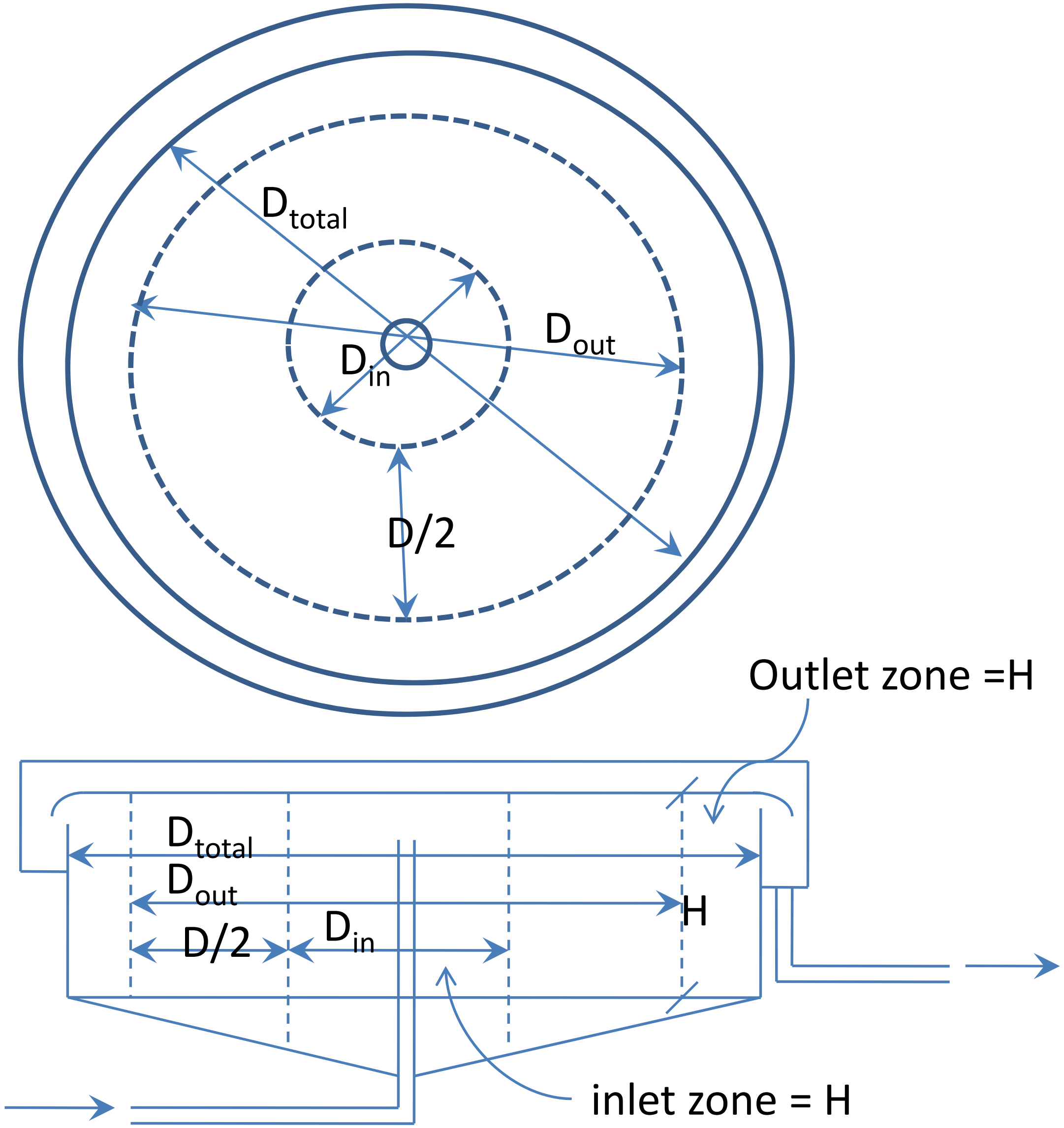

Figure 16 :
Circular sedimentation Tank Dimensions definition

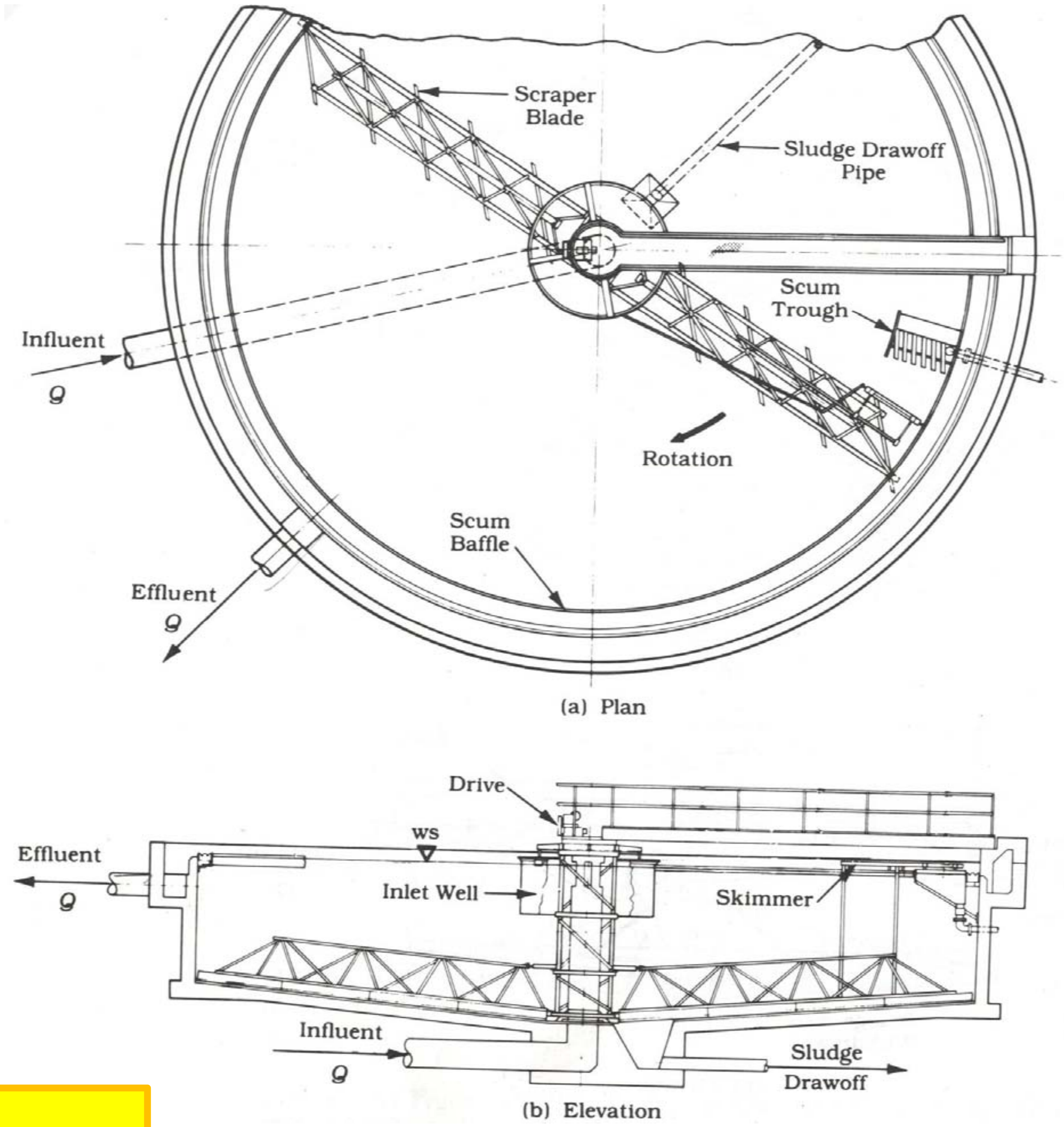

Figure 17 :
Circular sedimentation Tank

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4.5 Design of Sedimentation tanks

4.5.2 Flocculent Sedimentation (type 2 and 3):

The design procedure for sedimentation tanks of type 2 and 3 are the same as type 1. The difference is mainly in the overflow rate (v_0) . The following table gives the design criteria of these two types.

Process	Settling type	Detention time (h)	Surface loading rate ($m^3/m^2.d$)	Weir loading rate ($m^3/m.d$)
Coagulation	2	4-8	20-40	250
softening	3	2-6	40-60	250