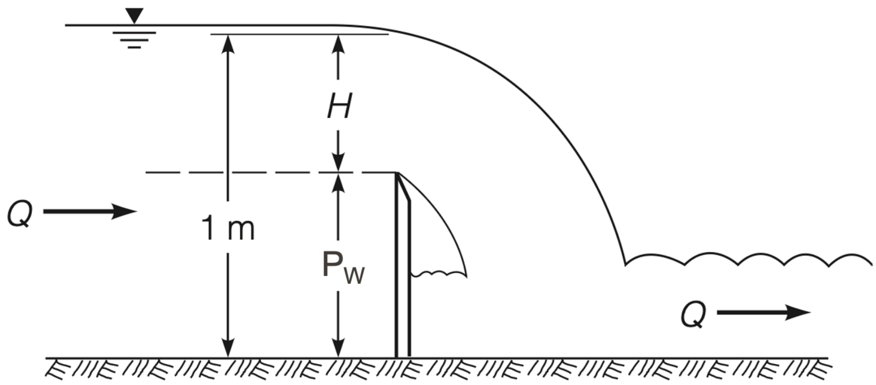
Example - Rectangular (suppressed/uncontracted) Weir

A weir is to be installed to measure flow rates in the range of 0.5–1.0 m3/s. If the maximum (total) depth of water that can be accommodated at the weir is 1 m and the width of the channel is 4 m, determine the crest height of a suppressed weir that should be used to measure the flow rate.



The height of the water over the crest is:

$$H = 1 - P_w$$

We assume that $H/P_w < 5$ and the widely used $C_d \approx 0.62$
$\Rightarrow$ this lead to:

$$C_w = \frac{2}{3} C_d \sqrt{2g} = 1.83$$

and we can use the general discharge formula:

$$Q = C_w b H^{2/3} = 1.83\,(4\,m)\,H^{2/3}$$

Taking $b = 4$ m and $Q = 1\ m^3/s$ (because the maximum flow rate will give the maximum head, H)

$$\Rightarrow H = \left[\frac{Q}{1.83 b}\right]^{2/3} = \left[\frac{1\ m^3/s}{1.83\,(4\,m)}\right]^{2/3} = 0.265\ m$$

So the crest height is:

$$P_w = 1 - 0.265\ m = 0.735\ m$$

$$\Downarrow$$

$$\frac{H}{P_w} = \frac{0.265}{0.735} = 0.36 << 5 \checkmark$$

The initial assumption is validated

Example 2 - comparison between weirs

Water flows in a rectangular channel of width b = 2 m with flowrates between and Qmin = 0.02 m3/s and Qmax = 0.60 m3/s. This flowrate is to be measured by using either (a) a rectangular sharp-crested weir, (b) a triangular sharp-crested weir with θ = 90, or (c) a broad-crested weir. In all cases the bottom of the flow area over the weir is a distance Pw=1m above the channel bottom.

(a) RECTANGULAR WEIR:

$$Q = C_d \frac{2}{3}\sqrt{2g}\, b H^{3/2}$$

$$= \left(0.611 + 0.075\frac{H}{P_W}\right)\frac{2}{3}\sqrt{2g}\, b H^{3/2}$$

$$= \left(0.611 + 0.075\frac{H}{1m}\right)\frac{2}{3}\sqrt{2 \cdot 9.81\, m/s^2}\,(2\,m)\, H^{3/2}$$

$$= 5.91\,(0.611 + 0.075 H)\, H^{3/2}$$

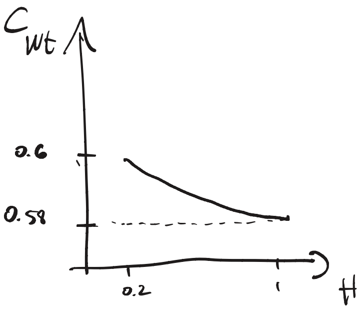
(b) TRIANGULAR WEIR

$$Q = C_{wt}\frac{8}{15}\tan\left(\frac{\theta}{2}\right)\sqrt{2g}\, H^{5/2}$$

$$= C_{wt}\frac{8}{15}\tan(45^\circ)\sqrt{2(9.81\, m/s^2)}\, H^{5/2}$$

$$= 2.36\, C_{wt} H^{5/2}$$

→ C_{wt} depends on θ and H. So we can take $C_w(\theta)$ following the line for θ = 90° in the graph shown in class



(c) BROAD CRESTED WEIR

$$Q = C_{bc}\, b \sqrt{g} \left(\frac{2}{3}\right)^{3/2} H^{3/2}$$

$$= 1.125 \left(\frac{1 + H/P_w}{2 + H/P_w}\right)^{1/2} b \sqrt{g} \left(\frac{2}{3}\right)^{3/2} H^{3/2}$$

with $P_w = 1m$

$$= 1.125 \left(\frac{1+H}{2+H}\right)^{1/2} (2m) \sqrt{9.81\, m/s^2} \left(\frac{2}{3}\right)^{3/2} H^{3/2}$$

$$= 3.84 \left(\frac{1+H}{2+H}\right)^{1/2} H^{3/2}$$

So now we have 3 relationships between Q & H for each weir. Q is in m^3/s and H is in m

$\Rightarrow$ we can plot the 3 equations for different values of H and compare the efficacy.

