Preliminary Wastewater Treatment

NPDES Operator Webinar Series

Larry W. Moore, Ph.D., P.E., WEF Fellow

July 25, 2023

Presentation Outline

I. Introduction
II. Screening
    A. Types of Screens
    B. Control/Operation/Maintenance of Screens
III. Comminutors
IV. Grit Removal
    A. Horizontal Flow Grit Chambers
    B. Aerated Grit Chambers
    C. Vortex Grit Chambers
V. Flow Equalization
VI. Troubleshooting Mechanical Bar Screens
VII. Troubleshooting Grit Removal Systems

Poll Question #1

Introduction

Preliminary Wastewater Treatment

Preliminary Treatment Facilities: Physical treatment units that are specifically designed to remove large and small objects that can potentially cause mechanical and/or operational problems for mechanical treatment processes.

- **Bar Racks/Coarse Screens/Fine Screens**
- **Comminutors**
- **Grit Chambers**
- **Flow Equalization**

Reducing Non-Compliance at Small WWTPs by Focusing on Preliminary Treatment

- Recognize the importance of preliminary treatment.
- If preliminary treatment units are poorly operated and maintained, the entire treatment process suffers.
- Rags, boards, grit, and sand can damage valves, pipes, pumps, clarifiers, thickeners, and digesters.
- Efficient preliminary treatment will make downstream unit processes more effective & reliable.

Reducing Non-Compliance at Small WWTPs by Focusing on Preliminary Treatment (cont.)

- Follow all O&M practices recommended by manufacturers of screens and grit systems.
- Participate often in training activities such as today's training.
- Through the pretreatment program, ensure that industries minimize the discharge of rags, boards, grit, etc.
- Implementing sound O&M of preliminary treatment units is much more cost-effective than implementing emergency repairs caused by poor O&M.

Screening

Types of Screens

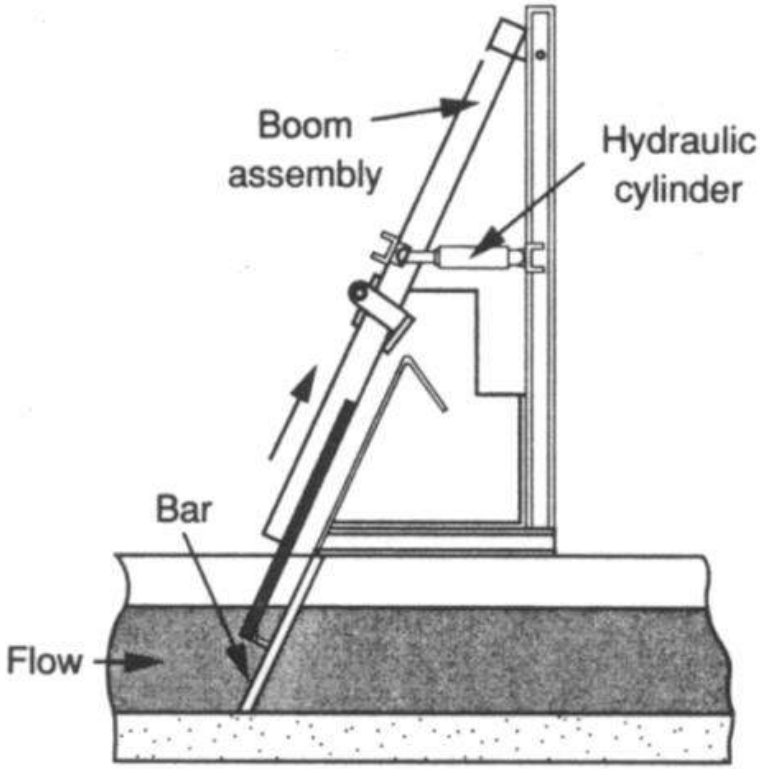
Preliminary Treatment – Screening

Types of Bar Screens:

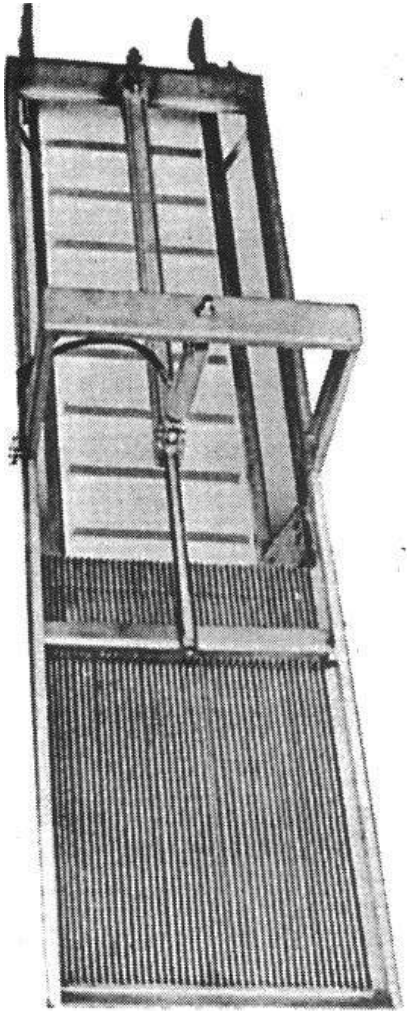
- Front-cleaning rakes
- Back-cleaning rakes
- Chain-driven screens
- Cable-driven screens
- Step screens
- Static fine screens
- Rotary drum fine screens

Preliminary Treatment - Bar Racks & Coarse Screens

- Bar Racks: are used to remove large objects that could potentially damage downstream treatment/pumping facilities.



