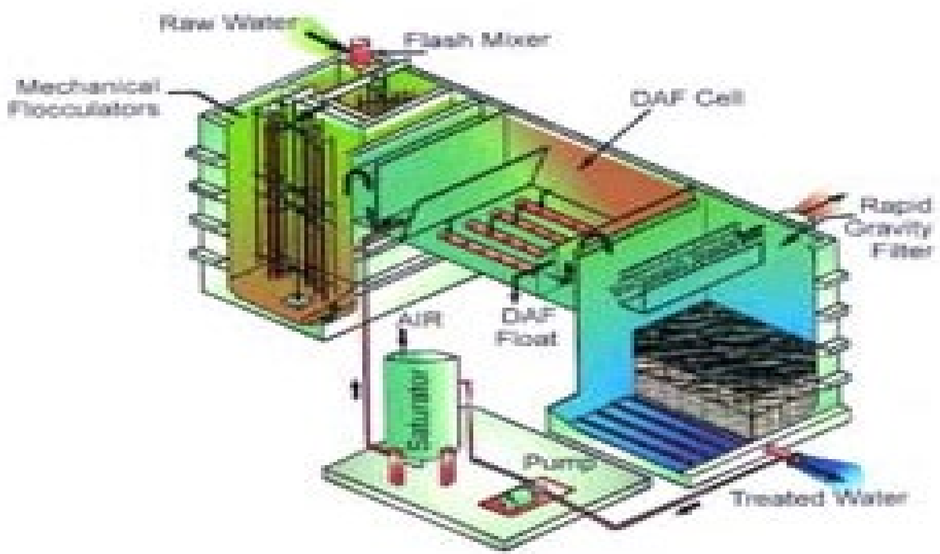
# Sedimentation




## VT/VDH Water Operator Short School

# “*Gonna take a* SEDIMENTAL *journey*” – two hours of memories in the making

# Welcome & demographics

**Participants**

- Water operators
- Technical staff
- Municipal staff
- Regulators
- Consultants



VDH VIRGINIA DEPARTMENT OF HEALTH

# Our learning objectives

At the conclusion of this session you should be able to:

1. Describe turbidity and its role in sedimentation
2. Identify the four zones in a sedimentation basin
3. Name the four types of settling that occur in sedimentation
4. Describe two methods of removing sludge from the sedimentation basin
5. Name two causes of short circuiting

# Thanks for contributions

- Open University
- VDH-ODW staff in Abingdon Field Office
- Previous presentations on sedimentation
- VT & Water Operators short school staff
- Others as noted

# Road map for our journey

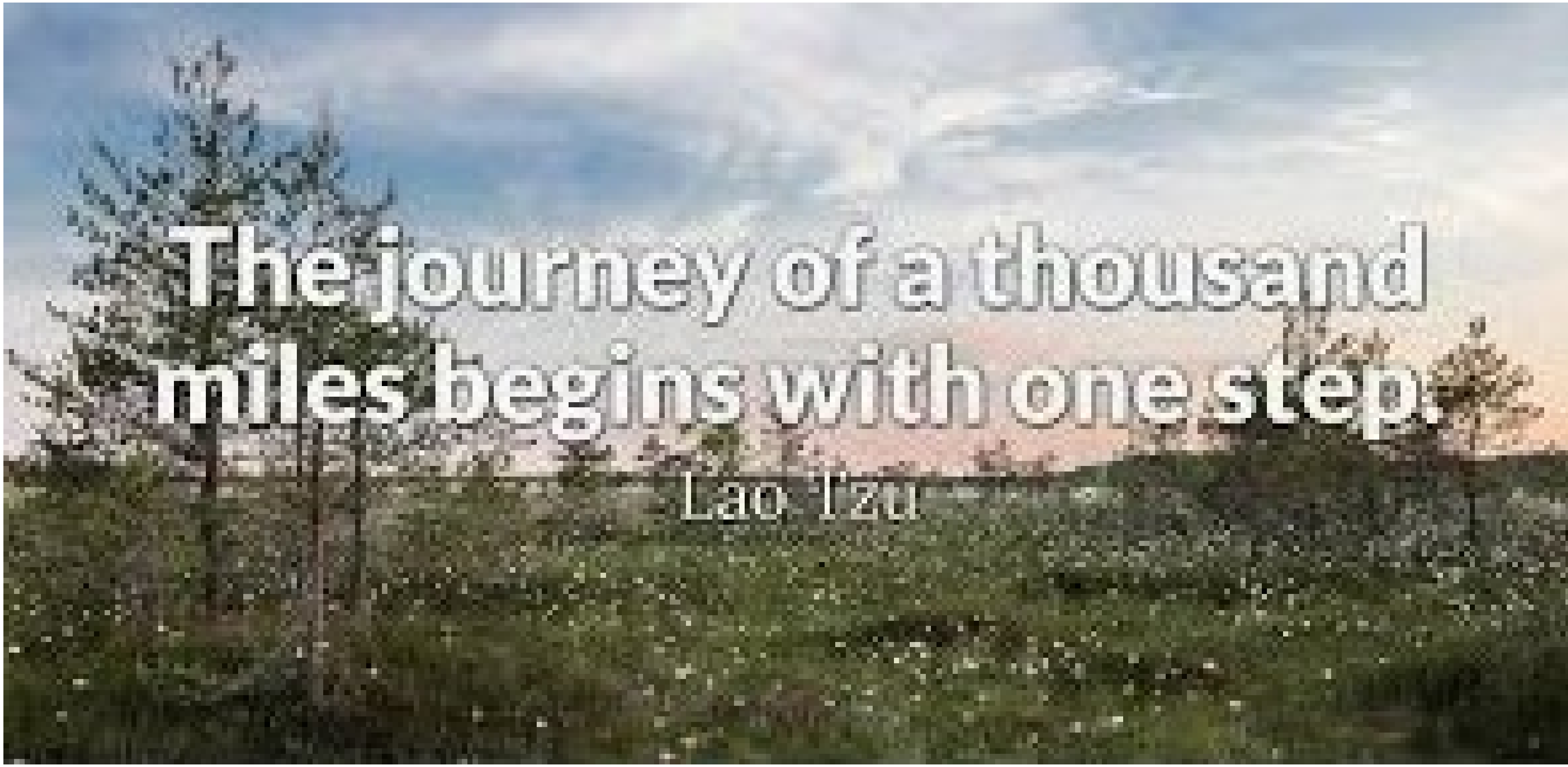
History of US drinking water treatment

WTP overview

Sedimentation

- Theory
- Regulations
- Practice
- Operational

Review and conclusion


The journey of a thousand miles begins with one step.
Lao Tzu

# Road map for our journey

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# Drinking water treatment through time

1500 BC: Egyptians used coagulation -Alum

800 BC: Prophet Elisha adds coagulation – salt

500 BC: Hippocrates – sieving water

250 BC: Roman aqueducts, Archimedes screw pump

1685 AD: Philippe de la Hire – sand filter

1804 AD: Paisley, Scotland – first municipal WTP

1828 AD: Richmond VA slow sand filter

1854 AD: Dr. John Snow & Broad St pump

1880 AD: Louis Pasteur – germ theory

# Drinking water delivery from long ago

# Broad Street Pump epidemiology


# 20th Century drinking water treatment

George W. Fuller

- 1895-97 & 1897-99:  Rapid sand filter development
- 1908: Designed/built chlorination system (40 MGD)

1906: UV disinfection (>1,000 by 1996)

1914: AWWA Standards

1936: Chloramines used in Denver

1974: Safe Drinking Water Act

1979: Total Trihalomethane Rule

1991: Lead and Copper Rule

1996: SDWA Amendments



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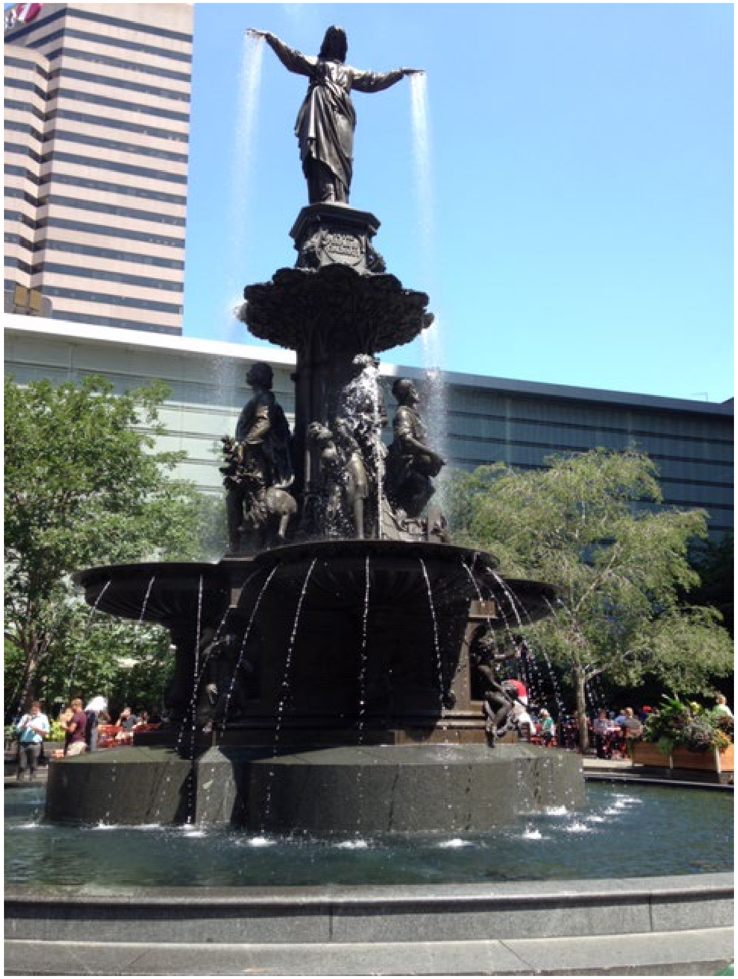
# Louisville & Cincinnati



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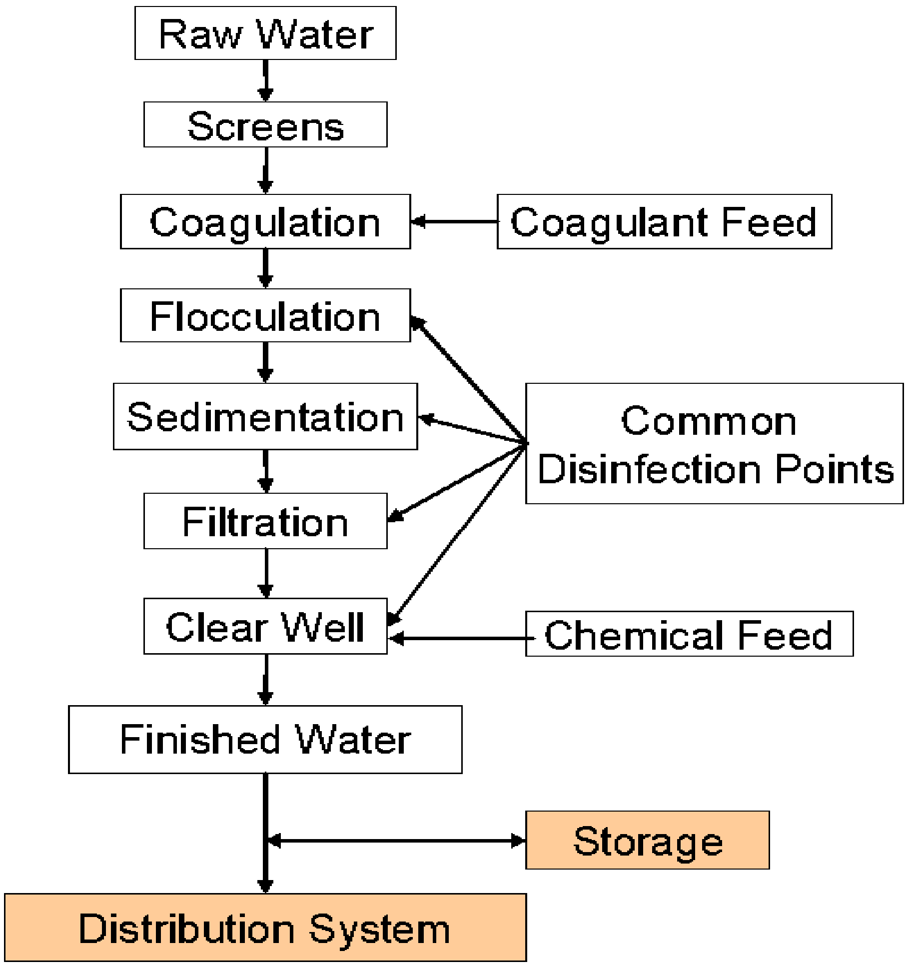
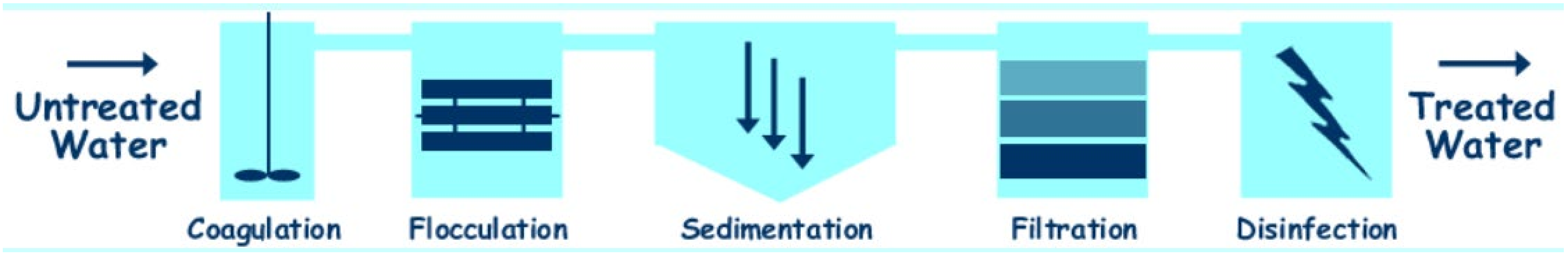
# WTP Overview

Lawrence Alexander, *Through Hiker's Eyes*

# Typical treatment components



# Typical WTP operations




**Make water potable**

- -Remove pathogens
- -Remove harmful materials

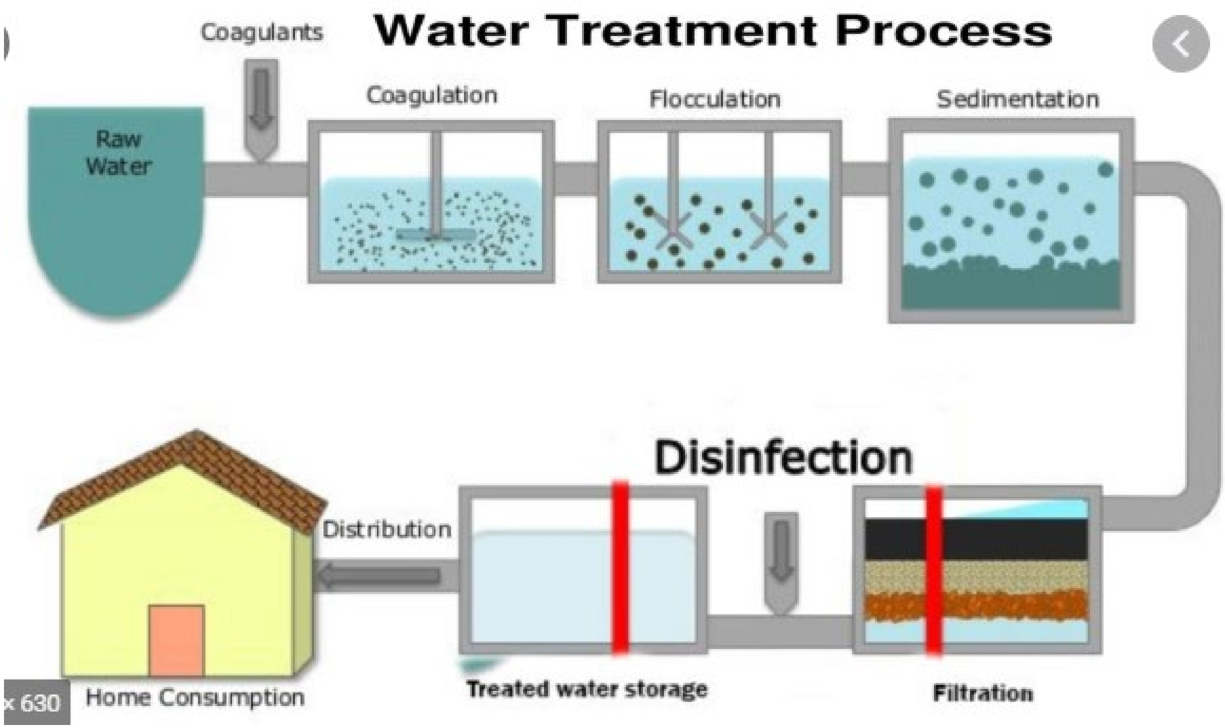
**Make water palatable**

- -Aesthetic qualities
  - -Taste & odor
  - -Mineral staining

# Contents of raw water

- Microorganisms
- Colloidal material
- Sediment
- Organic material

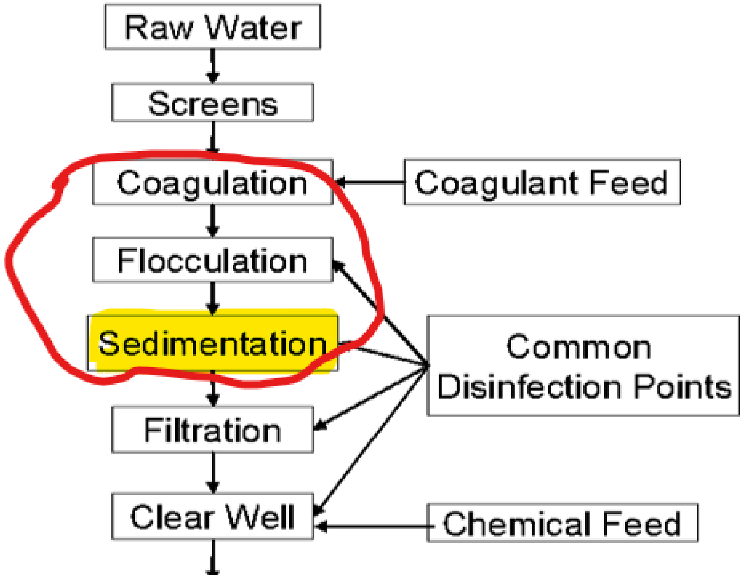
# Typical Treatment Scheme



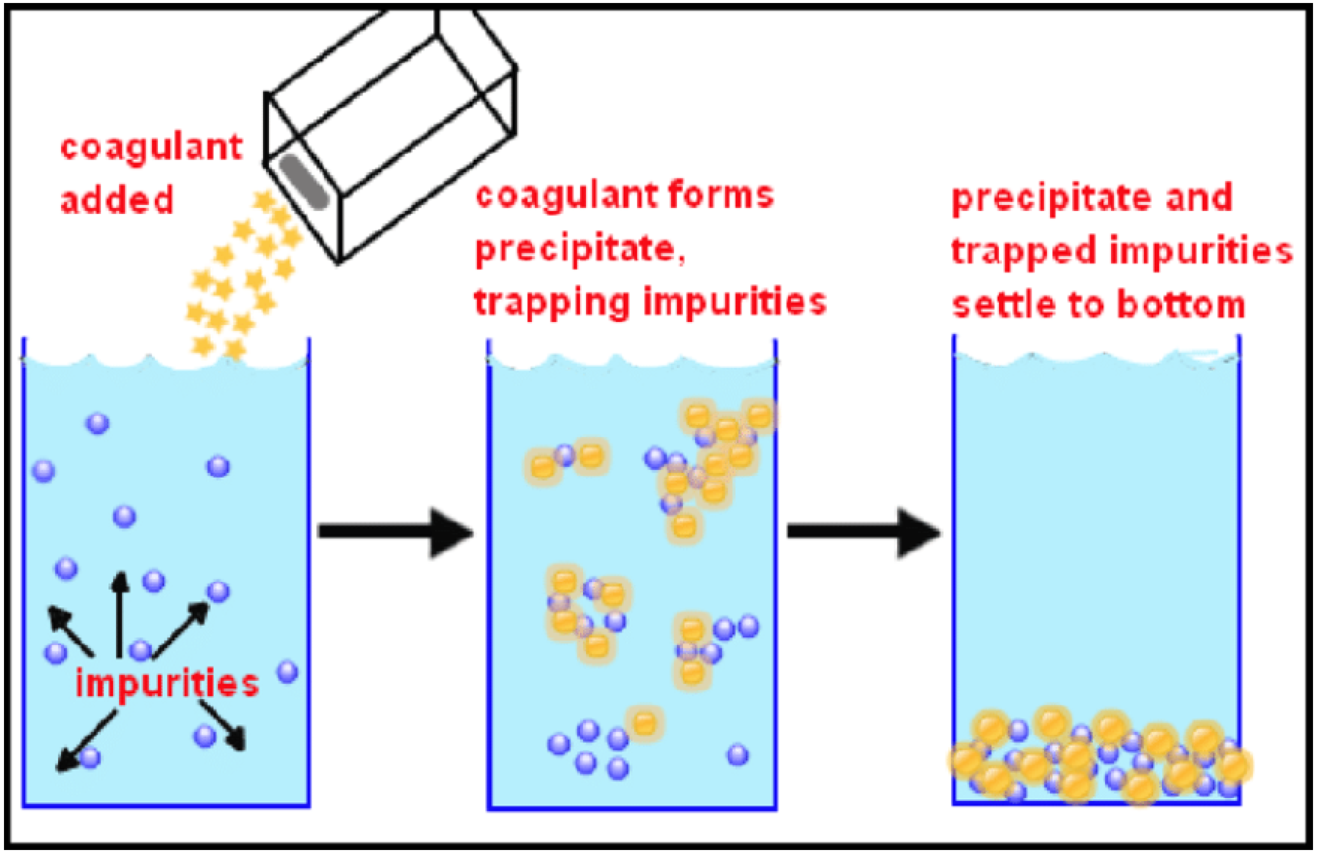

From Chemical Engineering World website

# Flocculators & sed basins

# Coagulation, flocculation, & Sedimentation work together



# Coagulation, flocculation, & Sedimentation work together




3: Coagulation, flocculation, and sedimentation processes [30].

