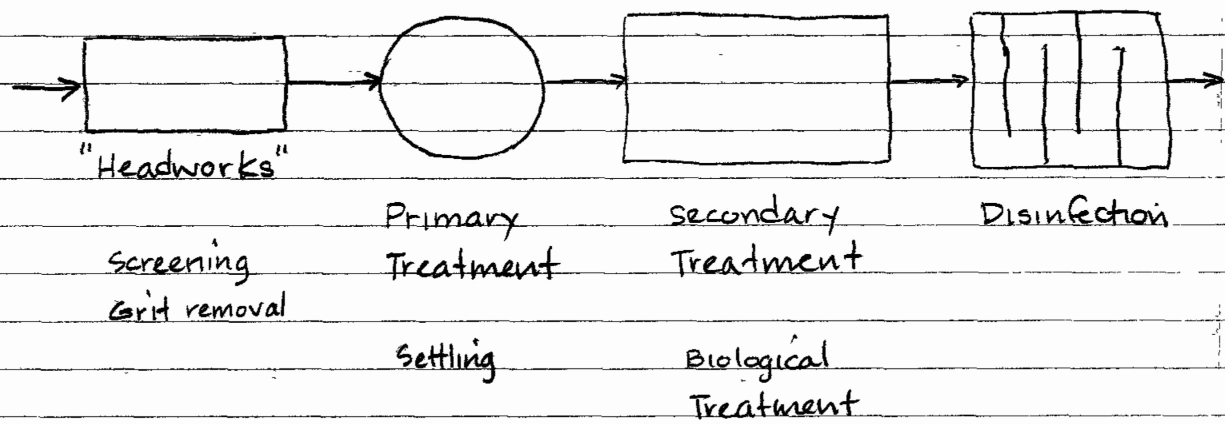
Lecture 14 - Wastewater Screening, Primary Treatment

General layout for wastewater treatment plant:



Screening

Removes large material to:

1. Protect process equipment
2. Prevent interference with treatment
3. Prevent discharge to waterways

Types of screens: (Figure 5-2 from M&E - page 2)

Coarse screens ("bar rack - Figure 8.1 from Mara - pg 3)

May be hand raked for small systems

Most are mechanically cleaned

often subject to mechanical problems

Design requires minimum velocity - 0.4 m/s - to keep grit suspended - maintained by downstream weir or flume

Screenings are disposed by landfilling or incineration; sometimes passed through grinder and into waste stream (grinder also called comminutor com-mih-NEW-ter)