Ref: Metcalf & Eddy, 1991



Preliminary Treatment Facilities

Reciprocating Rake Screen

- The rake moves to the base of the screen, engages the bars, and pulls the screenings to the top of the screen where they are removed
- Most use a cogwheel drive mechanism for the rake
- Drive motors are submersible electric or hydraulic type
- All parts requiring maintenance are above waterline
- The screen uses only one rake
- The front cleaned, front return feature minimizes solids carryover

Prelim. Treatment - Chain-Driven Screens

- Can be raked from the front or back
- Front cleaned, front return screens are more efficient but less rugged and are susceptible to jamming
- Front cleaned, back return screens: the cleaning rakes return to the bottom of the bar screen on the downstream side of the screen, pass under the bottom, and clean the screen as the rake rises
- Back cleaned screens: the bars protect the rake from damage by debris but are more susceptible to solids carryover

Preliminary Treatment – Step Screens

Step screens have step-shaped bars. As screenings mat on the screen, the screen rotates upward one step. The screenings are carried to the top of the screen where they are dropped into a screenings trough.

Preliminary Treatment Facilities

Preliminary Treatment – Static Fine Screens

- **Static screens** use passive filtration to maximize solids removal.
- Screen openings typically are 0.5 mm to 3.0 mm.
- There are no moving parts in the filter, no actuating equipment and it is self-cleaning.
- The components of the static screen include the feed box, filter channel, wire mesh and collection tank.
- Static screens allow water to fall through the screen and keep solids by sliding down into the collection area.

Example of a Static Fine Screen

Preliminary Treatment – Rotary Drum Screens

- **Rotary drum screens** are very versatile and offer good solids recovery.
- Two types – internally fed drum screens and externally fed drum screens
- Internally fed units handle pumped flow and are usually needed for higher flow rates.
- Externally fed units provide overflow protection and are best suited in plants with high oil or grease loadings.


Rotary Drum Screen

Control, Operation, and Maintenance of Screens

Prelim. Treatment – Control of Screens with Rakes

- Electric motors drive the raking mechanisms.
- Manual control with an on-off switch may activate the motors.
- Clock-operated timing switches, level sensing devices, or PLCs may control the motors automatically.
- Clock-operated timing switches are most frequently used.
- However, more and more WWTPS are using PLCs for control of the raking mechanisms.

Normal Operation of Mechanical Bar Screens

- Operators should visibly check the screens several times a shift to ensure proper functioning.
- The operator should check for:
  - unusual noises
  - scraping of the screen
  - jerking of the drive mechanism
  - need for proper disposal of screenings
  - lubrication of the chain or drive mechanism

Maintenance of Mechanical Bar Screens

Every 30 days:

- Remove screen from service for cleaning & inspection.
- Use high-pressure cleaner or steam cleaner.
- Lubricate chains and rails.
- Check speed-reducer lubricant for proper level and contamination.
- Check torque-limiting device for proper operation.
- Check for and repair bent or broken teeth and bars.

Maintenance of Mechanical Bar Screens (cont.)

Every 30 days:

- Check and align chains as necessary.
- Check rake wiper mechanism for proper operation.
- Lubricate wiper rake pivot pins and wiper rake shock absorber.
- Record voltage and amperage draw of the equipment.
- Test alarm systems.

Maintenance of Mechanical Bar Screens (cont.)

Every 90 days:

- Change the oil in speed reducer.

Annually:

- Clean and spot prime rust spots on the unit and its components and touch-up paint them.
- Inspect motor and wiring.
- Inspect motor control circuit.
- Inspect sprockets and chain pins for wear.
- Inspect and lubricate motor coupling and cables.
- Check magnetic brake for proper operation.
- Inspect channel for accumulation of debris.

Prelim. Treatment – Screening Storage Areas

- Make sure there are no overflows of storage containers.
- Screenings are a major source of odors.
- Wastewater-soaked debris harbors pathogens that can cause health problems.
- Screenings should be disposed of daily or even more frequently.
- During rainstorms, the cleaning frequency may have to be increased (more leaves, tree limbs, etc.)
- If there are multiple channels, make sure flow rate is uniform to each screen.

Prelim. Treatment – Problems with Screens

Problems related to screens are:

- Unusual operational conditions (sudden loads of debris that clog or jam the screening equipment
- Equipment breakdown (component failure)
- Control failure

* Operators need to read the O&M manuals for the specific screens used at the plant.

