Hydraulics Engineering Lec #3 : Flow Over Humps and through Constrictions

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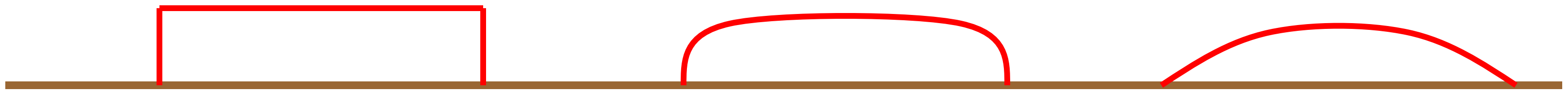
Steady Flow in Open Channels

- Specific Energy and Critical Depth
- Surface Profiles and Backwater Curves in Channels of Uniform sections
- Flow over Humps and through Constrictions
- Hydraulics jump and its practical applications.
- Broad Crested Weirs and Venturi Flumes

Flow Over Hump

- Hump:

  is a streamline construction provided at the bed of the channel. It is locally raised bed.



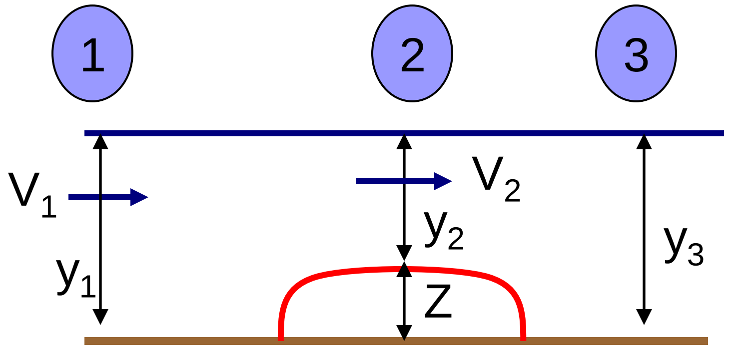
Let’s examine the case of hump in a rectangular channel. We will neglect the head loss.

Flow Over Hump

- For frictionless two-dimensional flow, sections 1 and 2 in Fig are related by continuity and momentum:

$$v_1 y_1 = v_2 y_2$$

$$\frac{v_1^2}{2g} + y_1 = \frac{v_2^2}{2g} + y_2 + Z$$



- Eliminating V_2 between these two gives a cubic polynomial equation for the water depth y_2 over the hump

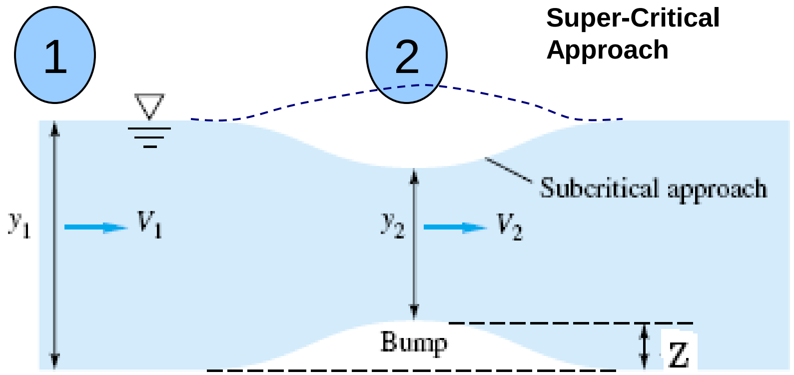
$$y_2^3 - E_2 y_2^2 + \frac{v_1^2 y_1^2}{2g} = 0$$

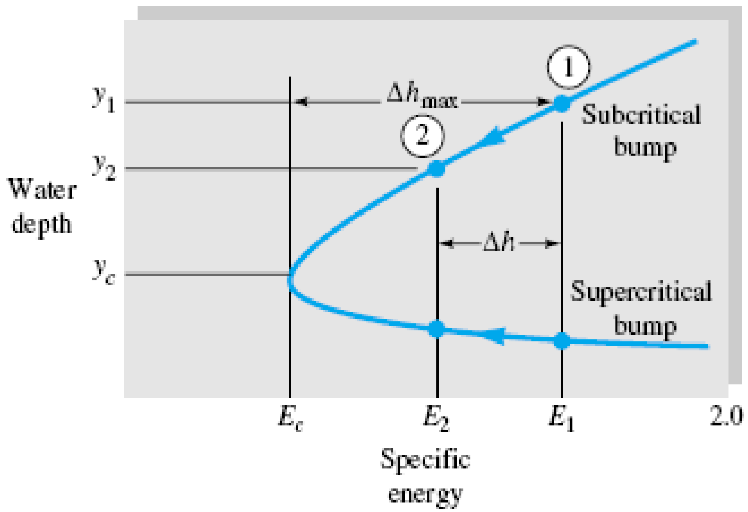
$$where \quad E_2 = \frac{v_1^2}{2g} + y_1 - Z$$

This equation has one negative and two positive solutions if *Z* is not too large. Its behavior is illustrated by *E~y Diagram* and depends upon whether condition 1 is Subcritical (on the upper) or Supercritical (lower leg) of the energy curve.

