10. Preliminary Treatment

- The objective of preliminary treatment is to remove coarse solids and other large materials often found in raw wastewater
- Removal of these materials is necessary to enhance the operation and maintenance of subsequent treatment units
- Preliminary treatment operations typically include a combination of the following processes:
  - Screening
  - Grinding or shredding
  - Flow measurement
  - Grit removal
  - Pre-aeration
  - Flow equalization

10.1 Process Elements of Preliminary Treatment

10.1.1 Screening

- Screening is typically the first unit in a preliminary treatment
- Screening allows for the capture of coarse solids as pieces of cloths garbage so as to protect pumps and other units from clogging.
- Screens may consist of vertical or inclined bars (bar racks or bar screens), wire mesh or perforated plates having either circular or rectangular openings.
- Screens remove the large, entrained, suspended or floating solids such as pieces of wood, cloth, paper, plastics, garbage, etc.
- Debris collected on the screen can be cleaned manually or automatically using chain driven rakes
- The retained material at screens - screenings, is collected and hauled to landfill for disposal
- The quantity of screenings removed varies by location and is a function of the clear opening of the screen.
- Barmuinitors combine the function of a screen and a grinder. The ground material is returned to the wastewater flow for removal during primary treatment.

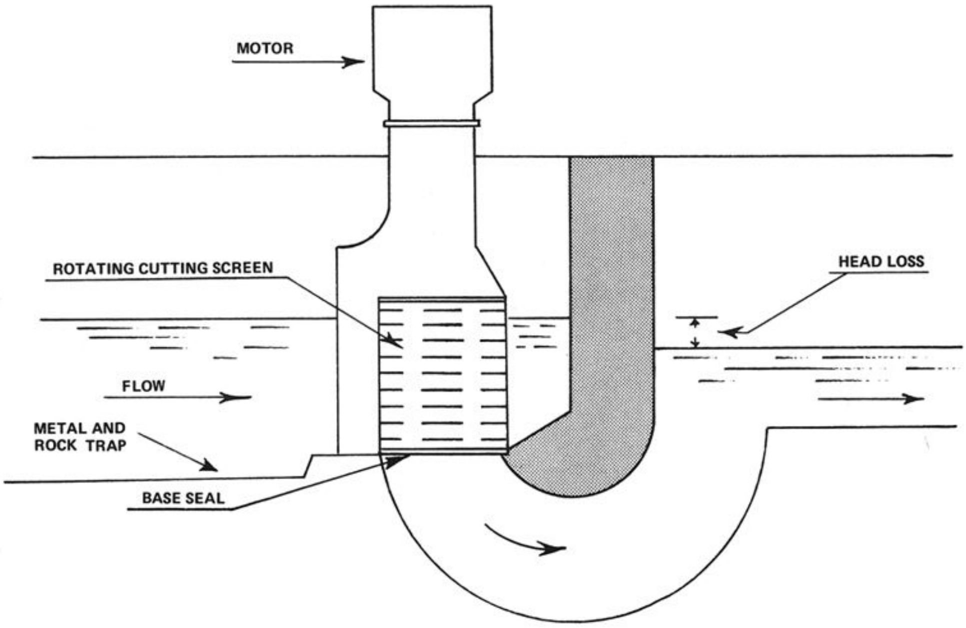
Barscreen - No rakes

Video: Automatic Barscreen

10.1.2 Grinding and Shredding

- Comminutor(Grinder) consist of fixed, rotating or oscillating teeth or blades, acting together to reduce the solids to a size which will pass through fixed or rotating screens grind rags into small chunks
- The comminutors are installed in wastewater channel and they grind the larger solids without actually removing them from the wastewater. These devices may be installed before the screens or as a combination of screen and cutters (barmunitors).

