CornellEngineering
Civil and Environmental Engineering

CEE 4540

Sustainable municipal drinking water treatment

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Class #4 09/10/2018 2:55 – 4:10pm

Sedimentation

A Process that utilize gravity to separate coagulated/flocculated particles from water

- Five operating parameters important to sedimentation.
- Identify the four zones of a sedimentation basin.
- Given the formula and required data, calculate each of the following: detention time, surface loading rate, mean flow velocity, and weir loading rate.
- Explain why tube or plate settlers increase settling efficiency.
- Identify five characteristics upon which the sedimentation process is dependent.

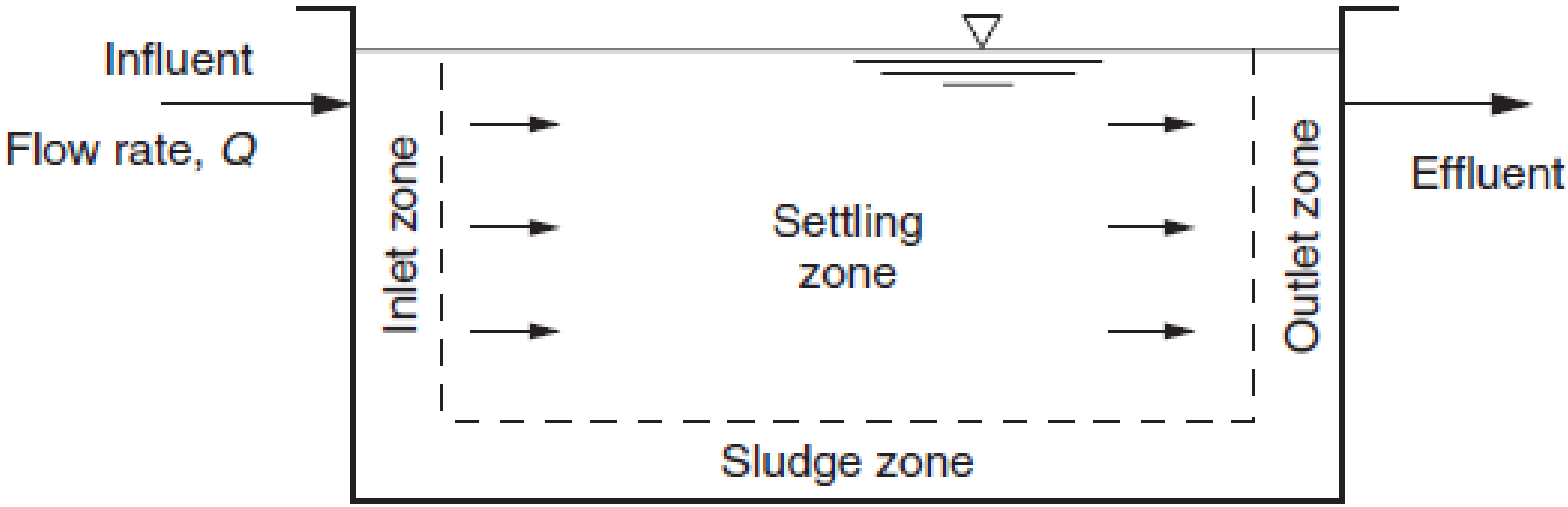
Basic Factors Affecting How Fast Particles Settle

1. Particle Size
2. Gravitational Settling Velocity
3. Particle Shape
4. Relationship of Downward Movement of Particle to Forward Flow Velocity
5. Water Temperature
6. Electrical Charge on Particles
7. Environmental Conditions

Sedimentation Basin (Sed. Basin)

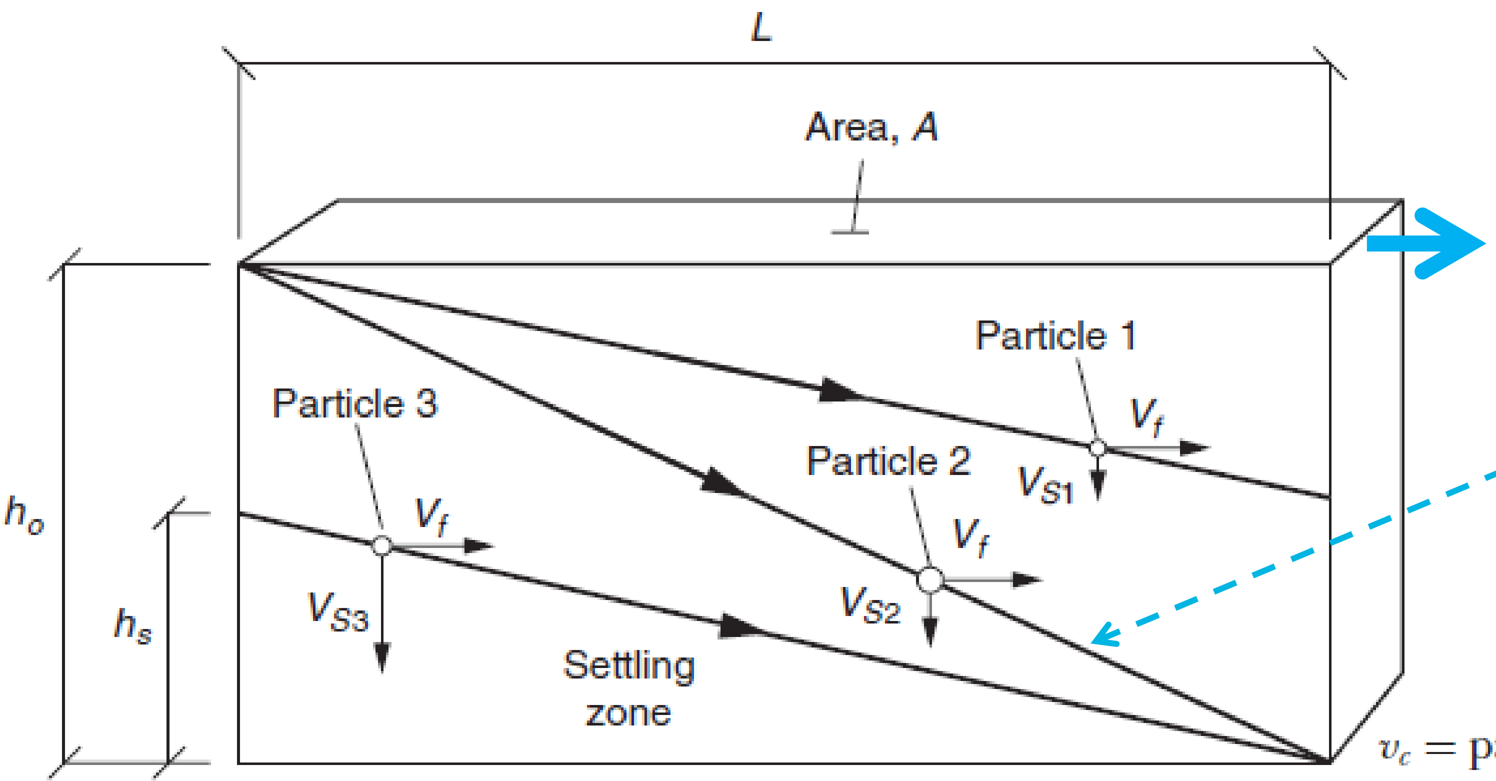
Zones Within a Sedimentation Basin (Sed Basin)

- Inlet Zone
- Settling Zone
- Sludge Zone
- Outlet Zone



Particle Settling

- Basic Assumption
  a. Plug Flow (no turbulence) & uniform horizontal velocity
  b. Particles are assumed to be removed if they reach the settling zone at the bottom



Critical Settling Velocity = Q/A

Depth of Sed Basin

$$v_c = \frac{h_o}{\tau}$$

Hydraulic Detention Time of a Sed Basin

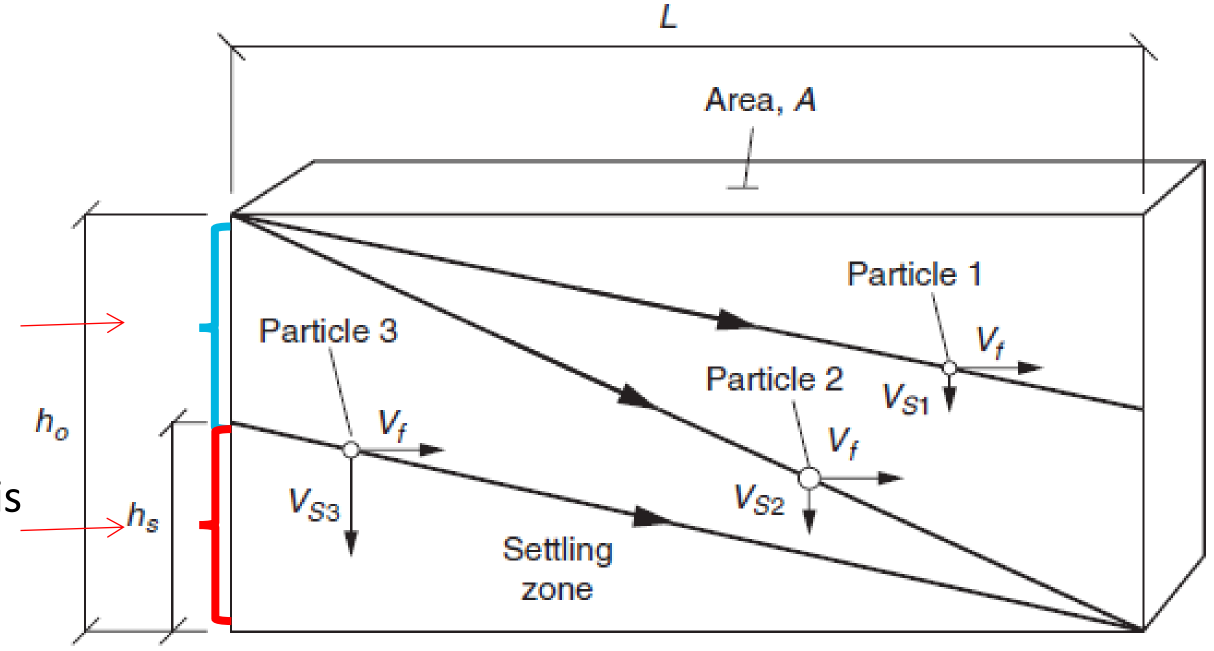
v_c = particle settling velocity such that particle at surface of inlet is removed in sludge zone just before outlet, m/h

For particles with a settling velocity < Vc…..

– Particles with a settling velocity Vc can also be removed; depending on their position in the inlet

Particles entering from this zone will not be removed

Particles entering from this zone will be removed



$$\text{Fraction of particles removed} = \frac{h_s}{h_o} = \frac{h_s/\tau}{h_o/\tau} = \frac{v_s}{v_c}\,(v_s < v_c) \qquad (10\text{-}18)$$

where h_s = height of particle from bottom of tank at position entering settling zone, m

v_s = particle settling velocity smaller than v_c, m/h

Example

Example 10-3 Particle removal in sedimentation basin

Calculate the particle removal efficiency in a rectangular sedimentation basin with a depth of 4.5 m, width of 6 m, length of 35 m, and process flow rate of 525 m^3/h. Compute the required sedimentation basin design parameters and plot the influent and effluent particle concentrations as a function of particle size using a histogram. Assume the following influent particle-settling characteristics (adapted from Tchobanoglous et al., 2003):

Settling Velocity, m/h	Number of Particles, #/mL
0–0.4	511
0.4–0.8	657
0.8–1.2	876
1.2–1.6	1168
1.6–2.0	1460
2.0–2.4	1314
2.4–2.8	657
2.8–3.2	438
3.2–3.6	292
3.6–4.0	292
Total	7665

Step 1

- Calculate Sed Basin's Overflow Rate (OR) & Critical Settling Velocity (Eq. 10-17)

$$OR = v_c = \frac{Q}{A} = \frac{525\ \text{m}^3/\text{h}}{(6\ \text{m})(35\ \text{m})} = 2.5\ \text{m}^3/\text{m}^2 \cdot \text{h}$$

Step 2

- Calculate Sed Basin's Overflow Rate (OR) & Critical Settling Velocity (Eq. 10-17)

$$\mathrm{OR} = v_c = \frac{Q}{A} = \frac{525\ \mathrm{m^3/h}}{(6\ \mathrm{m})(35\ \mathrm{m})} = 2.5\ \mathrm{m^3/m^2 \cdot h}$$

- Calculate particle % removal for each size range (use average of the range)

✓ Settling Velocity, m/h (1)	✓ Average Settling Velocity, m/h (2)	✓ Number of Influent Particles, #/mL (3)	✓ Fraction of Particles Removed (4)
0–0.4	0.2	511	0.08
0.4–0.8	0.6	657	0.24
0.8–1.2	1.0	876	0.40
1.2–1.6	1.4	1168	0.56
1.6–2.0	1.8	1460	0.72
2.0–2.4	2.2	1314	0.88
2.4–2.8	2.6	657	1
2.8–3.2	3.0	438	1
3.2–3.6	3.4	292	1
3.6–4.0	3.8	292	1
Total		7665	

