CE 356 Fundamental of Environmental Engineering

Primary Treatment of Wastewater

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Preliminary "Treatment"

- Equalization
  - Smooth out fluctuations in flow rate
  - Results in more consistent treatment
- Flow Measurement
  - Flow rate information needed for efficient operation, chemical addition, etc

Equalization

- Objective
  - Decrease fluctuations in flow rate, to provide more consistent treatment
- Accomplished by storing excess wastewater during high flow periods
- Excess wastewater is released during low flow periods

Pumping

- Sometimes needed to lift the water to a higher elevation than the discharge point of the main trunk sewer line.

- After pumping, the plant is designed to operate under gravity flow to the point of discharge at the receiving stream.

A Screw Pump

Flow Measurement

- Objective
  - Measure flow rate to facilitate plant operation
- Several operations need flow rate data for good operation
  - Chlorination
  - pH adjustment
  - Also required for NPDES reports

Design of Influent Channel

- Objective
  - Design a combination of circular sewer and rectangular channels to deliver wastewater to the head works of the treatment plant
- Apply open channel flow hydraulics – applying Manning's equation considering:
  - Minimum velocity to reduce solids deposition in the channel
  - Hydraulic grade, slope of channel invert to provide scour of solids
  - Channel dimensions that match or transition the influent circular sewer with a rectangular channel

Primary Treatment

- Designed to remove settleable solids and reduce the organic load (BOD) on the secondary units.
- Primary treatment includes
  - Bar screen
  - Comminutor
  - Grit chamber
  - Primary clarifier

Bar Screen
Vendor-Provided Equipment

- Purpose: to remove large objects (sticks, cans, etc) which may cause flow obstructions.
- Depending on the size of the plant, bar screens are either hand or mechanically cleaned.
- Hand cleaned: used primarily at small plants.

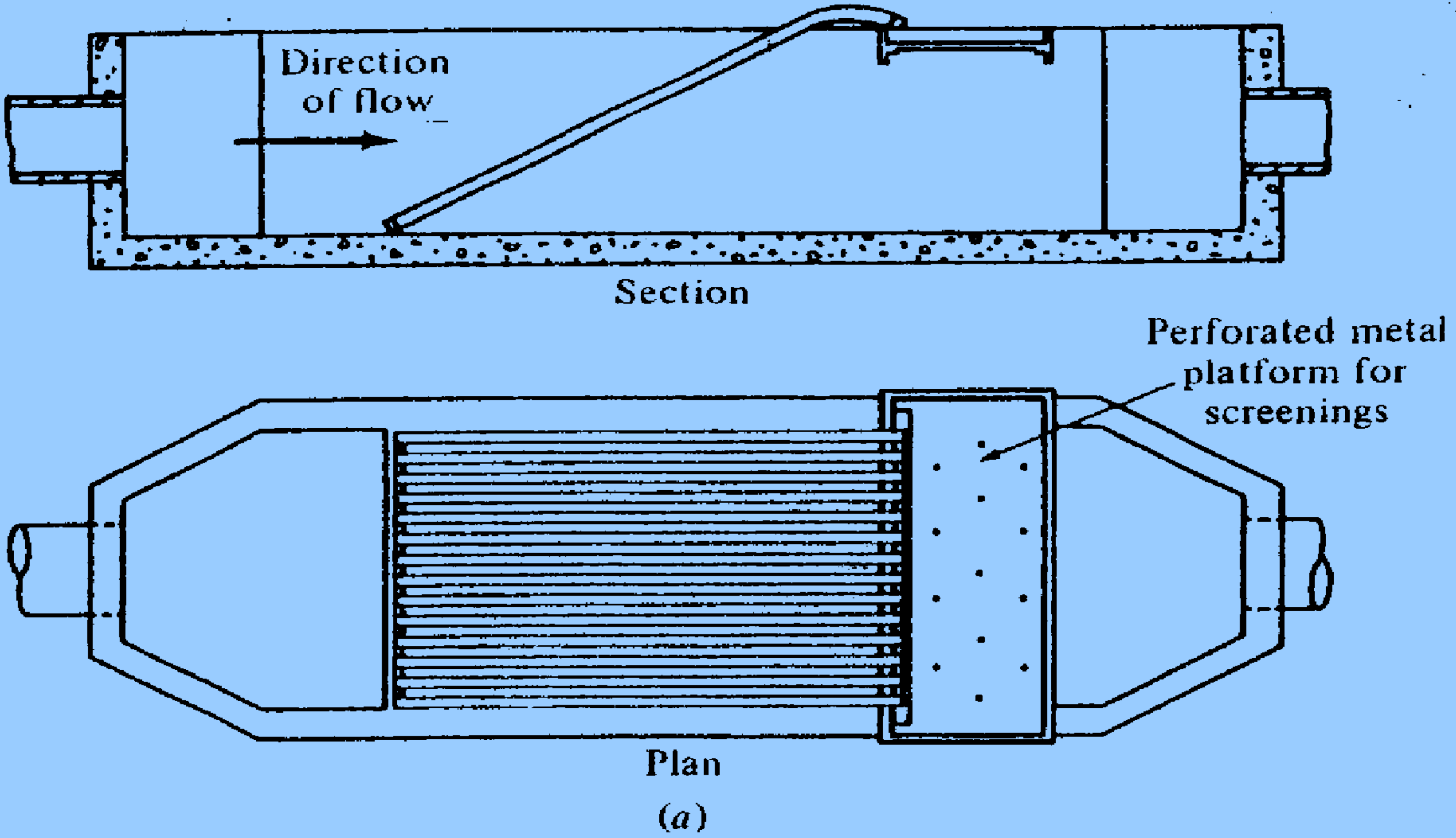
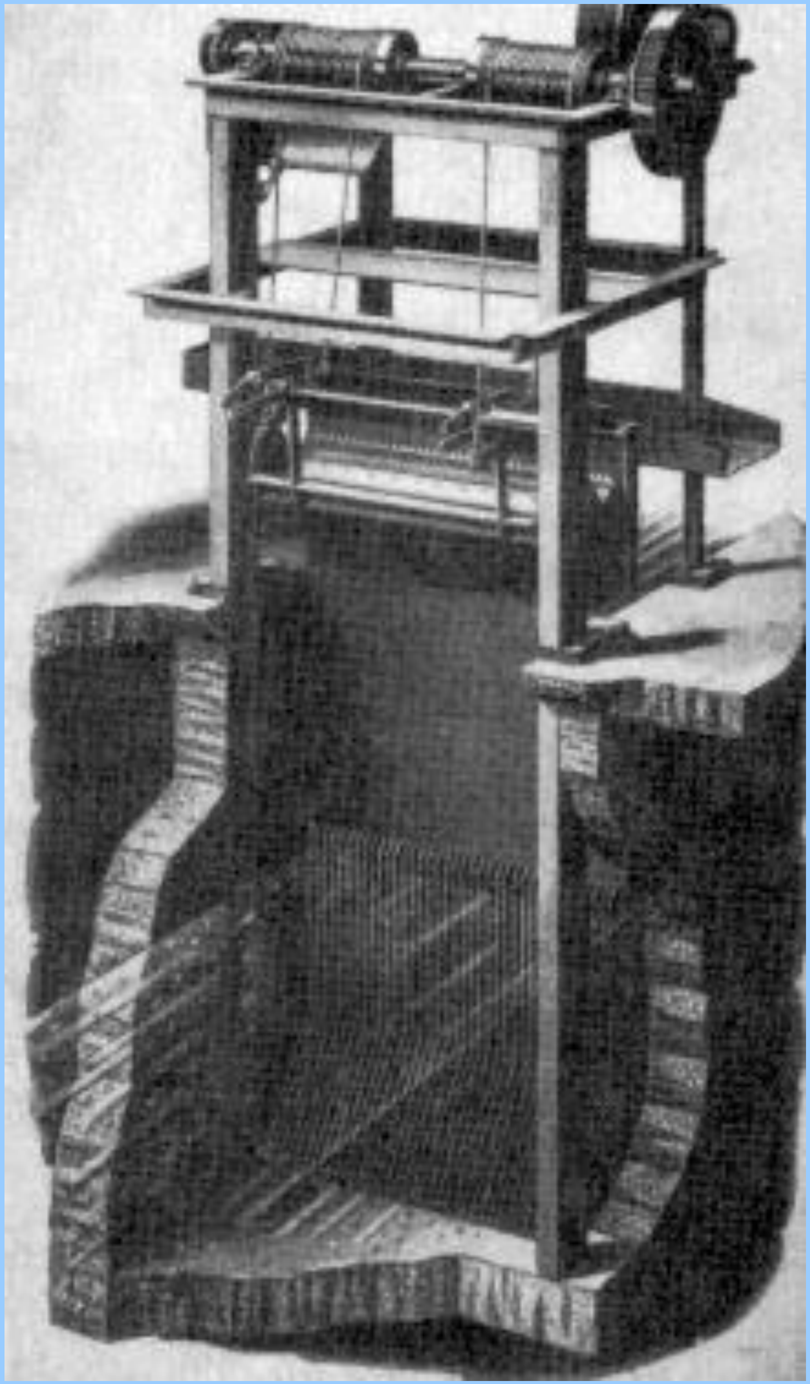