Coarse screens usually have ~5 cm openings

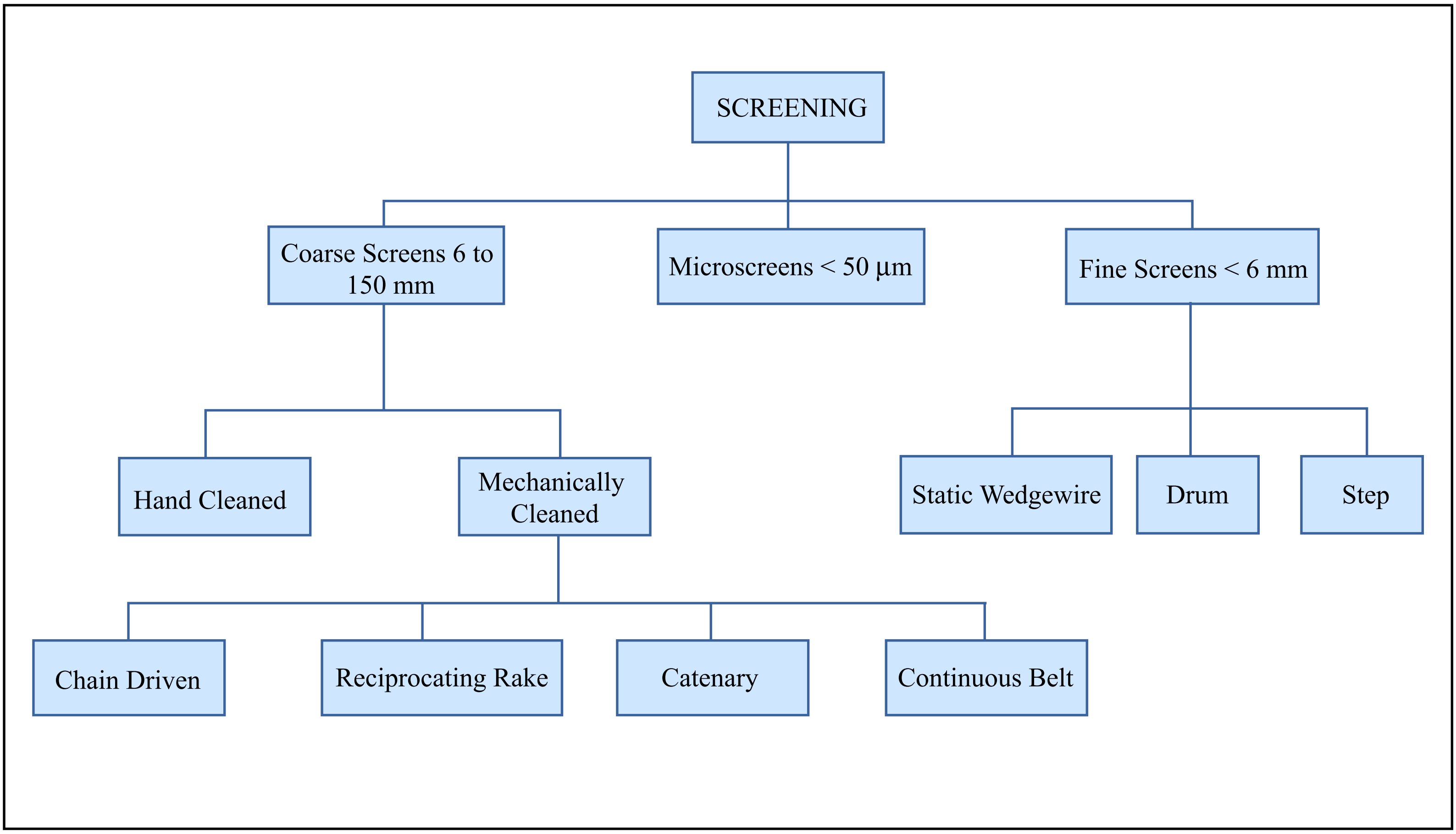
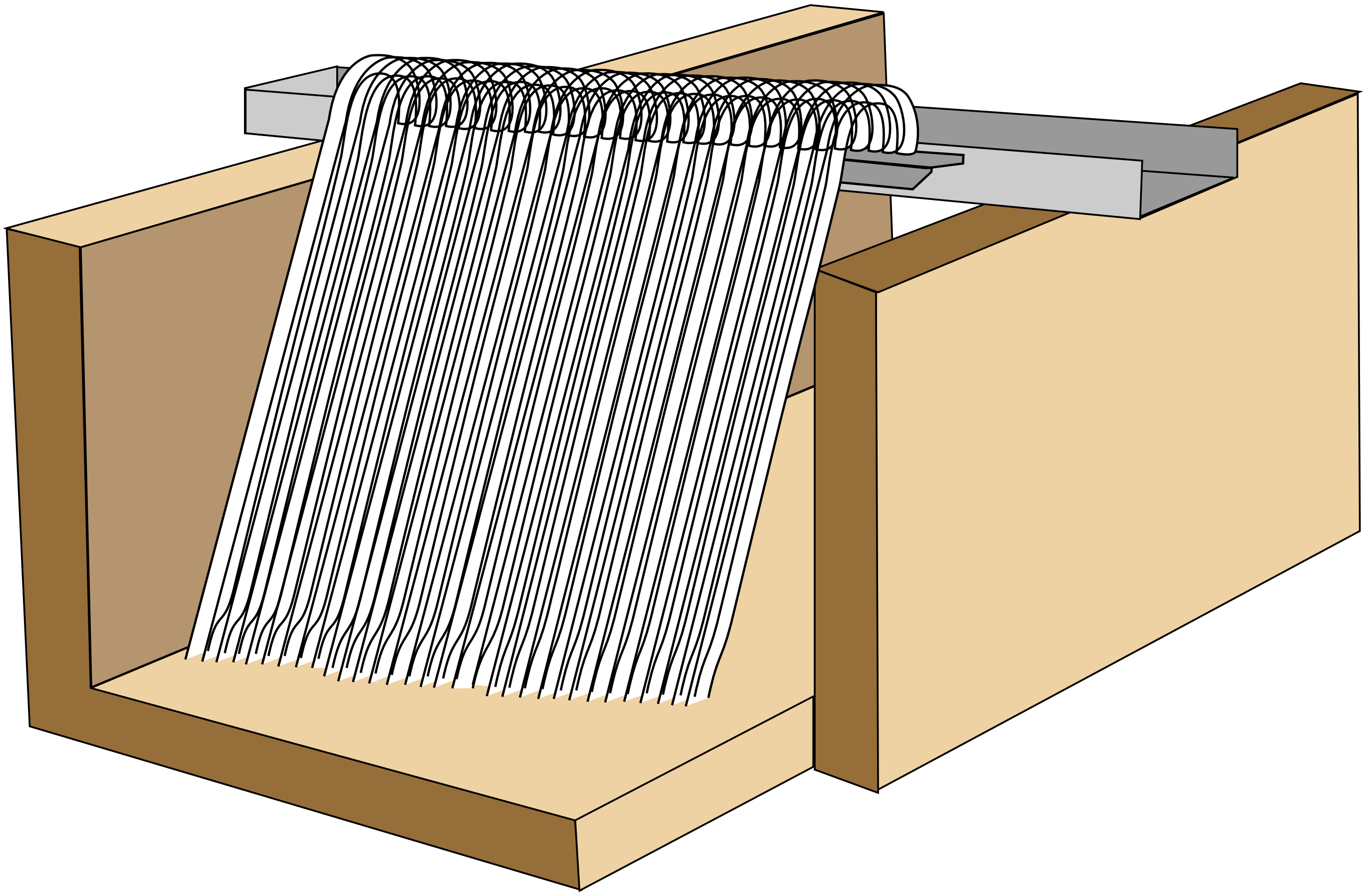