Fraction of particles removed

$$= \frac{h_s}{h_o} = \frac{h_s/\tau}{h_o/\tau} = \frac{v_s}{v_c}\,(v_s < v_c) \qquad (10\text{-}18)$$

where

h_s = height of particle from bottom of tank at position entering settling zone, m

v_s = particle settling velocity smaller than v_c, m/h

Step 3

- Calculate Number of particles removed for each size range

Settling Velocity, m/h (1)	Average Settling Velocity, m/h (2)	Number of Influent Particles, #/mL (3)	Fraction of Particles Removed (4)	Number of Particles Removed, #/mL (5)
0–0.4	0.2	511	0.08	41
0.4–0.8	0.6	657	0.24	158
0.8–1.2	1.0	876	0.40	350
1.2–1.6	1.4	1168	0.56	654
1.6–2.0	1.8	1460	0.72	1051
2.0–2.4	2.2	1314	0.88	1156
2.4–2.8	2.6	657	1	657
2.8–3.2	3.0	438	1	438
3.2–3.6	3.4	292	1	292
3.6–4.0	3.8	292	1	292
Total		7665		5090

Step 4

– Calculate number of particles remaining in the effluent

✓	✓	✓	✓	✓	✓
Settling Velocity, m/h (1)	Average Settling Velocity, m/h (2)	Number of Influent Particles, #/mL (3)	Fraction of Particles Removed (4)	Number of Particles Removed, #/mL (5)	Number of Particles in Effluent, #/mL (6)
0–0.4	0.2	511	0.08	41	470
0.4–0.8	0.6	657	0.24	158	499
0.8–1.2	1.0	876	0.40	350	526
1.2–1.6	1.4	1168	0.56	654	514
1.6–2.0	1.8	1460	0.72	1051	409
2.0–2.4	2.2	1314	0.88	1156	158
2.4–2.8	2.6	657	1	657	0
2.8–3.2	3.0	438	1	438	0
3.2–3.6	3.4	292	1	292	0
3.6–4.0	3.8	292	1	292	0
Total		7665		5090	2575

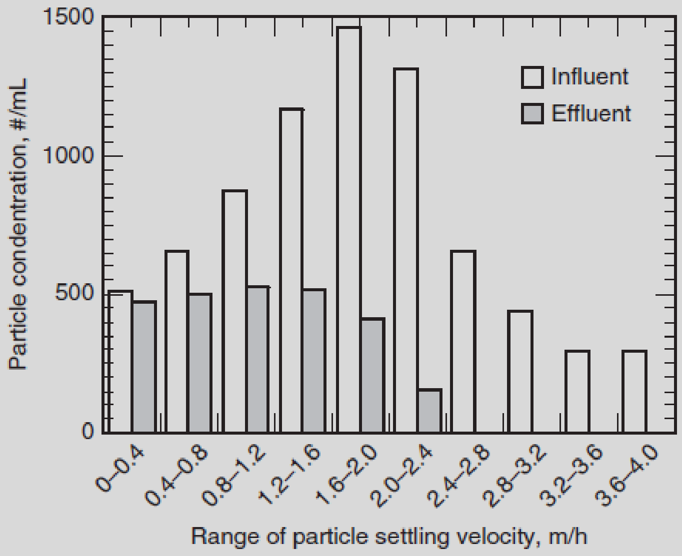
Step 5

- Compute the overall particle removal efficiency

$$\text{Removal efficiency} = \frac{5090}{7665} = 0.664 = 66.4\%$$

- Plot the influent & effluent particle concentrations for each settling velocity range

4. Plot the influent and effluent particle concentrations for each settling velocity range using a histogram.

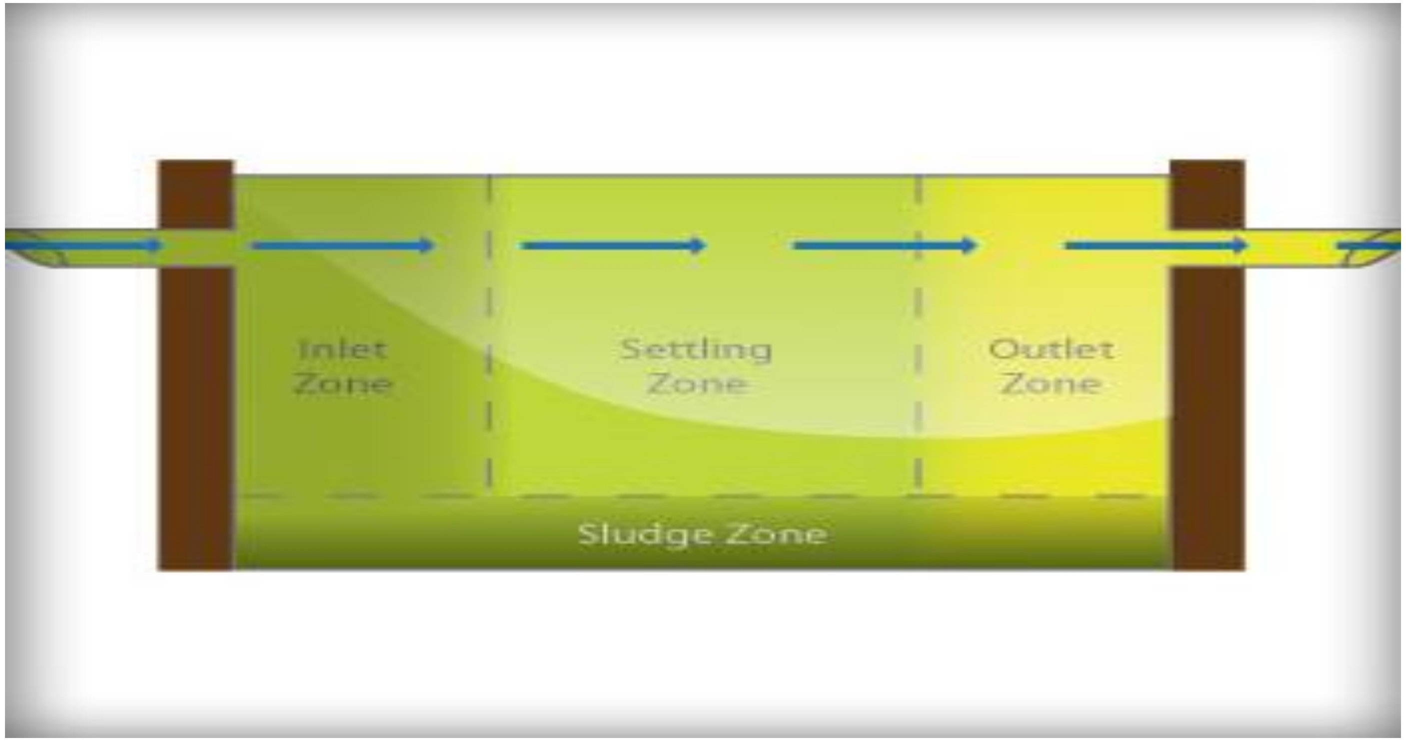


Differential Settling

- Particles aggregated at different sizes with different densities; thereby settling at different velocities
- Particles settle at different velocity will collides and form larger particles (and therefore flocculated)
- While theoretical particle settling rate can be calculated, actual settling rate in the field depends on water chemistry and temperature

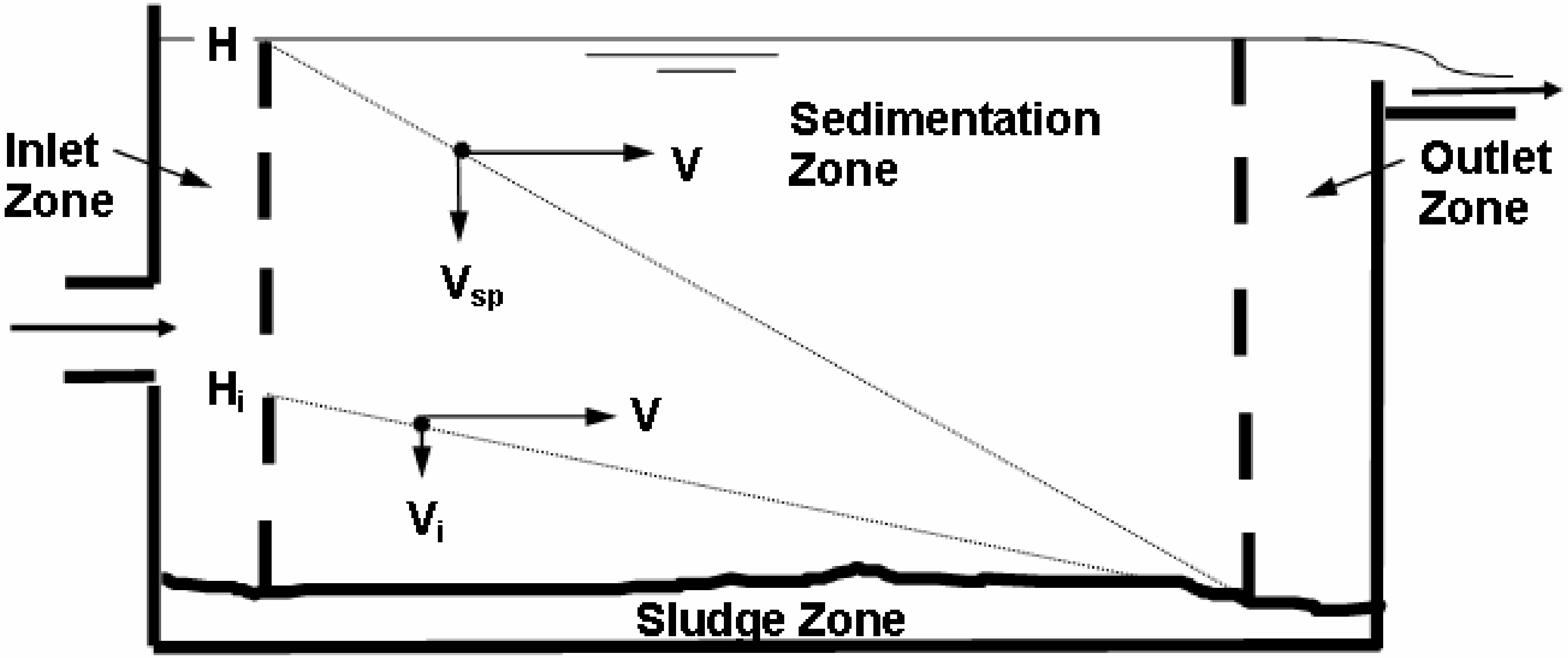
Potential Short Circuiting

- Short circuiting could happen when
  - Flowrate is much higher than design value (under designed)
  - Water temperature at the upper section is higher



Inlet Design for Sed Basin

– Multiple inlet points at various depth to avoid short circuiting and to increase particle removal



Note on Theoretical Design

- Theoretical design provides a solid foundation for modern water treatment
- Help to understand the reasons “behind the scene”
- Conventional treatment process performance can be affected by many factors
  - Raw water quality (pH, alkalinity, temperature, TOC level, etc.)
  - Type and quantity of chemicals used
  - Operational preferences
  - Level of raw water quality monitoring
  - Level of SOP for operation established and followed
- Level of operation knowledge, capability and level of sophistication varies from plant to plant

What are really used in the real world?

- Rely on experienced engineers’ years of design experience (Maybe an AI opportunity?)
- Follow design standards established by each state based on decades of knowledge and field operation performance experience.
- 10 State Standards for Drinking Water System Design
- Each State may have its own standards or requirements
- You are strongly encouraged to consult with the 10 State Standards in your design project

http://10statesstandards.com/waterrev2012.pdf

Homework

– Reading Assignment: Chapter 9 & 10

Homework: Calculate solid generation from coagulation using ferric chloride

- Plant Capacity: 10 mgd
- Coagulant dose is 10 mg/L as $FeCl_3$
- Assume water content in the dewatered sludge is 75%

Q: How many lbs of dewatered solid will be generated daily?

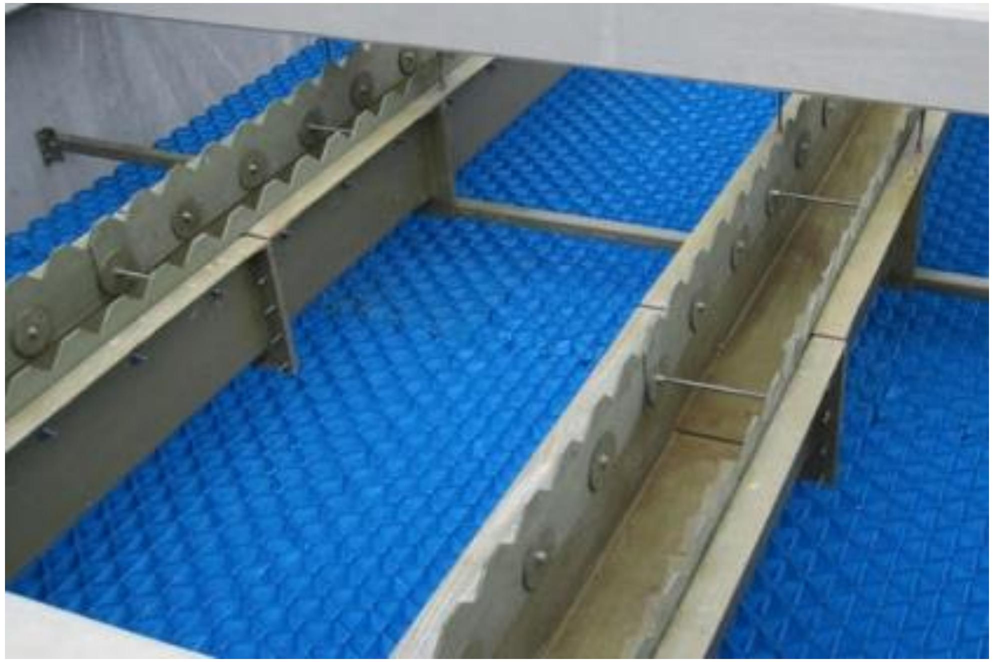
Hint: Mwt. for Fe is 55.85 and Mwt. For Cl is 35.45. When FeCl3 is hydrolyzed ferric hydroxides solid $Fe(OH)_3$ is formed.