Figure (a) Manually cleaned bar rack (from Peavy, Rowe, and Tchobanoglous, 1985, p. 218)

Bar Screen

Mechanically Cleaned

- More frequently used because labor and overflowing are greatly reduced.
- A by-pass channel with a hand cleaned bar screen must also be provided. A second mechanically cleaned bar screen can also be provided.
- The purpose of the by-pass channel is to provide treatment in case of a mechanical failure.
- Screens are either front or back cleaned.



Bar Screen

Mechanical Bar Screen

General Design Criteria

- Bar Width: 1/4 to 5/8 in
- Spacing: 5/8 to 3 in
- Depth: 1 to 1.5 inches
- Slope: 30 – 45^{o} from the vertical.

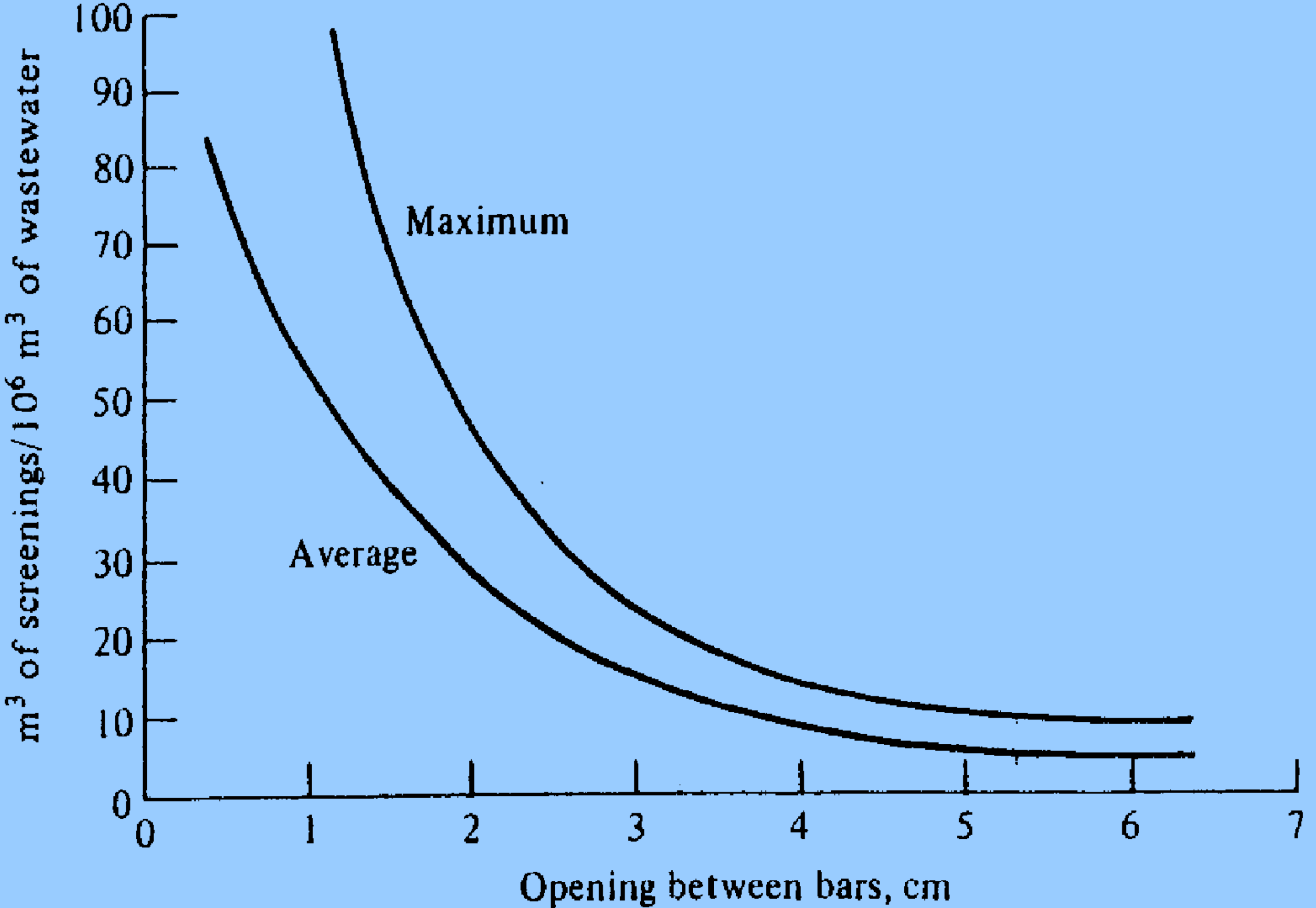


Figure 5-7 Quantity of screening from municipal wastewater as a function of bar spacing using mechanically cleaned bar screens. (*From Metcalf & Eddy, Inc.* [*5-36*].)

(from Peavy, Rowe, and Tchobanoglous, 1985, p. 219)

Mechanical Bar Screen

General Design Criteria

- Approach velocity – 1.25 fps @ minimum flow (as determined by the Manning Eqn.), the purpose in controlling the approach velocity is to prevent deposition of grit in the channel.
- Velocity through the screen - < 3 fps, to prevent excessive headloss and to prevent forcing of screenings through the openings.
- Quantities of screenings – 0.5-5 ft^3/ MG, average 2 ft^3/MG