Comminutor



Schematic of comminutor placement in a channel

10.1.3 Flow Measurement

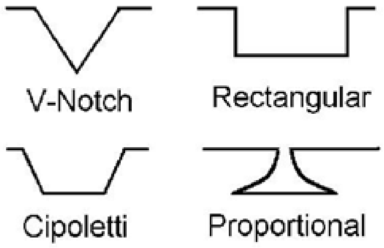
- Wastewater flow to a treatment plant is not constant but varies in a diurnal (daily) pattern reflecting domestic water use activity.
- Continuous flow measurement is necessary in order to monitor diurnal variations in flow which may affect treatment plant efficiency.
- Devices used for flow measurement as part of the preliminary treatment can be placed in a channel or in a pipe.

Devices for Flow Measurement in Channels

- Weirs:
  - Typically sharp crested weirs which are essentially metal plates installed perpendicular the flow. The plate may a straight edge, a V-notch, or a trapezoidal opening.
  - The weir plate in the channel causes an increase in the depth of the water behind the weir. which is proportional to the flow rate.

- The flow rate can be determined by calculation or by reading the corresponding flow value to the depth of the water, from a chart specific for that weir.

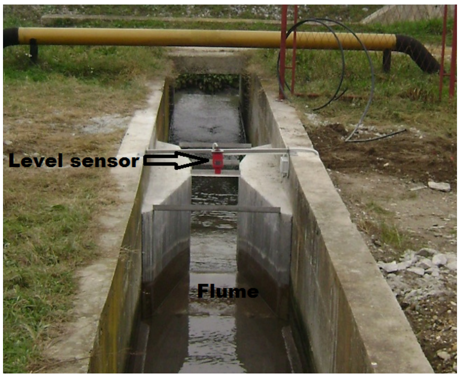
(a) Weir in a channel



(b) Weir types

- Parshall Flume:
  - Parshall flume uses a narrow section in the channel as the restriction rather than the vertical plate of a weir.
  - Like the weir, the restriction due to the narrow section of the flume, causes an increase in the depth of the water behind the weir (head) which is proportional to the flow rate.
  - The flow rate can be determined by calculation or by reading the corresponding flow value to the depth of the water, from a chart specific for that Parshall Flume.

(a) Parshall flume



(b) Parshall flume with level sensor

Devices for Flow Measurement in Pipes

- Venturi Tube:
  - Measures the difference in pressure in the inlet and center section (throat)
  - This pressure difference can then be mathematically converted to a flow rate.
  - Works only when a pipe if flowing full
- Magnetic Flow Meter (Magmeter):
  - Magmeter is a pipe spool which has an electromagnetic coil surrounding it. As the wastewater - a conducting material, flows through it, an electrical current is created proportional to the velocity of the conducting fluid (wastewater).
  - Flow is automatically calculated by multiplying the velocity by the cross- sectional area of the pipe.
  - Similar to the venturi meter, magmeter will read accurately only if the magmeter section of the pipe is flowing full and the wastewater is flowing through it at a certain minimum velocity.

(a) Magmeter

(b) Piping with magmeters

10.1.4 Grit Removal

- Grit includes sand, gravel, cinder, eggshells, bone chips, seeds, coffee grounds, and large organic particles, such as food waste.
- Purpose of Grit removal:
  - to protect mechanical equipment from abrasion and abnormal wear
  - to reduce clogging caused by deposition of grit particles in pipes and channels, and
  - to prevent loading the treatment plant with inert matter that might interfere with the operation of treatment units such as anaerobic digester and aeration tanks.
- Removal of organic material along with the grit is undesirable for two reasons:
  1. It causes odor issues, and
  2. Organic matter is a potential source of energy (digester gas)
- Grit Disposal: Grit removed is typically landfilled.
- Grit Volume: The volume of grit collected measured in ft^3/MG.
- The rate of grit collection can range from 0.5 ft^3/MG to 30 ft^3/MG.
- Wastewater plants having a combined collection system must deal with much larger volumes of grit.