High Rate Clarification Process

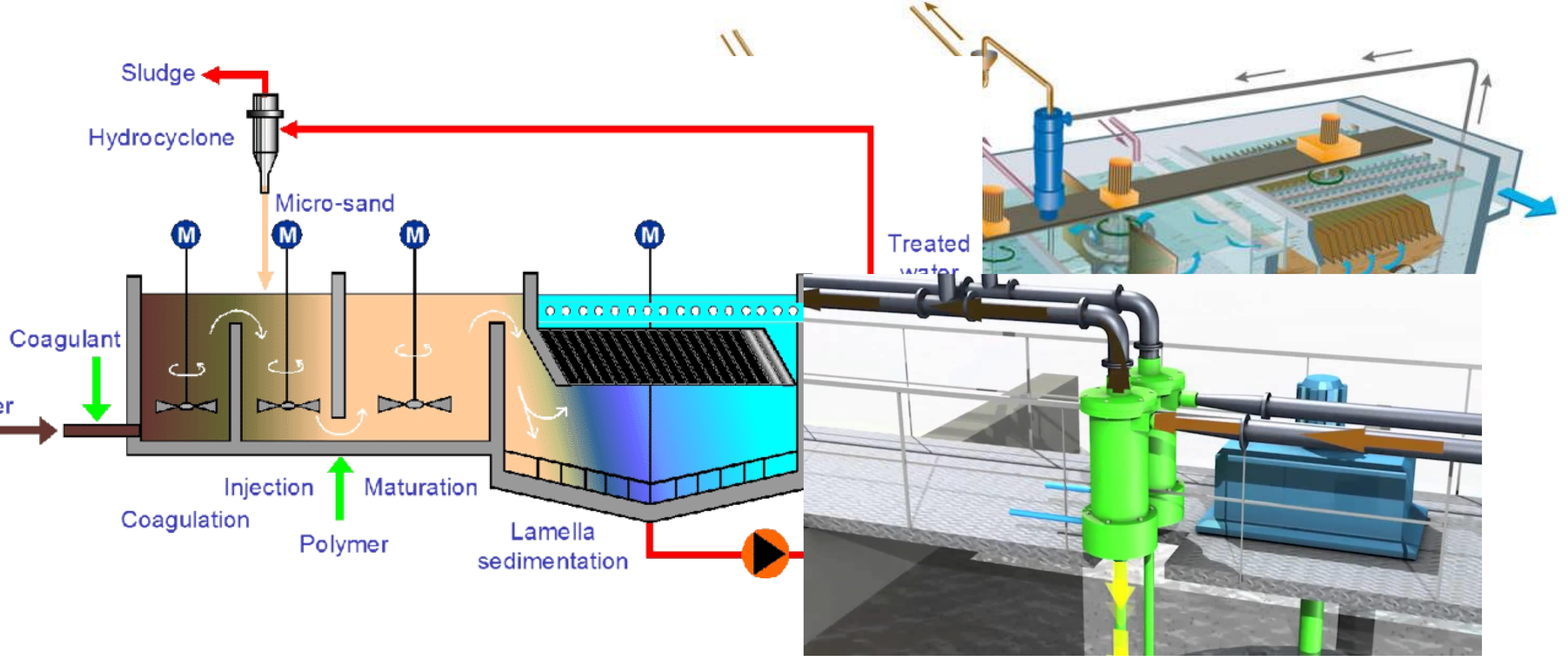
- Increasing surface loading rate from 3 – 4 gpm/ft^2 to > 12 gpm/ft^2
- High Rate Clarification is achieved via two main schemes
  - Reduce the distance that particles need to travel before they hit the “sludge zone”
  - Make particles heavier

Surface Loading Rate: Quantity of water can be treated per minute per ft^2 of surface area of a treatment process tank. A higher surface loading rate translates to a lower surface area needed of a treatment process, which translate to lower construction costs. However, it is also considered a more “aggressive operation scheme” in the eyes of regulators.

Tube Settler

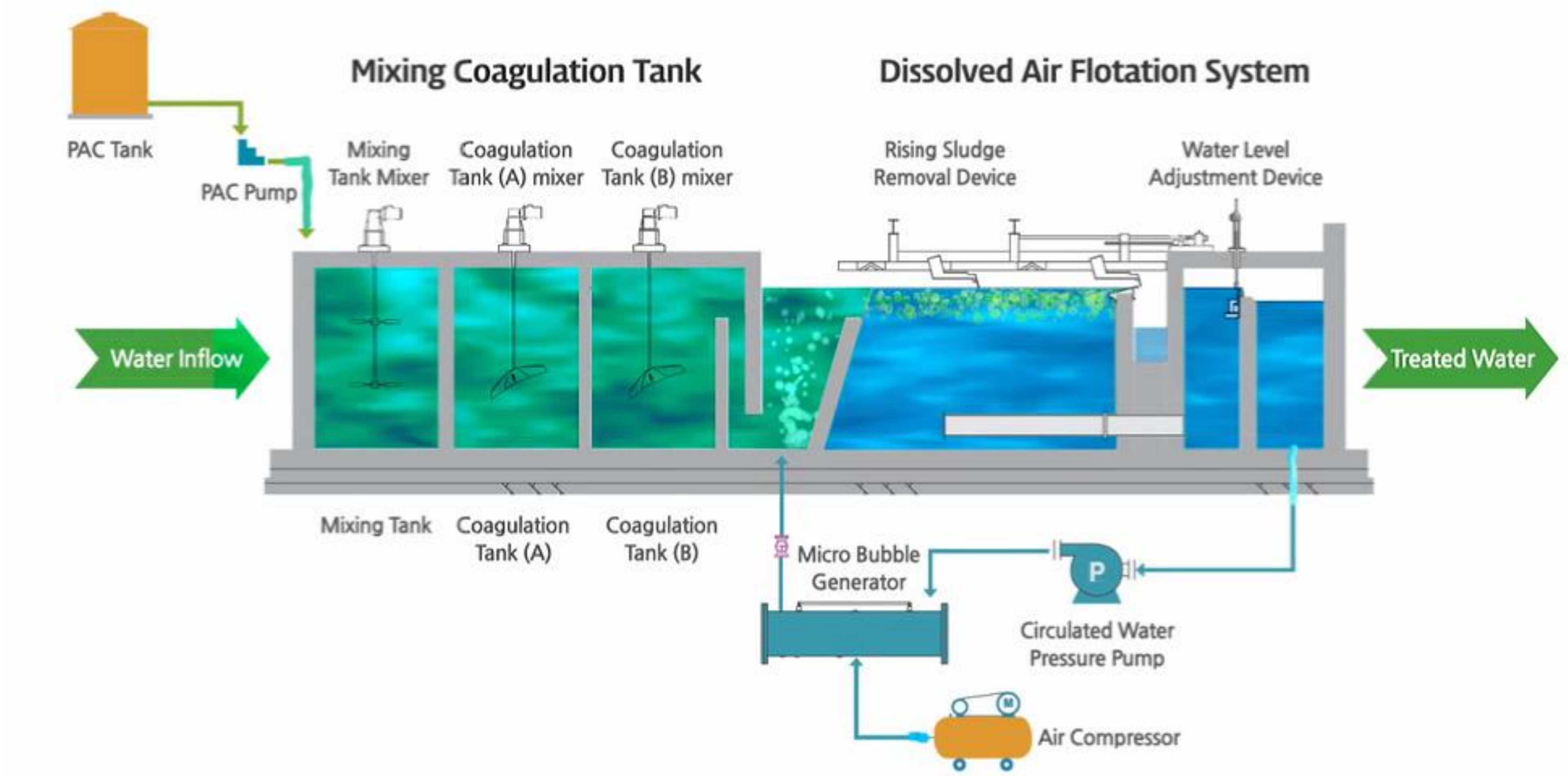


Actiflo

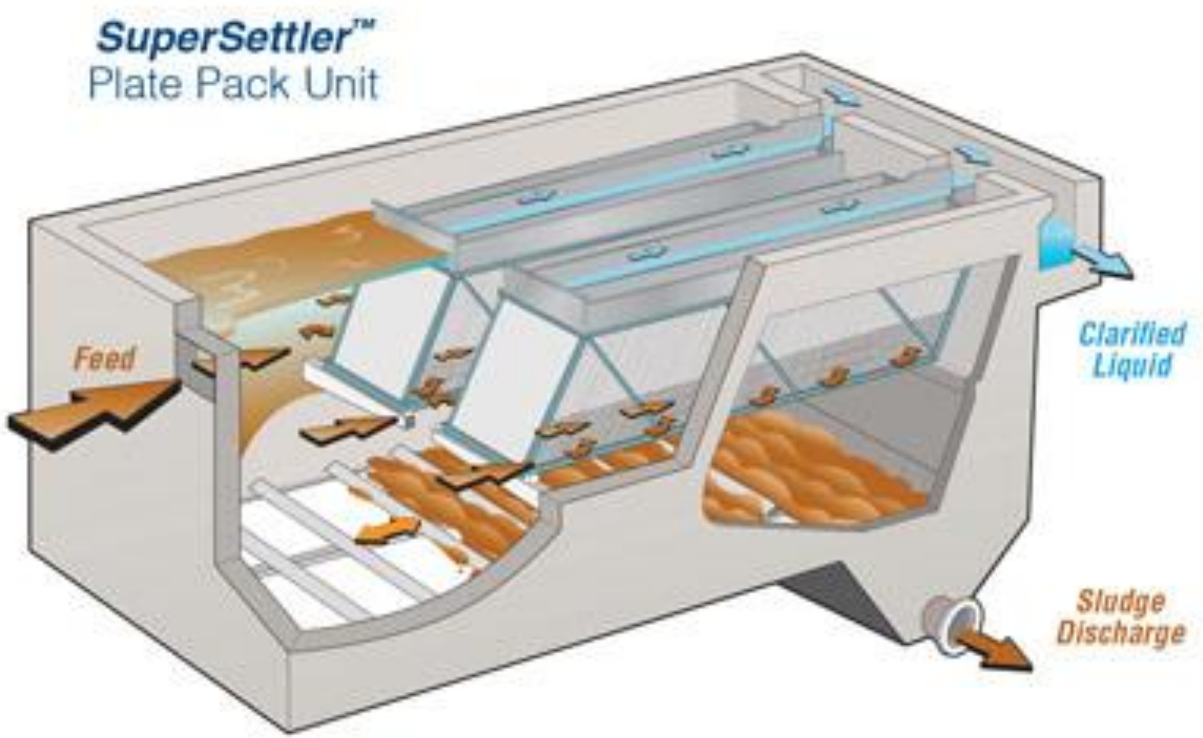

Sludge
Hydrocyclone
Micro-sand
M
M
M
M
Coagulant
Injection
Coagulation
Maturation
Polymer
Lamella
sedimentation
Treated

Loading rate

- Lamella Clarifier: 4 – 6 gpf/ft2
- DAF 4 – 6 gpf/ft2
- Actiflo: > 20 gpm/ft2



Mixing Coagulation Tank
Dissolved Air Flotation System
PAC Tank
PAC Pump
Mixing Tank Mixer
Coagulation Tank (A) mixer
Coagulation Tank (B) mixer
Rising Sludge Removal Device
Water Level Adjustment Device
Water Inflow
Treated Water
Mixing Tank
Coagulation Tank (A)
Coagulation Tank (B)
Micro Bubble Generator
Circulated Water Pressure Pump
Air Compressor


SuperSettler™
Plate Pack Unit
Feed
Clarified
Liquid
Sludge
Discharge

Sludge Production

- Enhanced Coagulation could lead to additional sludge generated
- Solid calculations