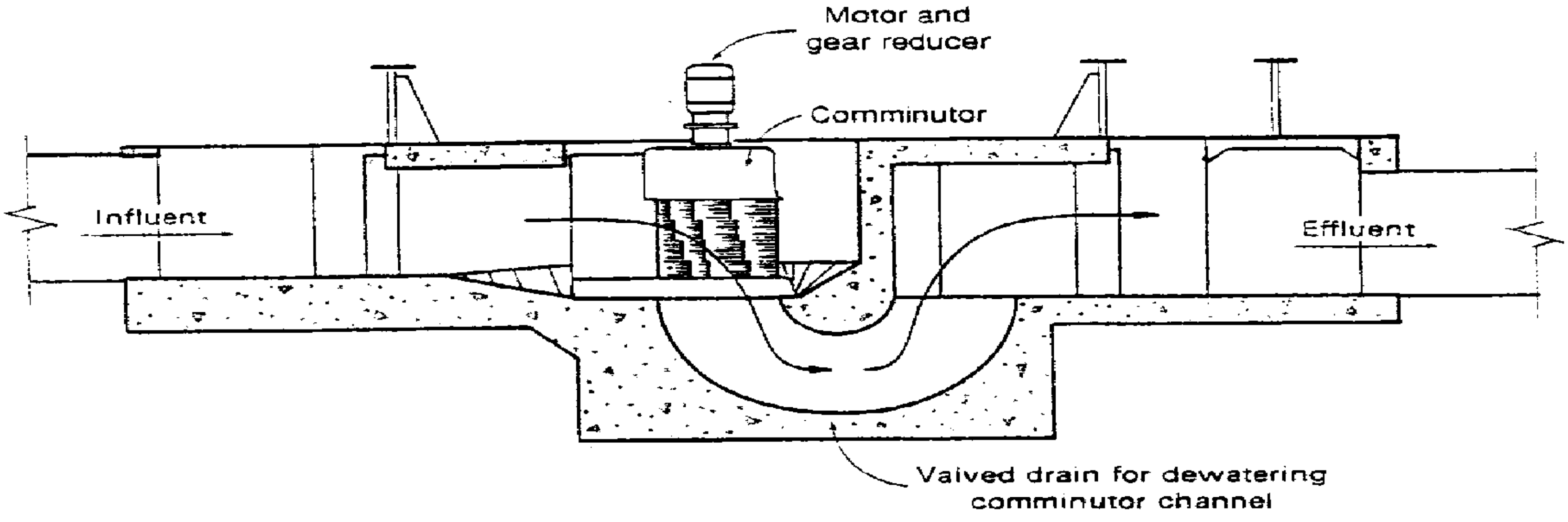
Mechanical Bar Screen

General Design Criteria

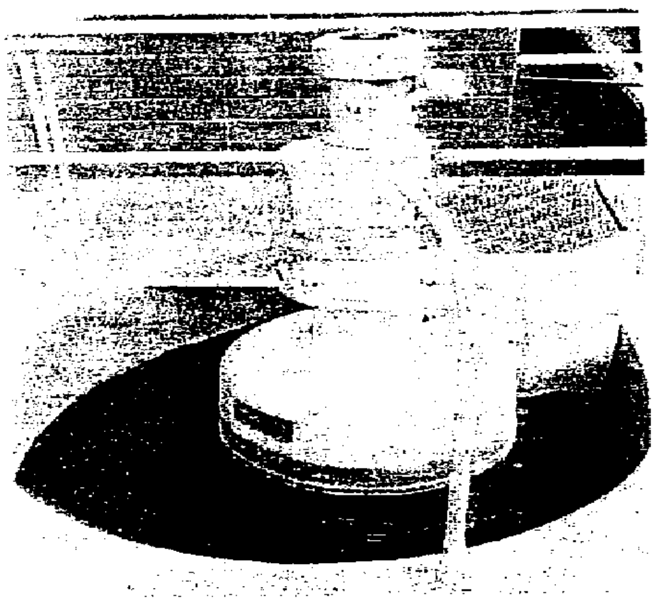
- Disposal of screenings – landfill or incineration
- Density: 80% moisture (60 pcf) right off the screen, dry (12 pcf)
- h_L = 0.5 – 2.5 ft (max)
- $h_L=(V_s^2-v_c^2)/(2g * 0.7)$
  - V_s= velocity through the bars
  - v_c= approach velocity in the upstream channel

Comminutors
Vendor-Provided Equipment

- Purpose: to chop solids between 1/4 - 3/8 inch to prevent pumps from being clogged.
- Comminutors are installed directly into the influent channel.
- Since comminutors come in a standard size, it is not unusual to select the comminutor first, then size the channel.
- Comminutors should be provided with a by-pass channel and a hand cleaned bar screen.



(a)



(b)

FIGURE 9-5
Typical comminutor installation: (*a*) cross-sectional view (from FMC, Chicago Pump) and (*b*) pictorial view of comminutor.

(from Peavy, Rowe, and Tchobanoglous, 1985, p. 220)

Grit Chambers

- Purpose: to remove inorganic material referred to as grit. Grit includes sand, eggshells, bone chips, coffee grounds, etc.
- Grit is removed to prevent abrasion of pumps and to reduce deposits in pipe lines, channels, and digesters.

Grit Chamber

General Design Criteria

- Specific gravity of grit: 2.65
- Diameter of grit: 0.22 mm
- Settling velocity: 0.075 fps
- Equivalent overflow rate: 48,400 gpd/ft^2

Grit Chamber

General Design Criteria

- Quantity of girt: 1/3 to 24 ft^3/MG
  - Ave = 4 ft^3 /MG
- Disposal of grit: land fill or incineration (Grit must be washed before disposal)
- Grit chamber storage:
  - Small plant: provide storage below the design invert depending on the quantity and frequency of removal.
  - Large plant: continuous removal, the conveyor hopper is designed based on the size of the equipment.

Grit Chambers

Types

- Square Clarifier (Detritus Tank)
- Aerated Tanks

Grit Chamber

Square Clarifier (Detritus Tank)

- Detritus tanks are designed so that the horizontal velocity is 1.0 fps at maximum flow. This means that at low flow, the velocity is less than 1.0 fps, and therefore, organic material will accumulate.
- Organics are removed by counter current washing as the grit moves up an incline for disposal.