Grit Removal Systems

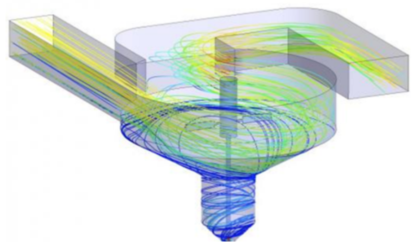
- HORIZONTAL GRIT CHAMBERS:
  - These are rectangular channels 30 to 60 feet long and the water detention time is between 45 to 90 seconds
  - Water passing through these channels is maintained at a relatively constant velocity of about 1 feet per second (fps) which allows for the grit to settle while keeping the lighter organic material to stay in suspension and continue on into the primary clarifiers.
- AERATED GRIT CHAMBERS:
  - The 1 fps velocity is maintained by using aerators to create a rolling flow in the tank.
  - Aeration is achieved using diffusers located on the bottom of one side of the grit chamber.
  - Aerated grit chambers help create aerobic conditions in septic sewage. Aerobic conditions help improve the settleability of the sludge and increase both BOD and suspended solids removal in the primary clarifiers.
  - Much larger and deeper than non-aerated units.
  - The detention times are increased to 3 to 5 minutes.
- CYCLONIC/VORTEX GRIT CHAMBER:
  - The wastewater flows into a cylinder that tapers to a cone at one end.
  - The flow whirls around the inside of the cylinder like a cyclone which causes the heavy grit to be slinged to the outside and it ultimately settles to the bottom from where it is withdrawn.

Grit Removal

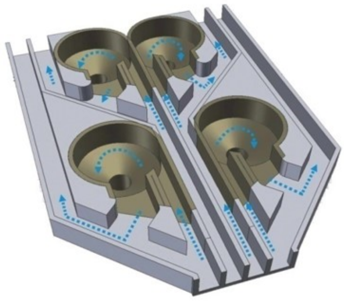
  - In the cyclonic/vortex grit chamber, the grit is scoured with water and is removed using pumps

(a) Horizontal grit chamber

(b) Aerated grit chamber



(a) Vortex grit chamber design



(b) Vortex grit chamber installed

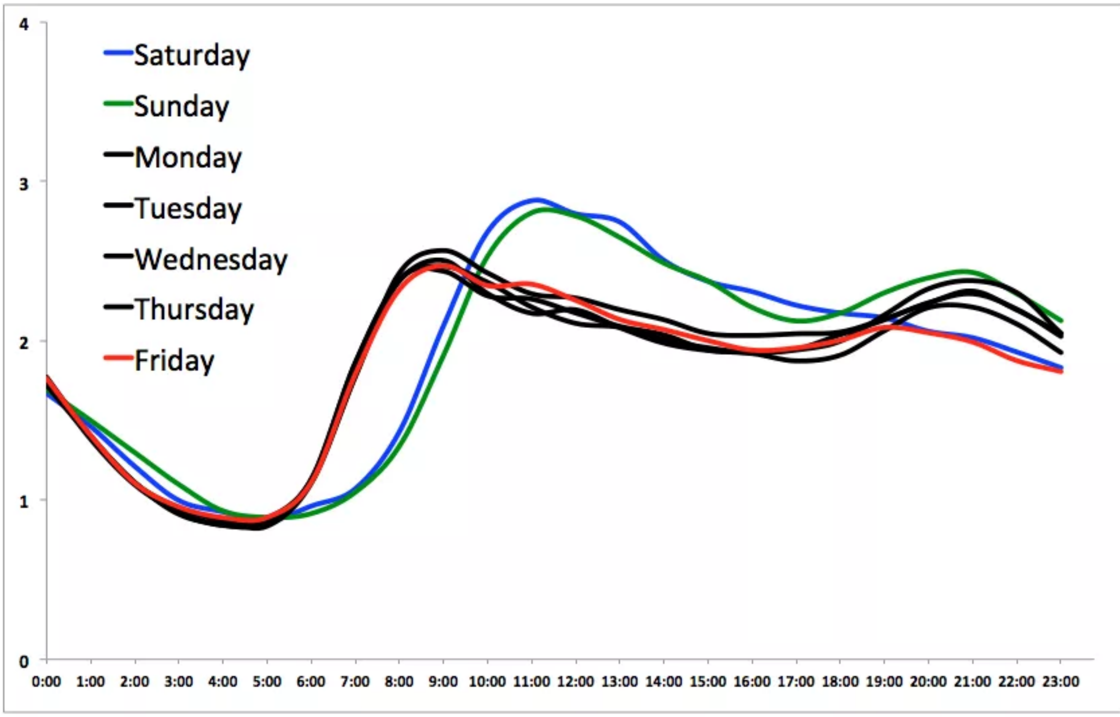
- For the horizontal and aerated grit systems:
  * Mechanical augers at the bottom of the grit chamber move the grit to one end of the tank where grit slurry pumps can pump it out of the tank to a grit separator.
  * In some cases steep bottom slope is provided which will collect the grit at Central Point of Removal.
  * Grit Removal is achieved by air pumps for small aerated grit chambers.
  * Grit can also be removed by tubular conveyors, buckets type collectors, elevators screws conveyors, grit pumps and clam shell buckets