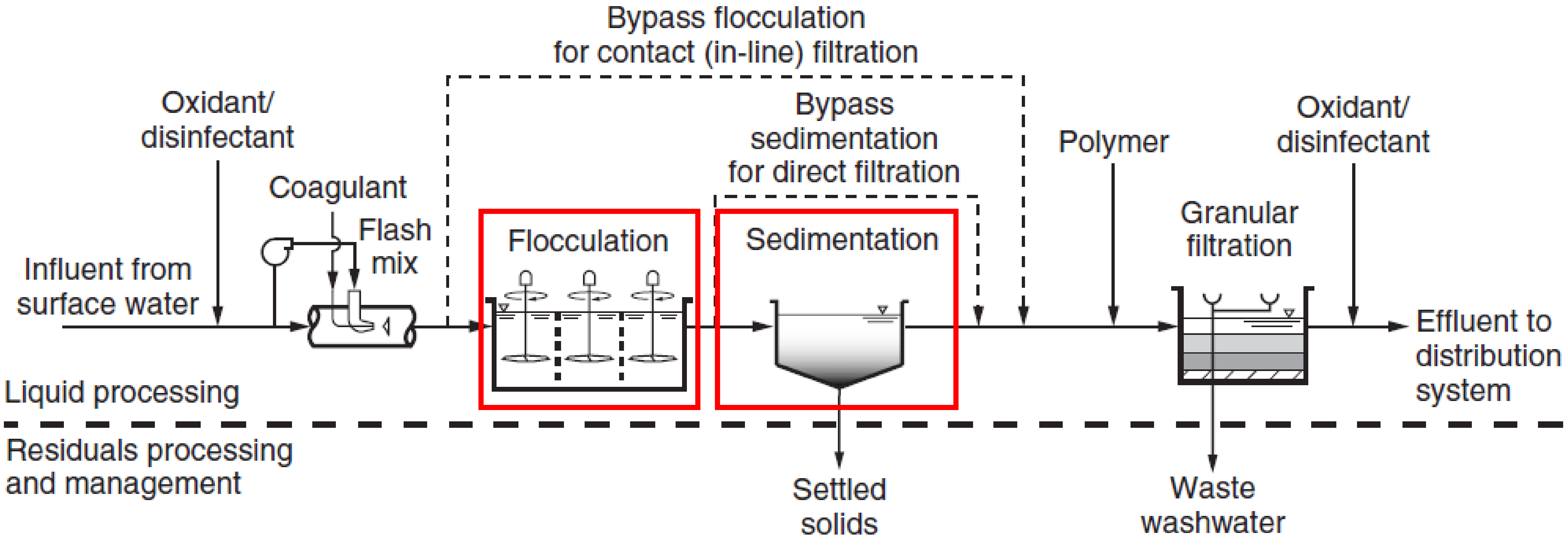
Homework: Calculate solid generation from coagulation using ferric chloride

- Plant Capacity: 10 mgd
- Coagulant dose is 10 mg/L as $FeCl_3$
- Assume water content in the dewatered sludge is 75%

Q: How many lbs of dewatered solid will be generated daily?

Hint: Mwt. for Fe is 55.85 and Mwt. For Cl is 35.45. When FeCl3 is hydrolyzed ferric hydroxides solid $Fe(OH)_3$ is formed.

Quick Review: Intake; Screening; Coagulation; and Sedimentation



Typical Design Criteria for Rectangular Tanks

Table 10-4
Typical design criteria for horizontal-flow rectangular tanks

Parameter	Units	Value
Type	—	Horizontal-flow rectangular tank
Minimum number of tanks	Unitless	2
Water depth	m (ft)	3–5 (10–16)
Length-to-depth ratio, minimum	Dimensionless	15:1
Width-to-depth ratio	Dimensionless	3:1–6:1
Length-to-width ratio, minimum	Dimensionless	4:1–5:1
Surface loading rate (overflow rate)	m/h (gpm/ft^2)	1.25–2.5 (0.5–1.0)
Horizontal mean-flow velocity (at maximum daily flow)	m/min (ft/min)	0.3–1.1 (1–3.5)
Detention time	h	1.5–4
Launder weir loading	m^3/m · h (gpm/ft)	9–13 (12–18)[a]
Reynolds number	Dimensionless	$<$20,000
Froude number	Dimensionless	$>10^{-5}$
Bottom slope for manual sludge removal systems	m/m	1:300
Bottom slope for mechanical sludge scraper equipment	m/m	1:600
Sludge collector speed for collection path	m/min (ft/min)	0.3–0.9 (1–3)
Sludge collector speed for the return path	m/min (ft/min)	1.5–3 (5–10)

Ensure enough time for settling

Avoid short circuiting

Source: Adapted from Kawamura (2000).
[a]Can be higher, depending upon characteristics of floc.

Hydraulic Detention Time (HDT) for a Sed Basin

– Hydraulic Detention Time: The time for a drop of water to travel from inlet to outlet; or the length of time a drop of water will stay within the tank

- Typical design value is 2 – 3 hours
- HDT = Tank Volume (gal)/Flowrate (gpm)

Example 1: Calculate the Detention Time in for a clarifier with a volume of 25,000 gallons that receives a flow of 310,000 gal/day.

$$\textbf{Detention Time} = \frac{\textbf{Volume}}{\textbf{Flow}}$$

$$= \frac{\text{25,000 } \cancel{\text{gallons}}}{\text{310,000 } \cancel{\text{gallons}}\text{/day}} = \textbf{0.08 Days or} \sim \textbf{1.94 Hrs}$$

Basic Terminologies & Calculations for "Loading Rates"

$$\text{Detention Time (DT)} = \frac{\text{Tank Volume, MG}}{\text{Flow into Tank, MGD}}$$

$$\text{Surface Overflow Rate (SOR)} = \frac{\text{Flow, gallons/day}}{\text{Surface Area, ft}^2}$$

$$\text{Weir Overflow Rate (WOR)} = \frac{\text{Flow, gallons/day}}{\text{Length of Weir, ft}}$$

$$\text{Solids Loading Rate (SLR)} = \frac{\text{Solids, lbs/day}}{\text{Surface Area, ft}^2}$$

Basic Calculations for Tank Volume

– Surface area & Volume calculations for both rectangular and circular tanks is simple

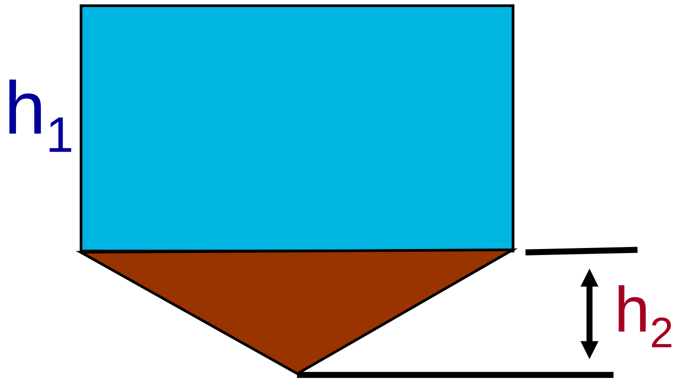
– What if it's a cylinder tank with a cone bottom?

- Cone bottom tanks is REQUIRED if there is potential solid settling

$$V_{cylinder} = \pi r^2 h_1$$

$$V_{cone} = 1/3\ \pi r^2 h \quad \text{or} \quad \frac{\pi r^2 h_2}{3}$$

$$V_{total} = V_{cylinder} + V_{cone}$$



Cone Bottom Tank

Understanding “Hydraulic or Surface Loading Rates”

- How may gallon per minuet (flow rate) is loading on per ft^2 of surface area
  - Focusing on how much water is “loaded” to the water surface of the tank
- Usually presented in gpm/ ft^2

$$\textbf{HLR, gpm/ft}^2 = \frac{\textbf{Flow, gallons/min}}{\textbf{Surface Area, ft}^2}$$

- Also called “Surface Loading Rate” or “Surface Overflow Rate”
- Typical Value: 0.28 – 0.56 gpm/ft^2

Example

Calculate the Hydraulic Loading Rate for a clarifier that is 50 ft long, 15 ft wide, 12 ft deep, and receives a flow of 338,000 gallons per day.

$$\text{SLR, gpd/ft}^2 = \frac{\text{Flow, gallons/day}}{\text{Surface Area, ft}^2}$$

$$\text{Surface Area, ft}^2 = 50\text{ ft} \times 15\text{ ft} = 750\text{ ft}^2$$

$$\text{SOR, gpd/ft}^2 = \frac{338{,}000\text{ gallons per day}}{750\text{ ft}^2}$$

$$= 451\text{ gpd/ft}^2 = 0.31\text{ gpm/ft}^2$$

Clarifier Solid Loading Rate (SLR)

- Lbs per day of solids in the clarifier influent per ft^2 of surface area

$$\text{SLR, lbs/d/ft}^2 = \frac{\text{Solids, lbs/day}}{\text{Surface Area, ft}^2}$$

Same Calculations as for Hydraulic Loading

$SA = L \times W$

$SA = \pi r^2$

The Pound Equation for Solids

Pounds = Conc. x Flow (or Volume) x 8.34 Lbs/gallon

Concentration Of Solids In the Water	**X**	**Quantity Of Water The Particles Are In**	**X**	**Weight Of The Water**

The “Pound Equation” for Solid Calculations

Pounds = Conc. x Flow (or Volume) x 8.34 Lbs/gallon

- Flow & volume should be in MG
- Concentration of solids must be in ppm (parts per million)
- If Flow is in MGD, the result solid generation would be Lbs/day

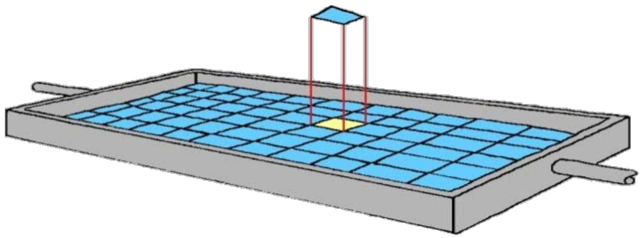
$$\frac{\cancel{\text{Lbs.}}}{\cancel{\text{M}}\ \cancel{\text{Lbs.}}} \times \frac{\cancel{\text{M}}\ \cancel{\text{gal}}}{\text{day}} \times \frac{\text{Lbs.}}{\cancel{\text{gal}}}$$

Clarifier Solid Loading

Solids Loading - **Solids Loading Rate (SLR)**

The pounds per day of solids in the clarifier influent <u>per square foot of surface area</u>

$$\text{SLR, lbs/d/ft}^2 = \frac{\text{Solids, lbs/day}}{\text{Surface Area, ft}^2}$$



Typical Design Value = Max 30 lbs/d/ft^2

Example for Clarifier Solid Loading Calculations

– Calculate the Solids Loading Rate for a clarifier with a 50 ft diameter and a depth of 12 feet, and receives a flow of 2.4 MGD with a suspended solids concentration of 1800 mg/L.

$$\textbf{SLR, lbs/d/ft}^2 = \frac{\textbf{Solids, lbs/day}}{\textbf{Surface Area, ft}^2}$$

Solids, lbs/day = 1800 mg/L X 2.4 MGD X 8.34 lbs/gal = 36,029 lbs/d

SA = 3.14 X 25 ft X 25 ft = 1962.5 ft^2

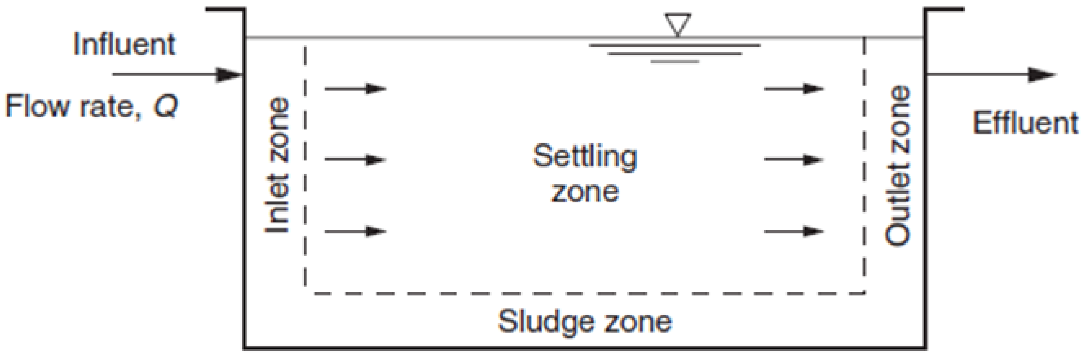
$$\textbf{SLR, lbs/d/ft}^2 = \frac{\textbf{36,029 lbs/day}}{\textbf{1962.5 ft}^2} = \textbf{18.4 lbs/d/ft}^2$$