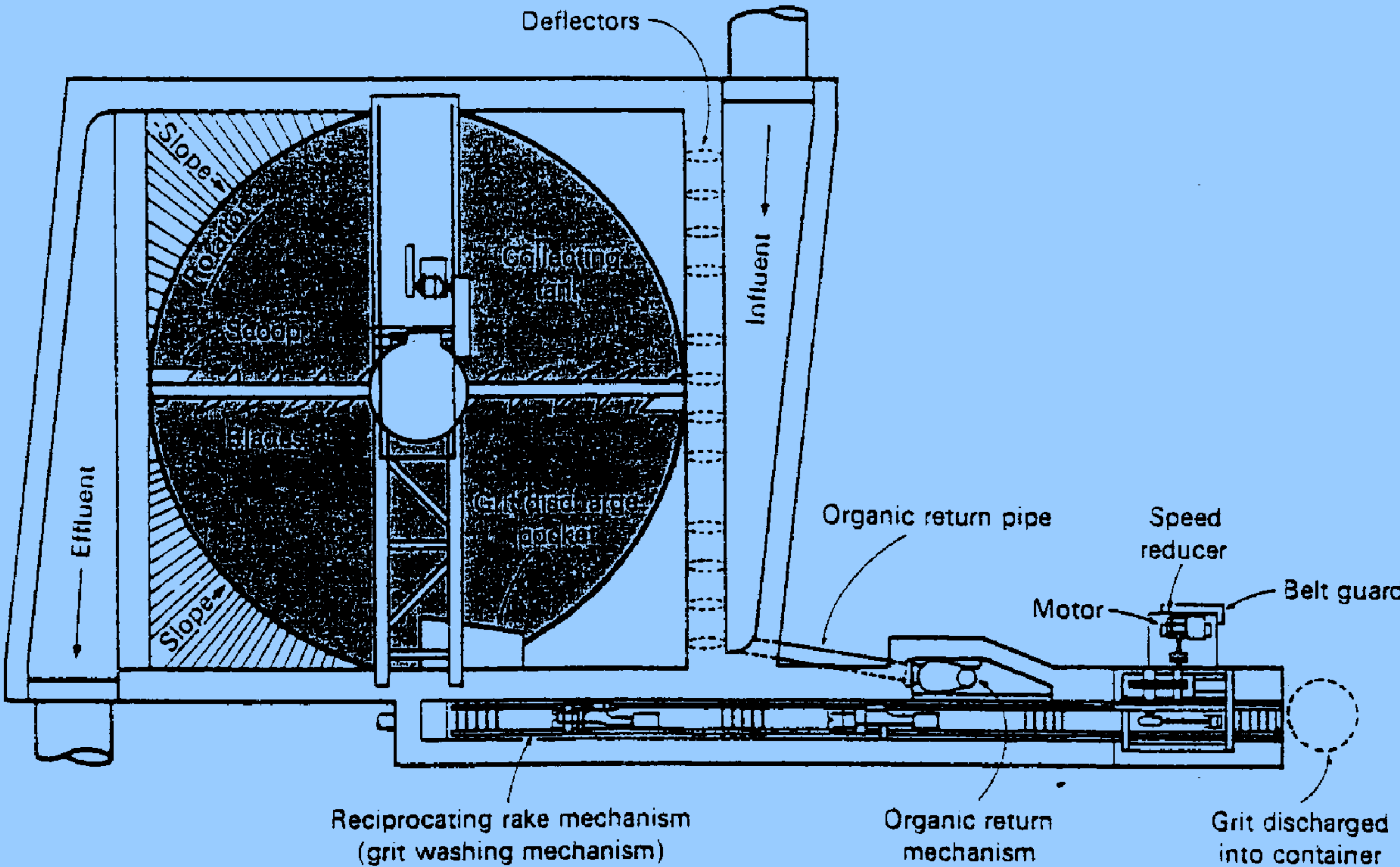


FIGURE 9-6
Typical square horizontal-flow grit chamber (from Dorr-Oliver).

(from Tchobanoglous and Burton, 1991, p. 456)

Grit Chamber

Square Clarifier (Detritus Tank)

- Basic Design Criteria
  - V_s = 0.075 fps @ Average Flow
  - td < 1 min
  - Overflow rate: 48,400 gpd/ft^2
  - $V_{h:}$ 0.75-1.25 fps (keeps organics in suspension)

Grit Chamber

Aerated Grit Chamber

- Upon discovering that grit accumulated in the bottom of activated sludge aeration basins, it has became common practice to use aerated grit chambers.
- Aeration also provides pretreatment of the waste by removing odors and inducing flocculation of the organic material making primary clarification more effective.

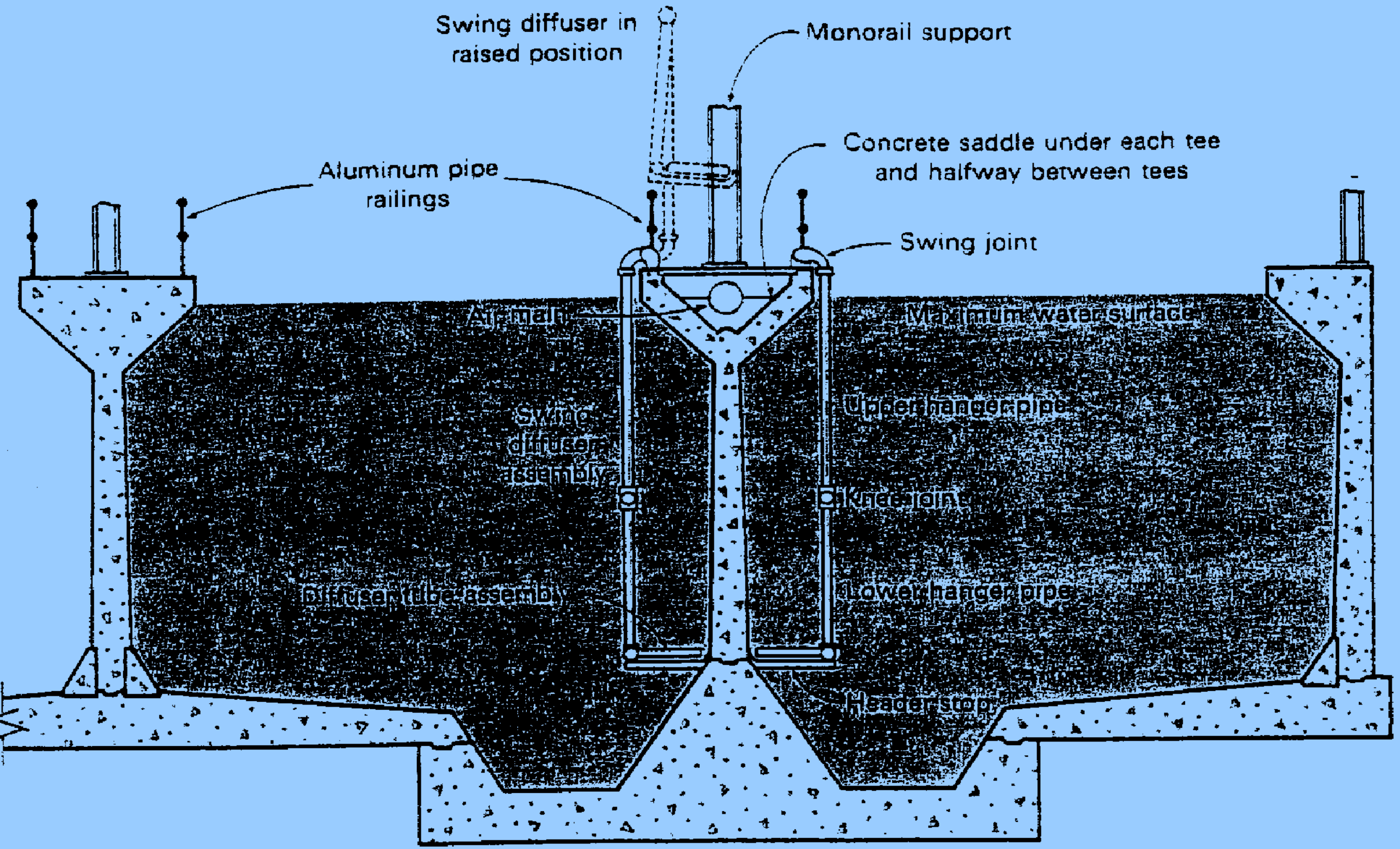


FIGURE 9-8
Typical section through an aerated grit chamber.