Figure by MIT OCW. Adapted from Metcalf & Eddy Inc., G. Tchobanoglous, F. L. Burton, and H. D. Stensel, 2003. Wastewater Engineering: Treatment and Reuse, Fourth Edition. McGraw-Hill, New York.



Simple Manually Raked Screen (flow is from left to right)

Figure by MIT OCW.

Adapted from: Mara, D. *Domestic Wastewater Treatment in Developing Countries*. London, UK: Earthscan, 2005, p. 79.

Coarse screens are sometimes followed by fine screens
($\leq$ 6 mm opening – usually 6 mm) –

Fine screens are expensive, high in maintenance
Not used commonly for municipal wastewater

Fine screens can remove 10 - 80% TSS
average removal = 55%

Grit chambers

Designed to remove sand, gravel, cinders, coffee grounds, egg shells, other high-density organics and inorganics

Purposes:
1. Protect moving equipment from abrasion
2. Reduce deposition in pipelines, channels
3. Reduce frequency of digestor cleaning

Grit characteristics:
- 0.004 – 0.04 m^3 grit / m^3 wastewater (higher with combined sewers)
- Solids content = 35 - 80%
- Volatile content = 1 - 55%
- Typical density $\approx$ 1.6 gm/cm^3

Grit chamber design

Design goal: Provide sufficient detention time for grit to settle
Maintain constant velocity to scour organics

Velocity needed to scour organics given by Camp-Shields equation (Camp, 1942, Grit Chamber Design, Sewage Works Journal, Vol 14, pp 368-381)

$$V_c = \sqrt{\frac{8Kgd}{f}\left(\frac{\rho_p - \rho_w}{\rho_w}\right)}$$

V_c = scour velocity [L/T]
g = gravitational acceleration [L/T^2]
d = partical diameter [L]
f = Darcy-Weisbach friction factor [–]
= 0.002 for domestic sewage
ρ_p = particle density [M/L^3]
ρ_w = water density [M/L^3]
k = empirical constant related to "stickiness" of organic particles = 0.04 - 0.06

Typically V_c = 15 to 30 cm/s for organic particles

Challenge in grit chamber design is to maintain V_c through fluctuations in flow rate