Coarse Bar Screens at Large WWTP

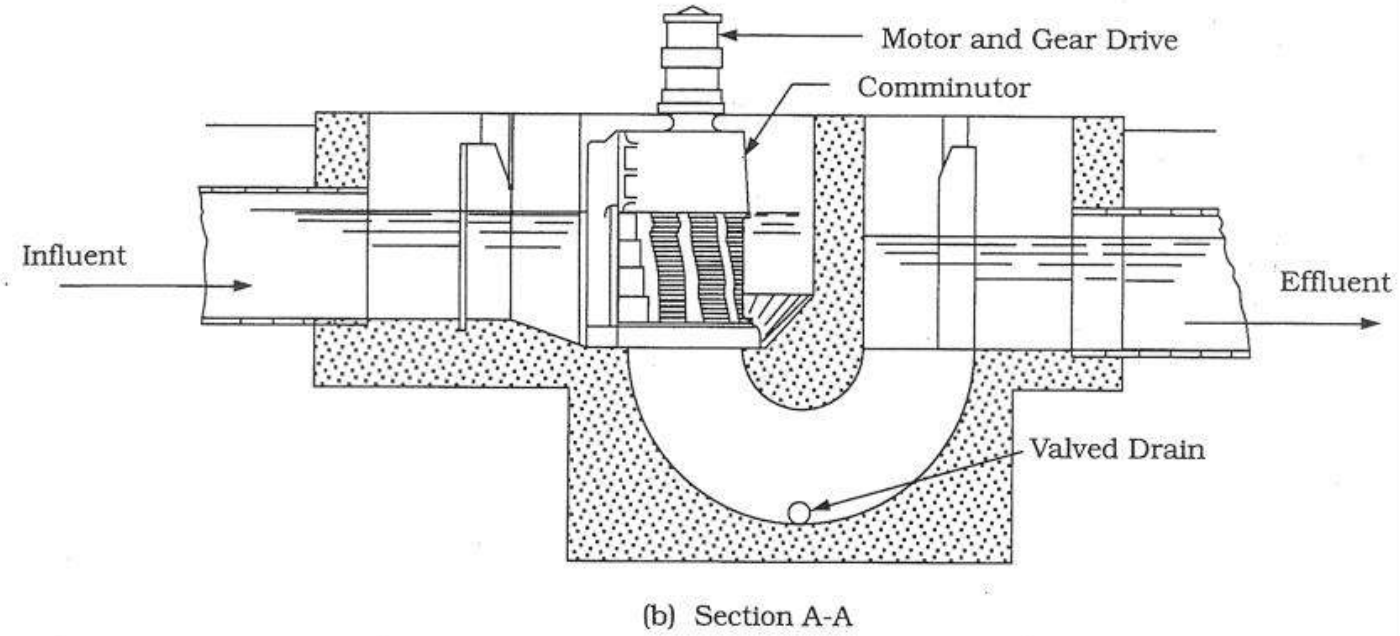
Coarse Bar Screens at Large WWTP

Storage of Screenings in Roll-off Box at Large WWTP

Comminutors

Preliminary Treatment - Comminutor

- Comminutors: are used to grind/chop up particles so that they can be removed easier in downstream processes.



(b) Section A-A

FIGURE 7.4 *Comminutor Installation*
Courtesy of Chicago Pump Company.

Ref: Reynolds & Richards, 1996, Unit Operations and Processes in Environmental Engineering

Poll Question #2

Questions?

Grit Removal

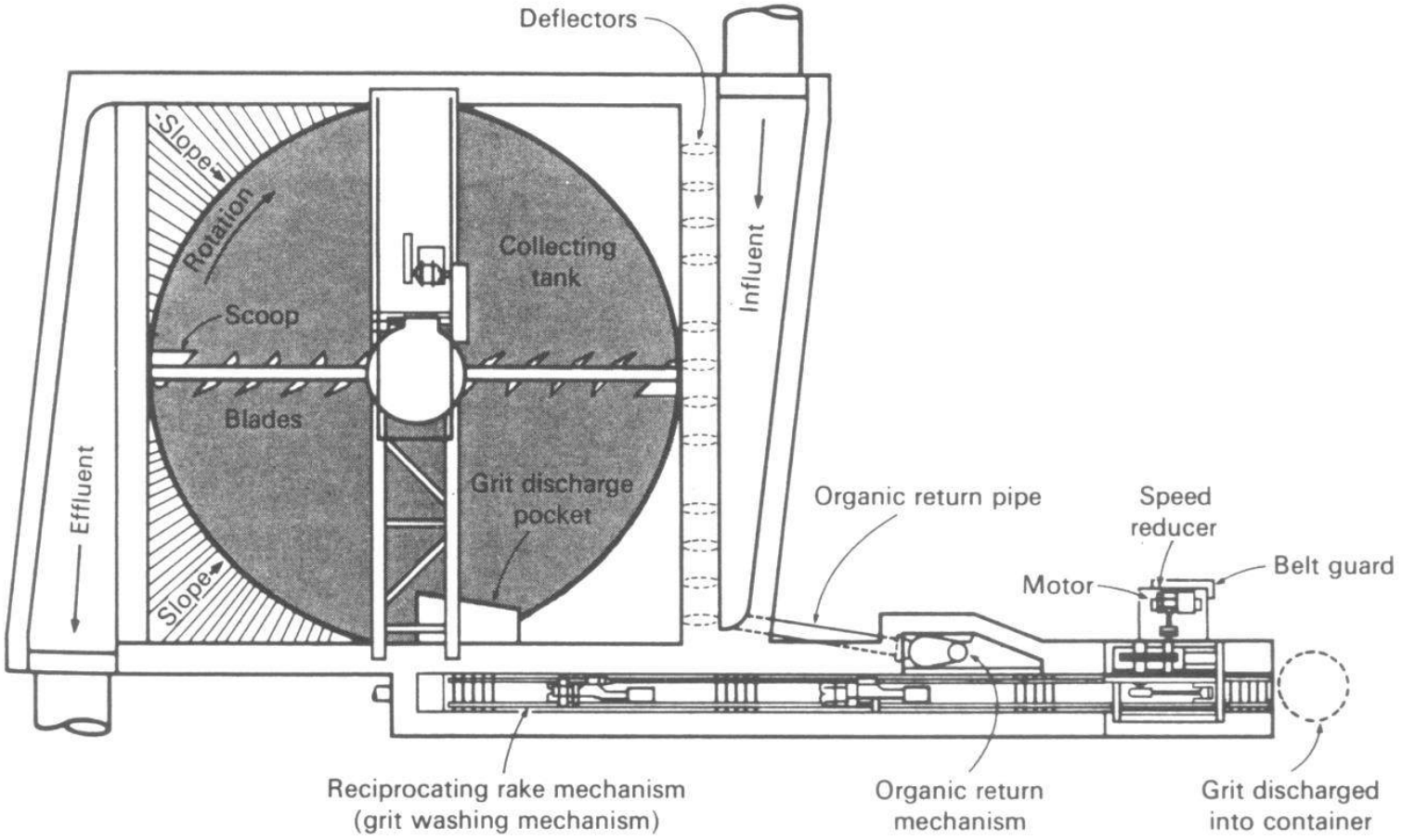
Preliminary Treatment - Grit Removal

Grit Removal: is used to remove small to medium sized objects such as sand, broken glass, bone fragments, pebbles, etc.