From Oleiwi, Hussein



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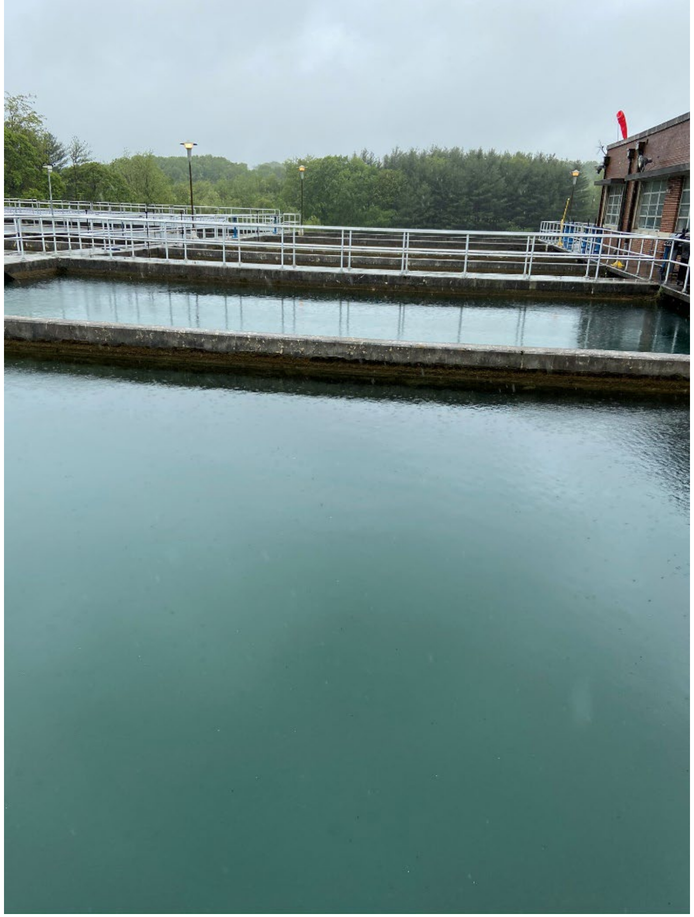
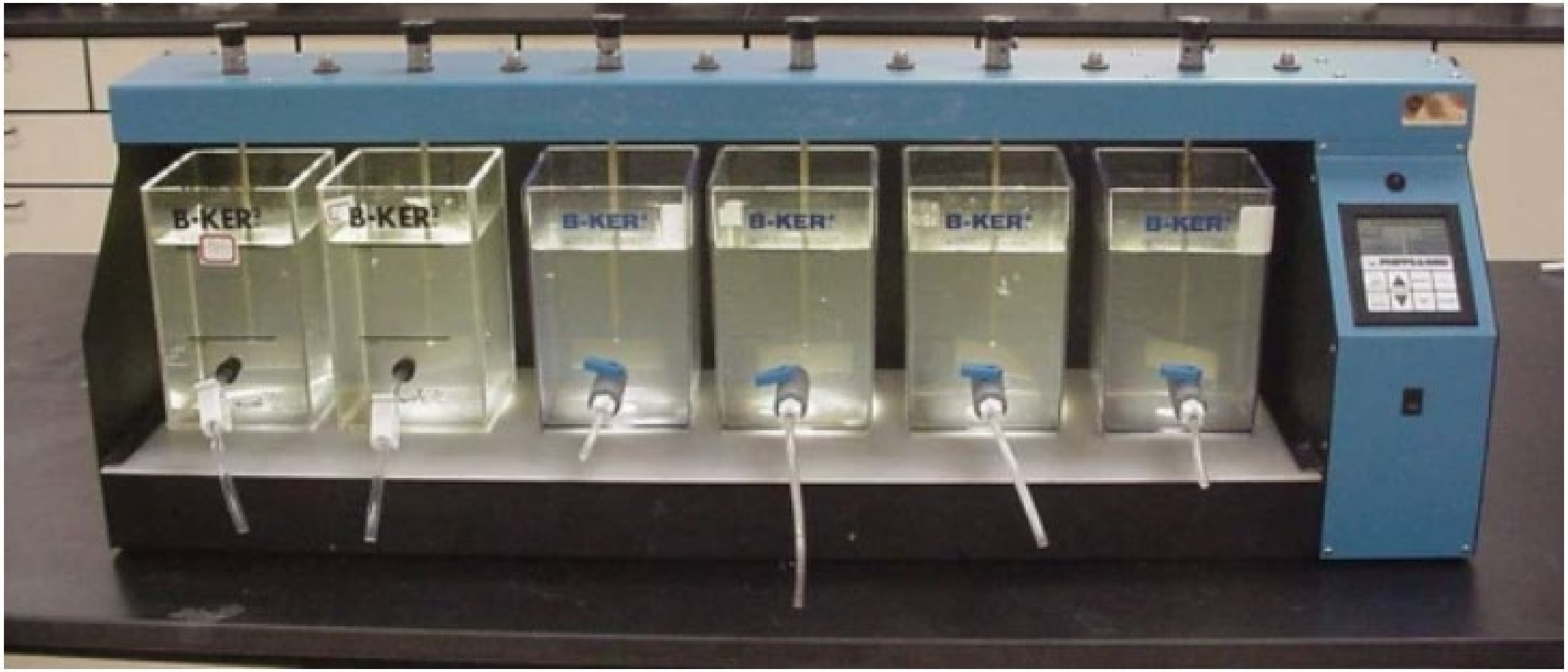
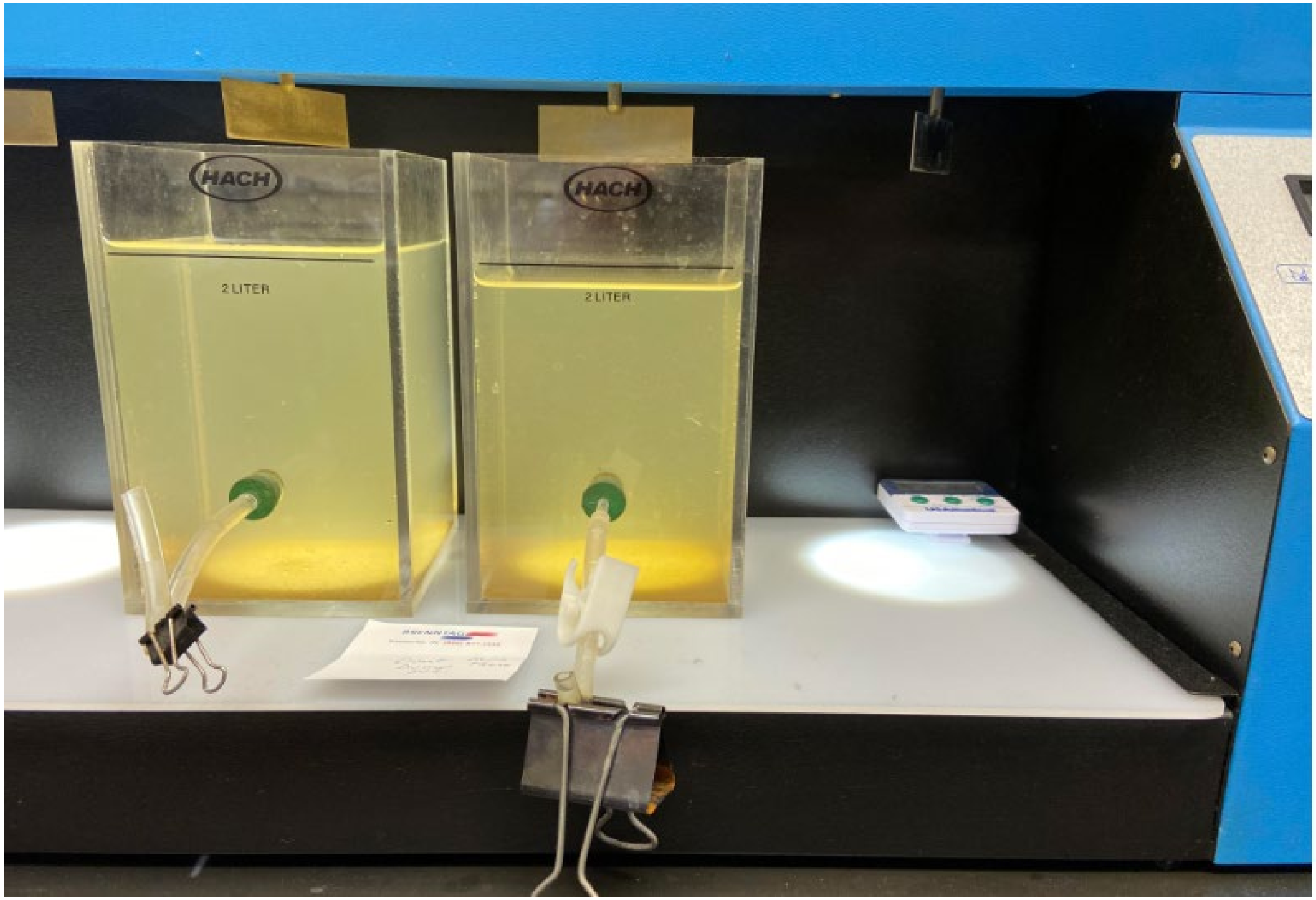
# Sedimentation basin good floc



# Jar Test Apparatus



# Jar Test apparatus



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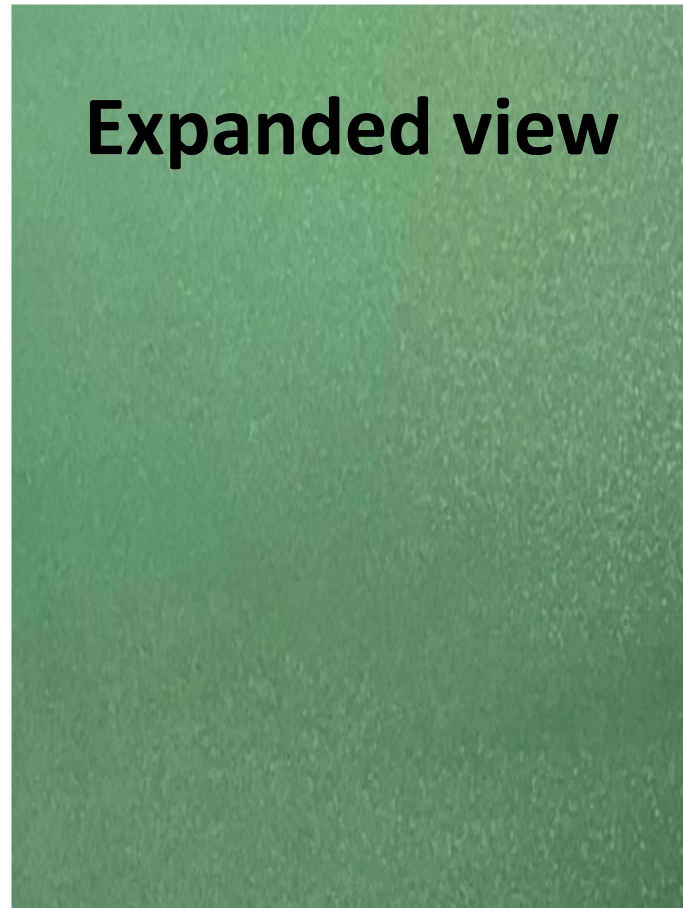
# Well-formed floc



# Coagulation, flocculation, & Sedimentation work together

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# Sedimentation

- Also called *clarification*
- Removal of settleable material by gravity
- The process upstream of filtration (typically)
- Water moves slowly through tank with a minimum of turbulence at entry and exit points with minimum short-circuiting (quiescent conditions)

# Quantifying water purity

**Turbidity** describes the cloudiness or haziness of water

**Turbidity** measures the amount of light that is scattered by material in water, the degree which water loses its transparency

**Turbidity** is a surrogate measure for water treatment effectiveness

# Our learning objectives

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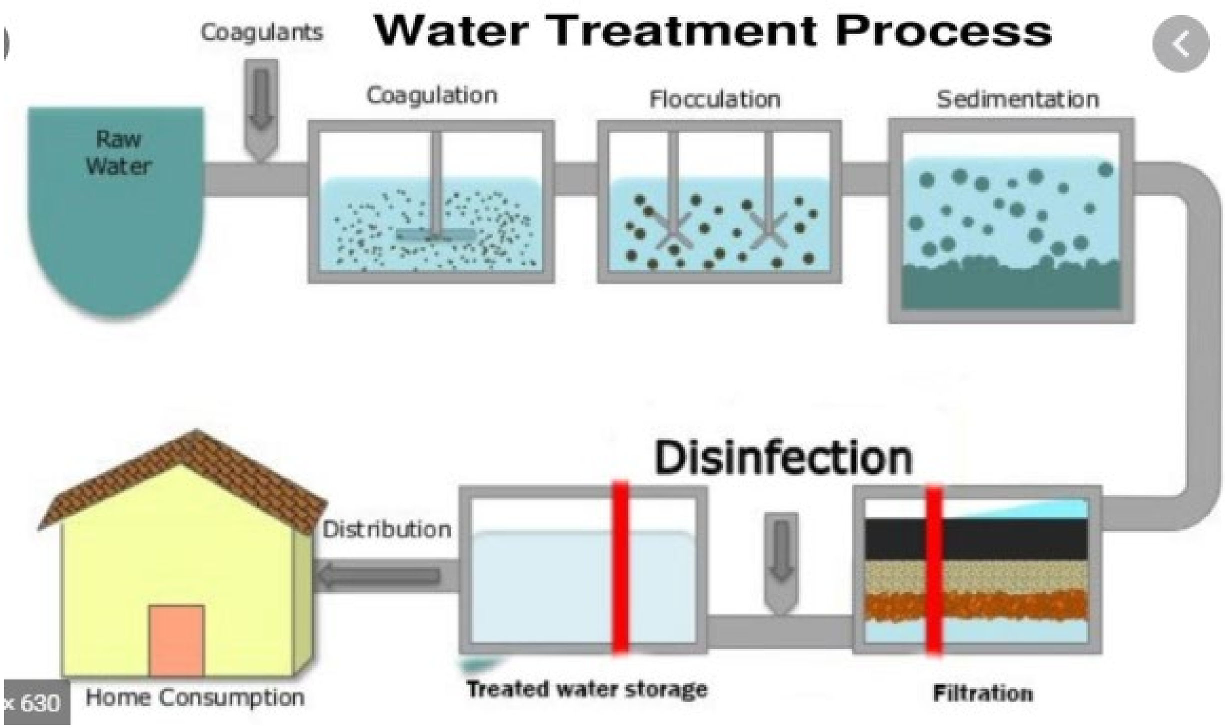
5. Name two causes of short circuiting

# Goals of sedimentation

- Optimum removal of pathogens
- Settled water sent (“applied”) to filters has low turbidity
- Effectiveness not dependent on the initial raw water turbidity

# Typical Treatment Scheme




From Chemical Engineering World website

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# Sedimentation basin zones

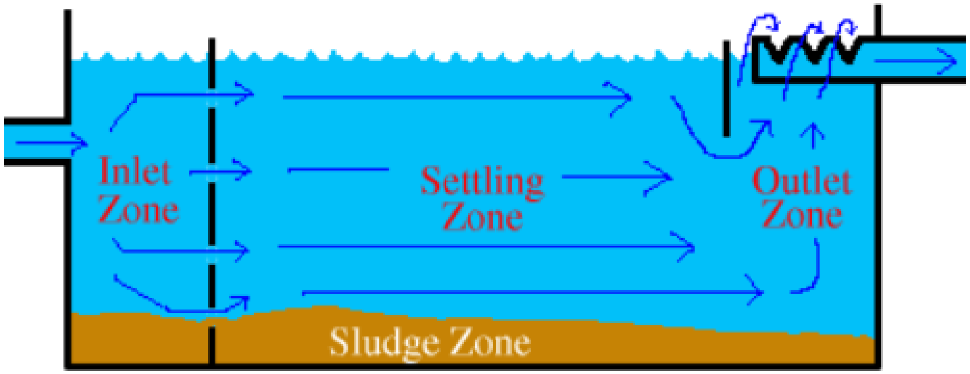
Influent Zone - decreases the velocity of the incoming water and distributes the flow evenly across the basin

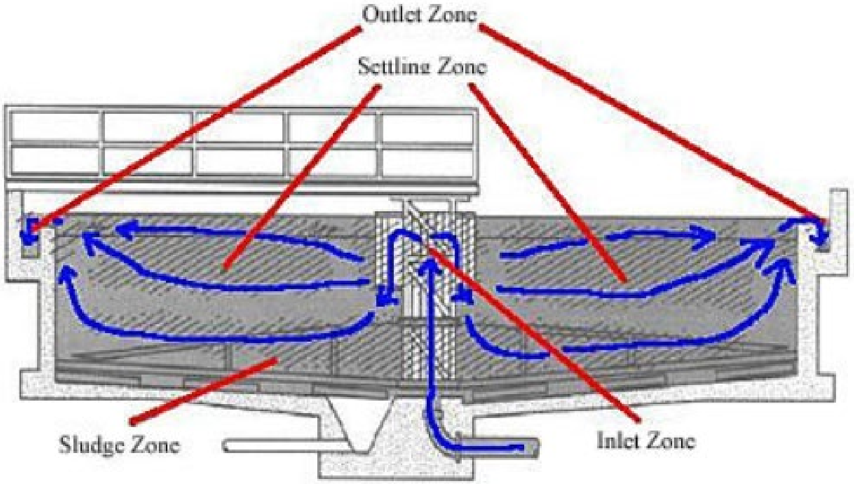
Settling Zone - provides the calm(quiescent) area necessary for the suspended material to settle

Effluent Zone - provides a smooth transition to the effluent flow area from the settling zone

Sludge Zone - receives the settled solids

# Sedimentation Basin Zones



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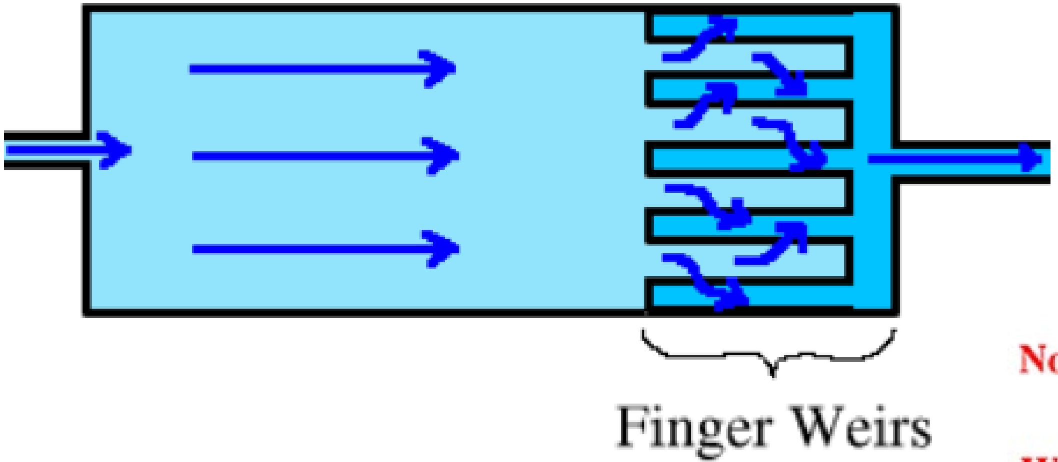
# Parts of a sedimentation basin

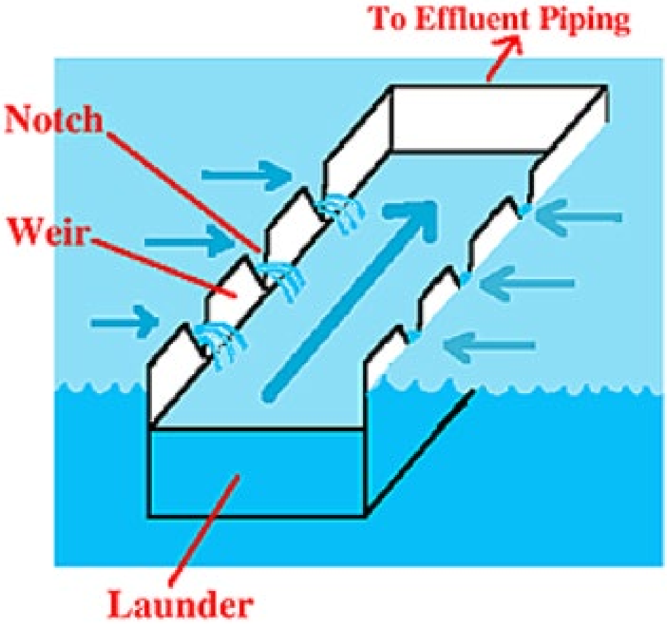
**Inlet** - distributes the influent evenly across the (or around) the basin so the water will flow uniformly

**Inlet Baffle** - reduces the velocity of the incoming water and helps produce calm, nonturbulent flow conditions for the settling zone

**Effluent Launder** (***trough***) - collects settled water exiting the basin and conveys it to the effluent pipeline (channel) to the filters

# Effluent launder



# Types of sedimentation

Type 1 – discrete
Type 2 – flocculant
Type 3 – hindered
Type 4 - compression

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# Basin depth & settling velocity