One alternative - design outflow weir to maintain velocity in rectangular channel

$$V_c = \frac{Q}{wh} = \text{constant}$$

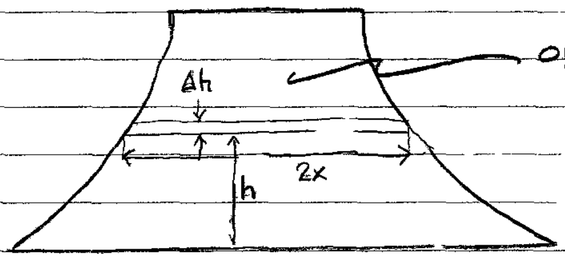
w = channel width = constant for rect. channel
h = elevation above weir crest

$$\rightarrow \quad w V_c = \frac{Q}{h} = \text{constant}$$

Flow over a weir = $Q = C_w \sqrt{2g}\, h^{3/2}\, W$

L = length of weir ⊥ to flow
C_w = weir coefficient, which varies with characteristics of weir
$C_w \simeq 0.4$ for sharp-crested weir

Constant flow velocity is achieved by proportional or Sutro weir



Flow in increment Δh is $\Delta Q = C\sqrt{2gh}\; 2x\, \Delta h$

Total flow is $Q = \int_0^h C\sqrt{2gh}\; 2x\, dh$

where $2x$ = function of h $= \dfrac{K}{\sqrt{h}}$

$$Q = \int_0^h C\sqrt{2gh}\;\frac{K}{\sqrt{h}}\, dh$$

$$= \sqrt{2g}\, CK \int_0^h dh = \sqrt{2g}\, CKh$$

$$\frac{Q}{h} = \sqrt{2g}\, CK = \text{const}$$

Fig 7.9 shows actual vs. theoretical proportional weir construction – pg 7

Fig 7.7 shows grit chamber design with proportional weir – pg 8

Both figures from Reynolds & Richards, 1996

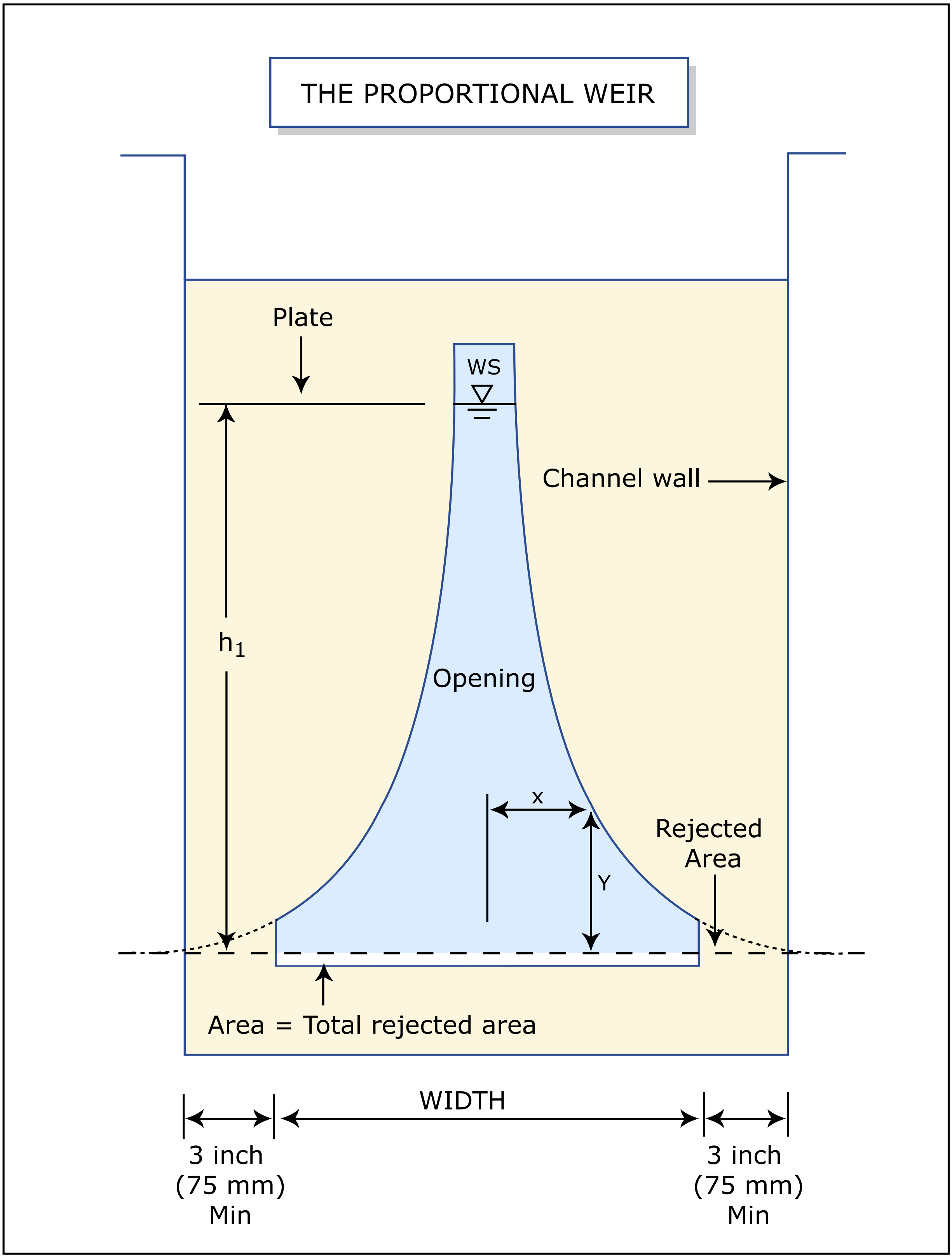
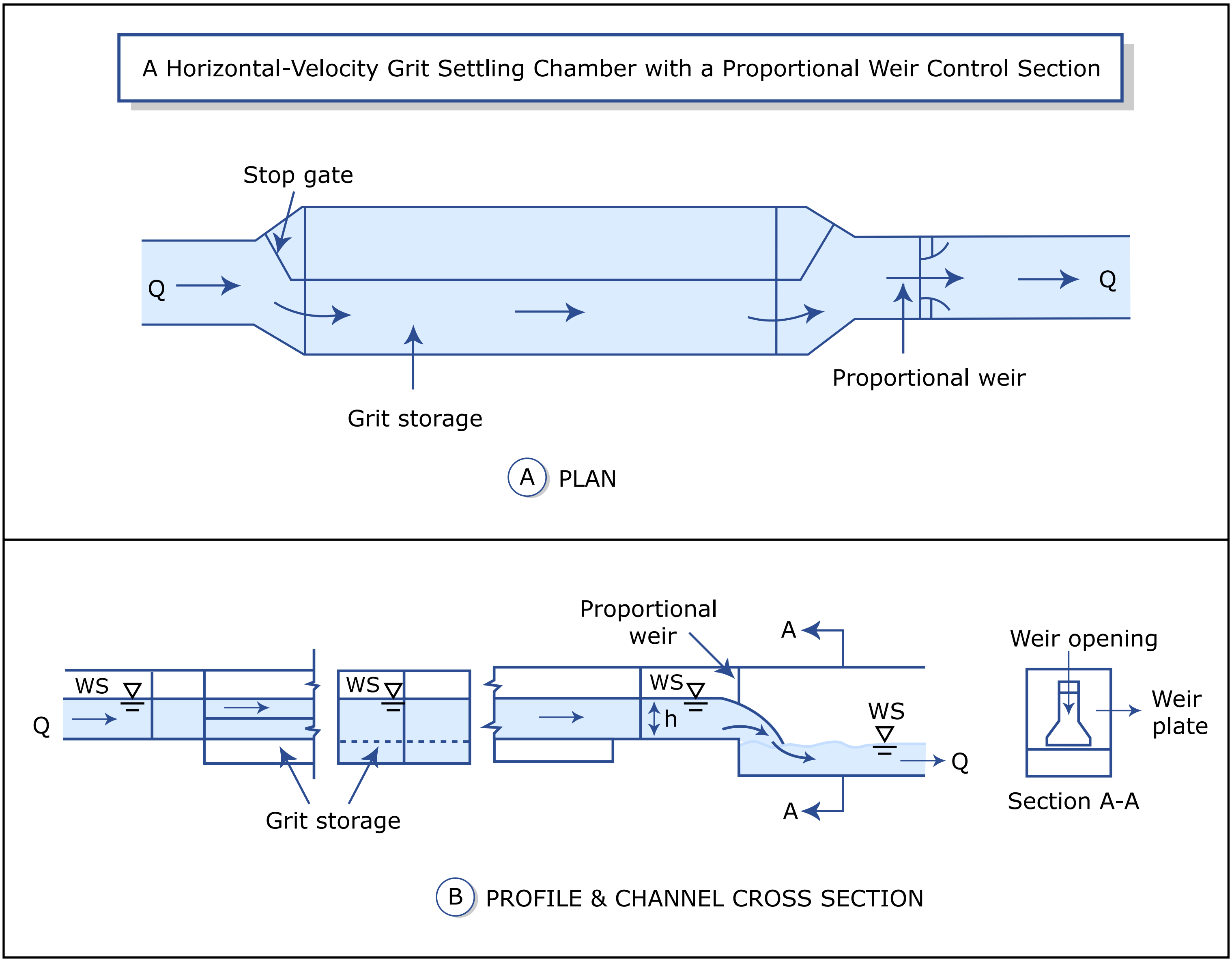


Figure by MIT OCW.