- Protects moving mechanical equipment from abrasion and abnormal wear
- Reduces the formation of heavy deposits in pipelines, channels, and conduits
- Reduces the frequency of digester cleaning caused by excessive accumulations of grit

Horizontal Flow Grit Chambers

Preliminary Treatment
Horizontal Flow Grit Chamber



Ref: Metcalf & Eddy, 1991

Preliminary Treatment
Horizontal Flow Grit Chamber

Typical design information for horizontal-flow grit chambers

Item	Value	
	Range	Typical
Detention time, s	45–90	60
Horizontal velocity, ft/s	0.8–1.3	1.0
Settling velocity for removal of:		
65-mesh material, ft/min[a]	3.2–4.2	3.8
100-mesh material, ft/min[a]	2.0–3.0	2.5
Headloss in a control section as percent of depth in channel, %	30–40	36[b]
Allowance for inlet and outlet turbulence	$2D_m - 0.5L^c$	

[a] If the specific gravity of the grit is significantly less than 2.65, lower velocities should be used.

Ref: Metcalf & Eddy, 1991

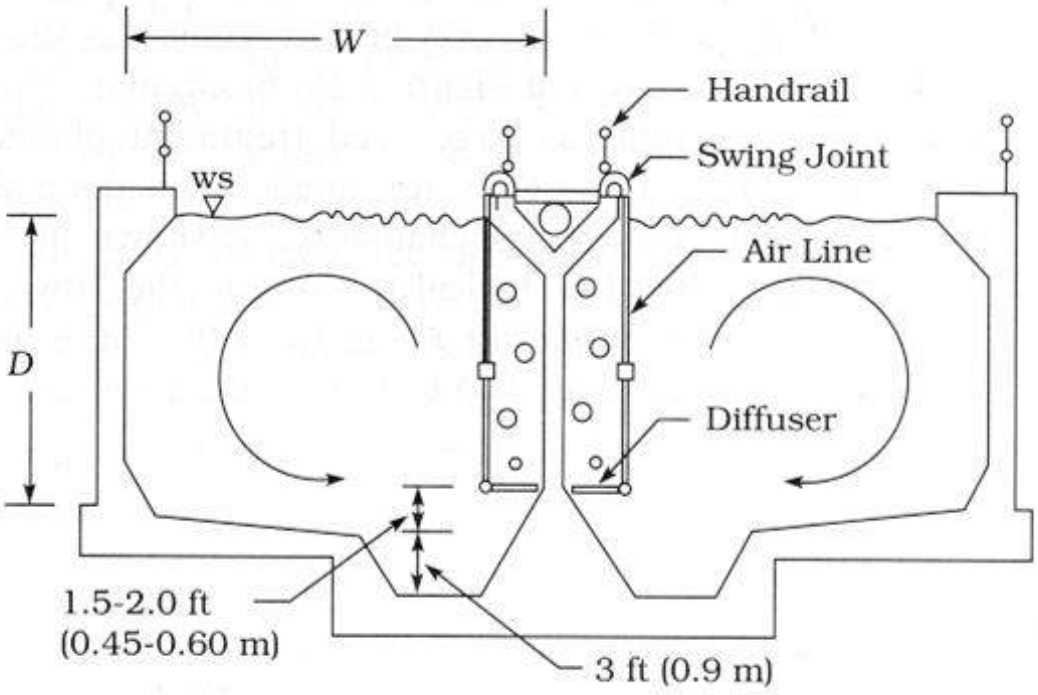
Horizontal Flow Grit Chamber at Large WWTP

Horizontal Flow Grit Chamber Filled with Grit

Emergency Grit Removal at Large WWTP

Aerated Grit Chambers

Preliminary Treatment - Grit Removal
Aerated Grit Chamber

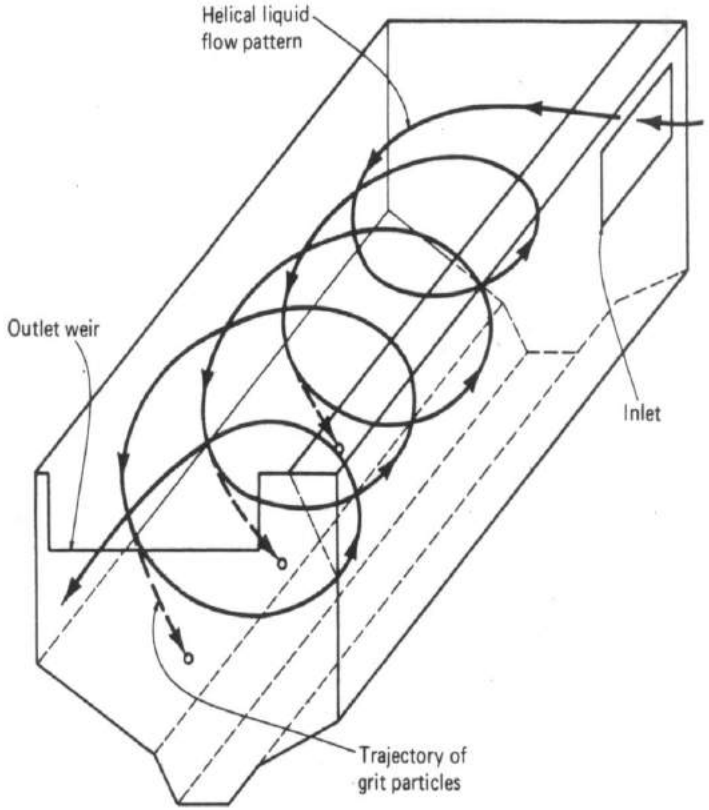


(b) Section

FIGURE 7.14 ***Aerated Grit Chamber with Spiral-Roll Flow***

Adapted from *Wastewater Engineering: Treatment, Disposal and Reuse*, 3rd ed. by Metcalf & Eddy, Inc. Copyright © 1991 by McGraw-Hill, Inc. Reprinted by permission.