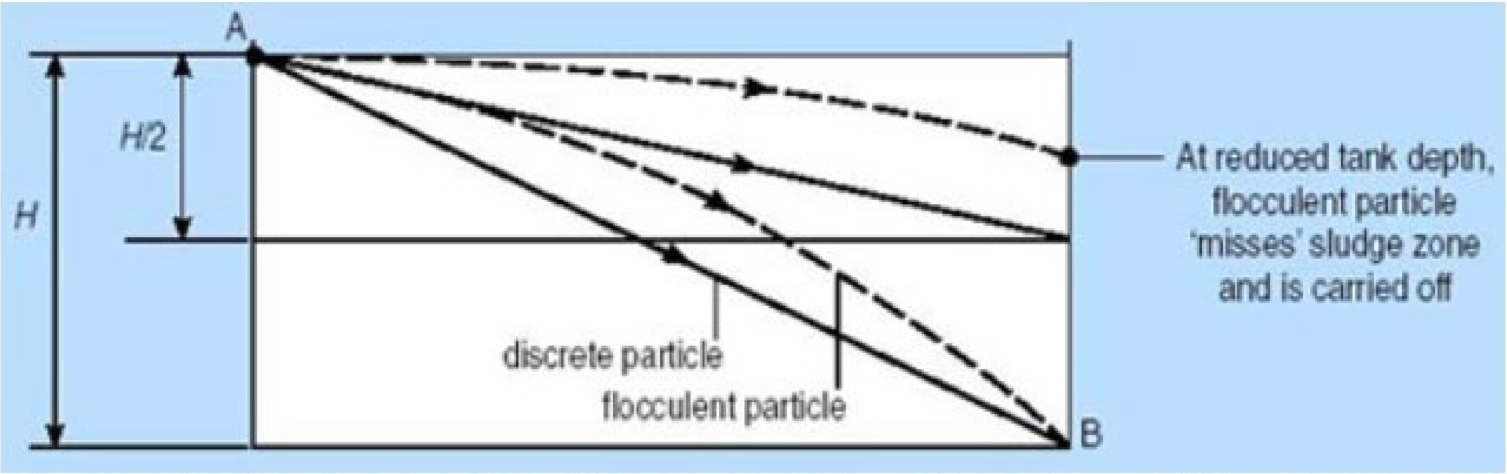


Figure 26 Effect of tank depth on removal of discrete and flocculent particles

From Open University

# Settling velocity constraints

- Horizontal – flocs settle in less time than forward flow
- Vertical – flocs settle in less time than overflow rate

- Overflow rate $= \dfrac{\text{FLOW}}{\text{Surface Area}} \dfrac{(gpm)}{(ft2)}$



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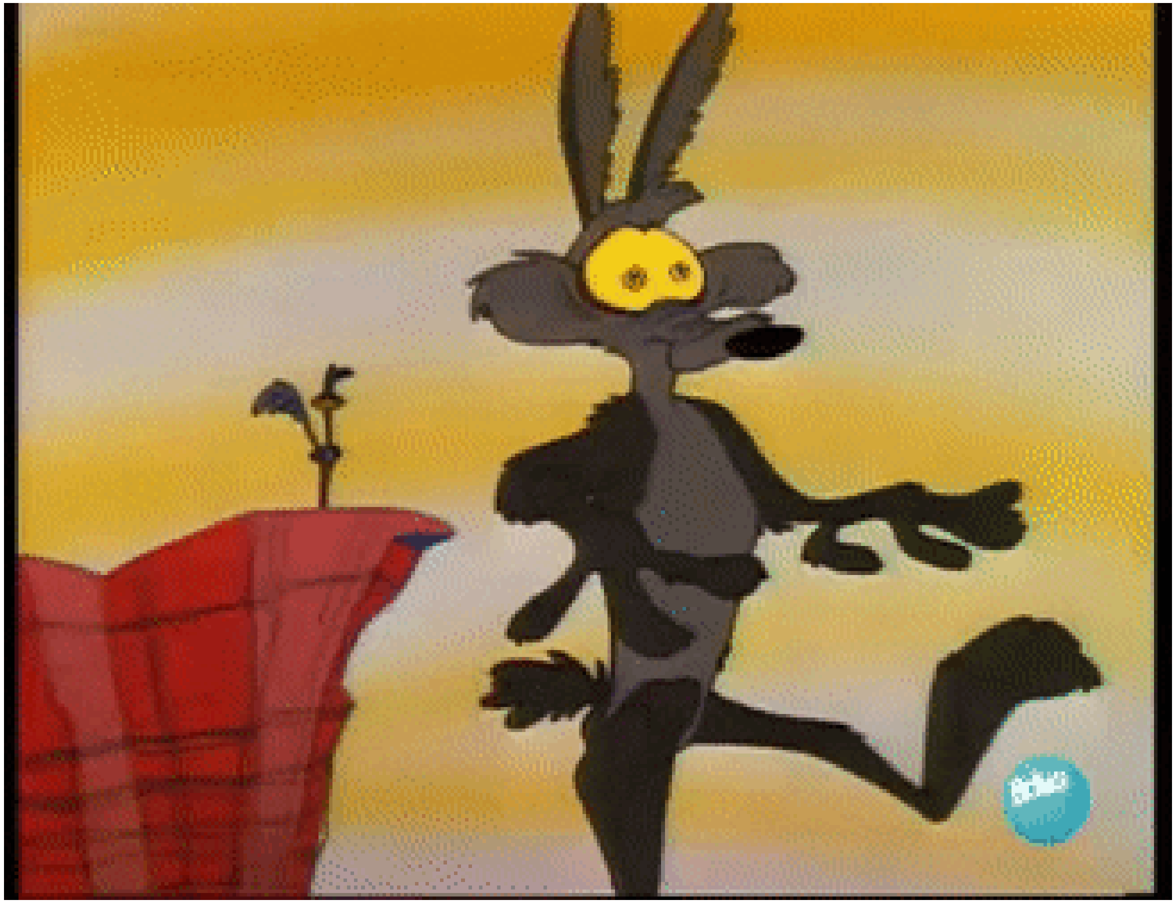
# Settling velocity



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# VA *Waterworks Regulations*

## 12VAC5-590-871. Coagulation and flocculation.

A. Rapid mixing is the rapid dispersion of chemicals throughout the water to be treated, usually by violent agitation, to promote coagulation.

1. Rapid mix basins or inline static mixers shall be provided.

2. Basins shall be equipped with mechanical mixing devices. Other arrangements, such as baffling, may be acceptable under special conditions and only when approved by the department. Where mechanical mixing devices are utilized, duplicate units or spare mixing equipment shall be provided.

3. Rapid mix basins with mechanical mixers should be based upon the mean temporal velocity gradient "G" (expressed as units of seconds$^{-1}$). The owner's engineer shall submit the basis for the selected velocity gradient considering the chemicals to be added and water temperature. Typical values for G and T are:

TABLE 871.1

Rapid Mix Basin GT Values

| T (seconds) | G (seconds$^{-1}$) |
|---|---|
| 20 | 1,000 |
| 30 | 900 |
| 40 | 700 |
| 60 | 600 |

a. The point of application of the coagulant shall be at the point of maximum mixing intensity;

b. The physical configuration of the mixing basin shall be designed to eliminate vortexing; and

c. Mechanical mixers should be designed to allow speed variation with a highest speed of at least three times the lowest speed.

# VA *Waterworks Regulations*

B. Flocculation mixing is the agitation of treated water at low velocity gradients for sufficient time to agglomerate coagulated particles.

1. Basin inlet and outlet design shall prevent short circuiting and destruction of floc. A drain and overflow shall be provided. Multiple units shall be provided for continuous operability, and each basin shall be designed so that individual basins may be isolated without disrupting plant operation. Basins shall be arranged to allow for either series or parallel operation.

2. Design parameters:

a. The minimum detention time shall be 30 minutes for water treatment plants employing rapid rate gravity filters, and 20 minutes for water treatment plants using high rate gravity filters. Basin flow-through velocity should not be less than 0.5 ft/min or greater than 1.5 ft/min.

b. The design of the flocculation units shall be based upon the value of GT, which is ordinarily in the range of 20,000 to 200,000. The owner's engineer should establish the value of GT through experimentation.

c. Agitators shall be driven by variable speed drive units with peripheral tip speed of the paddles ranging from 0.5 to 3.0 ft/sec.

d. To control short circuiting in mechanical flocculators, at least three successive compartments should be provided. In addition, special attention should be given to the ports between compartments to further suppress short circuiting.

e. To accomplish maximum power input and reduce particle shearing, tapered flocculation should be provided.

f. In basins utilizing vertical shaft flocculators, wing walls, or stators shall be provided to prevent vortexing.

# VA *Waterworks Regulations*

## 12VAC5-590-872. Sedimentation.

A. The water treatment plant capacity, source water quality, and filtration process used shall be considered in determining the number and design of sedimentation basins.

B. The minimum settling time shall be four hours for water treatment plants employing rapid rate gravity filters, and a minimum of three hours for water treatment plants using high rate gravity filters. Reduced settling times may be approved by the department where effective settling is demonstrated. Effective settling time shall be calculated using the volume of the basins from the stilling wall to the submerged effluent orifice or weir, including the volume under launders or finger weirs.

C. Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, stilling walls, and similar entrance arrangements are required. Port velocities should be in the range of 0.5 to 1.5 ft/sec. Where stilling walls are not provided, a baffle shall be constructed across the basin close to the inlet and shall project several feet below the water surface to dissipate inlet velocities and provide uniform flows across the basin.

D. Outlet weirs or submerged orifices shall be designed to maintain settling velocities in the basin and minimize short circuiting. Outlet weirs and submerged orifices shall be designed as follows:

**Darth Vader's rarely photographed wife--Ella. Ella Vader.**

# VA. *Waterworks Regulations* Design Requirements

**Detention Time**:

- 4-hour detention time for conventional sedimentation with rapid rate filtration ($\leq$ 2 gpm/ft$^2$)
- 3-hour detention time for conventional sedimentation with high rate filtration (2 to 4 gpm/ft$^2$)
- Proprietary types of sedimentation may only require 1 to 2 hours of detention time

**Rectangular basins**

- 4 to 1 length to width ratio
- Surface overflow rates 0.25 to 0.38 gpm/sq. ft.
- velocity: 1 ft/min through basin

# Our journey continues …

# Road map for our journey

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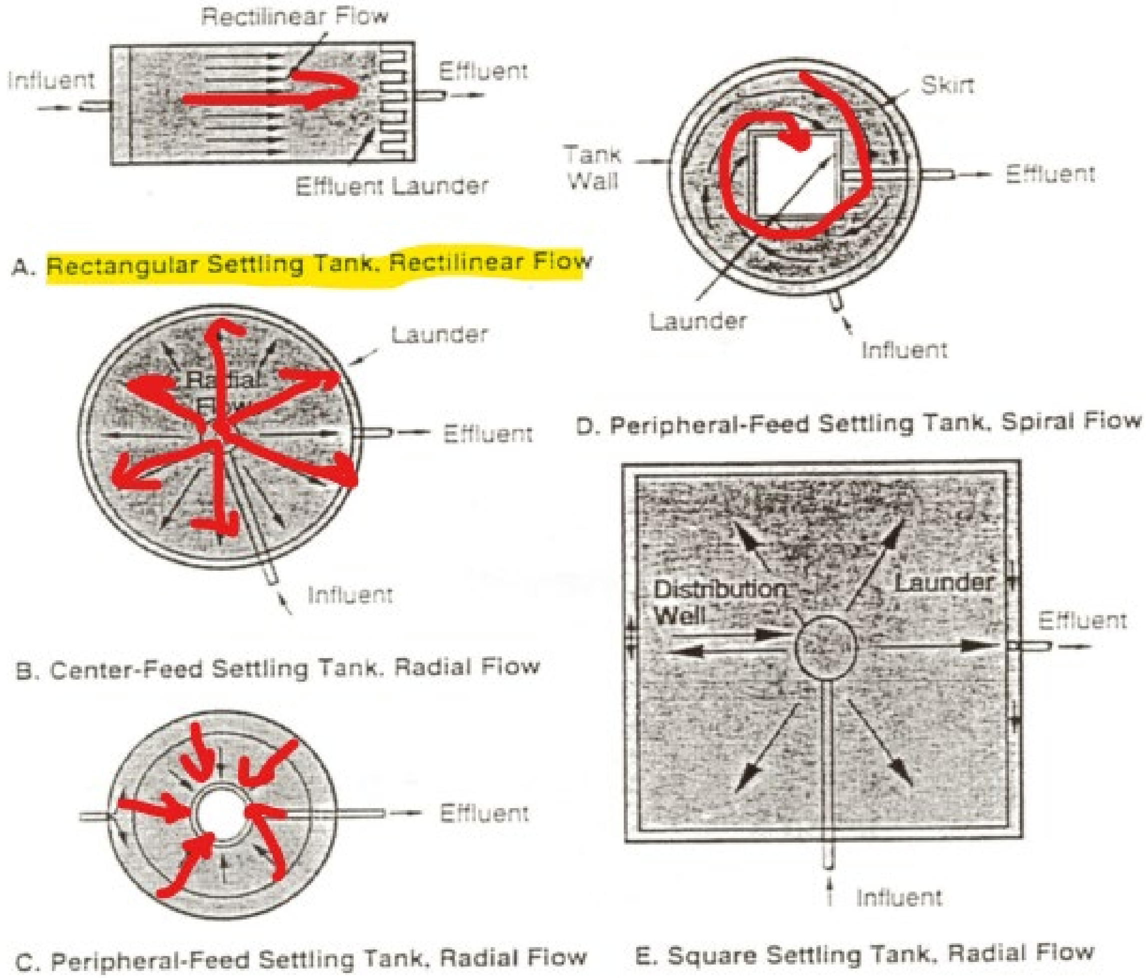
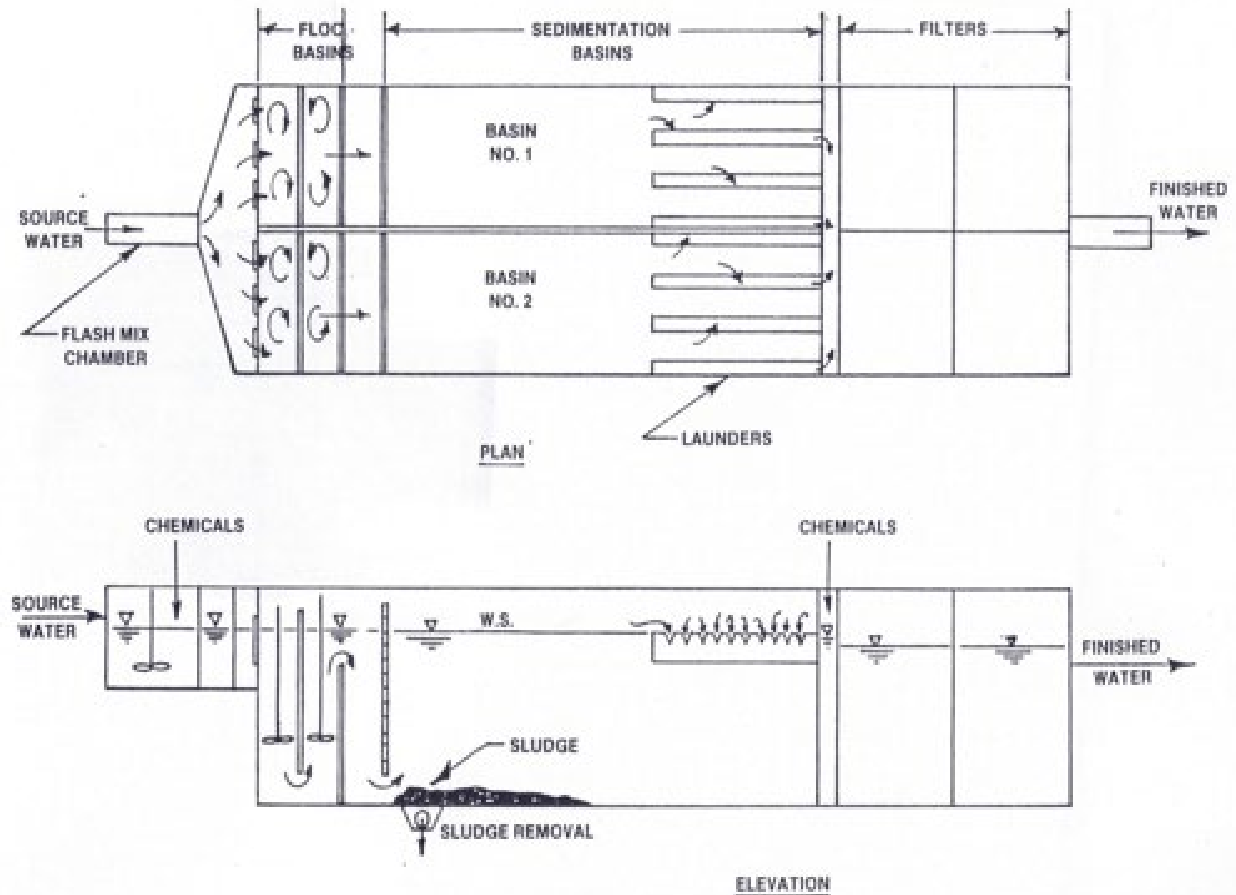
# Types of basins/tanks

- Conventional rectangular basins
- Conventional center-feed basins
- Peripheral-feed basins
- Spiral-flow basins

# Types of basins/tanks



# Rectangular sedimentation basin



# Baffle wall

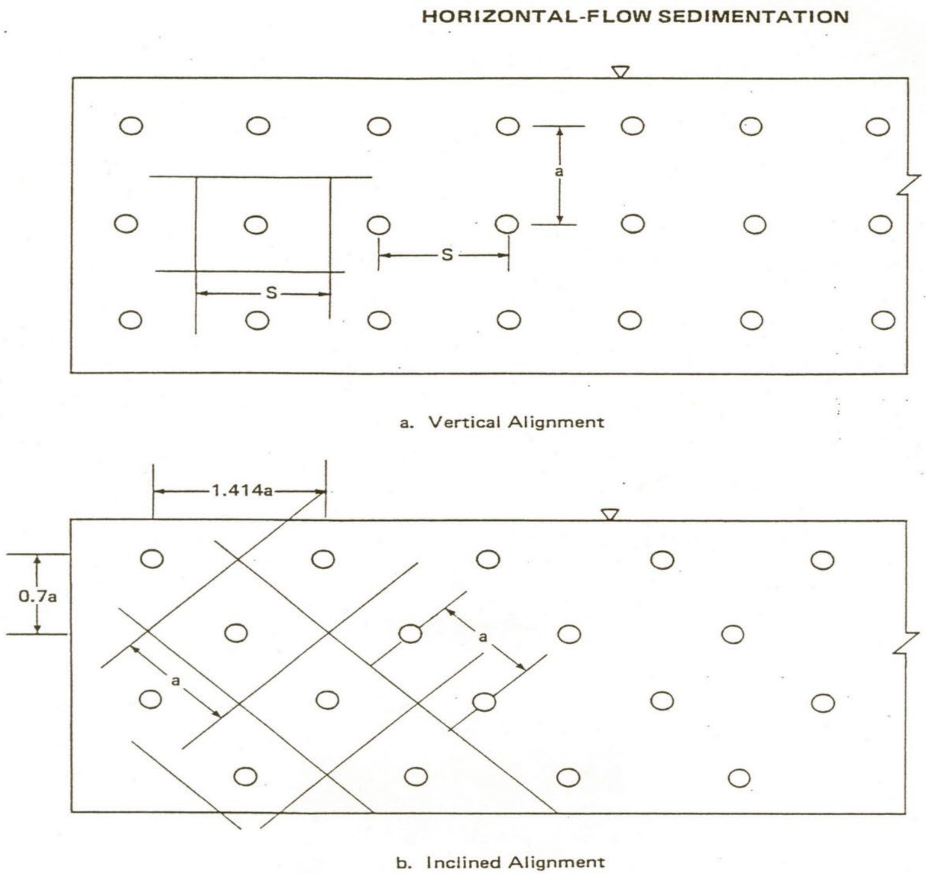



Figure 8–2. Port arrangements in perforated-baffle basin inlet wall.