Adapted from: Reynolds, T. D., and P. A. Richards. *Unit Operations and Processes in Environmental Engineering*. 2nd ed. Boston, MA: PWS Publishing Company,1996, p. 142.



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Alternative is to have outlet be a Parshall flume to measure flow into WWTP - see Fig 10.2 from VH, pg 10

Flow and head in flume related as $Q = Kwh^{3/2}$

In grit chamber $V_c = \frac{Q}{A}$

Need to find chamber x-section shape such that Q/A = constant for all Q

Differentiate weir equation to get incremental flow over depth interval dh:

$$dQ = \frac{3}{2} Kwh^{1/2}\, dh$$

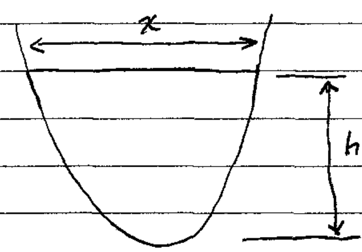
Flow through channel x-section must be the same:

$$dQ = V_c x\, dh = \frac{3}{2} Kwh^{1/2}\, dh$$

x = width of x-section at height h

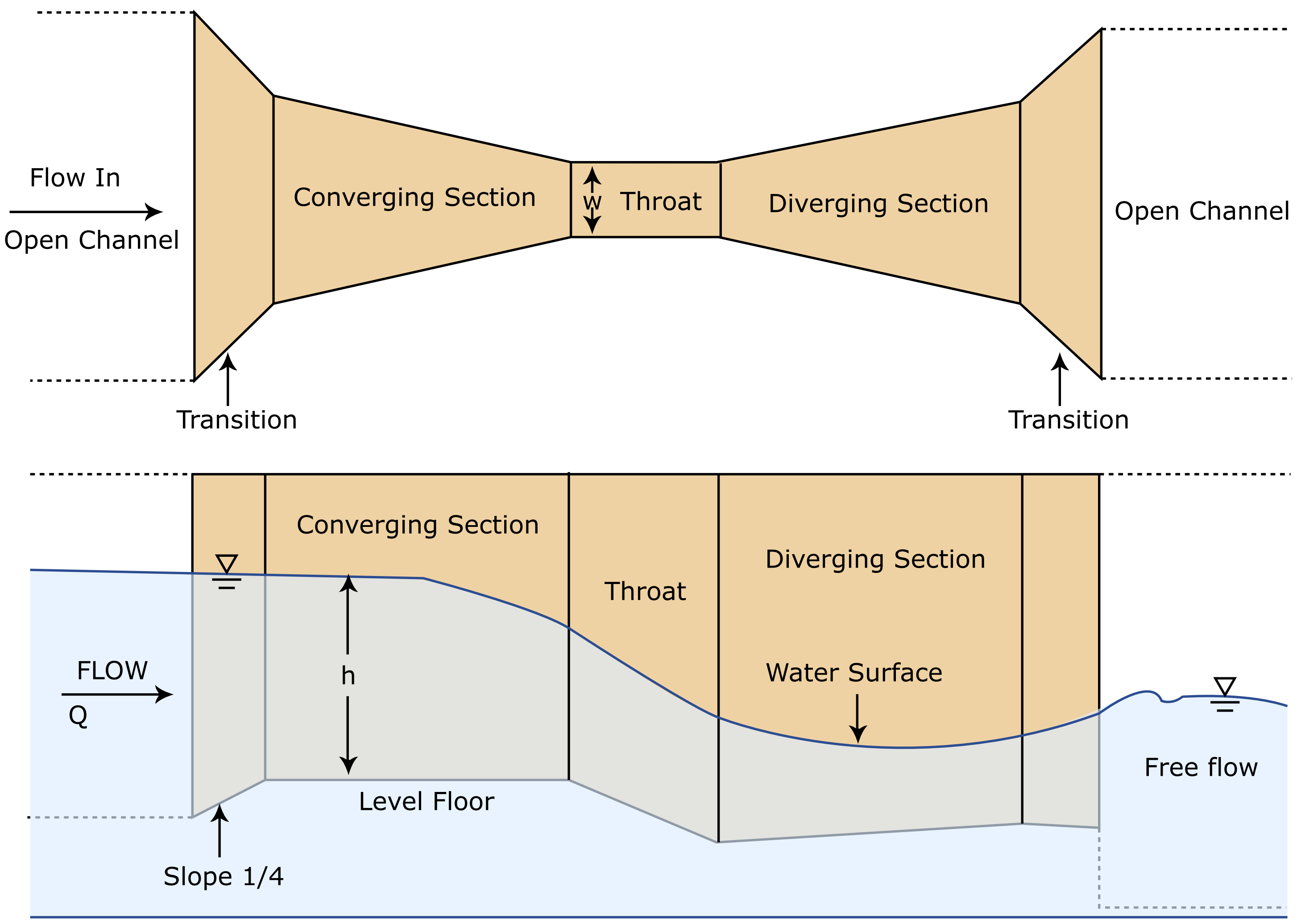
$$x = \left(\frac{3\,Kw}{2\,V_c}\right) h^{1/2}$$