(from Tchobanoglous and Burton, 1991, p. 461)

Aerated Grit Chamber

Benefits of Pre-aeration

- By providing preaeration, primary treatment is improved through:
  - Grit removal
  - Flocculation
  - Odor Control
  - Grease Separation

- Design the detention time and aeration rate to control all four

Aerated Grit Chamber

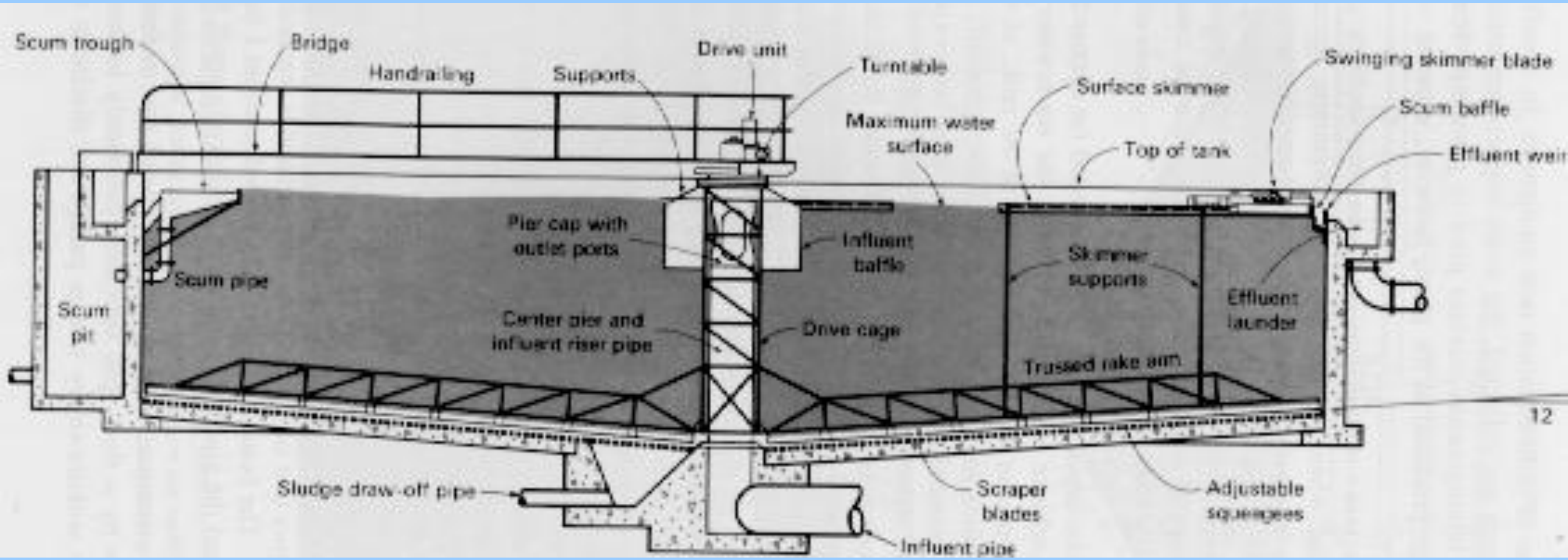
General Design Criteria

- Rate of aeration: 5 cfm/ft length (provide for variable rates of aeration which is adjusted according to the flow and efficiency of grit removal).
- Width to Depth Ratio: a critical factor in providing an effective spiral-rolling action in the grit chamber
  - W:D = 1 – 2.2 : 1
- Depth = 10 – 15 ft (starting point: set depth first)
- Length:Width Ratio = 3:1, final dimensions are adjusted so that the detention time is 3-10 minutes.