# Circular sedimentation basin

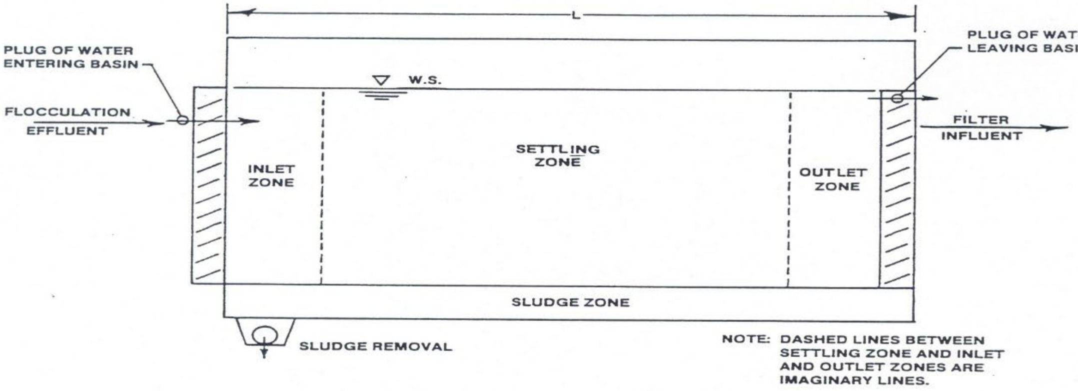
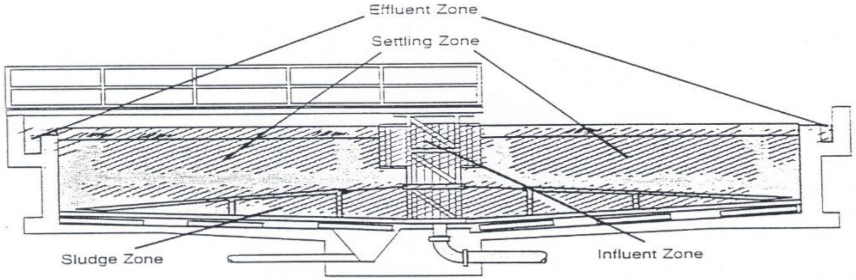
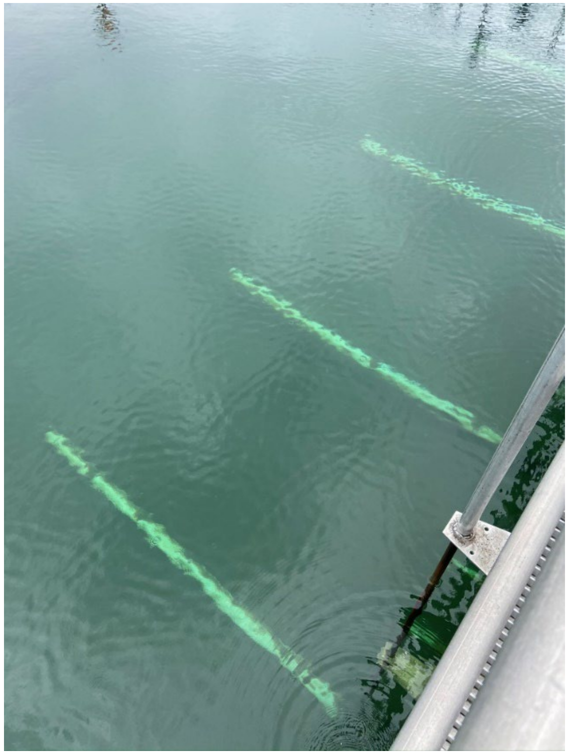


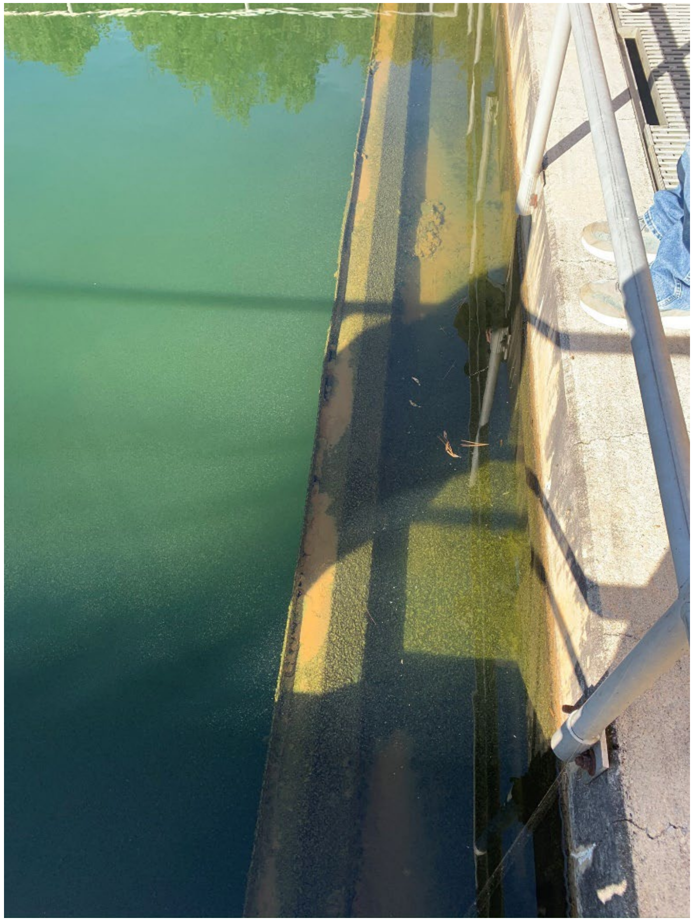

*Fig. 5.3 Sedimentation basin zones*



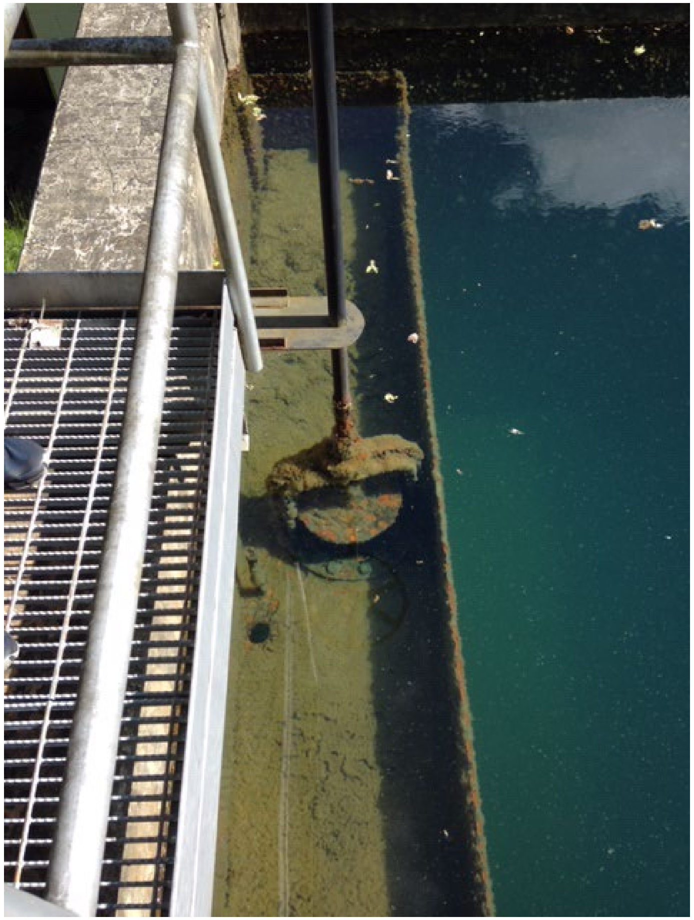
# Effective sedimentation basins



# More basins

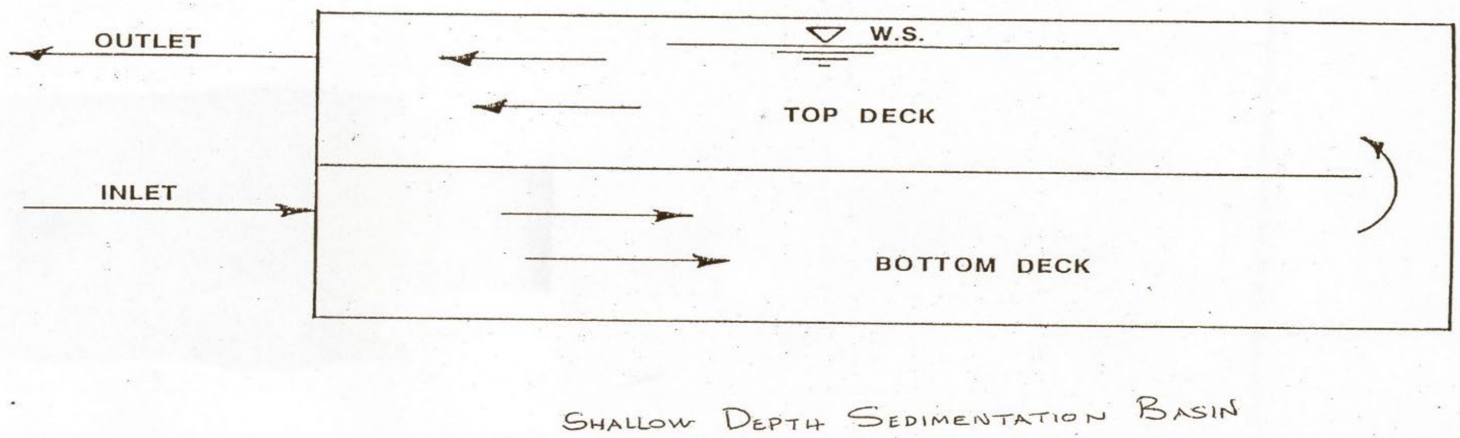


# More basins



# Shallow depth sedimentation

- Reduce time for the floc to settle to the bottom
- Often multiple levels, one over the other with parallel flow



# Tube Settlers

Modules of plates or tubes tilted at angles

Increases stability of flow conditions to enhance gravity settling

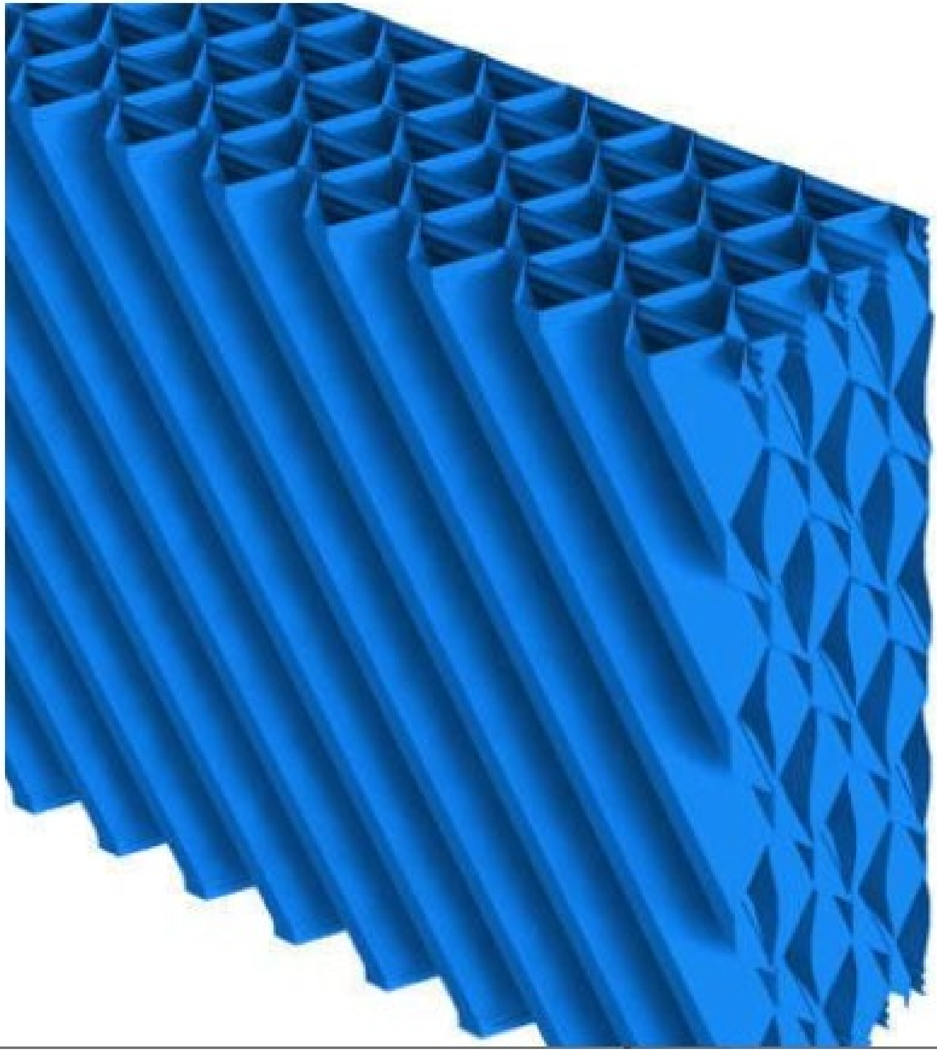
Usually 2 inches between “roof” and “floor”

Upflow condition

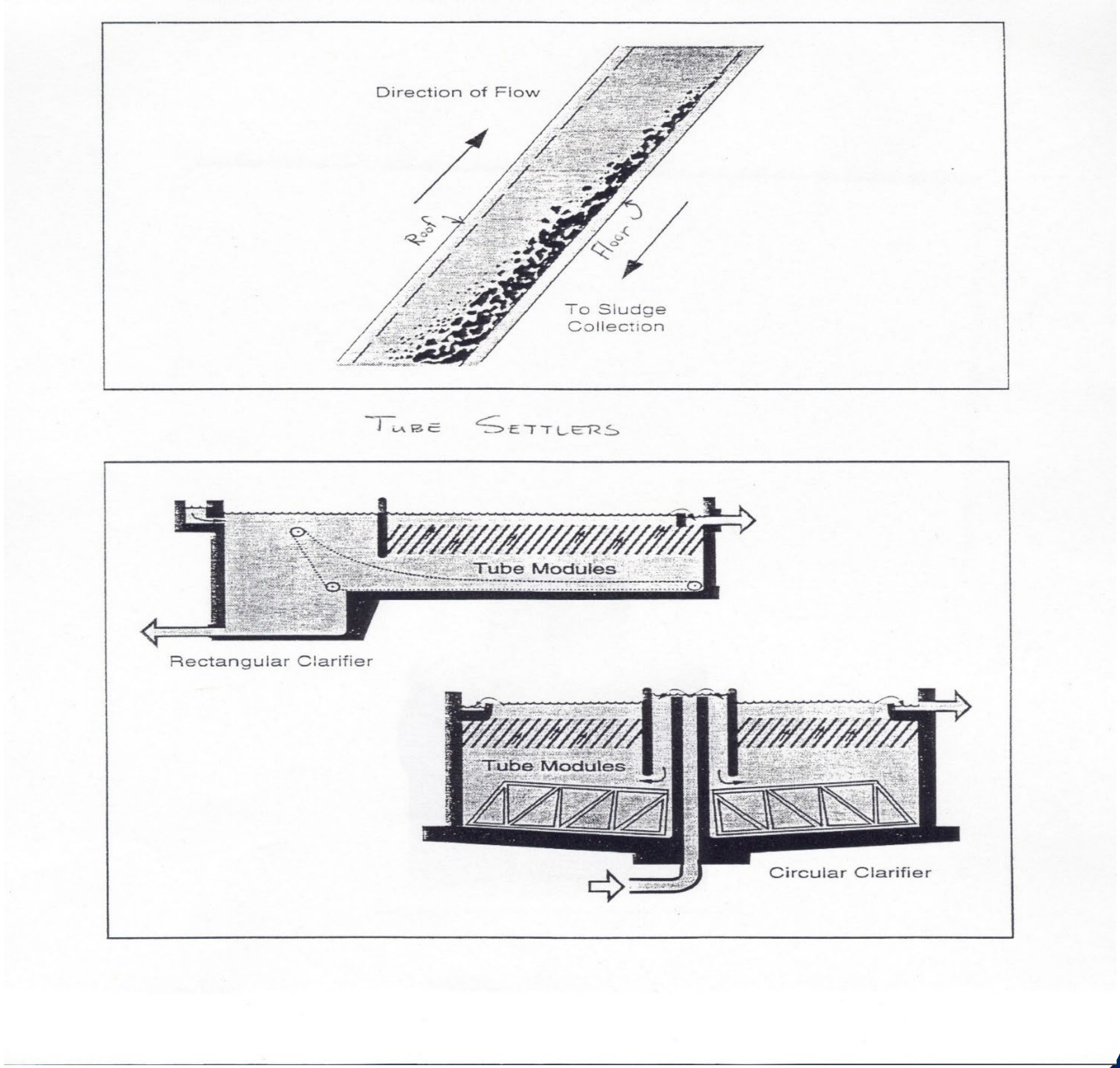
Two ideal angles of tilt:

- 60 degrees for self cleaning
- 7 degrees used where a backflush is provided

# Tube settlers



# Tube settlers



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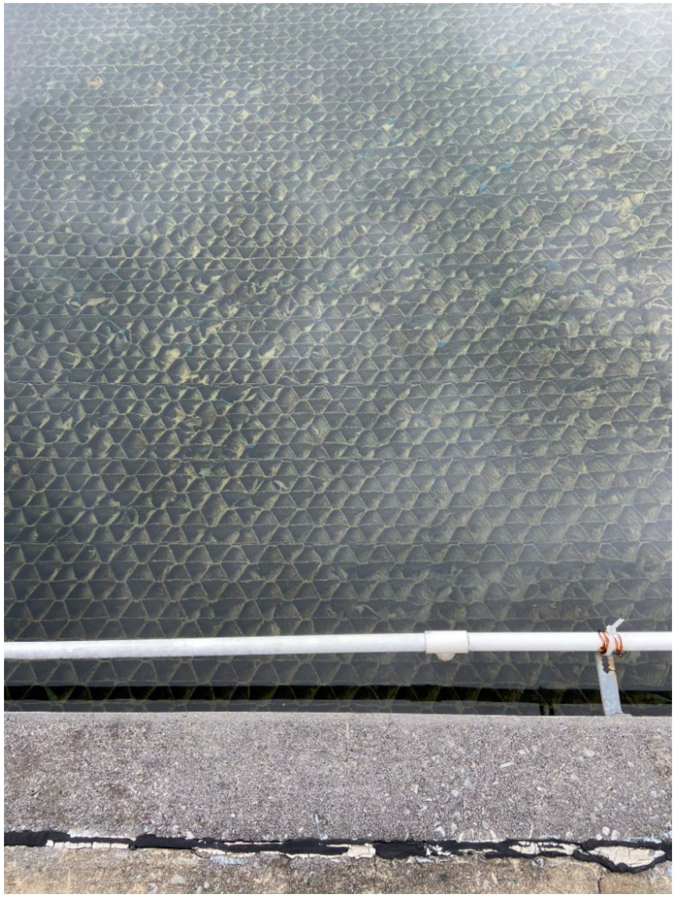
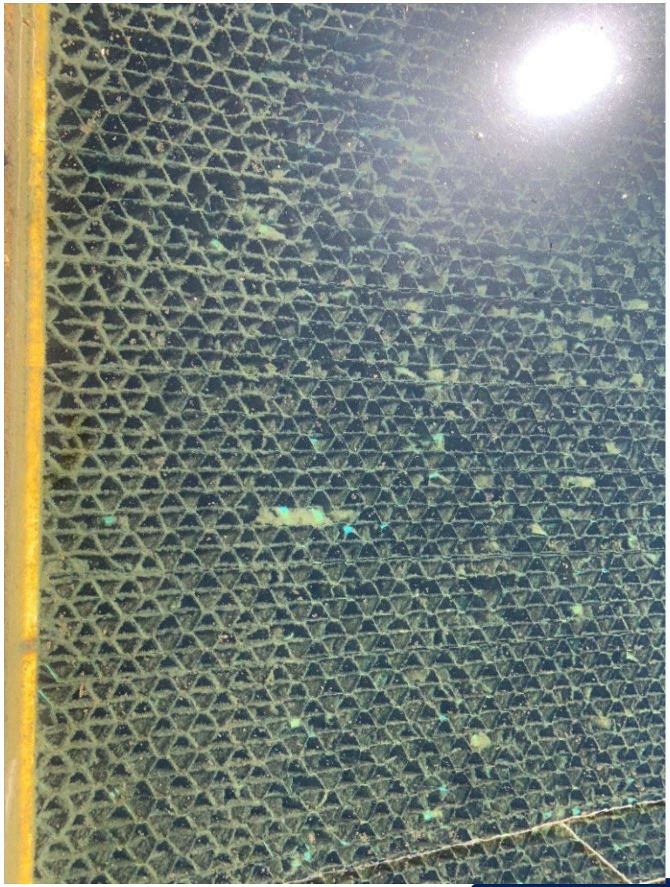
# Tube settlers





# Plate settlers

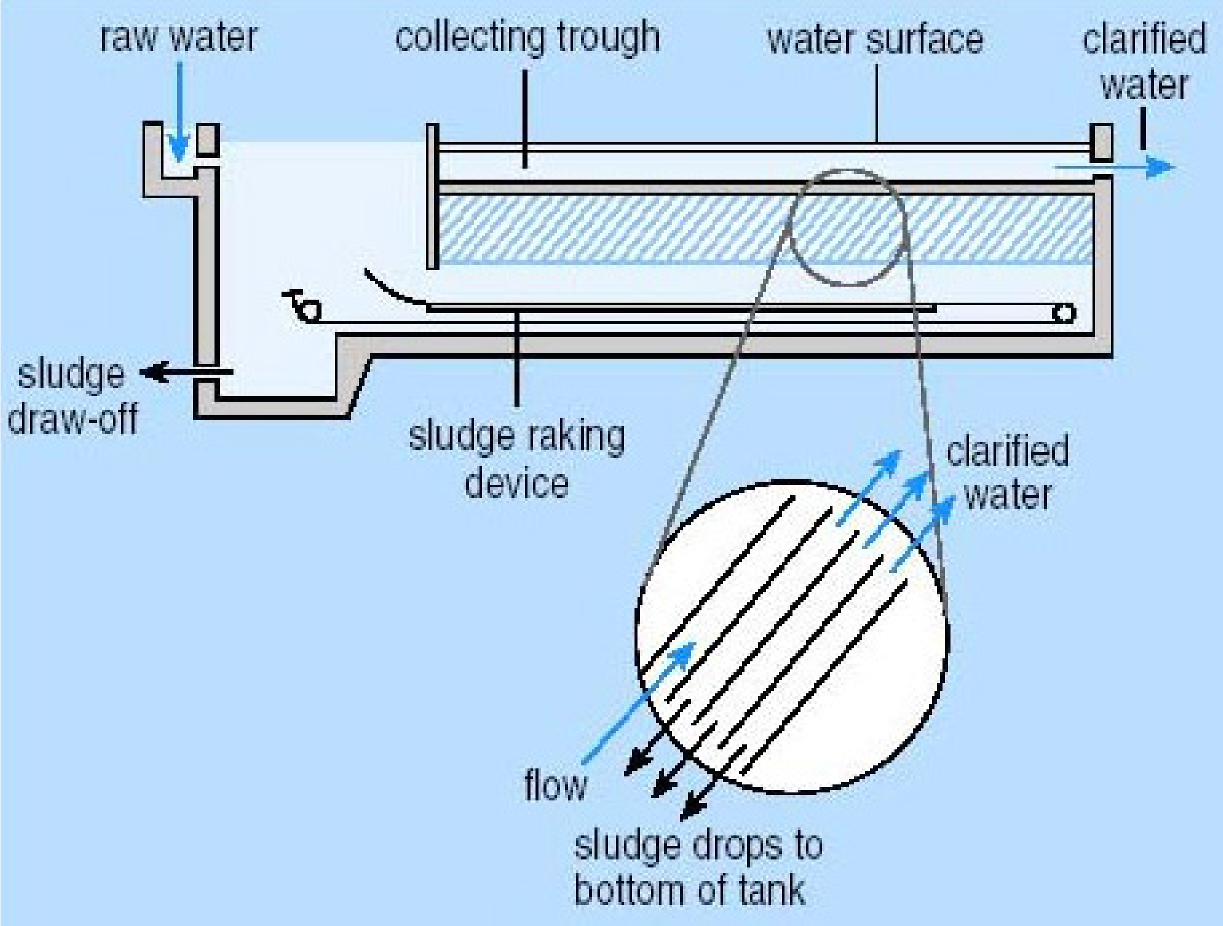



Figure 25 A parallel plate separator within a sedimentation tank

# Plate settlers

# My perception of how it's going!

Aberdeen Magazine



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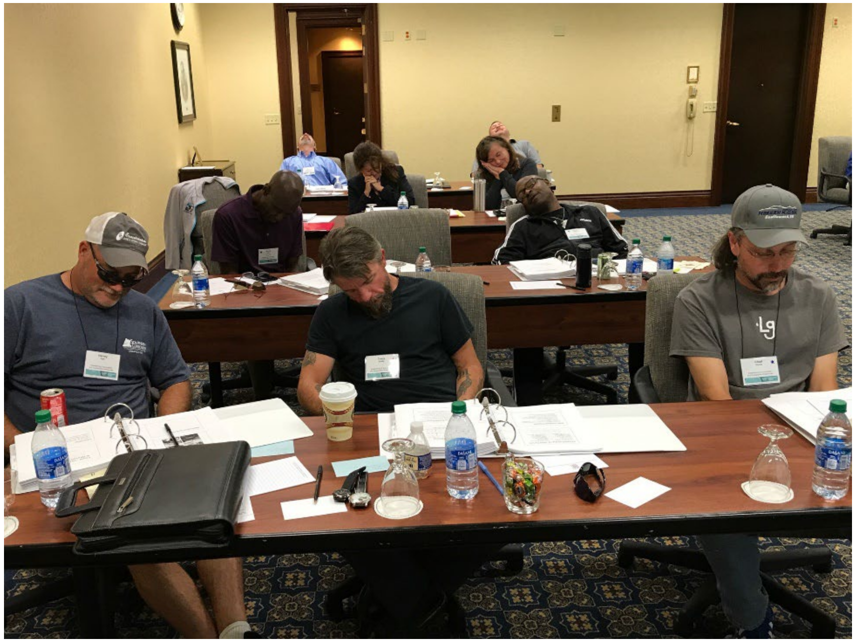
# The reality of how it's going …