This defines parabolic x-section:



In practice, parabolic section is approximated by trapezoidal section for ease of construction - see Figure 7.10 of Reynolds & Richards - pg. 11

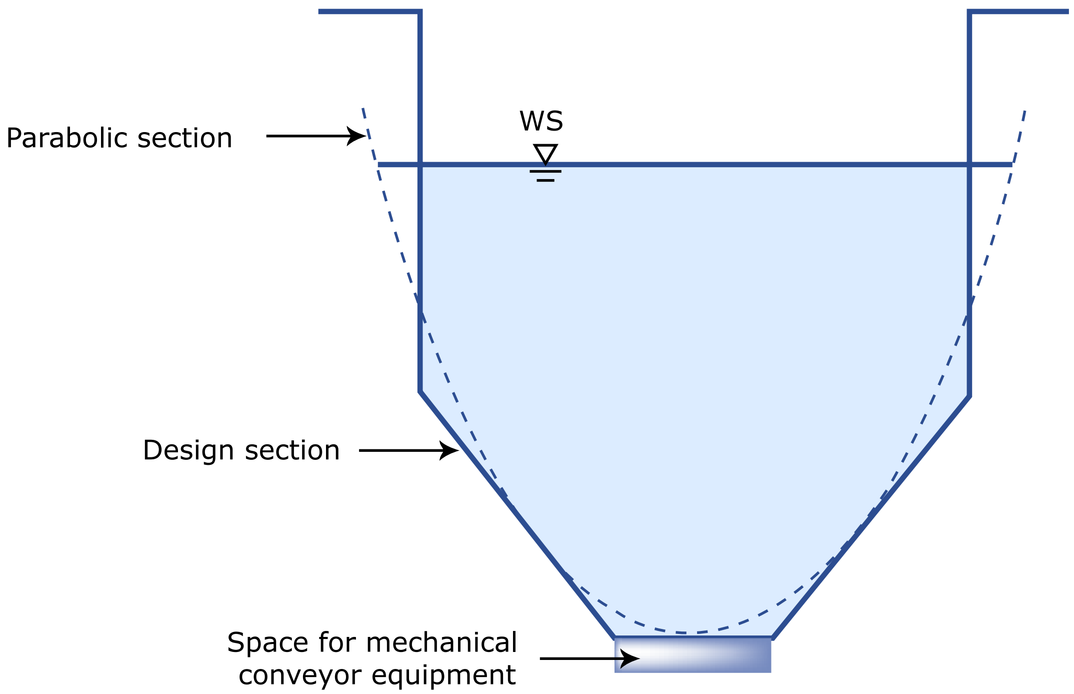
Figure 7.6 of Reynolds & Richards, pg. 12 - shows grit chamber and flume design



Parshall flume for measuring flow in an open channel by measuring the free-flowing upper head h.

Figure by MIT OCW.