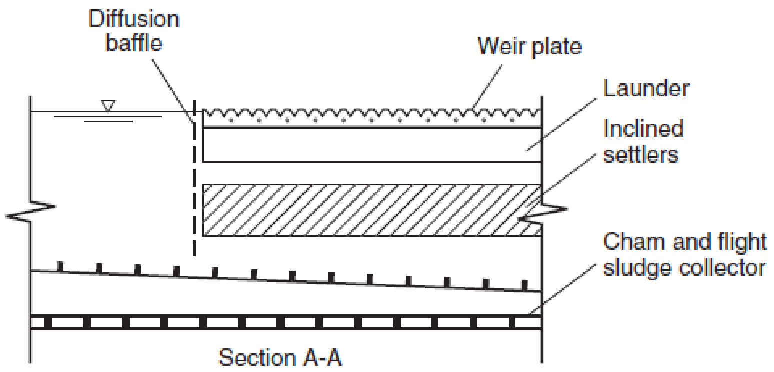
Sludge Collection for a Sed Basin

- Chain and flight
- Sludge scraper,
- Hose-less vacuum

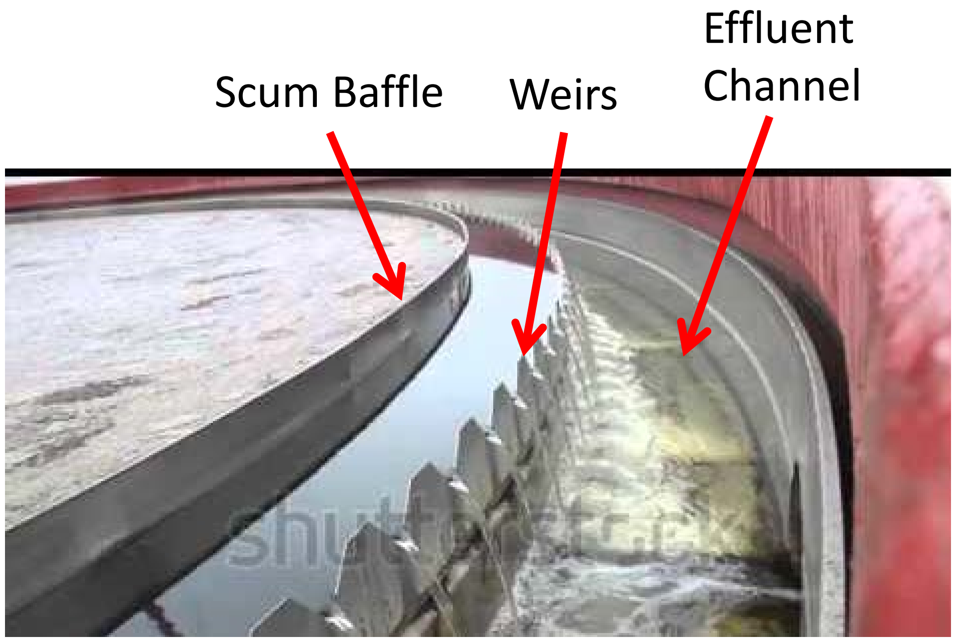
Weirs at a Sed. Basin

- The outlet zone (or Launder) should provide a smooth transition from the sed basin to the outlet without disturbing the flocs
- Weirs installed at the edge of sed basins
- Weirs is used to measure the flow rarte
- Enough length of weirs should be provided
- 20,000 gal/day/ft is the rule of thumb



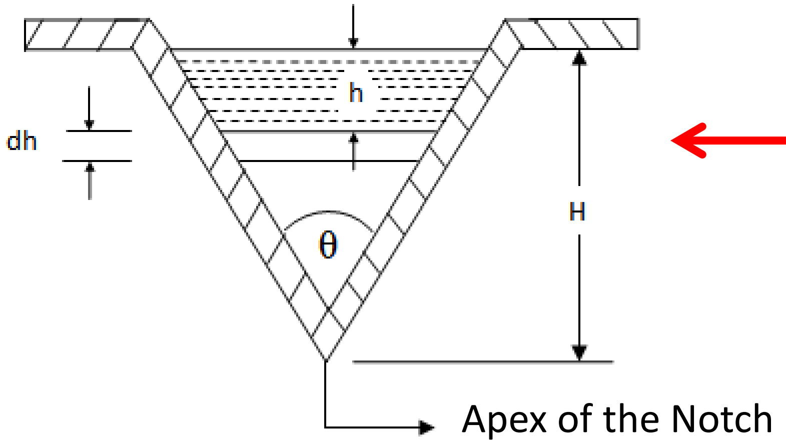


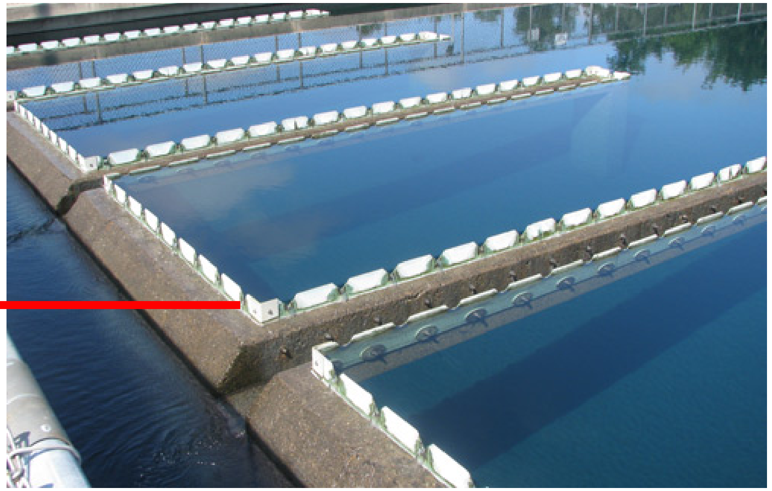
(b)



How does weirs work?

- Assuming Triangular Notch
- The outlet zone (or Launder) should





- H = Height of the liquid above the apex of the notch
- θ = Angle of the notch
- C_d = Coefficient of discharge

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

Example for Weir Calculations

– A right Angle V-notch weir (Thomson Weir) was used to measure the discharge rate of a centrifugal pump. If the depth of water at V-notch is 200 mm, calculate the discharge rate over the notch in L/min; assuming coefficient of discharge is 0.62

Given,

- $\theta = 90°$
- $H = 200\ mm = 0.2\ m$
- $C_d = 0.62$

We know that the discharge over the triangular notch,

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

$$\Rightarrow Q = \frac{8}{15} \times 0.62 \times \sqrt{2 \times 9.81} \tan 45° \times (0.2)^{\frac{5}{2}}$$

$$\Rightarrow Q = 1.465 \times 0.018 = 0.026 m^3/s$$

$$\therefore Q = 26\ liter\,s/s = 1560\ liter\,s/min$$

Advanced Sedimentation Technologies

- High-Rate Sedimentation Processes (Chapter 10-7)
  - Plate Settlers
  - Tube Settlers
- Very High-Rate Clarification Process
  - Ballasted Sedimentation (Actiflo)
  - Contact Clarifiers (Densadeg)
- Dissolved Air Floatation (DAF)

High-Rate Sedimentation/Clarification Processes

- Solids must reach the “Sludge Zone” to be removed
- High-Rate Clarification utilizes tubes or plates to enhance solid settling process

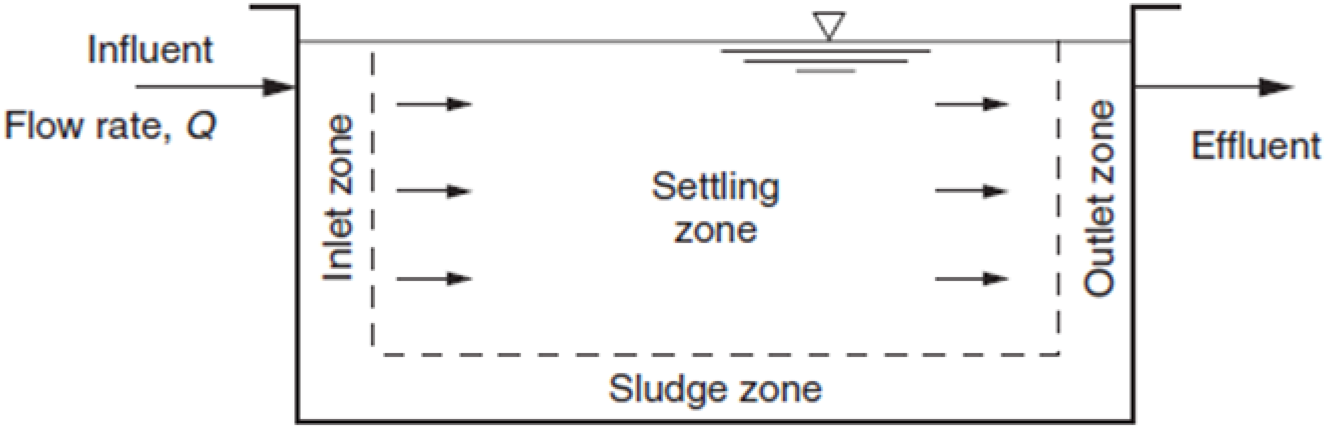
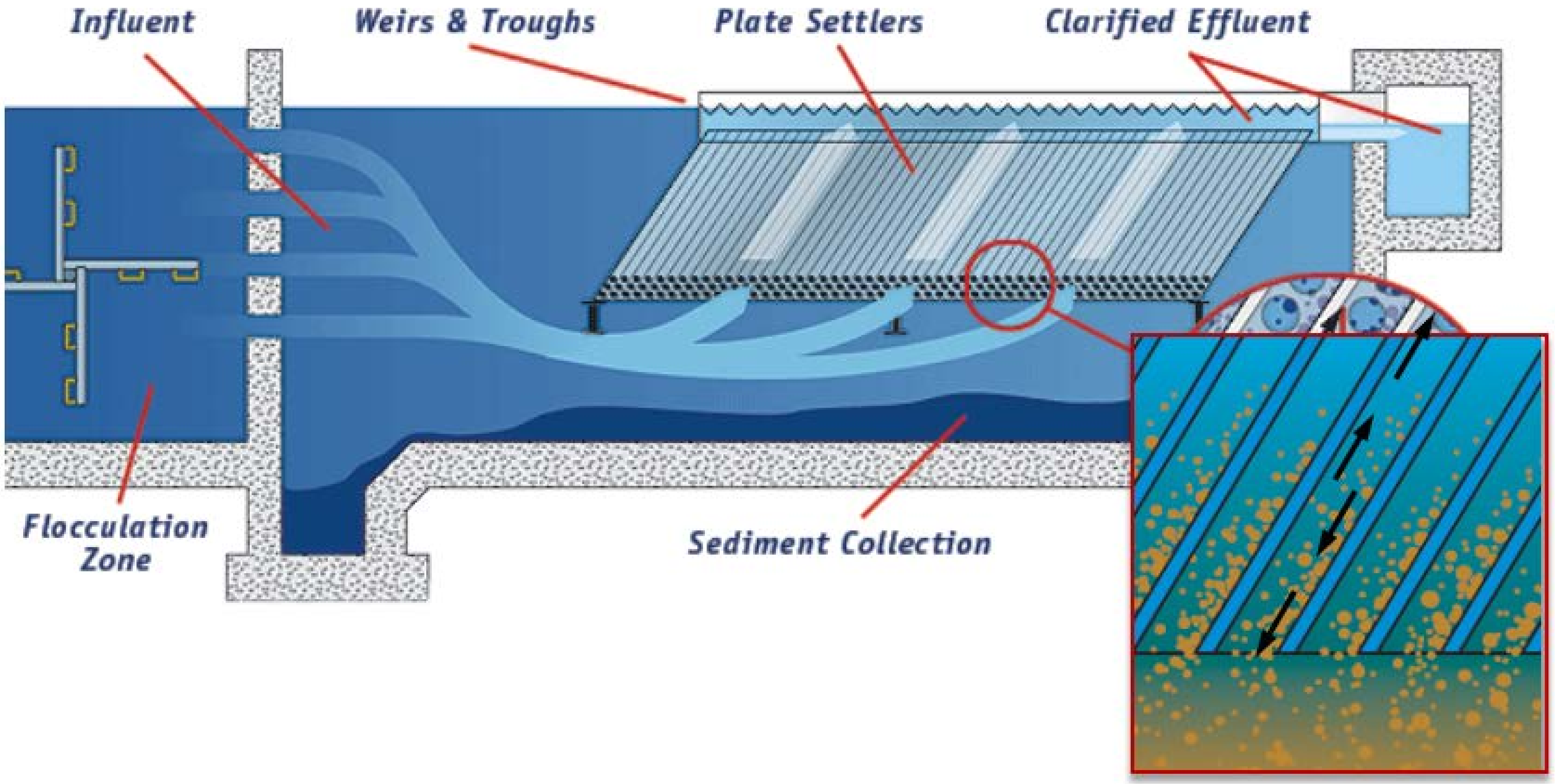


Plate Settlers

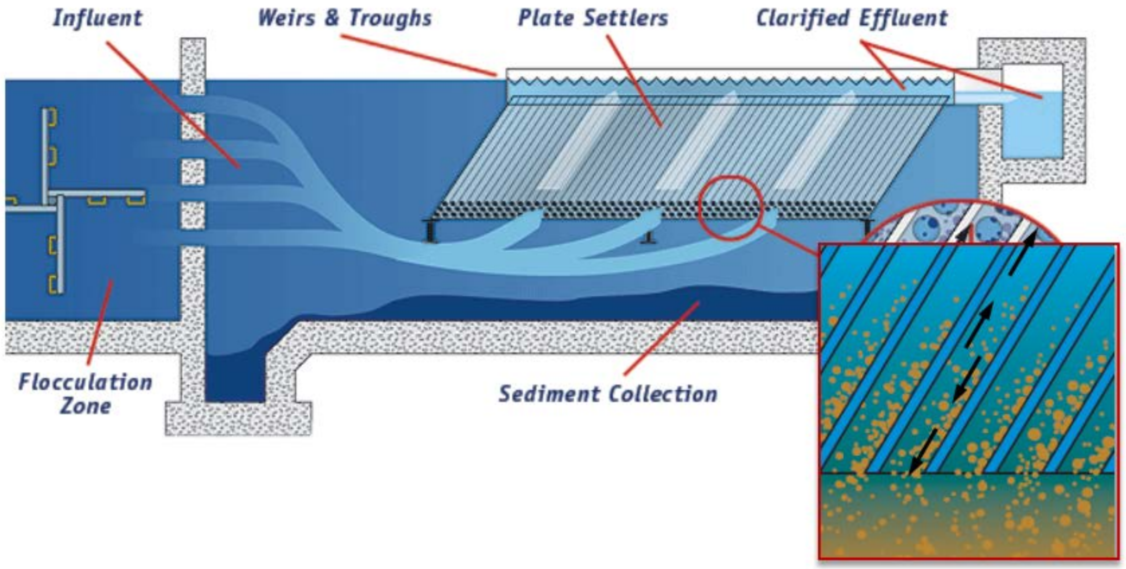
How does plate/tube settlers work?