Preliminary Treatment - Grit Removal
Aerated Grit Chamber



Ref: Metcalf & Eddy, 1991

Preliminary Treatment Facilities

Preliminary Treatment - Grit Removal
Aerated Grit Chamber

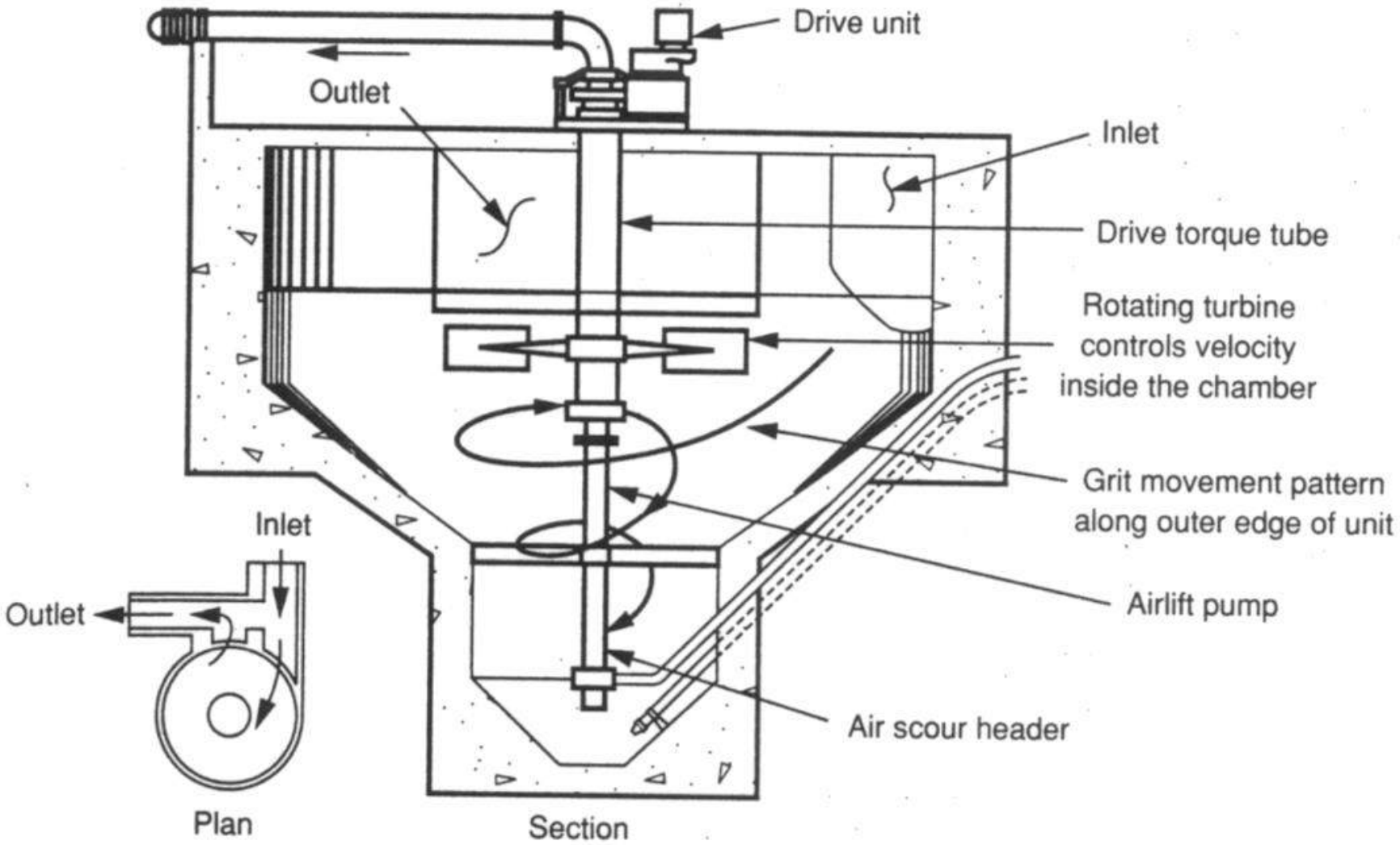
Typical design information for aerated grit chambers

Item	Value	
	Range	Typical
Detention time at peak flowrate, min	2–5	3
Dimensions:		
Depth, ft	7–16	
Length, ft	25–65	
Width, ft	8–23	
Width-depth ratio	1:1–5:1	1.5:1
Length-width ratio	3:1–5:1	4:1
Air supply, $ft^3/min \cdot ft$ of length	2.0–5.0	
Grit quantities, $ft^3/Mgal$	0.5–27	2.0

Ref: Metcalf & Eddy, 1991

Vortex Grit Chambers

Preliminary Treatment - Grit Removal
Vortex Type Grit Chamber



Ref: Metcalf & Eddy, 1991

Preliminary Treatment - Grit Removal
Vortex Type Grit Chamber

- Removes grit by centrifugal and gravitational forces
- Rotating turbine maintains constant flow velocity, and its adjustable-pitch blades promote separation of organics from the grit
- Action of propeller produces a toroidal flow path for grit particles
- Grit settles by gravity into the hopper in one revolution of the basin's contents
- Solids are removed from the hopper by a grit pump or airlift pump

Poll Question #3

Questions?