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# Sludge removal

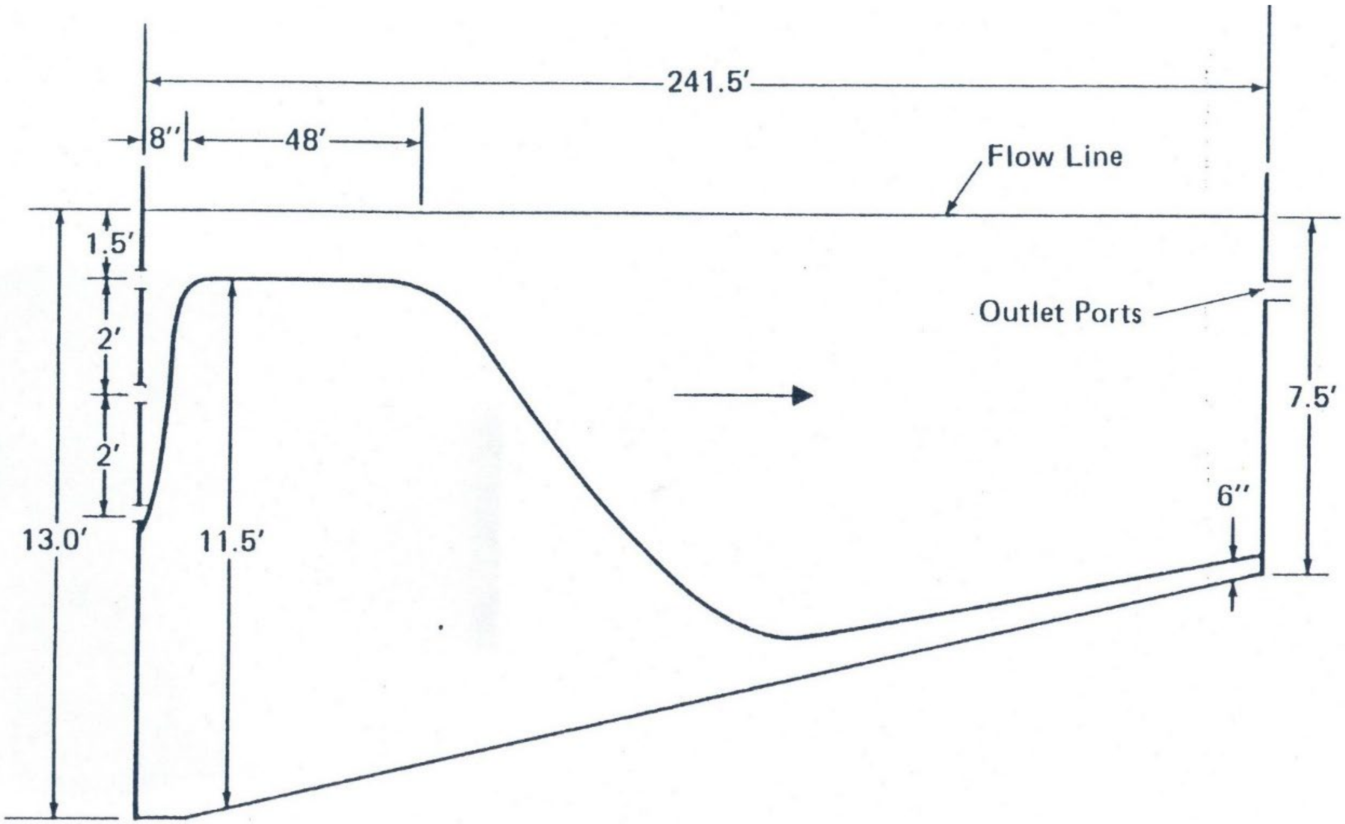
Manual

- valve entry point
- stationary sludge collector

Mechanical

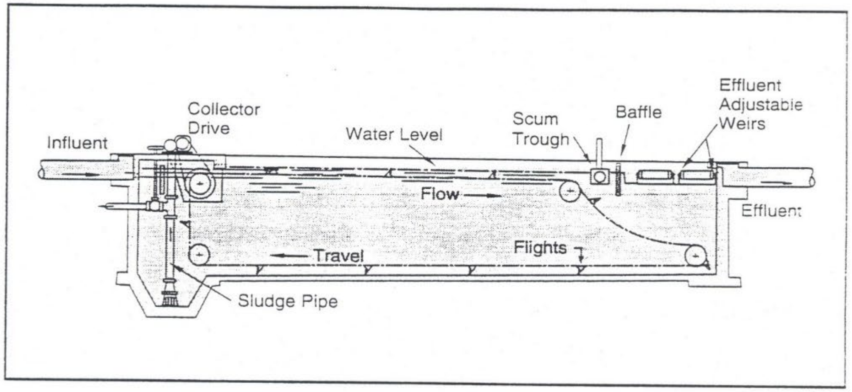
- chain and flight collector
- traveling-bridge collector
- floating bridge siphon collector

# Gravity Settling Sludge Profile
## (exaggerated)

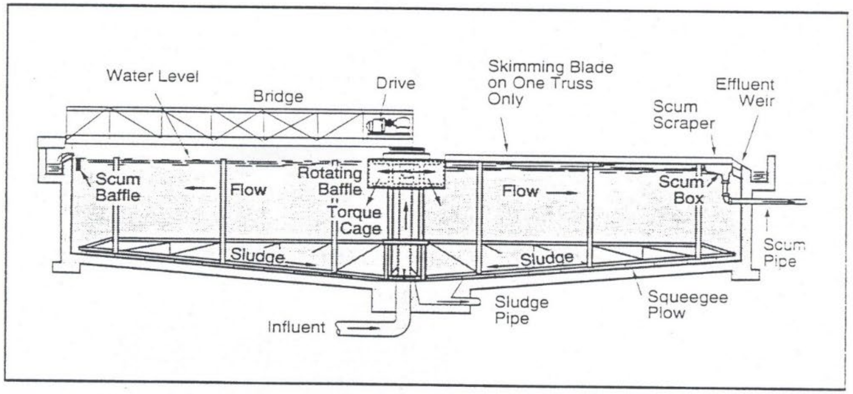


# Common sludge removal technology

# Chain & flight




A
typical rectangular
sedimentation
basin (with a
continuous chain
collector sludge
removal system)




A
typical circular
sedimentation
basin



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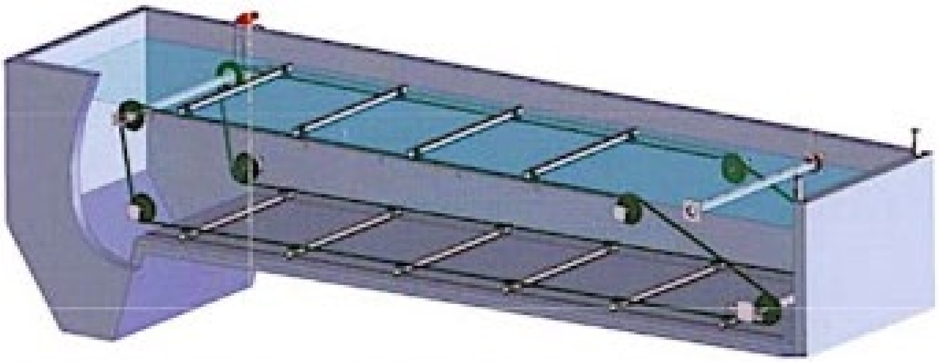
# Chain & flight

Chain-and-flight sludge collector



http://www.incineratorsystem.com/chain_and_flight_type_sludge.htm

*Chain and flight collector, coated steel construction*



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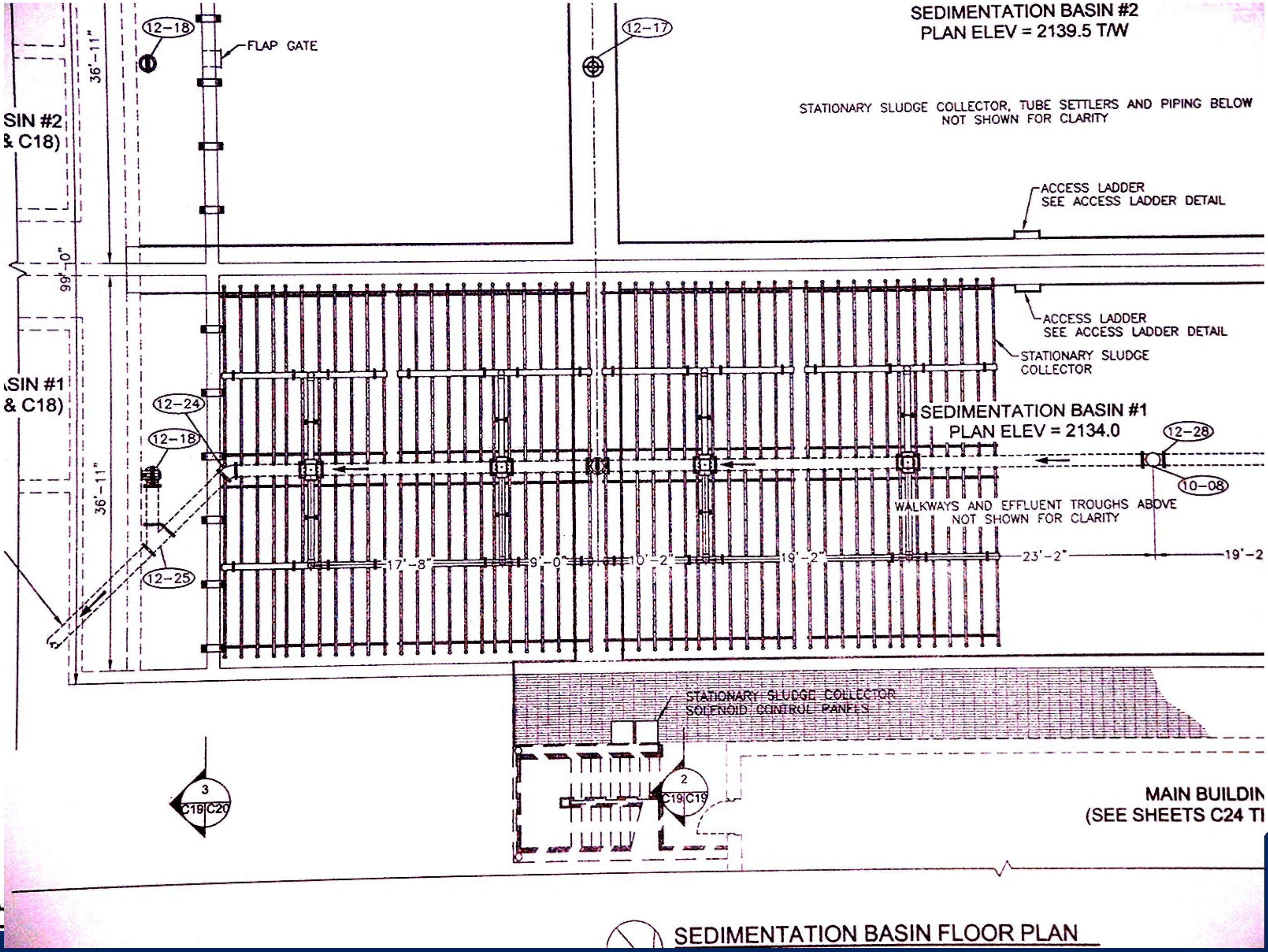
# Chain & flight



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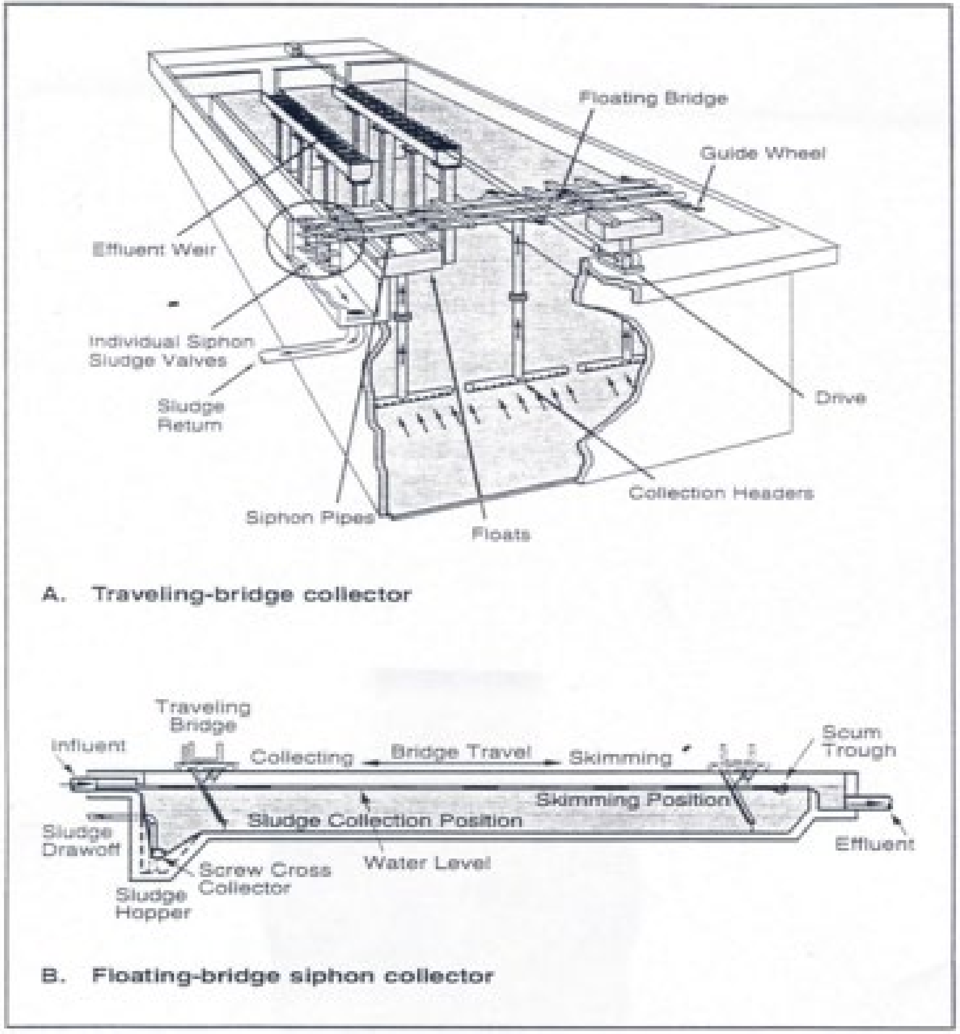
# Traveling bridge siphon



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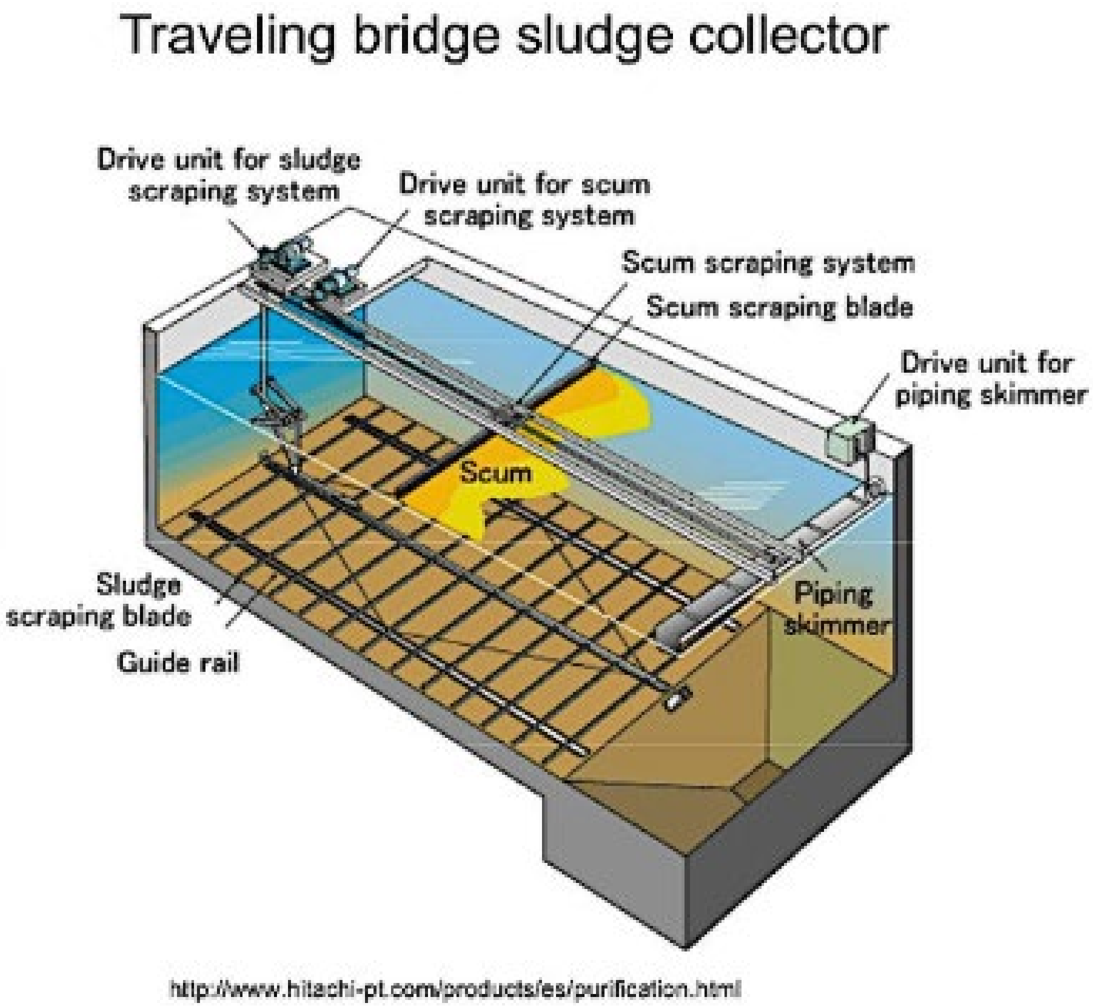
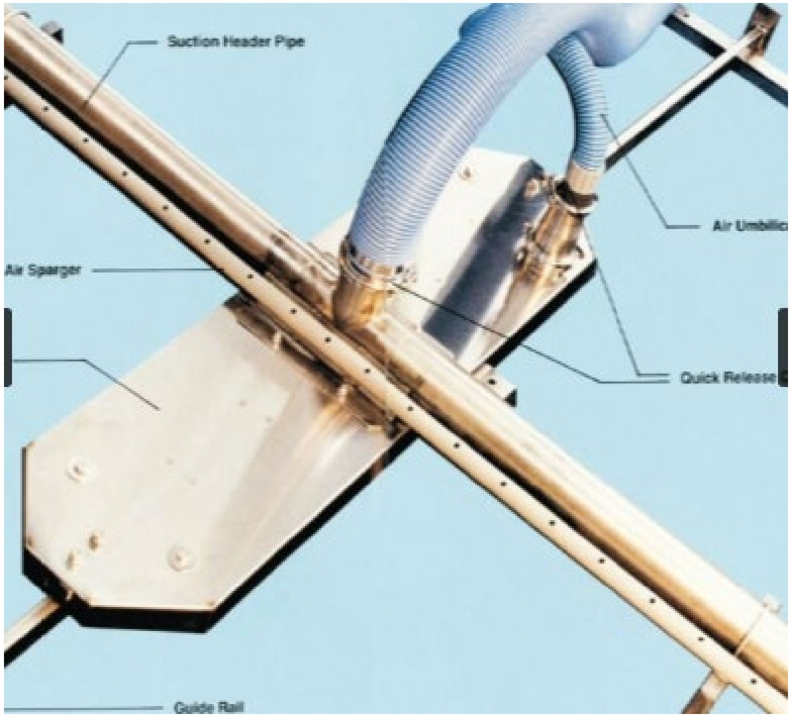
# Traveling bridge siphon