- Plate/tube settlers offer large settling area in a small footprint



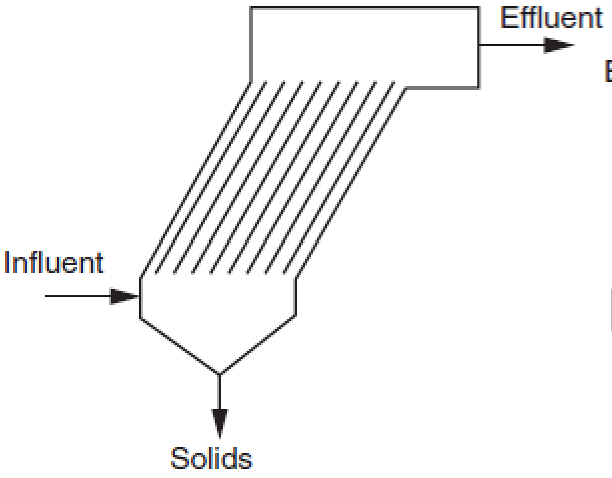
How does plate/tube settlers work?

- Processes that utilize tubes or plates to
  - Increase area of “sludge zone” on the surface of tubes or plates
  - Reduce the distance for particles to get to the “Sludge Zone”
  - Particles usually do not retain at the surface; but rather fall down to the bottom of the tank

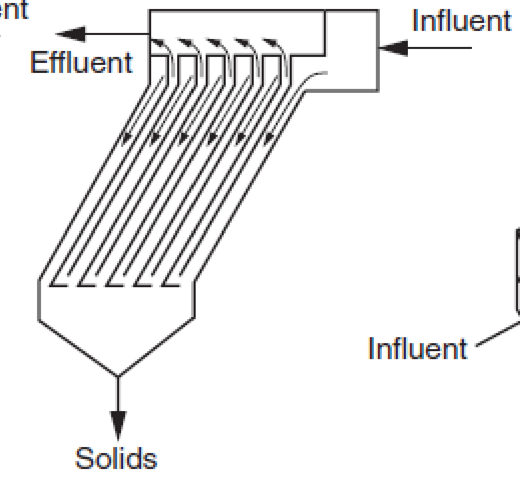


Different Flow Patterns for Tube/Plate Settlers

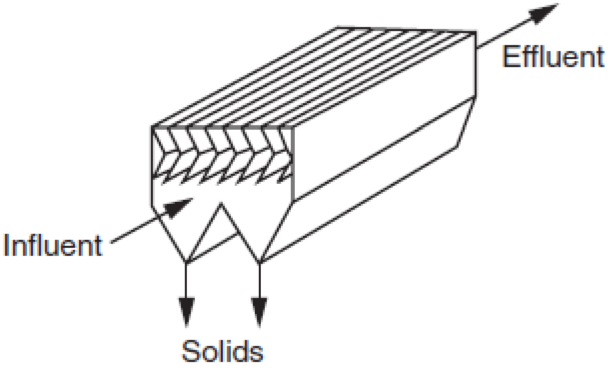
- Countercurrent
- Concurrent
- Crossflow



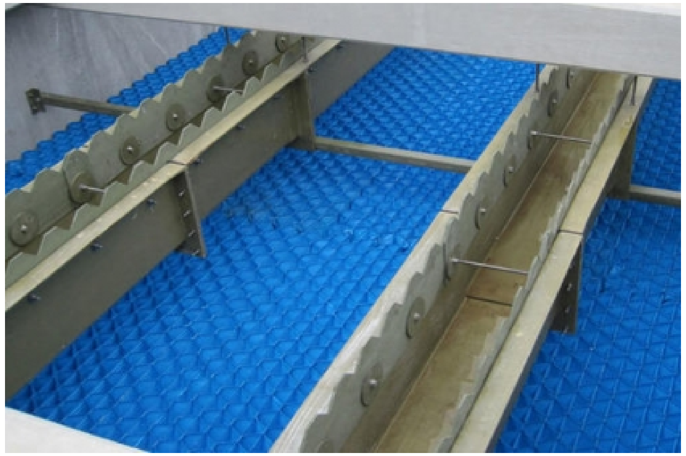
Countercurrent



Concurrent



Crossflow



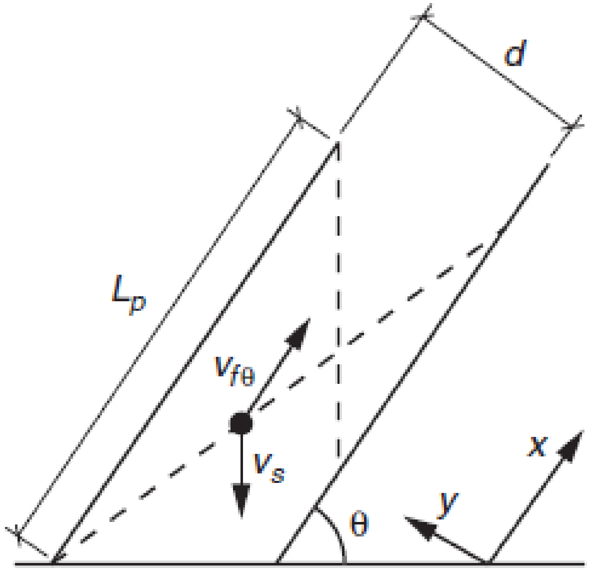
Tube Settlers

Counter Current Plate Settler Calculation

The settling time for a particle to move between countercurrent parallel plates is given by the expression

$$t = \frac{d}{v_s \cos\theta} \tag{10-34}$$

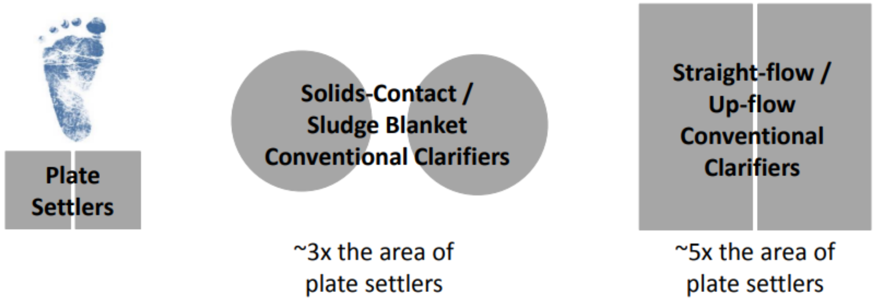
where
t = settling time, s
d = distance between two parallel plates (perpendicular to plates), m
v_s = particle settling velocity, m/s
θ = inclination angle of plates from horizon, deg



- Calculation for plate or tube settlers is well established and can be obtained from the manufacturers
- Countercurrent is often used especially when a larger angle (>60º) is desired for a smaller foot-print application

Advantages of Plate/Tube Settlers

- Provides better settled water quality
- More reliable than conventional sed. basins
- Requires smaller footprint than conventional clarifiers
- Lower cost (in most cases)
- Usually requires less coagulant dosage
- Easier O&M
  - Sludge collection mechanism is the only moving part
  - Hosing down the sludge is fairly easy (~monthly)



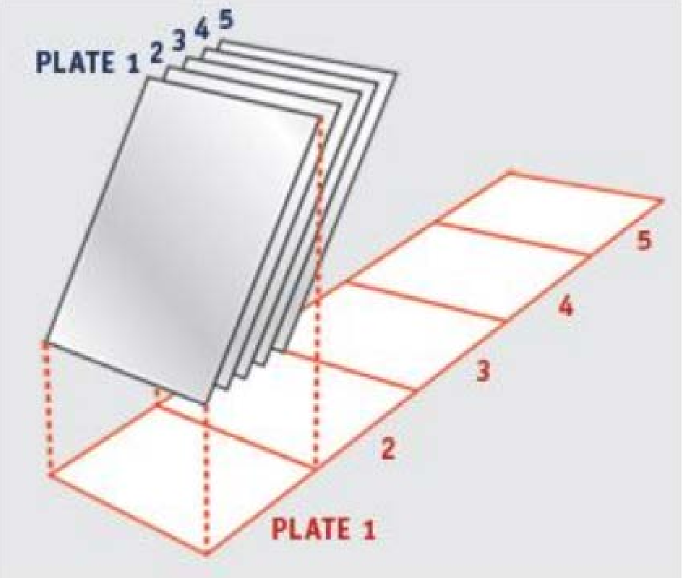
Capacity is Proportional to Horizontal Surface Area

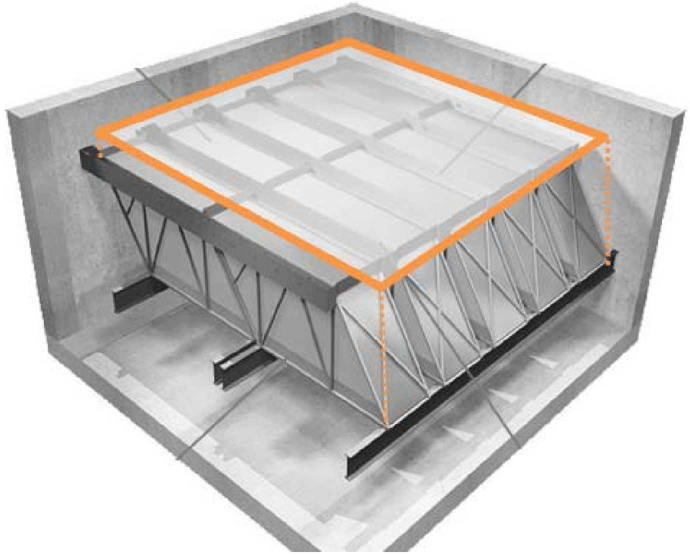
Capacity = Loading Rate x Horizontal Surface Area

gpm gpm/sf sf

For Plate Settlers, Capacity is Based on Surface Loading Rate

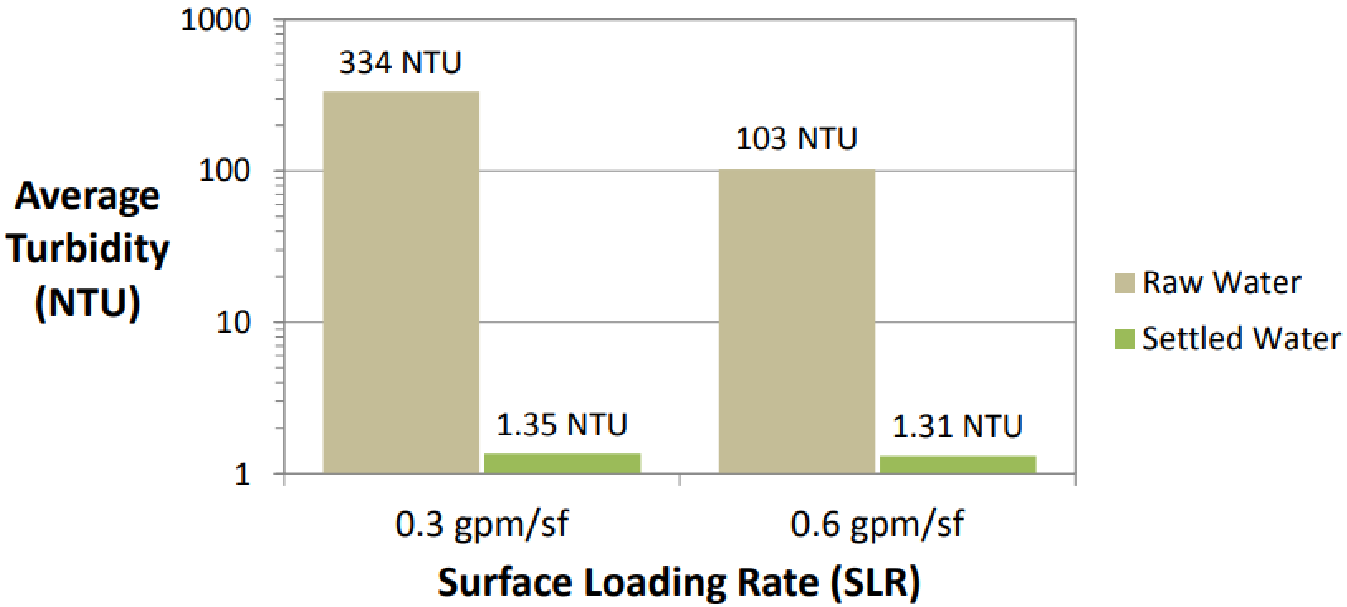
- Surface Loading Rate (SLR) is calculated over vertically projected area
- Typically 0.3 – <1 gpm/sf for conventional sedimentation basins
- Plate/tube settlers could achieve ~ 3 gpm/sf
- Different SLR for different states and projects; pilot data usually required





Example from Missouri City Pilot Study

- Pilot data suggest increasing SLR from 0.3 gpm/ft2 to 0.6 gpm/sf did not increase settled water turbidity
- Doubled the treatment capacity from 11 mgd to 22 mgd



Average Turbidity (NTU)		
Month	Raw Water	Settled Water
April 2013	33	0.70
May 2013	33	0.72
June 2013	43	0.75
July 2013	33	0.84

Tubes or Plates?