Flow Equalization

Preliminary Treatment - Flow Equalization

- Used to “dampen” the effects of excessive peak hydraulic or organic loading on a wastewater treatment plant.
- Allows the WWTP to operate at a near constant flow
- May allow a WWTP to have a smaller design capacity
- Most equalization facilities are seldom sized large enough to provide adequate hydraulic equalization.

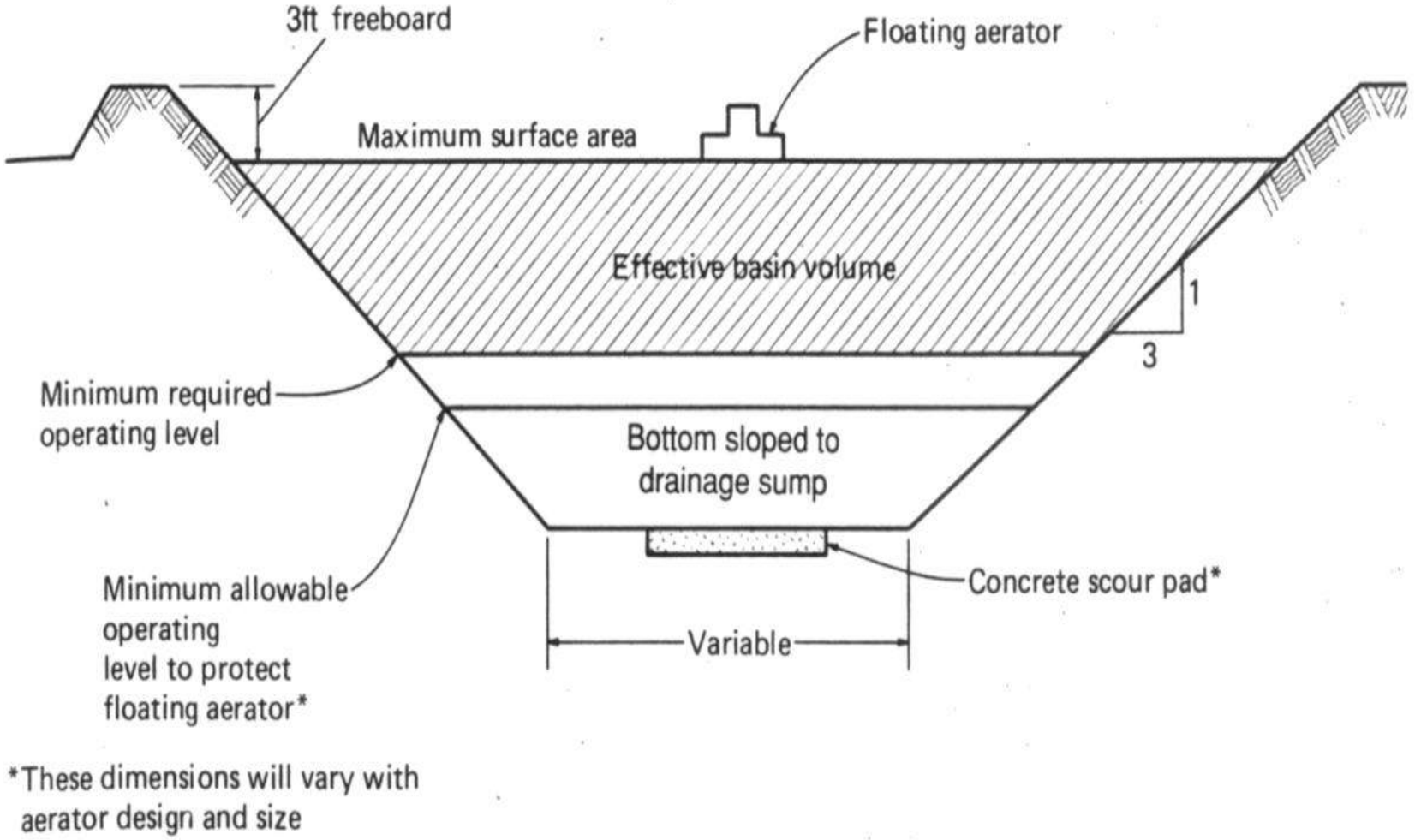
Preliminary Treatment - Flow Equalization

- Typically located downstream of grit chamber
- Requires aeration facilities for mixing and odor control