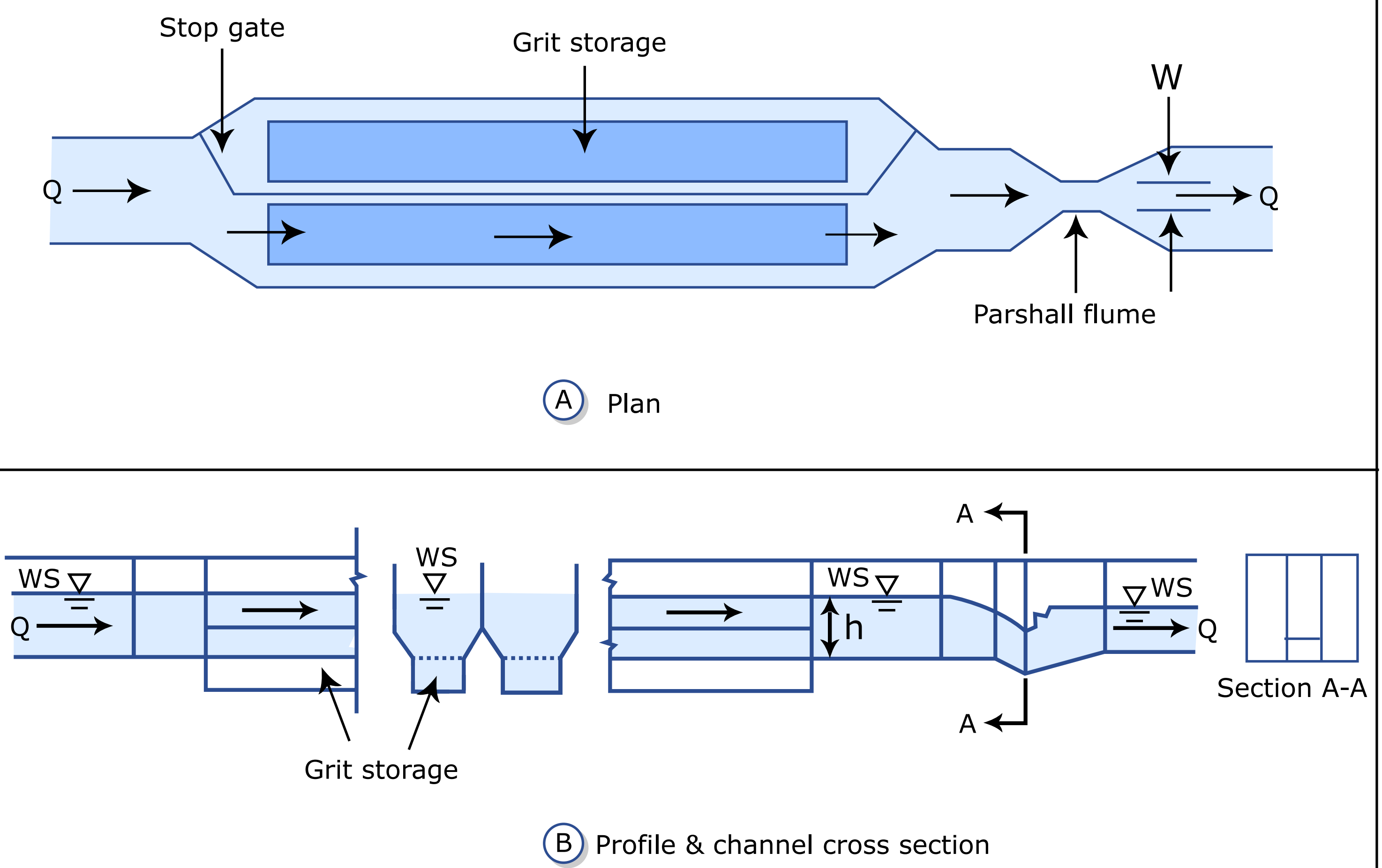
Adapted from: Viessman, W., Jr., and M. J. Hammer. *Water Supply and Pollution Control*. 7th ed. Upper Saddle River, NJ: Pearson Education, Inc., 2005, p. 353.



Ideal parabolic cross section and design cross section for chamber with a Parshall flume.

Figure by MIT OCW.

Adapted from: Reynolds, T. D., and P. A. Richards. *Unit Operations and Processes in Environmental Engineering*. 2nd ed. Boston, MA: PWS Publishing Company,1996, p. 143.



A horizontal-velocity grit settling chamber with a Parshall flume control section.

Figure by MIT OCW.

Adapted from: Reynolds, T. D., and P. A. Richards. *Unit Operations and Processes in Environmental Engineering*. 2nd ed. Boston, MA: PWS Publishing Company,1996, p. 140.