	Advantages	Disadvantages
Tube Settlers	• Available in blocks; easily fitted into many different sizes and shapes of tanks and can be held in place by steel supports • Most of them are made in PVC so they are lightweight and economical	• May experience flow distribution issue due to small flow path • Possible blocking • Easier to break • Broken pieces could move downstream to filters or membranes • Settling zone may interfere with incoming water
Plate Settlers	• Constructed in stainless steel with high durability and longevity • Low maintenance • Mounted on stainless steel frames in a modular design for easy installation • Size of basin could be 2X less than that with tube settlers due to its high efficiency	• Requires a certain height of building for installation (plant-specific design could be available from the manufacturers, such as shorter plate) • Initial cost could be higher; but could be offset by it’s longer service life

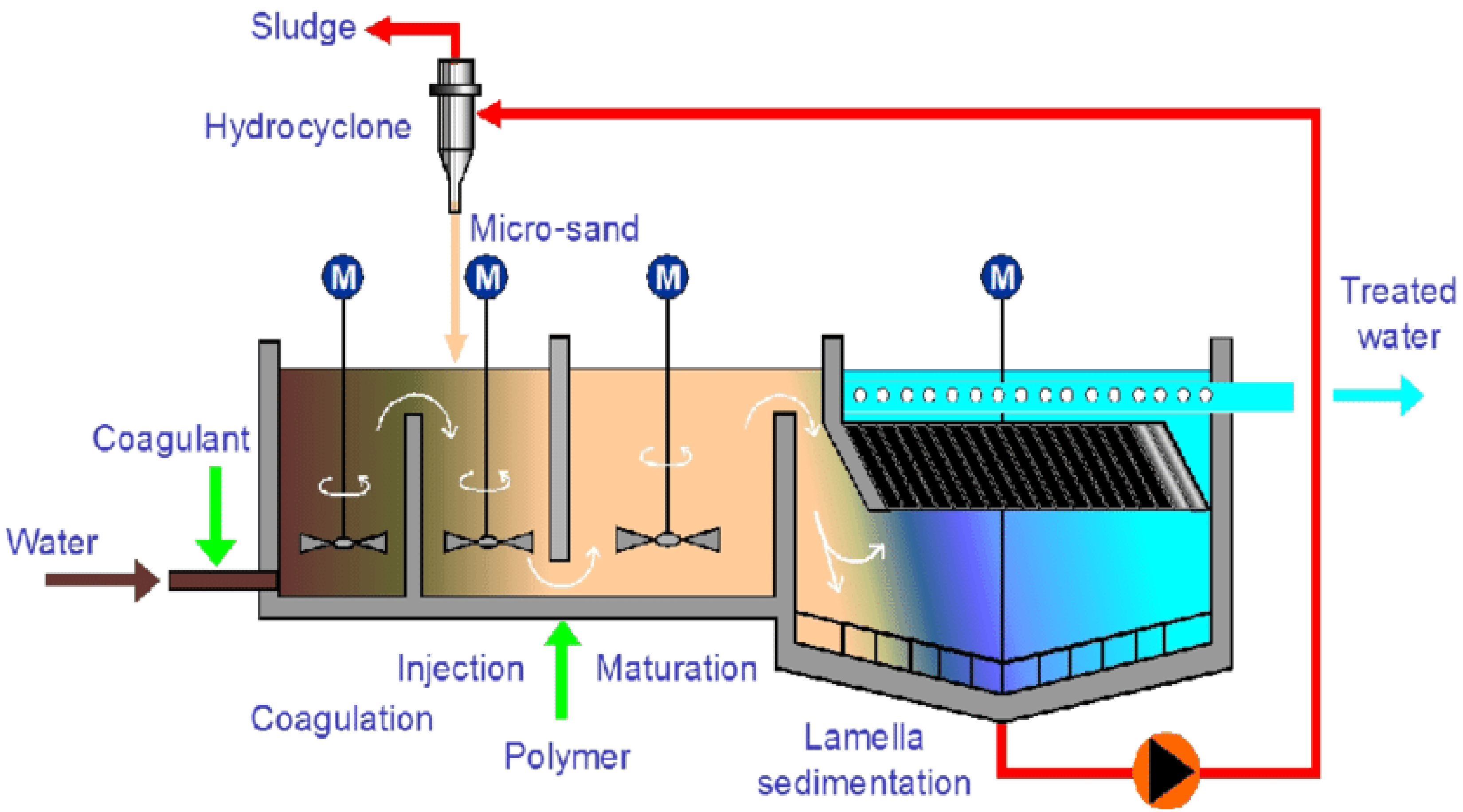
Very High Rate Clarification Process

- Increasing surface loading rate from < 1 gpm/ft^2 to > 30 gpm/ft^2
- High Rate Clarification is achieved via two main schemes
  - Reduce the distance that particles need to travel before they hit the "sludge zone"
  - Make particles heavier

Surface Loading Rate: Quantity of water can be treated per minute per ft^2 of surface area of a treatment process tank. A higher surface loading rate translates to a lower surface area needed of a treatment process, which translate to lower construction costs. However, it is also considered a more "aggressive operation scheme" in the eyes of regulators.

Actiflo Process (by Kruger Veolia)

1. Coagulant added to the feed water
2. Flash mixing
3. Polymer and micro-sand addition
4. Maturation
5. Plate settler
6. Hydrocyclone for the separation of lighter flocs and heavy microsand
7. Return microsand



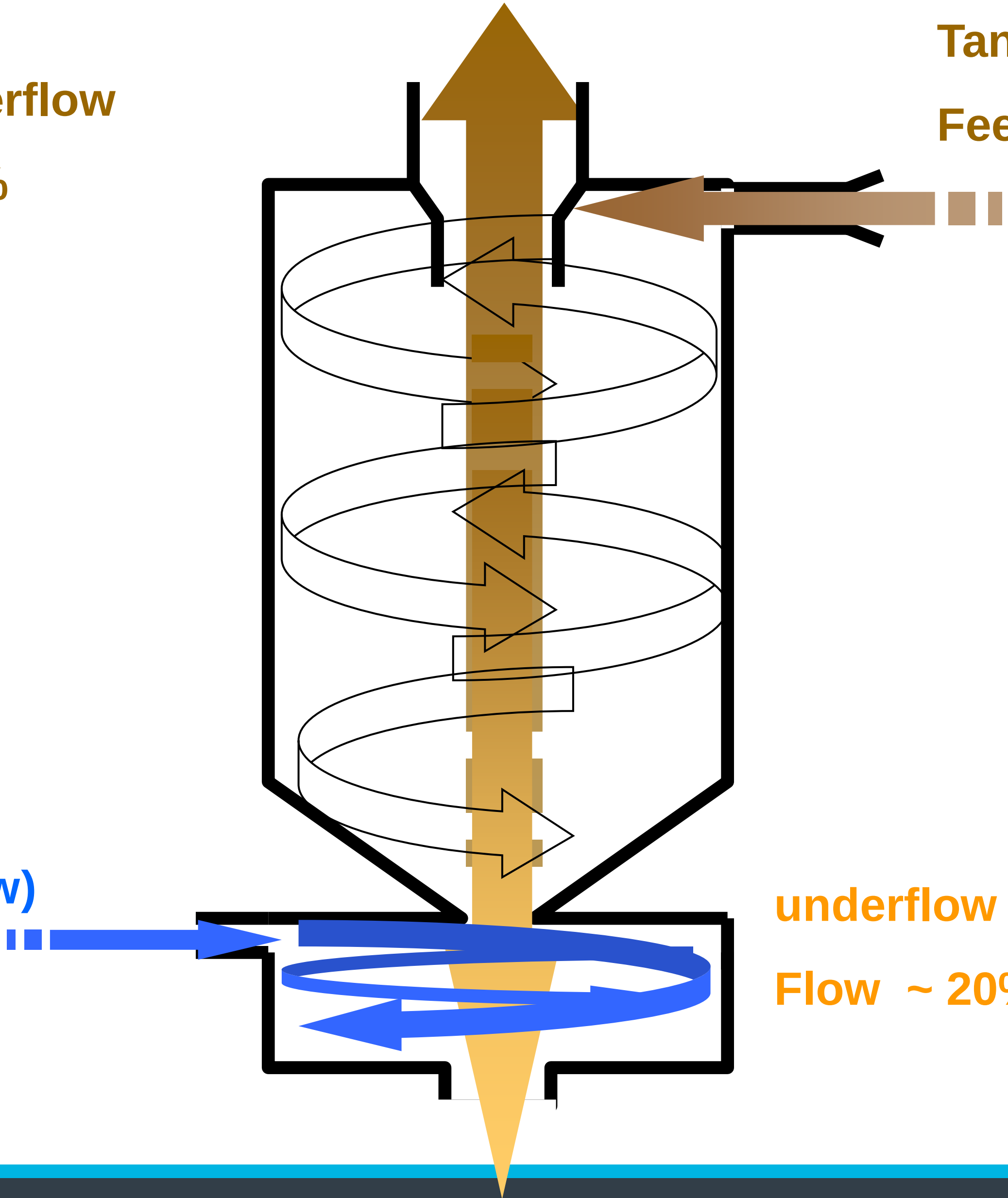
HydroCyclone

Sludge overflow

Flow ~ 90%

Tangential Feed

Feed flow ~ 100%

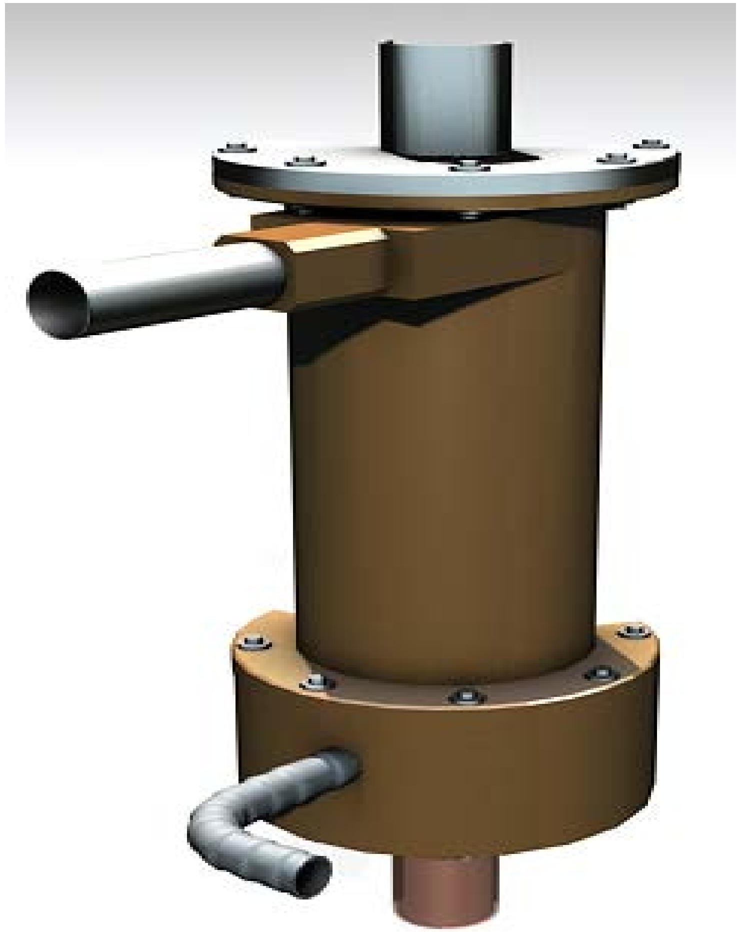


Service water

(10% of feed flow)