1.25 to 2.0 cfm/1000 gal

0.02 to 0.04 HP/1000 gal

Preliminary Treatment - Flow Equalization



Ref: Metcalf & Eddy, 1991

Preliminary Treatment - Flow Equalization

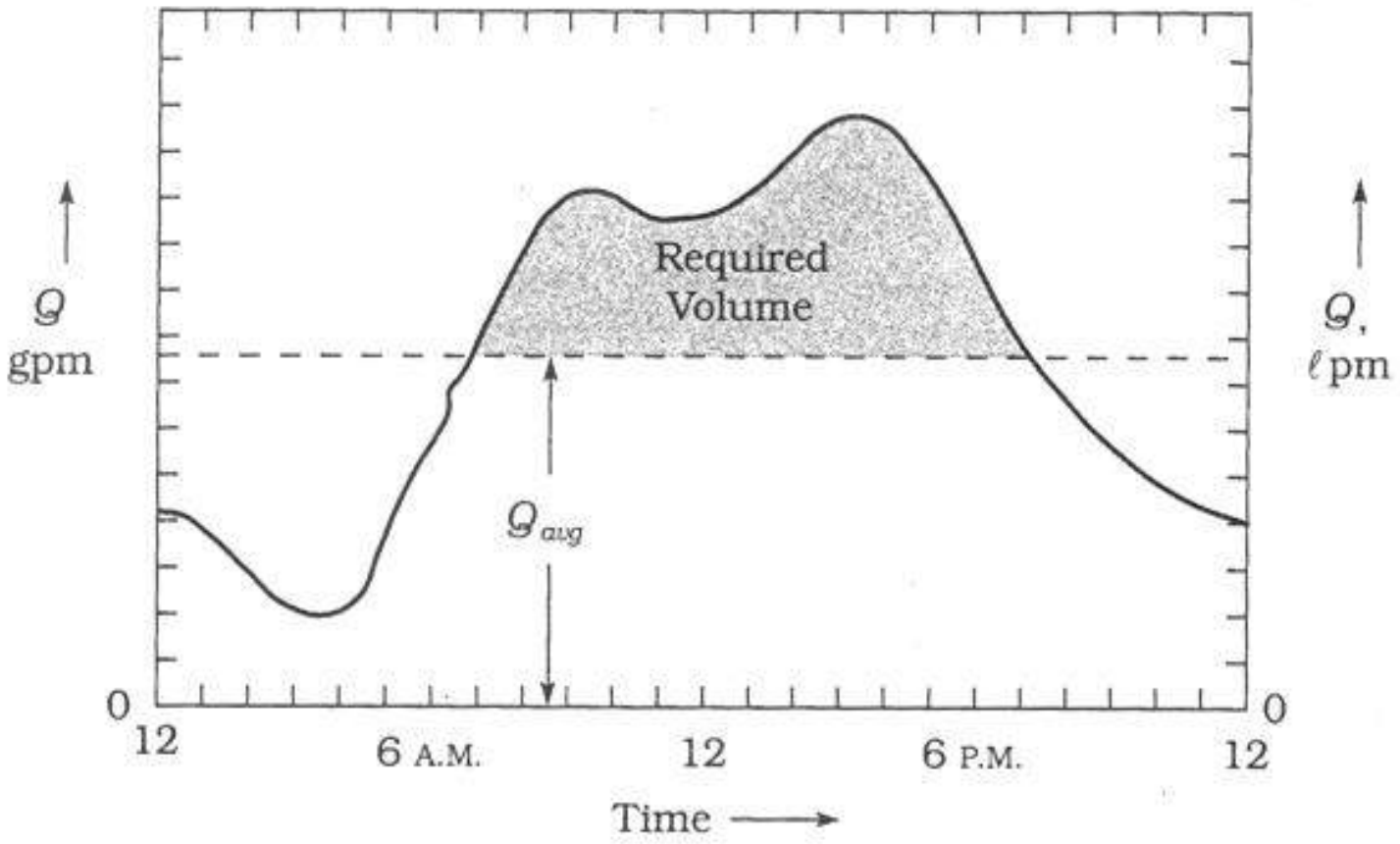


FIGURE 7.19 *Fluctuating Volume Determined by Hydrograph*

Ref: Reynolds & Richards, 1996, Unit Operations and Processes in Environmental Engineering