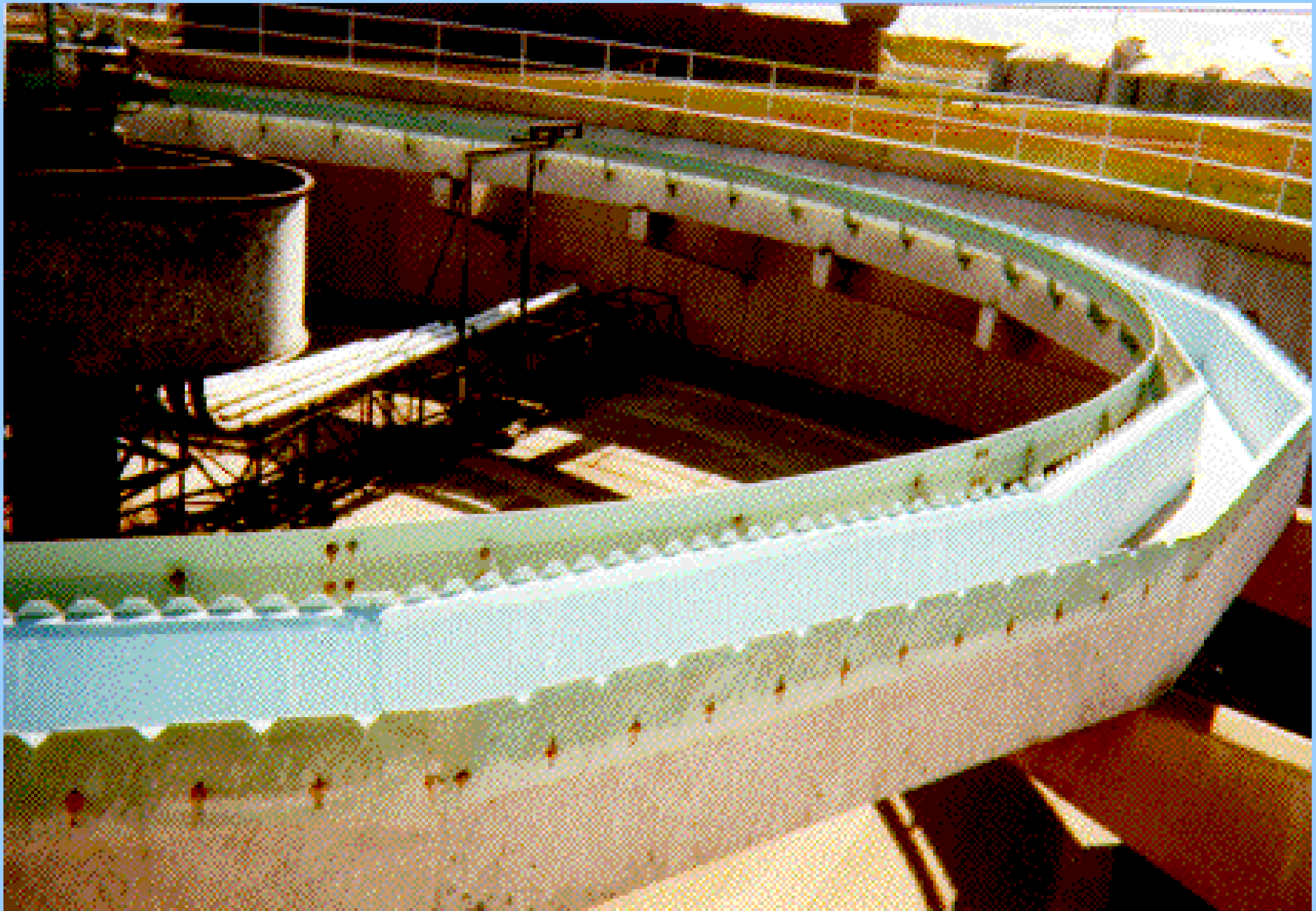
Primary Clarifier

- Purpose: to remove settleable organics and floating scum (grease and oils).
- Efficiencies:
  - Suspended solids 50 – 65%
  - BOD 30 – 35%
- Primary clarifiers are either circular or rectangular. They are very similar to sedimentation basins used in water treatment except that scum removal is always provided in addition to sludge collection.

A Circular Primary Sedimentation Tank



An Empty Primary Clarifier



An Operating Primary Clarifier

Oil Skimmer in a Primary Clarifier

Primary Clarifiers

Design Criteria

- Type II Settling Clarifier: during settling organic solids come in contact with each other and aggregate increasing the particle size and settling rate. Aggregation increases with time, therefore detention time is important.
- T_d: 90 – 150 min at average flow (Avg 2 hr)
- Overflow rate: 600 – 1,200 gpd/ft^2
- Weir loading rate: 10,000 – 15,000 gpd/ft.

DESIGN CRITERIA FOR SEDIMENTATION BASINS

Type of Basin	Overflow Rate, gpd/ft^2	Detention Time, hr
Water Treatment		
Presedimentation	300- 500	3-4
Clarification following coagulation and flocculation		
1. Alum coagulation	350- 550	4-8
2. Ferric coagulation	550- 700	4-8
3. Upflow Clarifiers		
a. Ground water	1500-2200	1
b. Surface water	1000-1500	4
Clarification following lime-soda softening		
1. Conventional	550-1000	2-4
2. Upflow clarifiers		
a. Ground water	1000-2500	1
b. Surface water	1000-1800	4
Wastewater Treatment		
Primary Clarifiers	600-1200	2
Fixed Film Reactors		
1. Intermediate and final clarifiers	400- 800	2
Activated Sludge	800-1200	2
Chemical Precipitation	800-1200	2

Weir Loadings:

1. Water Treatment - weir overflow rates should not exceed 20,000 gpd/ft
2. Wastewater Treatment -
   a. Flow $\leq$ 1 MGD: weir overflow rates should not exceed 10,000 gpd/ft
   b. Flow $\geq$ 1 MGD: weir overflow rates should not exceed 15,000 gpd/ft

Horizontal Velocities:

1. Water Treatment - horizontal velocities should not exceed 0.5 fpm
2. Wastewater Treatment - no specific requirements (use the same criteria as for water)

Dimensions:

1. Rectangular tanks
   a. Length:Width ratio = 3-5:1
   b. Basin width is determined by the scaper width (or multiples of the scraper width)
   c. Bottom slope is set at 1%
   d. Minimum depth is 7 ft
2. Circular Tanks
   a. Diameters up to 200-300 ft, 100 ft is preferred
   b. Diameters must match the dimensions of the sludge scraping mechanism
   c. Bottom slope is set at 8%
   d. Minimum depth is 7 ft

Aerial View Housatonic Wastewater Plant, Milford, CT

(Avg. Flow Rate = 8 MGD)

Aerial View of Blue Plains Wastewater Treatment Plant, Washington D.C. (avg. flow rate = 309 Million gals/day)

Sludge Quantities

- Quantity of sludge collected in the primary clarifier depends on:
  - Specific gravity of the dry solids
  - % moisture
  - Efficiency of settling

- The following relationship is used to determine the specific gravity of the sludge (mixture of solids and water):

$$\frac{1}{S} = \frac{P_s/100}{S_s} + \frac{P_w/100}{S_w}$$

S = Sp. Gr. of sludge
S_s = Sp. Gr. of dry solids
S_w = Sp. Gr. of water (1.0)
P_s = % solids (sludge)
P_w = % water (sludge)

Sludge Quantities

- The volume of sludge can be determined from the following relationship:

$$V = \frac{7.48\ Ws}{\left(\frac{100 - Pw}{100}\right)\gamma\ S} = \frac{7.48\ Ws}{\left(\frac{\%\ S}{100}\right)\gamma\ S}$$

S = specific gravity of sludge

V = sludge volume, gals

Ws = dry weight of solids, lb

γ = specific weight of water (62.4 lb / ft^3)