# Pneumatic sludge removal



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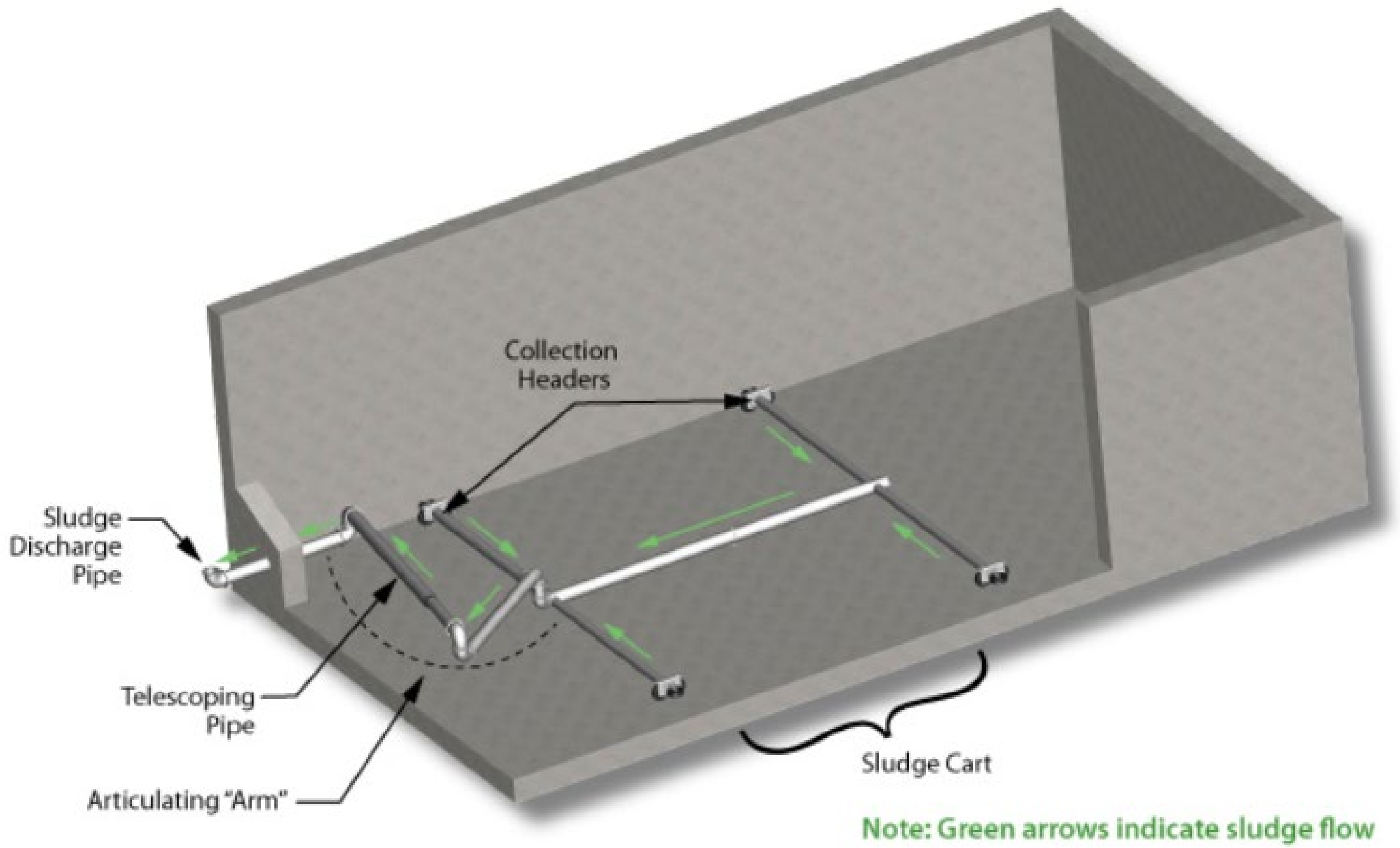
# Hoseless sludge collector



# Our learning objectives

At the conclusion of this session you should be able to:

1. Describe turbidity and its role in sedimentation
2. Identify the four zones in a sedimentation basin
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4. Describe two methods of removing sludge from the sedimentation basin
5. Name two causes of short circuiting



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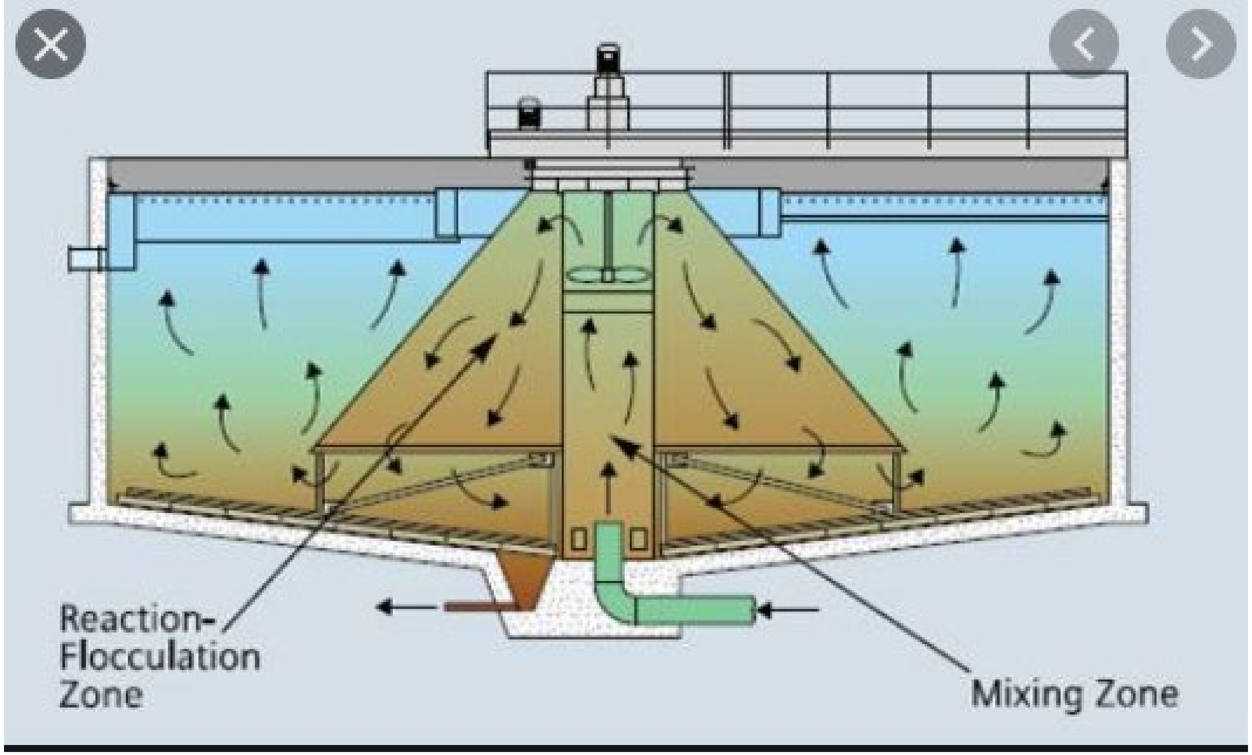
# The journey continues

# Alternate sedimentation processes

1. Solids contact basins - (**upflow clarifier**) include equipment for mixing, flow circulation & sludge removal
2. Dissolved air-flotation **(DAF)** - gas bubbles are generated to attach to solids particles, causing the particles to rise to the surface
   - electrolytic
   - dispersed-air flotation
3. Contact clarifiers
   - **Superpulsator**
   - **adsorption clarifier**

# Upflow Clarifier



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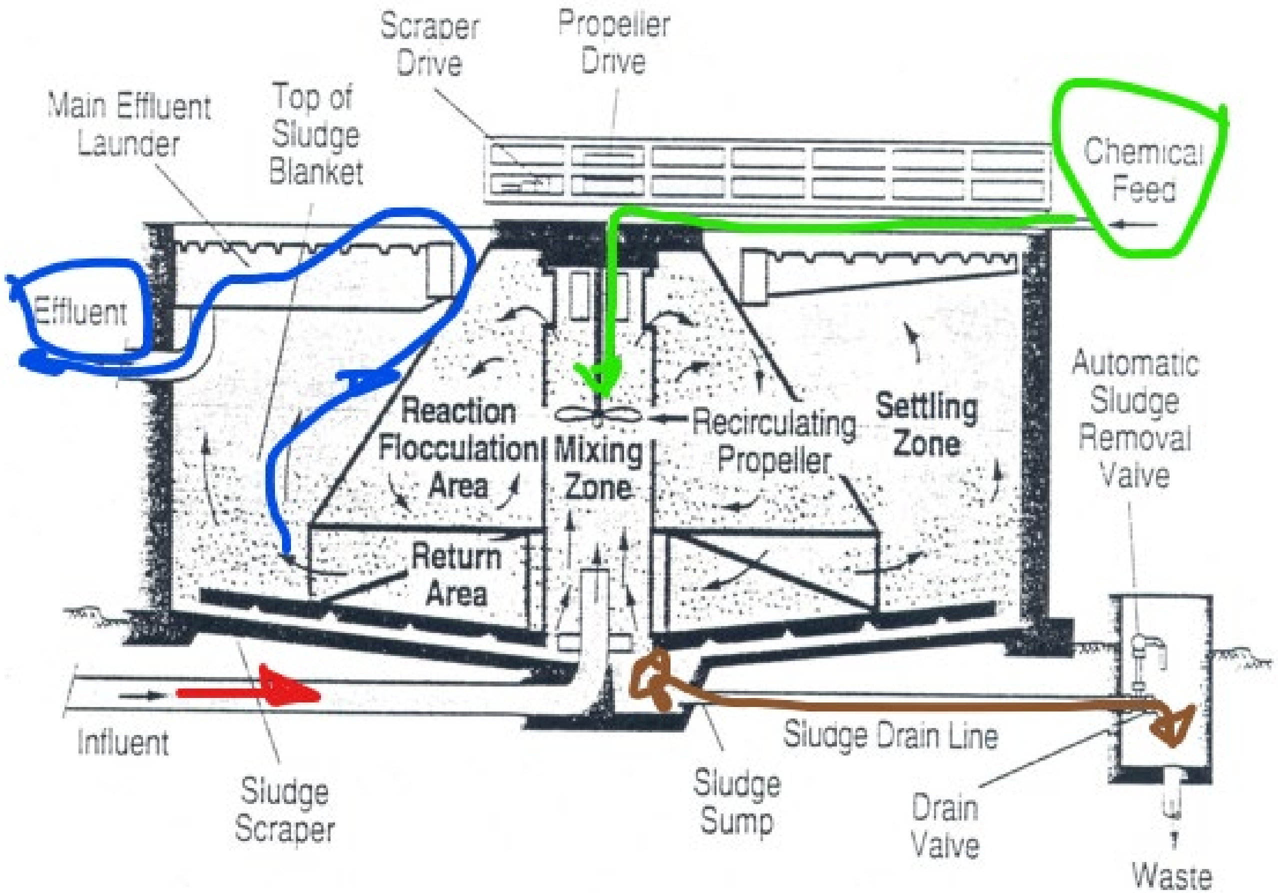
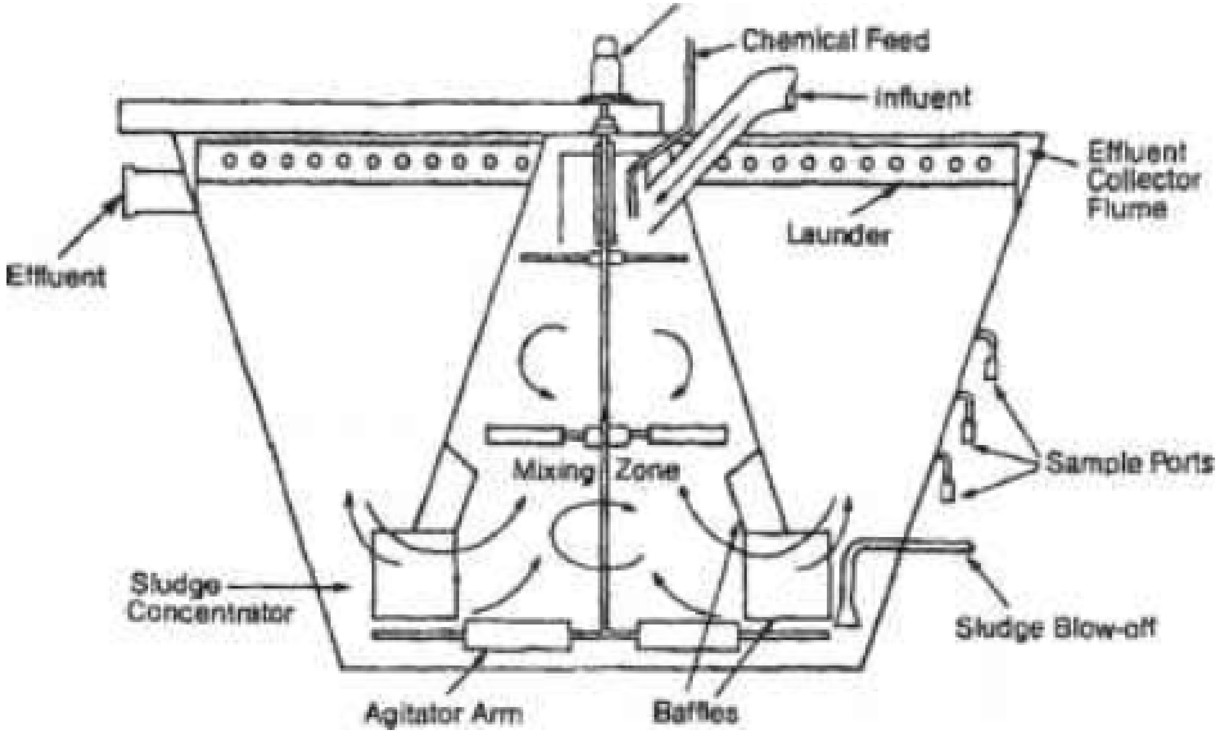
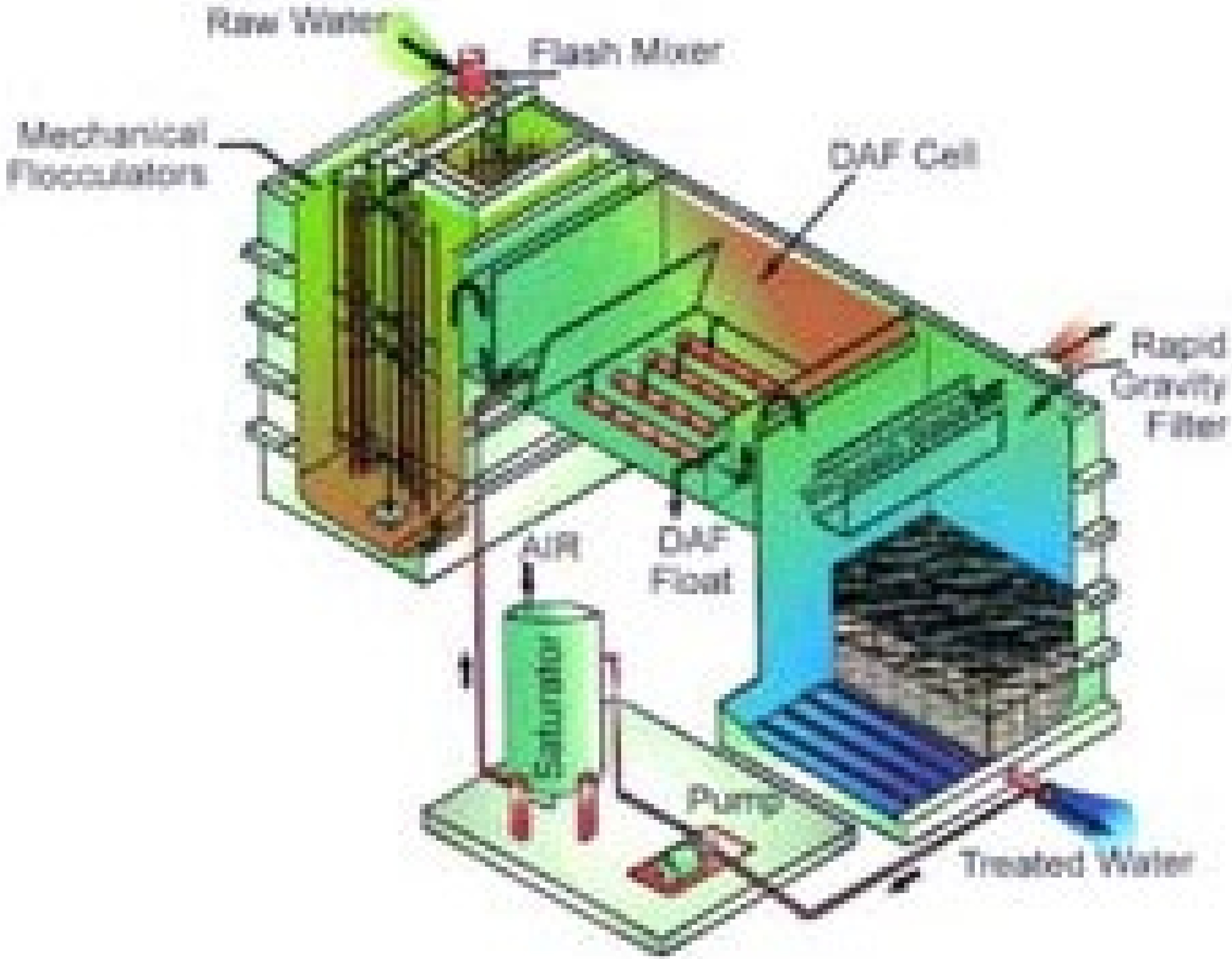
# Upflow Clarifier