10.1.5 Flow Control

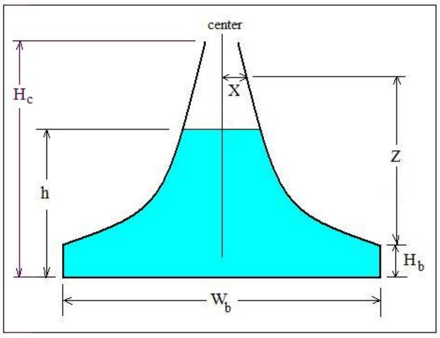
- Flow control is critical for grit removal, specifically for the horizontal and aerated grit chambers as excessive or inadequate velocities would lead to poor grit removal or cause excessive organic material settling along with the grit, respectively
- As the wastewater flows vary diurnally, it is important that velocity of the wastewater in the grit chamber should be maintained nearly constant - near 1 fps.
- Constant velocity in a grit chamber is achieved by providing a proportional (Sutro) weir at the outlet end of grit chamber.
- The shape of the opening between the plates of a proportional weir is made in such a way that the discharge is directly proportional to liquid depth in grit chamber resulting in maintaining a constant velocity of water even a the flow changes.

10.1.6 Pre-aeration

- Pre-aeration of the wastewater as part of the preliminary treatment may be provided as a separate process or increased detention time in an aerated grit chamber.
- Pre-aeration provides the follwoing benefits:
  - freshens up wastewater by dissolving oxygen thereby reducing the wastewater septicity
  - reduction of septicity allows for better settling - solids and BOD removal, in the following primary treatment process
  - promotes grease separation which facilitates its removal during primary treatment



Diurnal wastewater flow profile



(a) Proportional weir design

(b) Installed Proportional weir

10.1.7 Flow Equalization

- Flow equalization involves storing a portion of peak flows for release during low-flow periods
- It prevents surges and allows for the operation of processes at design flows thus allowing for optimal physical, biological and chemical processes to take place.
- It results in saving capital costs as the processes may be built with a treatment capacity which is less than the peak flows

10.2 Preliminary Treatment Math Problems

Preliminary Treatment math problems relate to the following:

10.2.1 Channel Velocity and Flow Rate

Flow Rate - Q (volume/time) = velocity (distance or length traveled /time) * surface area
Velocity is the speed at which the water is flowing. It is measured in units of length/time – ft./sec.

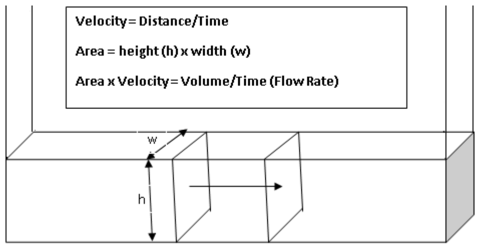
Velocity of water flowing through can be calculated by dividing the flow rate by area of the flow stream.

$$Velocity\ \frac{length}{time} = \frac{flow\ rate(\frac{volume\ or\ cubic\ length}{time})}{surface\ area\ in\ the\ direction\ of\ flow - square\ length}$$