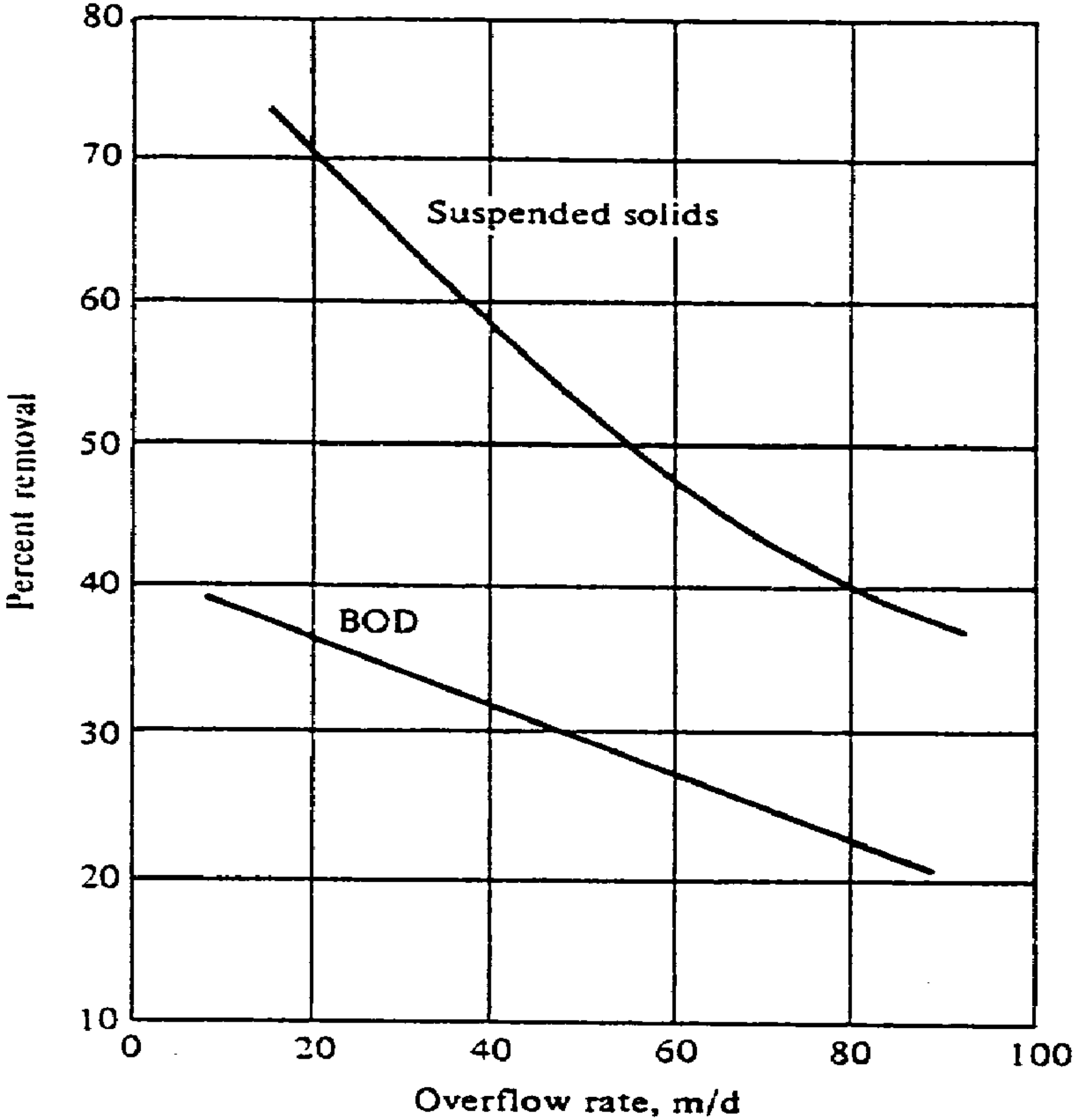


Figure 5-13 Suspended solids and BOD removal as a function of overflow rate. (*Adapted from Steele and McGhee* [*5-50*].)

(from Peavy, Rowe, and Tchobanoglous, 1985, p. 228)

Primary Treatment Efficiency

- BOD = 30 – 35%   SS = 50 – 65%
- Wastewater entering secondary treatment

Strong: BOD = 260–280 mg/L
SS= 120–175 mg/L

Medium: BOD= 145–155 mg/L
SS= 80–110 mg/L

Weak: BOD= 70–80 mg/L
SS= 35–50 mg/L

Forms of BOD: (a) Colloidal
(b) Soluble/Dissolved

Ex. Determine the quantity of primary sludge per million gallons for domestic sewage with the following characteristics: SS = 200 mg/L

Ss = 1.4 % moisture = 95%

Suspended solids removal efficiency = 60%

$$M_{sludge} = QC * Efficiency$$

$$M_{sludge} = \left(1MG * 200mg/L * \frac{8.34lb}{MG * mg/L} \right) 0.6$$

$$M_{sludge} = 1000lb$$

$$\frac{1}{S} = \frac{Ps/100}{Ss} + \frac{Pw/100}{Sw} = \frac{0.05}{1.4} + \frac{0.95}{1.0} = 0.99$$

$$S = 1.01$$

$$V = \frac{7.48Ws}{(\%s/100) + \gamma S} = \frac{7.48 * 1000}{0.05 * 62.4 * 1.01} = 2375 \frac{gal}{MG}$$

References

- Peavy, Howard S., Rowe, Donald R., and Tchobanoglous, George (1985) Environmental Engineering. McGraw-Hill. New York.
- Tchobanoglous, George and Burton, Franklin L. (1991) Wastewater Engineering Treatment, Disposal, and Reuse. Metcalf and Eddy, Inc. Irwin McGraw-Hill, Boston.