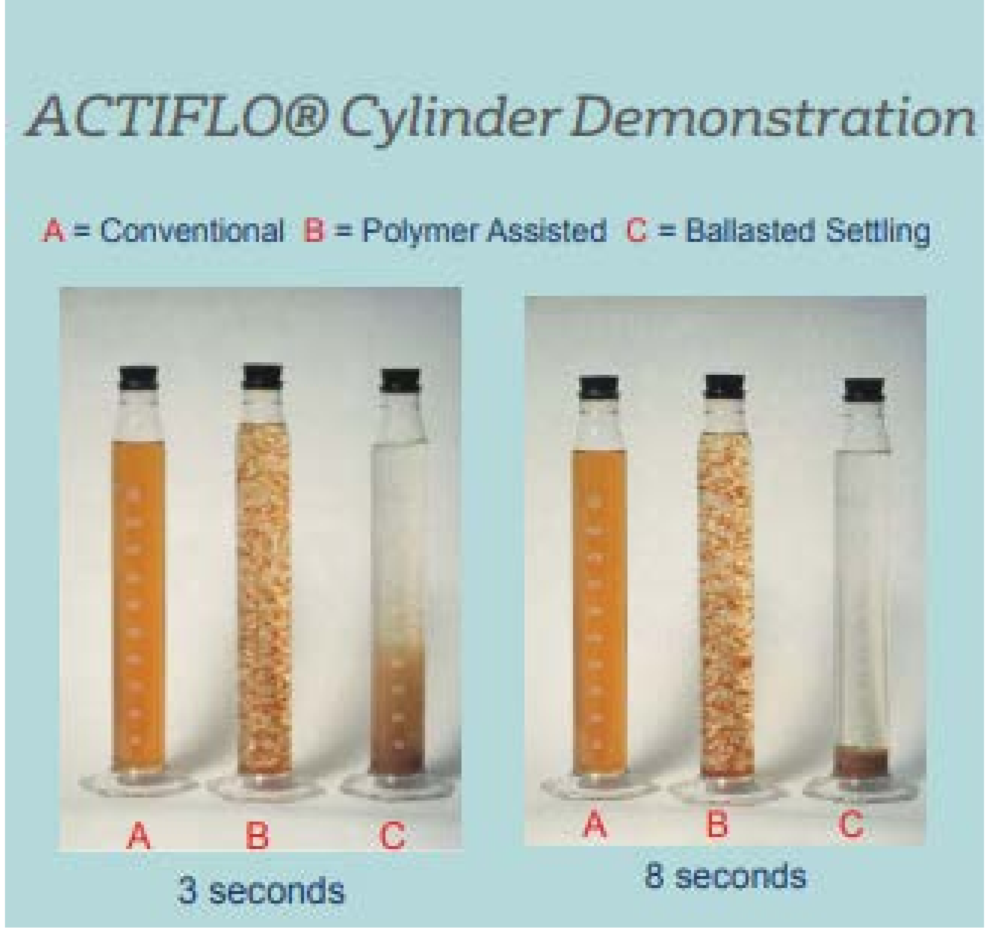
underflow

Flow ~ 20%



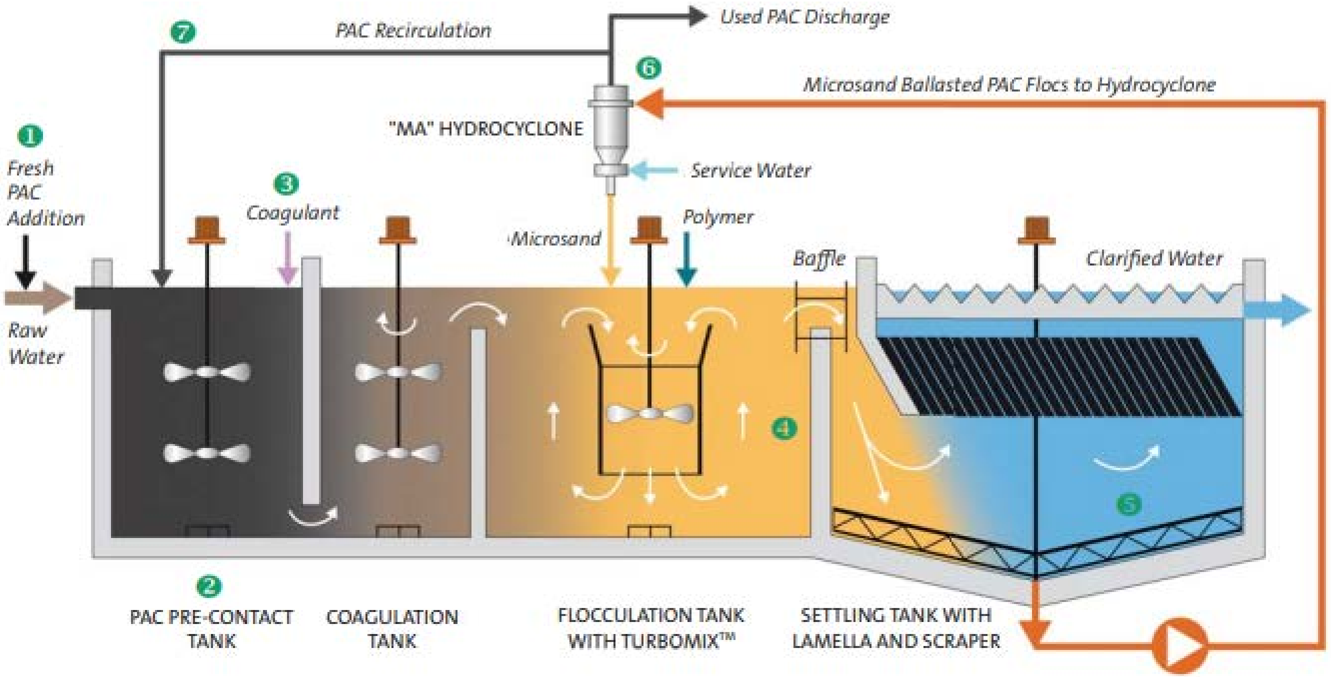
Benefits of Actiflo Process

- Very high clarification rate (> 30 gpm/ft2)
- Requires much smaller footprint (could be 10X smaller)
- Can handle rapid water quality change very well (optimization phase is pretty short; < 15 -20 minutes)
- Sometimes natural sand from the river can be used for sand replacement



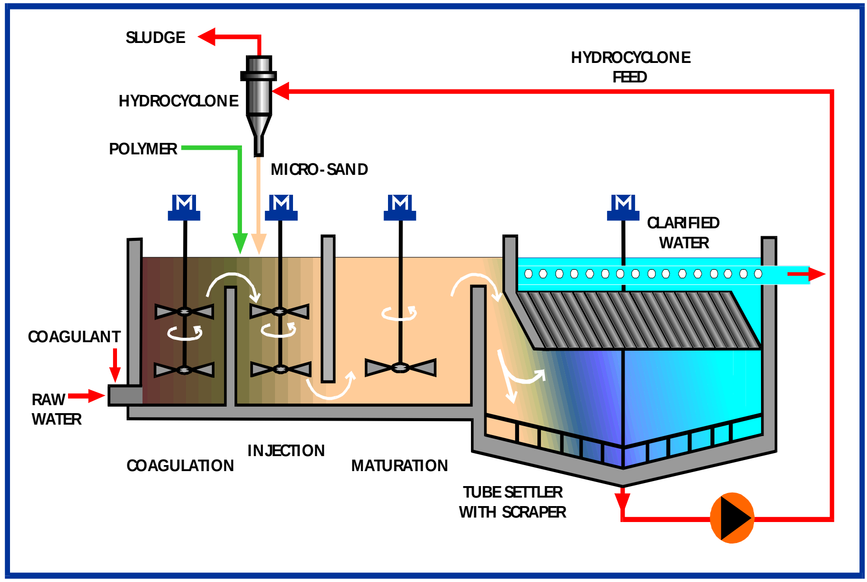
Actiflo Carb (by Kruger)

- Same concept and principles as Actiflo
- Powdered Activated Carbon (PAC) is added to the pre-contact tank for the removal of organic contaminants
- No polymer is used to avoid impact to PAC
- Most of the PAC is recycled



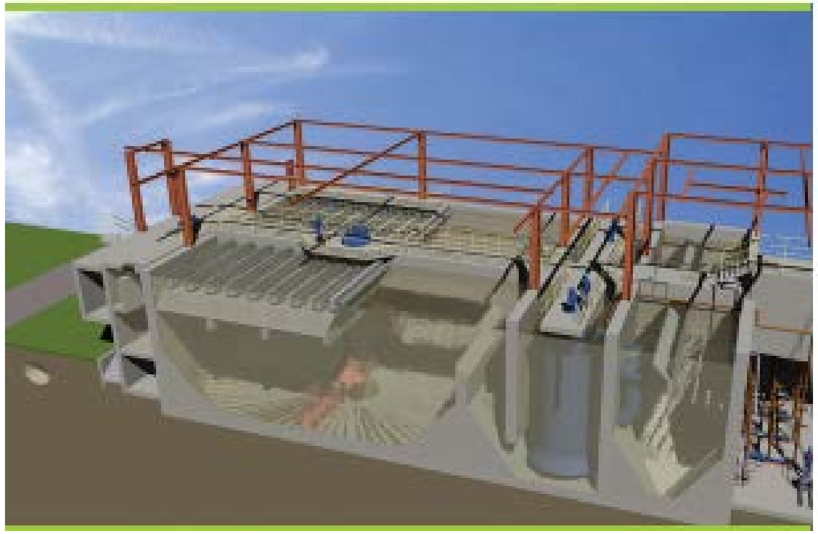
Potential Challenges for Actiflo

- Process depend on mechanical equipment
- Coagulant & polymer doses requirement is higher than conventional processes
- Excessive microsand carry over could happen during initial startup and commissioning
- There will be polymer and sand carry over; depending on dosing scheme
  - Could cause excess solid loading to downstream filters
  - Could cause filter media aggregation if polymer is over-fed
  - Could cause fouling and physical damage to downstream membrane processes



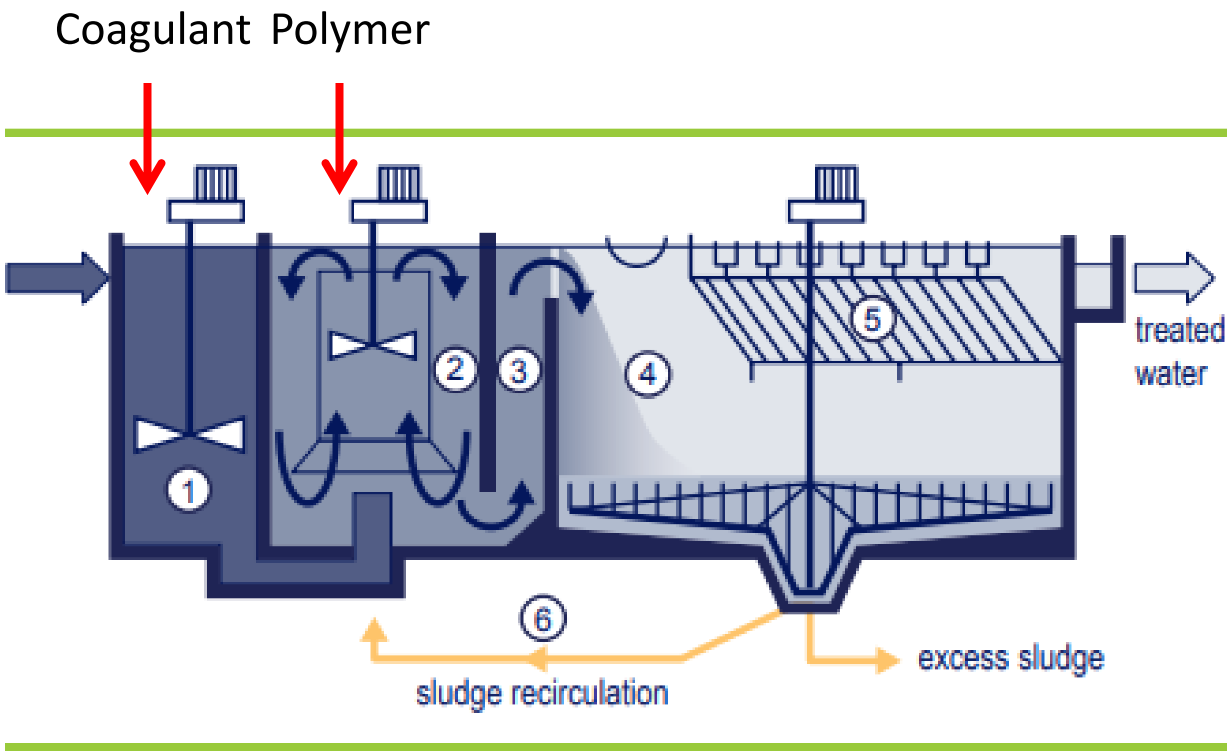
Densadeg

- A “Sludge Contact Clarifier”
- Can be used for drinking water, wastewater, industrial, and storm water
- Combines physical and chemical process to enhance settling rate
- Can produce higher concentration of solids (pre-thickening)



Working Principals for Densadeg

- Step 1: Flash Mixing
- Step 2: Flocculation & thickening (with sludge recirculation)
- Step 3: Transition to sed basin via an upward plug flow
- Step 4: Clarification with larger, denser particles settling down
- Step 5: Lamellar settlers used to settle smaller, less dense particles
- Step 6: Sludge thickening
- Step 7: Sludge to dewatering with partial sludge return



Considerations for Densadag

- Hydraulic Loading Rate: 10 – 15 gpm/ft2
- Could be more sensitive to water quality changes; thereby could experience transient operational challenges at time
- Could provide thicker sludge
- Not as widely used as Actiflo for drinking water treatment

Homework

Homework #1.

Calculate the Surface Loading Rate for a circular clarifier that has a diameter of 60 ft, and receives an influent flow of 1.65 MGD.

Homework #2.

Calculate the Solids Loading Rate for a clarifier with a 31 ft diameter and a depth of 9 feet, and receives a flow of 750,000 gallons per day with a suspended solids concentration of 2,600 mg/L.

Homework #3.

Problem 10-9 on Page 723. Hint: This problem is similar to Example 10 – 6 on Page 684

Homework Due 9/24