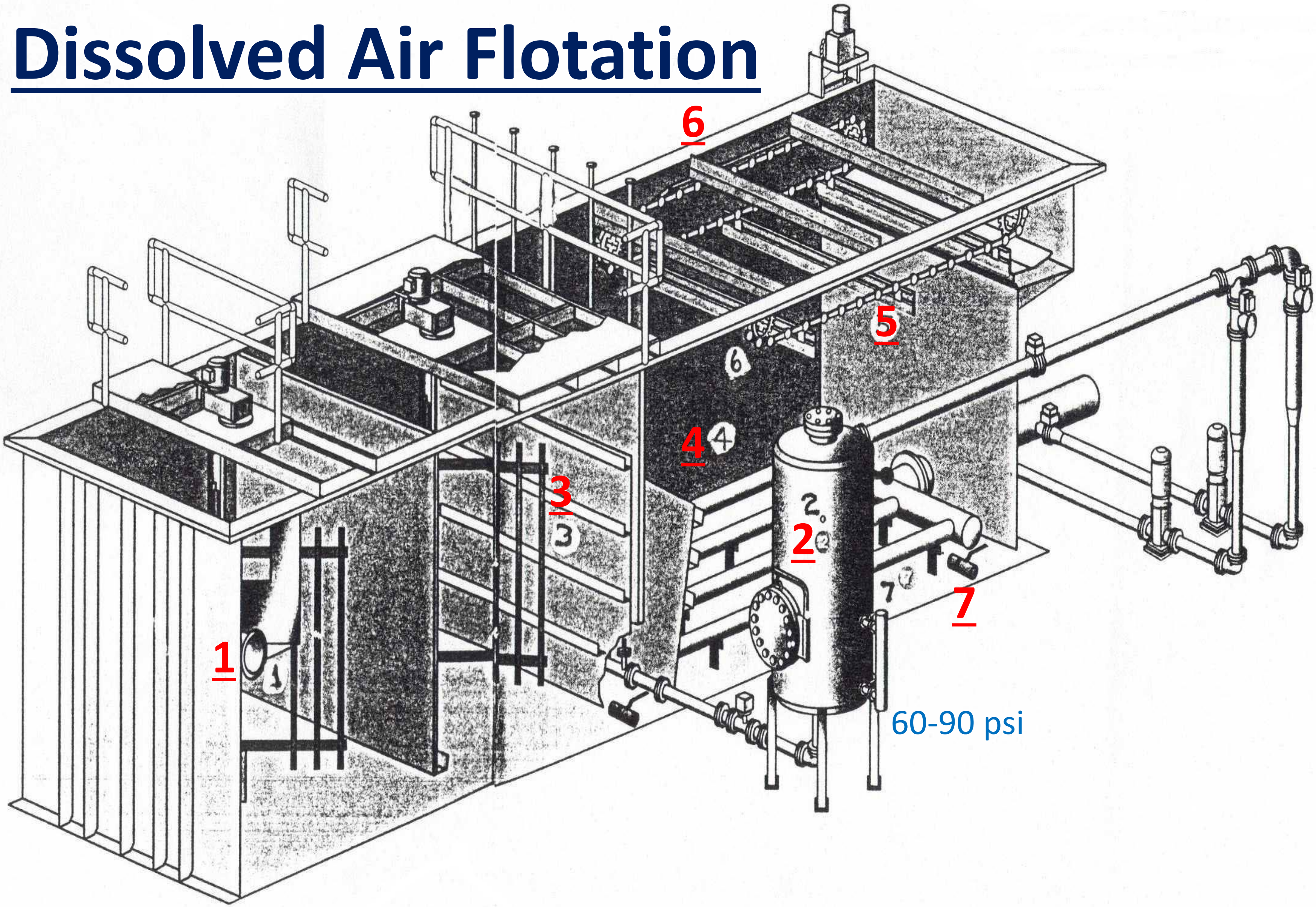
# Upflow Clarifier



# Dissolved Air Flotation



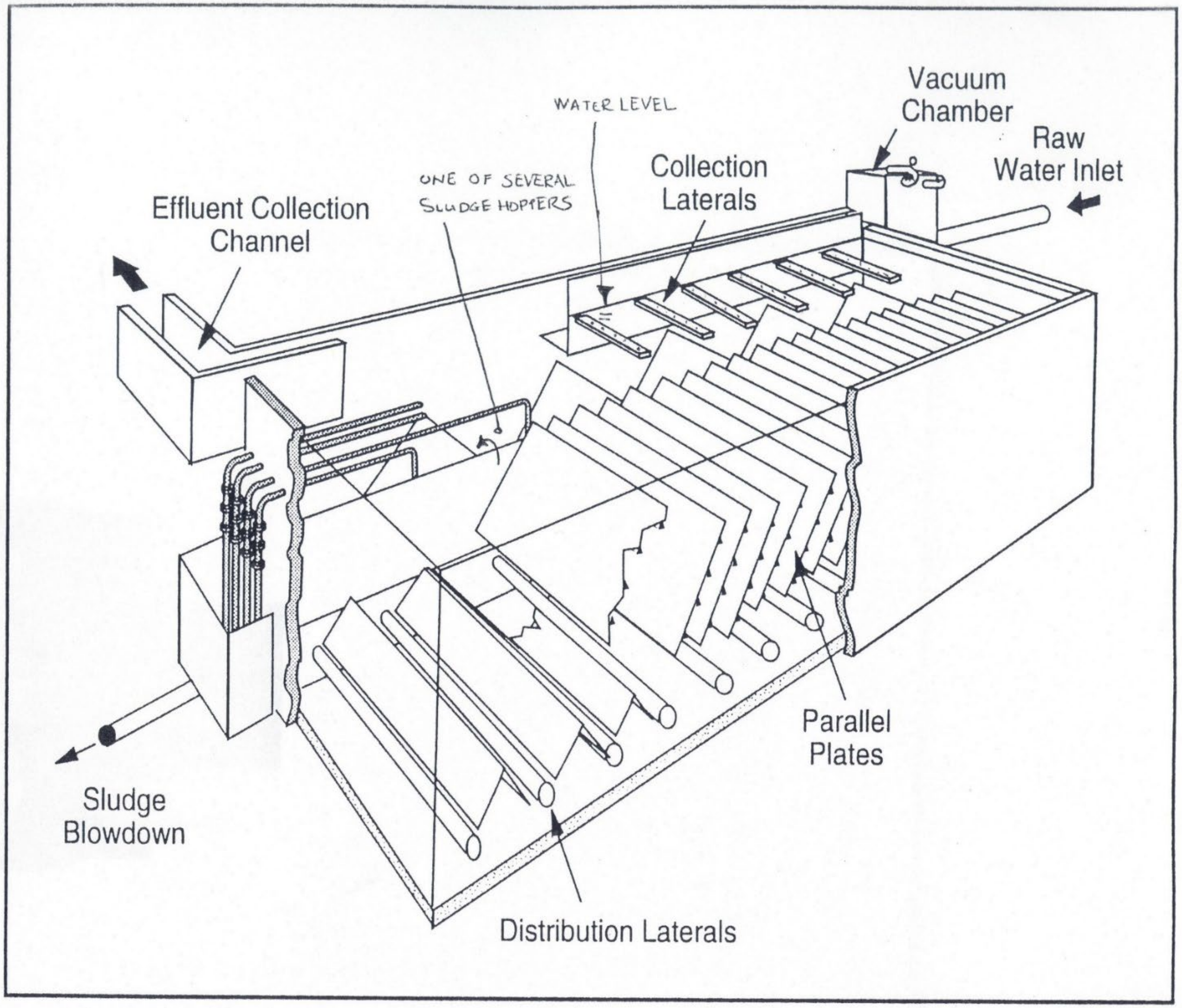
# Dissolved Air Flotation



# DAF solids removal

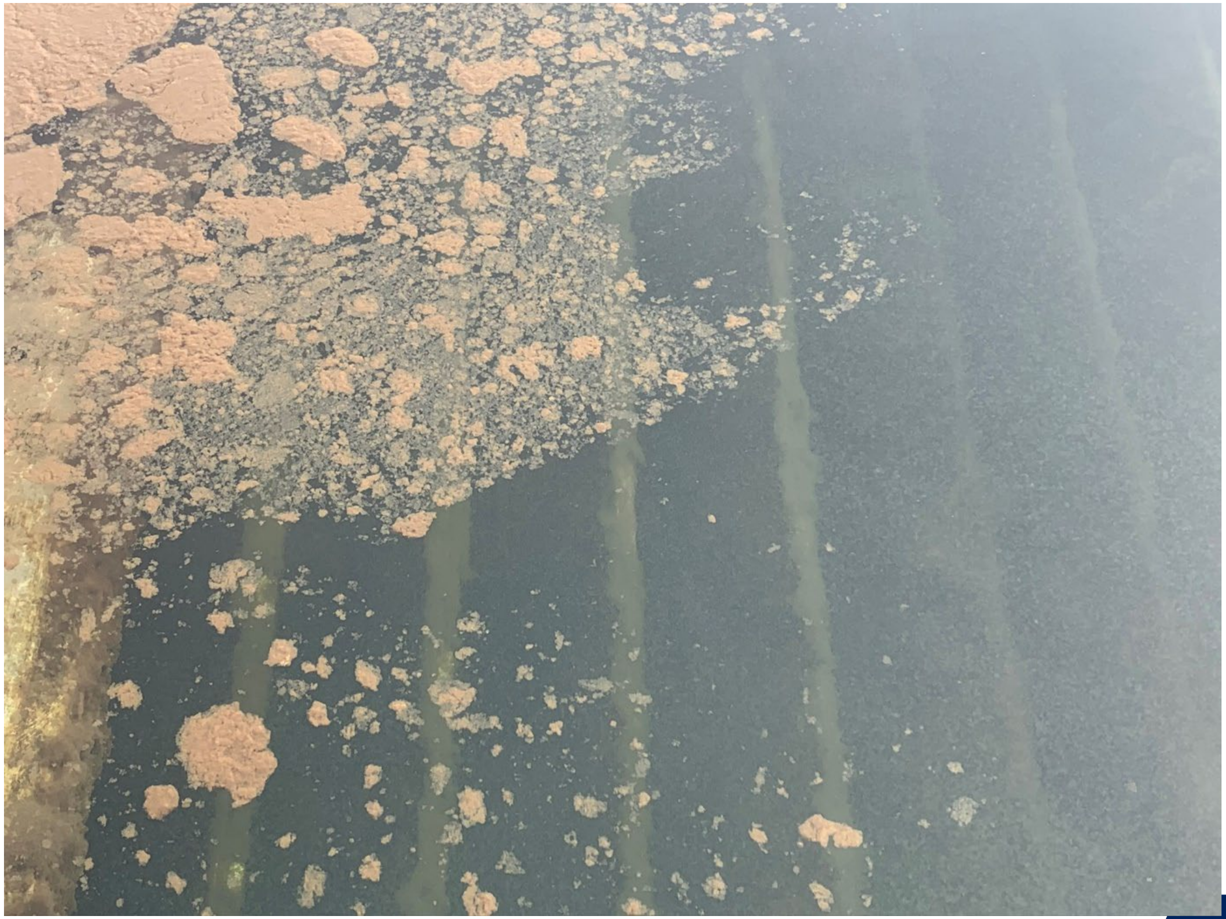
# DAF solids removal

# Superpulsator

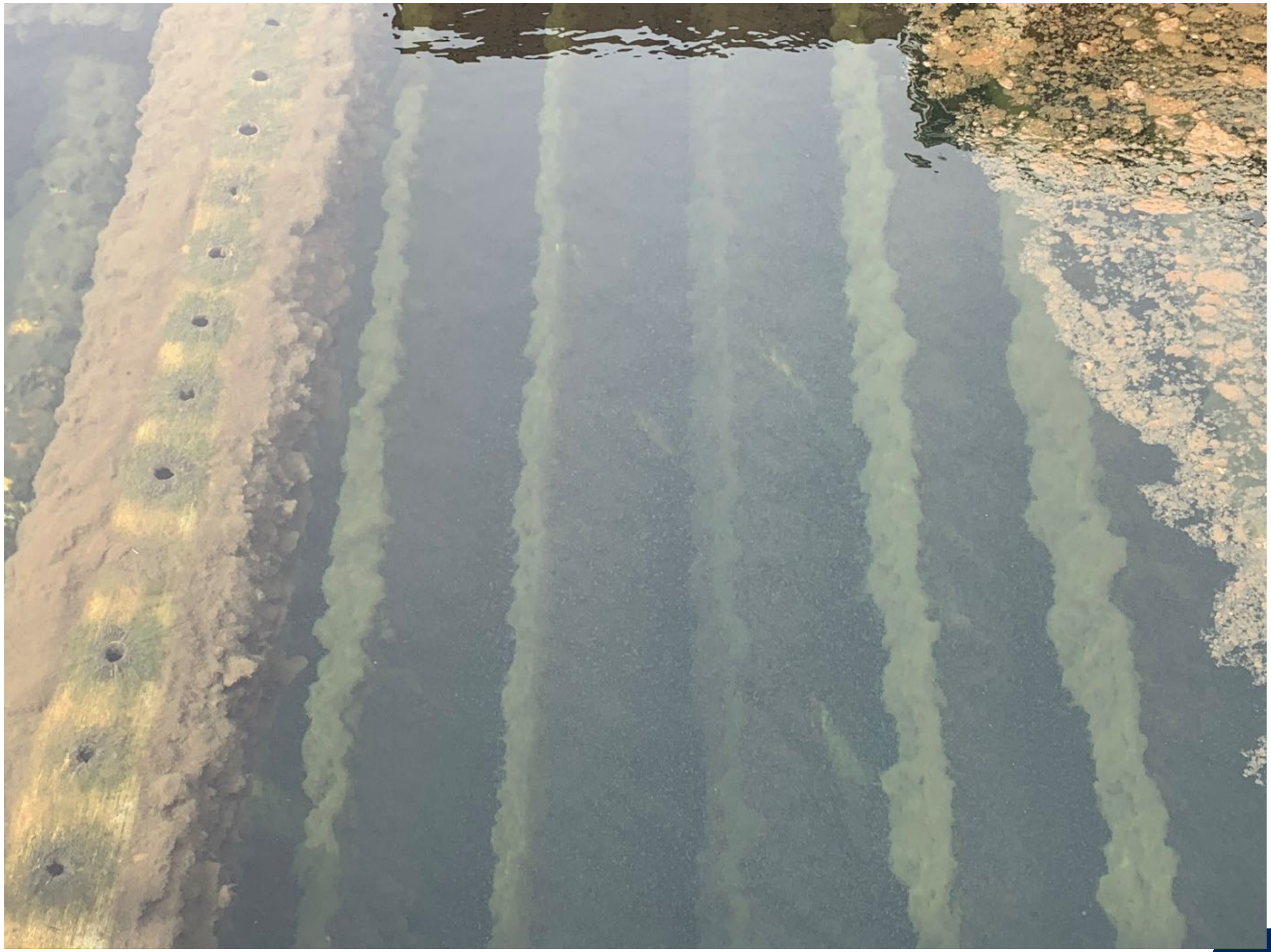



The Superpulsator flat-bottom clarifier with lateral flow distribution

# Superpulsator

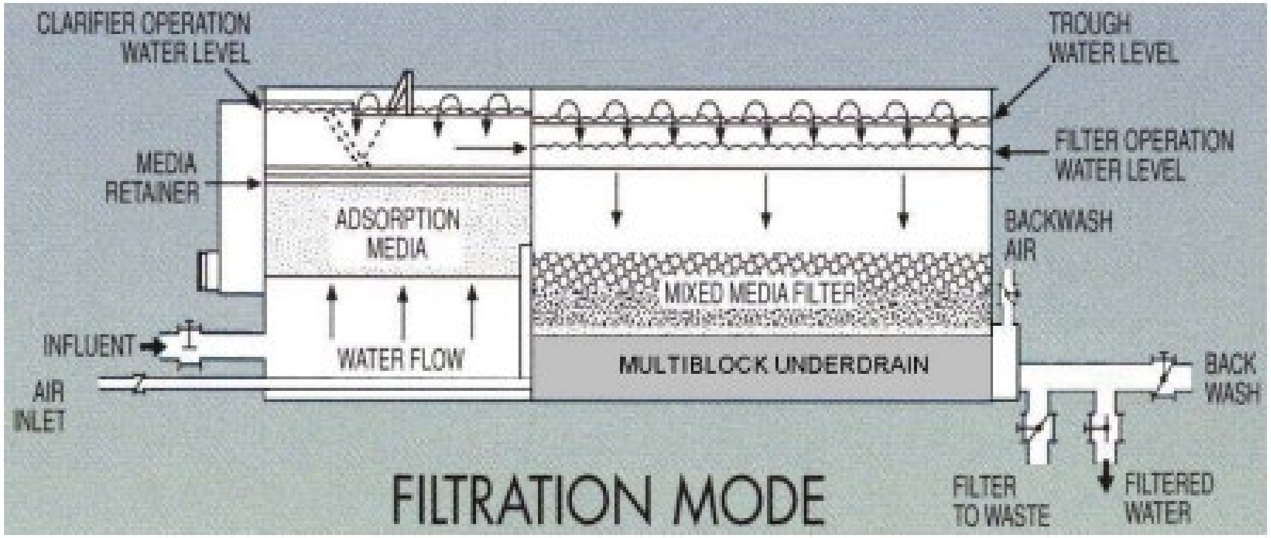


# Superpulsator



# Adsorption clarifier

## Operation: Filtration




David Reckhow CEE 397B L#3 14



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# Adsorption vs Absorption

# Adsorption Clarifier Media

Specific Gravity slightly less than 1.0

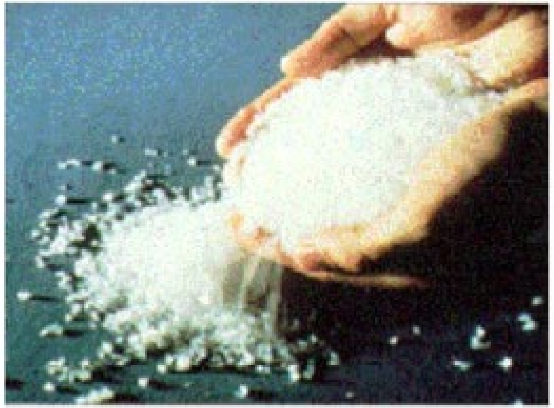
Permanent for life of plant

Minimal maintenance

Effective size ~ 2.5 mm

NSF 61 approved

Rolled and scarified design increases surface area for floc capture



WesTech



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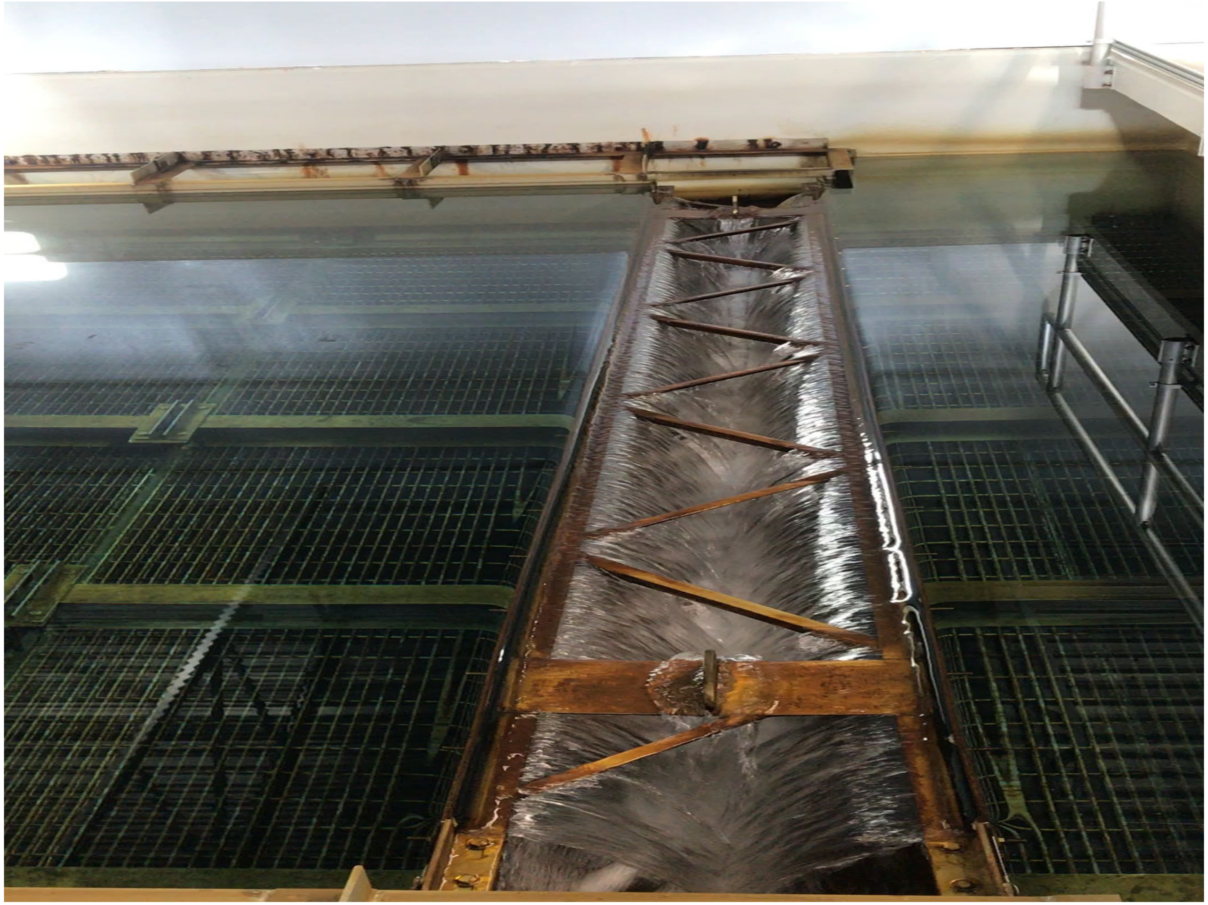
# Adsorption Clarifier



# You'll remember adsorption


Three actors in use pie throwing for comedic effect in the 1947 flick 'The Perils of Pauline.' PARAMOUNT PICTURES/COURTESY OF GETTY IMAGES



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# Road map for our journey

History of US drinking water treatment

WTP overview

**Sedimentation**

- Theory
- Regulations
- Practice
- **Operational**

Review and conclusion

# Process control monitoring

- Turbidity
- Temperature
- Settled sludge depth/sludge blanket depth
- Floc settling (visual observation)
- pH
- alkalinity

# Virginia Optimization Program (VOP)

Sedimentation Basin (individual)

- Clarified water turbidity **< 1 NTU 95% of time** when monthly average raw water turbidity ≤ 10 NTU
- *Clarified water turbidity **< 2 NTU 95% of time** when monthly average raw water turbidity > 10 NTU*

Filters

- ***Combined*** filter effluent - **Regulatory performance requirement**; 95% or more turbidity ≤ 0.3 NTU
- ***Individual*** filter effluent - **Performance goal**; 95% or more ≤ 0.1 NTU

# Routine maintenance

Remove basin from service for cleaning

Remove algal buildup from weirs and troughs

Exercise valves, including drain valves

# Opportunity for maintenance

# Operating problems

1. poorly formed floc
2. short circuiting
3. density currents
4. wind effects
5. algae problems

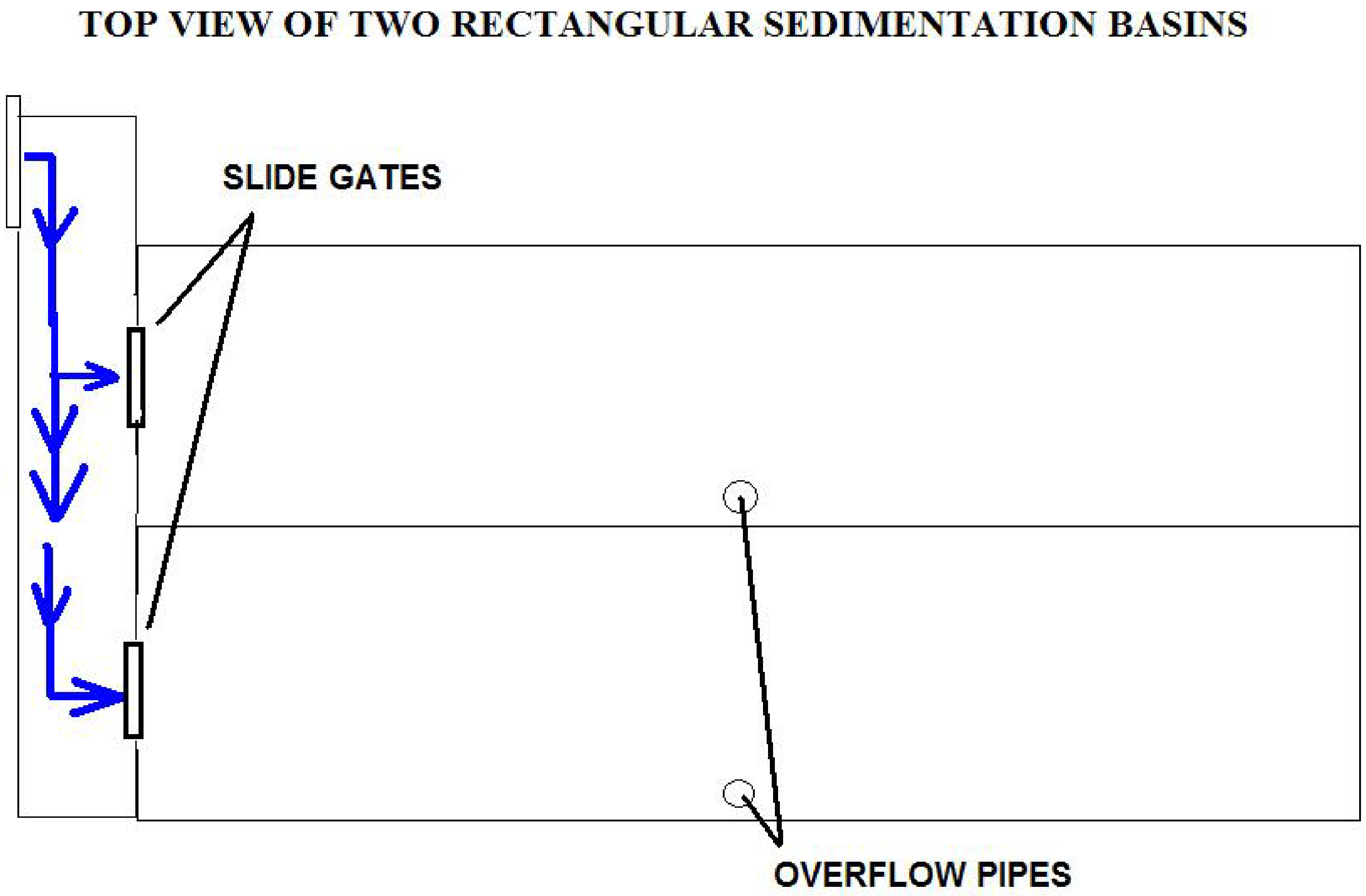
# Poorly formed floc

Coordinate coagulation & flocculation. Remember:

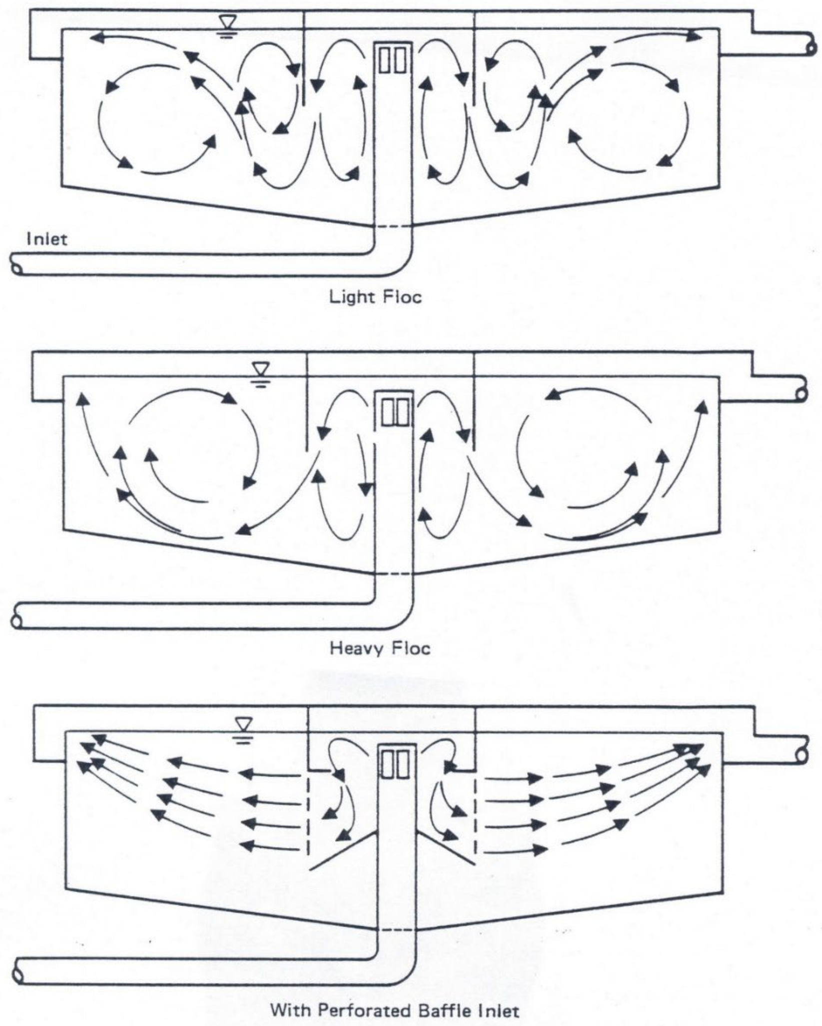
# Short Circuiting

- Hydraulic short circuiting
- Floc density
- Water density short circuiting
- Tracer studies may be necessary to pinpoint

# Hydraulic Short-Circuiting Example



# Shortcircuiting-Floc Effect




Behavior of center feed clarifiers.