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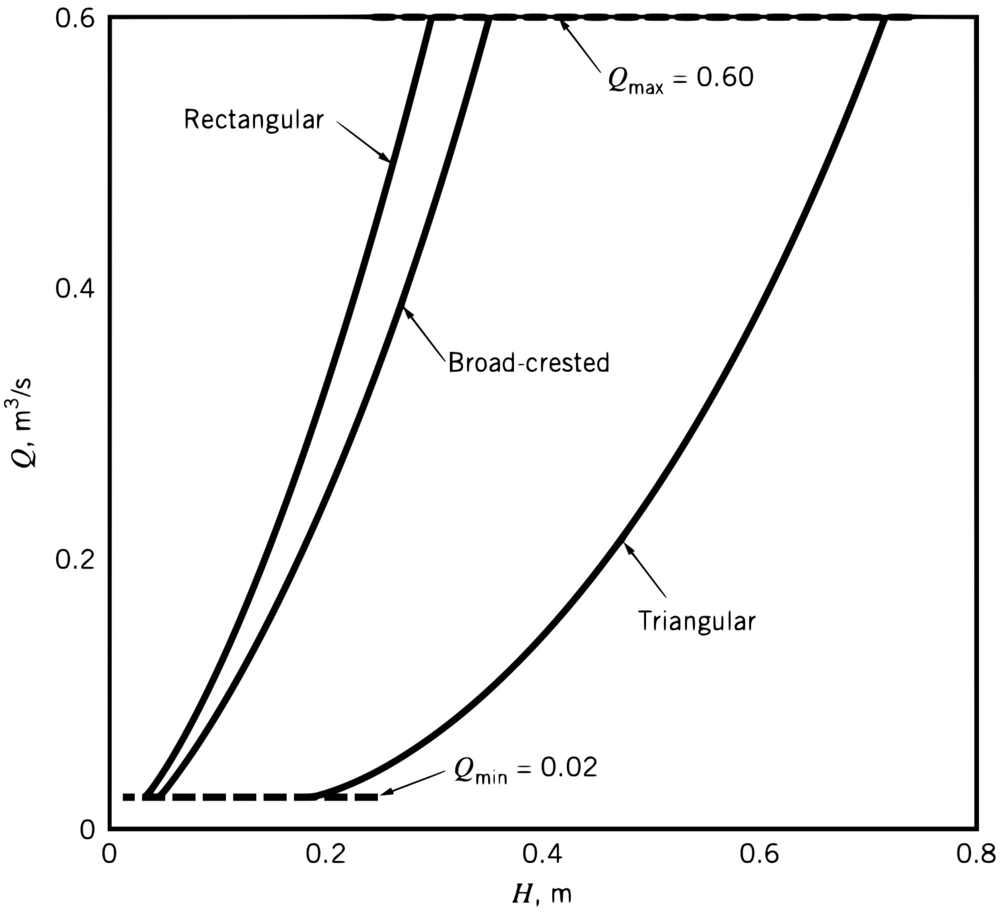

Although it appears as though any of the three weirs would work well for the upper portion of the flow range given, neither the rectangular not the broad crested weir would be very accurate for small flow rates near Q=Qmin. This is because for small flow rates, the variability of H would be very small so harder to measure and leading to more uncertainty. The triangular weir on the other hand has wide range of H values for low flow rates. This is in general true in practice: triangular weirs are preferred for low flow measurements.

In addition, as we discussed in the notes, to ensure the proper operation of broad-crested weirs (i.e., guarantee critical values on top of it) the geometry of the weir has to be restricted to 0.08<H/L_w<0.5., where L_w is the weir block length. Let's check that requirement; from the broad-crested weir expression we derived:

- With maximum Q = Qmax = 0.6 m3/s —> Hmax = 0.349 —> L_w > Hmax/0.5 = 0.698 m to maintain critical flow conditions at the largest flow rate in the channel.
- With minimum Q = Qmin = 0.02 m3/s —> Hmin = 0.0375 m —> l_w < Hmin/0.08 = 0.469 to ensure frictional effects ar not important.

Clearly these two constraints on the geometry of the weir block L_w are incompatible. Therefore, the broad-crested weir will not function properly under the wide range of flow rates considered in this example.

The sharp-crested triangular weir is the best options of the three types considered,