For a flow in a channel:

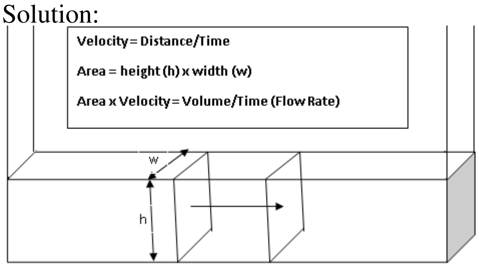
Example Problems:

1. Calculate the velocity of a 14 MGD flow in a 6 ft wide channel with a water depth of two feet.



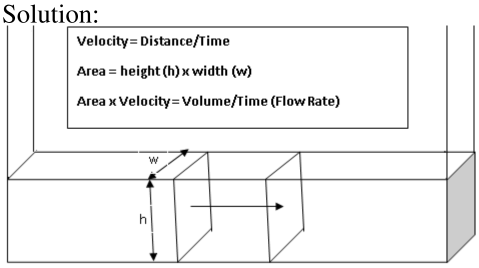
$$Flow(Q) = Velocity(V) * Area(A)$$
$$\implies 14\frac{MG}{day} * \frac{10^6 gal}{MG} * \frac{ft^3}{7.48gal} * \frac{day}{24*60*60} = V\frac{ft}{sec} * 6ft * 2ft \implies 21.7\frac{ft^3}{sec} = 12V\frac{ft^3}{sec}$$
$$\implies V\frac{ft}{sec} = \frac{21.7}{12} = \boxed{1.8\frac{ft}{sec}}$$

2. Calculate the flow, in gpd, that would pass through a grit chamber 2 feet wide, at a depth of 6 inches, with a velocity of 1 ft /sec
Solution:



$$Q = V * A$$
$$Q = 1\frac{ft}{s} * (2*0.5)ft^2 = 1\frac{ft^3}{s}$$
$$Q = 1\frac{\cancel{ft^3}}{\cancel{s}} * \frac{(1440*60)\cancel{s}}{day} * 7.48\frac{gal}{\cancel{ft^3}} = \boxed{646,272\frac{gal}{day}}$$

3. A wastewater channel is 3.25 feet wide and is conveying a wastewater flow of 3.5 MGD. The wastewater flow is 8 inches deep. Calculate the velocity of this flow.
Solution:



$$Q = V * A \implies V = \frac{Q}{A}$$

$$\implies V\frac{ft}{s} = \frac{3.5\frac{\cancel{MG}}{\cancel{day}} * \frac{1000000\cancel{gal}}{\cancel{MG}} * \frac{ft^{\cancel{3}}}{7.48\cancel{gal}} * \frac{\cancel{day}}{(1440*60)s}}{(3.25*0.75)\cancel{ft^2}} = \boxed{2.2\frac{ft}{s}}$$

4. A plastic float is dropped into a wastewater channel and is found to travel 10 feet in 4.2 seconds. The channel is 2.4 feet wide and is flowing 1.8 feet deep. Calculate the flow rate of this wastewater in cubic feet per second.
   Solution:
   $Q = V * A$
   $$\implies Q\left(\frac{ft^3}{s}\right) = \frac{10ft}{4.2s} * (2.4*1.8)ft^2 = \boxed{10.3\frac{ft^3}{s}}$$

10.2.2 Grit Removal Rates

Typical grit removal ranges from 0.5 to 30 ft^3/MG

Example Problems:

1. At a wastewater treatment plant which receives a flow rate of 650,000 gallons per day, a total of 50 cubic feet of grit was removed for the month. Calculate the rate of grit removal assuming 30 days in a month.
   Solution:
   $$GritRemoval\frac{ft^3}{MG} = 50\frac{ft^3}{\cancel{month}} * \frac{\cancel{month}}{30\cancel{days}} * \frac{\cancel{day}}{650,000\cancel{gal}} * 1,000,000\frac{\cancel{gal}}{MG} = \boxed{2.6\frac{ft^3}{MG}}$$