# Density

Temperature density current

**colder water weighs more**

- (at 18 C) density = 0.99862 grams/ml.(8.33348 lb/gal)

  [1,000,000 gal. weighs 8,333,480 lb.]

- (at 20 C) density is 0.99823 grams/ml.(8.33023 lb/gal)

  *[1,000,000 gal. weighs 8,330,230 lb.]*

  weight difference = 3,250 lb.( 1.6 tons )

**Turbidity density current**

sharp turbidity rise will result in “heavier” water



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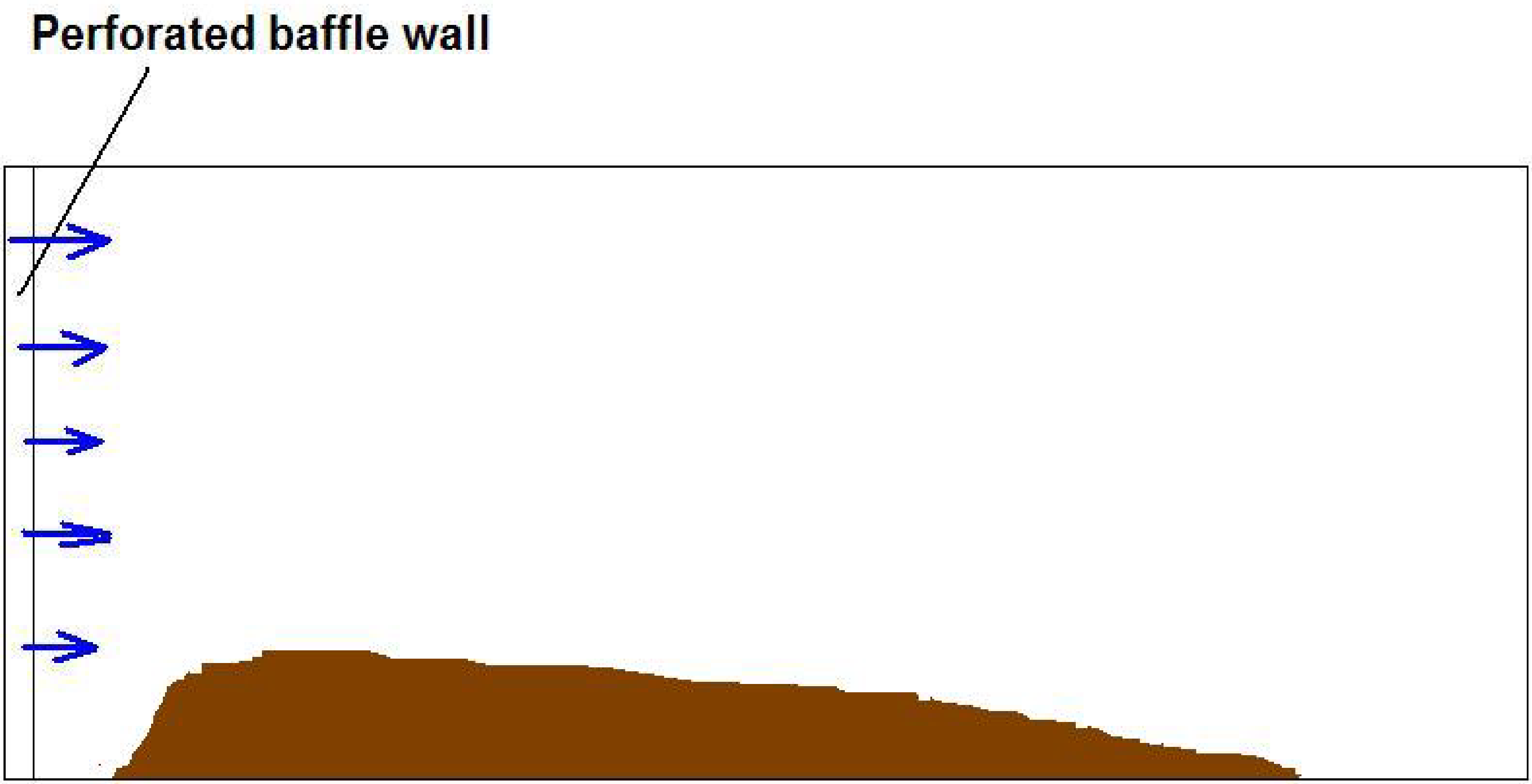
# DENSITY EXAMPLE

## SIDE VIEW RECTANGULAR SEDIMENTATION BASIN

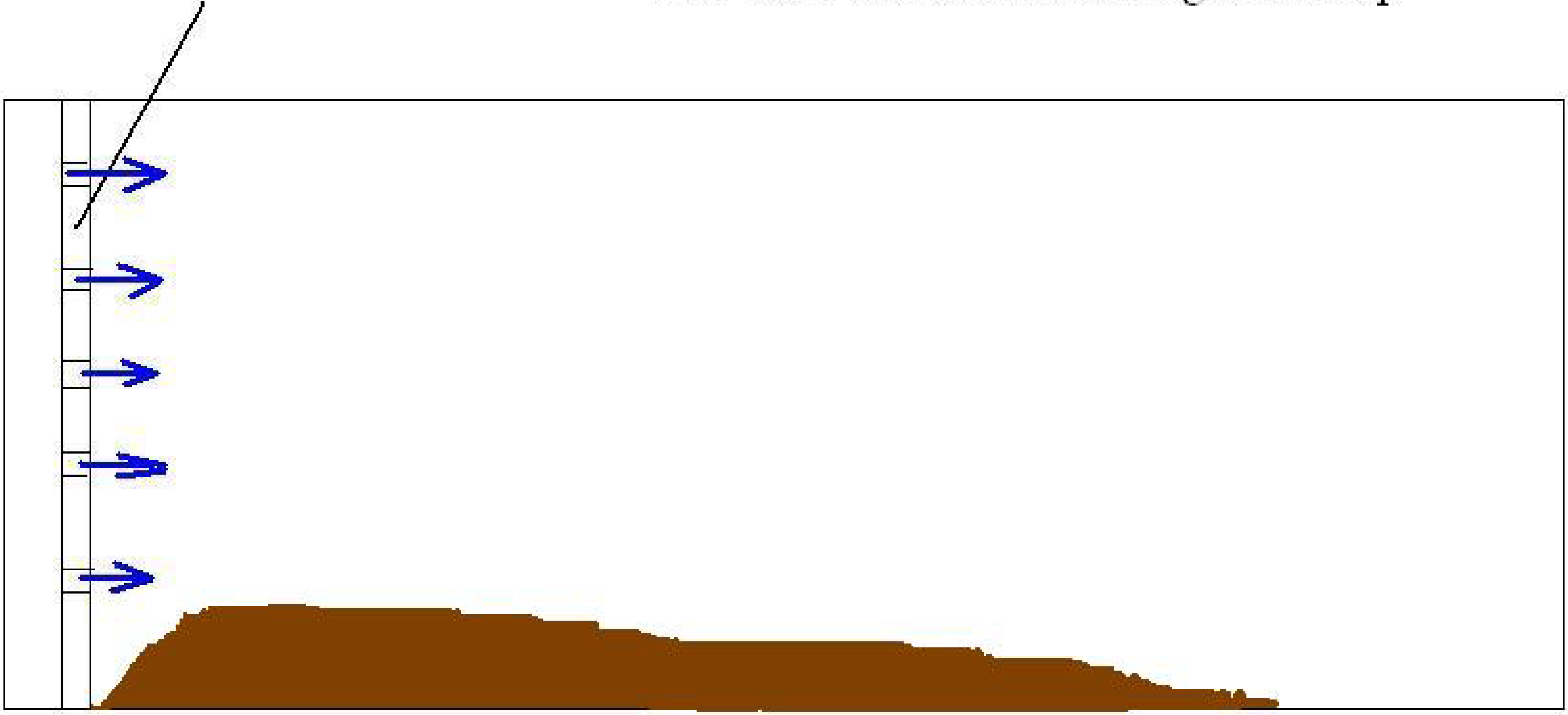


# DENSITY EXAMPLE

## SIDE VIEW RECTANGULAR SEDIMENTATION BASIN

Situation - wtp runs two shifts and shuts down at night. River water is colder than than basin water next morning at start up

Perforated baffle wall



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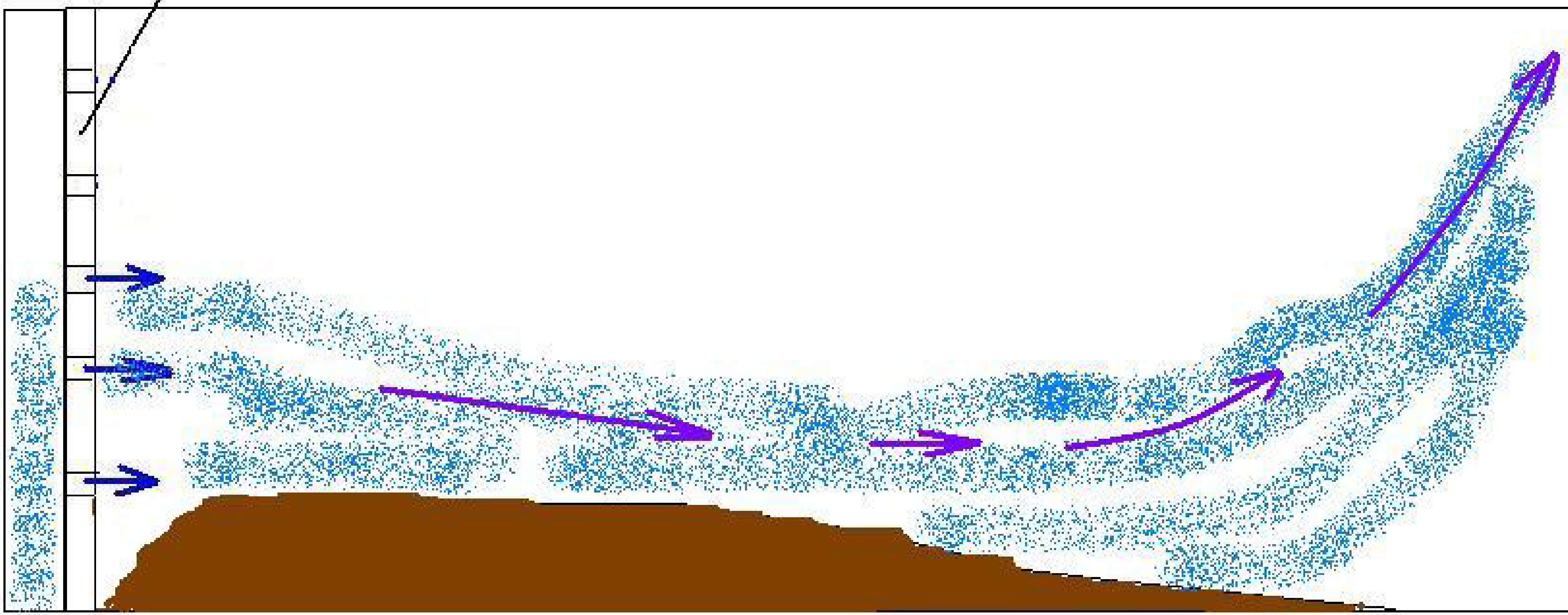
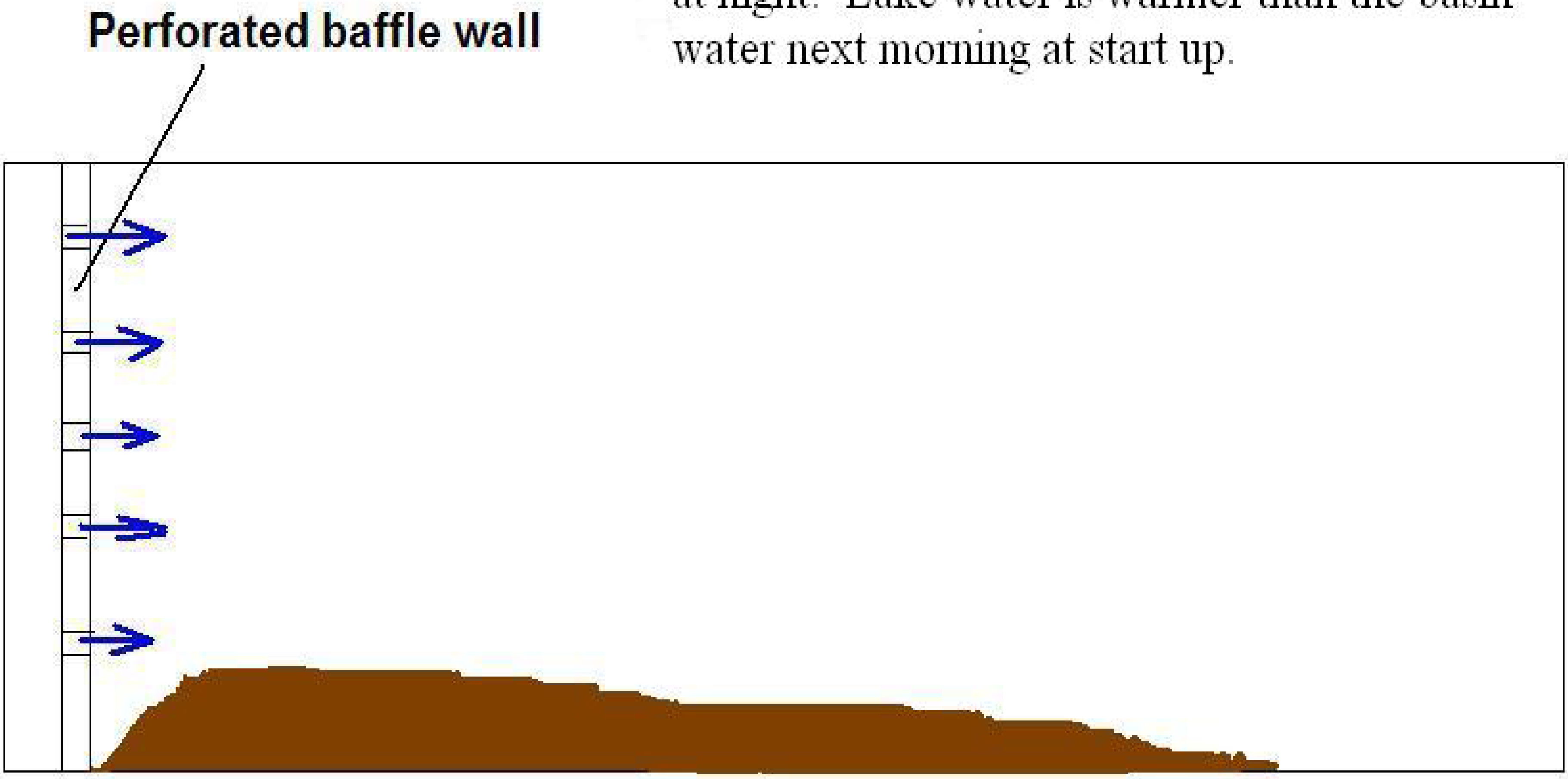


# DENSITY EXAMPLE

## SIDE VIEW RECTANGULAR SEDIMENTATION BASIN

Situation - wtp runs two shifts and shuts down at night. Lake water is warmer than the basin water next morning at start up.

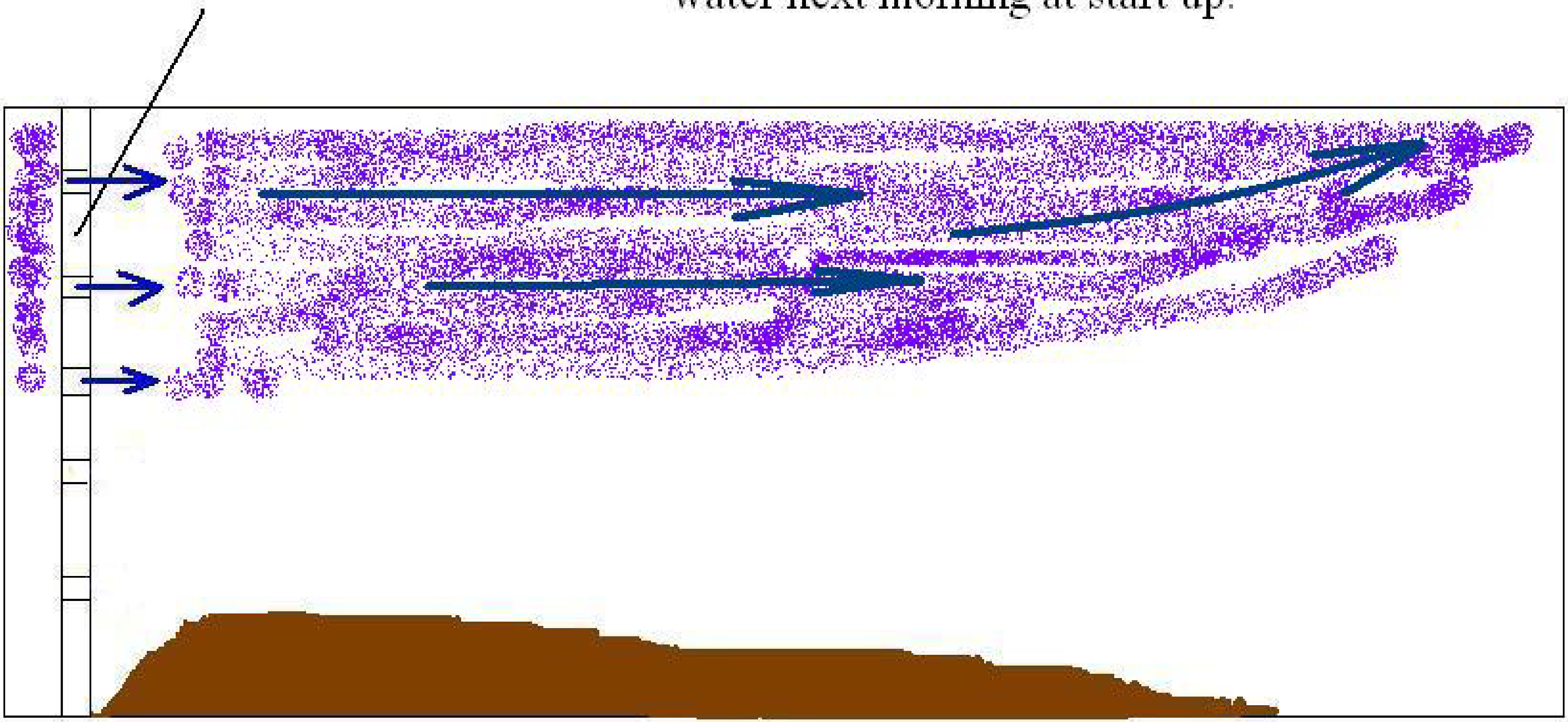


# DENSITY EXAMPLE

## SIDE VIEW RECTANGULAR SEDIMENTATION BASIN

Situation - wtp runs two shifts and shuts down at night. Lake water is warmer than the basin water next morning at start up.

**Perforated baffle wall**



# Wind effects

- Can cause currents resulting in short circuiting
- Intermediate baffle may solve problem

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# Algae

Excessive growth may cause taste and odor problems – this problem is not solved in the sedimentation basin.

Activated carbon or in conjunction with potassium permanganate as oxidant.

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# Review and conclusion



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# *For follow-up*

<u>Please contact:</u>

David Dawson, PhD, PE
Abingdon Field Office Director
VDH Office of Drinking Water
(276) 698-4906 cell

david.dawson@vdh.virginia.gov