Preliminary Treatment - Flow Equalization

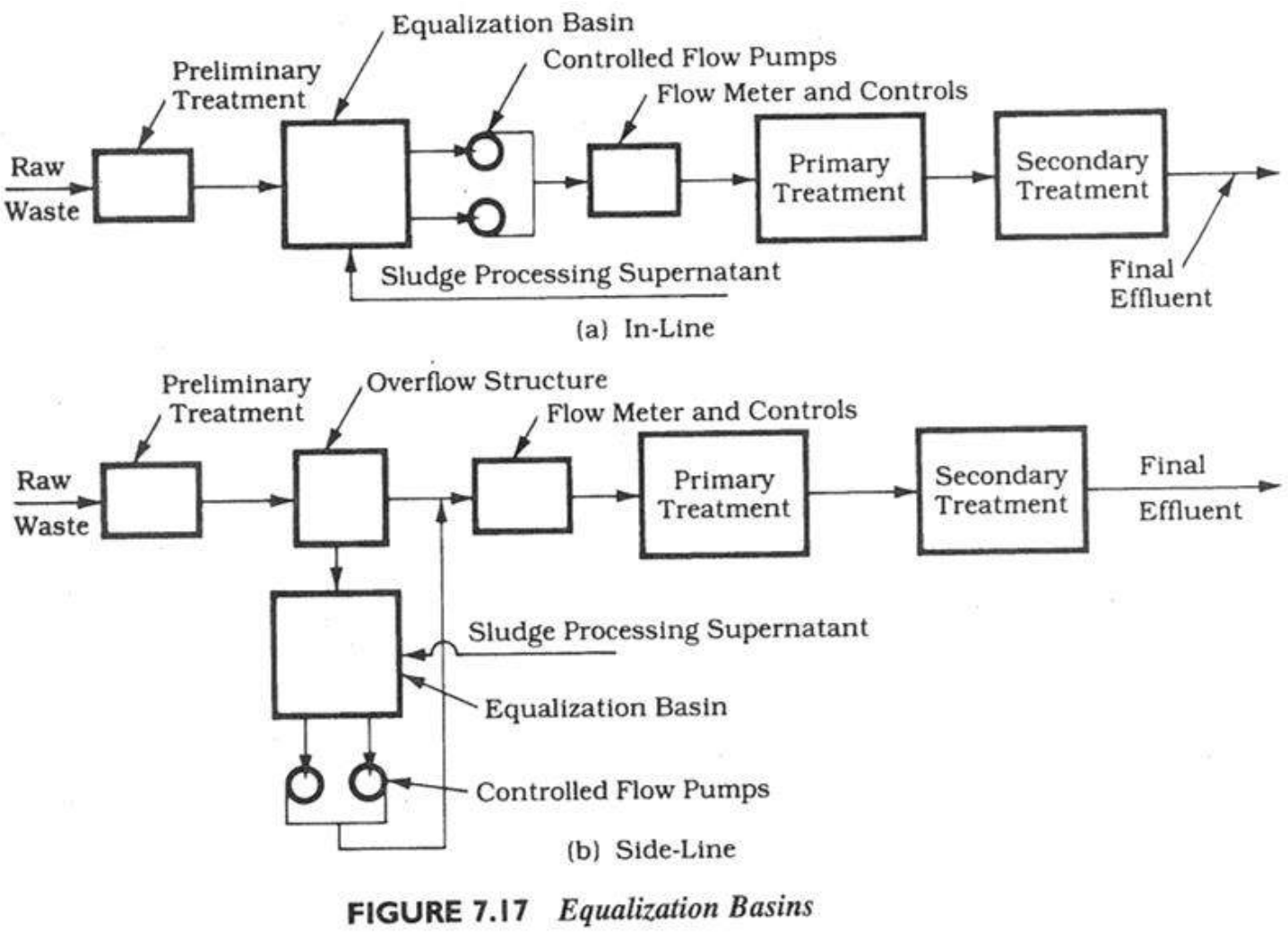


FIGURE 7.17 *Equalization Basins*

Ref: Reynolds & Richards, 1996, Unit Operations and Processes in Environmental Engineering

Troubleshooting Mechanical Bar Screens

Reference: WEF Manual of Practice OM-2

Troubleshooting Mechanical Bar Screens
Problem: Obnoxious Odors, Flies, and other Insects

Probable Cause: Accumulation of rags and debris

Solution: Increase frequency of removal and disposal to an approved disposal facility

Troubleshooting Mechanical Bar Screens
Problem: Excessive Grit in Bar Screen Chamber

Probable Cause: Flow velocity too low

Solution: Remove bottom irregularity or re-slope the bottom

Increase flow velocity in a chamber or flush regularly with a hose

Troubleshooting Mechanical Bar Screens
Problem: Excessive Screen Clogging

Probable Cause: Unusual amount of debris in wastewater. Check industrial wastes (food, other)

Solution: Use a coarser screen or identify source of waste causing the problem so its discharge to the system can be stopped

Probable Cause: Inadequate cleaning frequency

Solution: Increase cleaning frequency

Troubleshooting Mechanical Bar Screens
Problem: Mechanical Rake Inoperable, Circuit Breaker Will Not Reset

Probable Cause: Jammed mechanism

Solution: Remove obstruction. Adjust spring tension if appropriate

Troubleshooting Mechanical Bar Screens
Problem: Rake Inoperative, But Motor Runs

Probable Cause: Broken shear pin

Solution: identify cause of break; replace shear pin

Probable Cause: Broken chain or cable

Solution: Replace chain or cable

Probable Cause: Broken limit switch

Solution: Replace limit switch

Troubleshooting Mechanical Bar Screens
Problem: Rake Inoperative, No Visible Problem

Probable Cause: Defective remote-control circuit

Solution: Replace circuit. Replace motor

Troubleshooting Mechanical Bar Screens
Problem: Marks or Metal Against Metal on Screen Binding

Probable Cause: Screen needs adjustment

Solution: Manufacturer's adjustments recommended in O&M manual

Troubleshooting Grit Removal Systems

Reference: WEF Manual of Practice OM-2

Troubleshooting Grit Systems
Problem: Grit Packed on Collectors

Probable Cause: Collector operating at excessive speeds

Solution: Reduce collector speed.

Probable Cause: Removal equipment operating at slow speeds

Solution: Increase speed of grit removal from collector.

Troubleshooting Grit Systems
Problem: Rotten Egg Odor in Grit Chamber

Probable Cause: Hydrogen sulfide formation

Solution: Wash chamber and dose with hypochlorite.

Troubleshooting Grit Systems
Problem: Accumulated Grit in Chamber

Probable Cause: Submerged debris

Solution: Wash chamber daily. Remove debris.

Probable Cause: Flow velocity too low or broken chain or flight

Solution: Repair equipment.

Troubleshooting Grit Systems
Problem: Corrosion of Metal & Concrete

Probable Cause: Inadequate ventilation

Solution: Increase ventilation and perform annual repair and repainting.

Troubleshooting Grit Systems
Problem: Removed Grit is Gray, Smelly & Greasy

Probable Cause: Inadequate air flow rate in aerated grit chamber

Solution: Increase air flow rate in aerated grit chamber.

Probable Cause: Grit removal system velocity too low in horizontal-flow-through grit chamber

Solution: Increase velocity in horizontal flow-through grit chamber to 1 ft/sec.

Troubleshooting Grit Systems
Problem: Reduced Turbulence in Aerated Grit Basin

Probable Cause: Diffusers covered by rags or grit

Solution: Clean diffusers.

Correct screens or other pretreatment steps to prevent rags/debris from covering the diffusers.

Troubleshooting Grit Systems
Problem: Low Grit Recovery Rate

Probable Cause: Bottom scour at excessive speeds

Solution: Maintain velocity near 1 ft/sec in horizontal flow-through grit chamber.

Probable Cause: Too much aeration

Solution: Reduce aeration in aerated grit chamber.

Increase retention time by using more units or reducing flow to unit.

Troubleshooting Grit Systems
Problem: Overflowing Grit Chamber

Probable Cause: Pump surge problem

Solution: Adjust pump controls.

Control infiltration and inflow.

Troubleshooting Grit Systems
Problem: Septic Waste Rising in Grit Basin

Probable Cause: Sludge on bottom of chamber

Solution: Wash chamber daily and remove debris.

Repair chain.

Repair shear pin on conveyor.

Questions?