Flow Over Hump

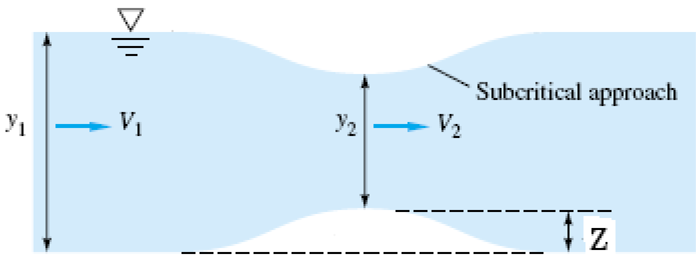
- The specific energy E_2 is exactly Z less than the approach energy $E1$, and point 2 will lie on the same leg of the curve as E_1.
- A sub-critical approach, F_{r1} <1, will cause the water level to decrease at the bump. Supercritical approach flow, F_{r1}>1, causes a water-level increase over the bump.
- If the hump height reaches $Z_{max}=Z_{c=}E_1\text{-}E_c$, as illustrated in fig, the flow at the crest will be exactly critical (Fr=1).
- If Z= Zmax, there are no physically correct solutions to Eqn. That is, a hump too large will "choke" the channel and cause frictional effects, typically a hydraulic jump.

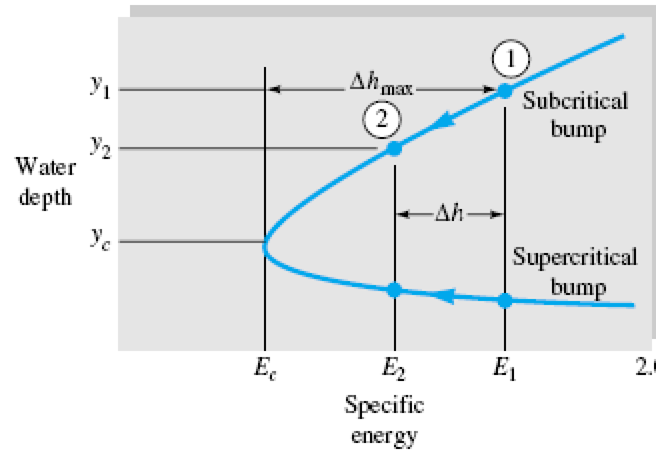


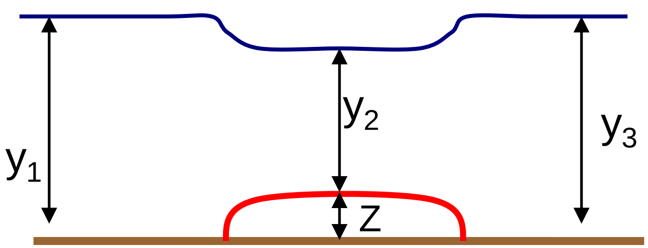


These hump arguments are reversed if the channel has a *depression* (Z<0): Subcritical approach flow will cause a water-level rise and supercritical flow a fall in depth. Point 2 will be $|Z|$ to the right of point 1, and critical flow cannot occur.

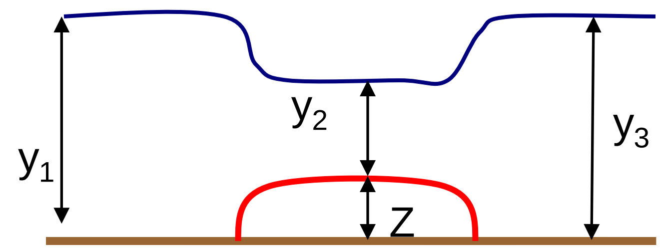
Flow Over Hump







$Z<<Z_c$ $y_1=y_o, y_2>y_c, y_3=y_o$



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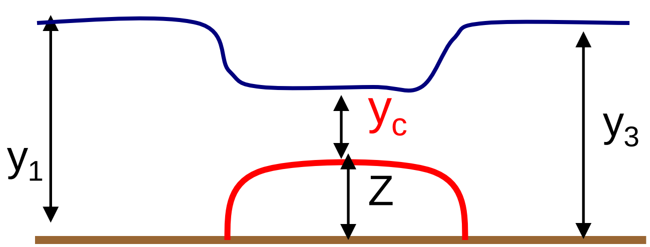

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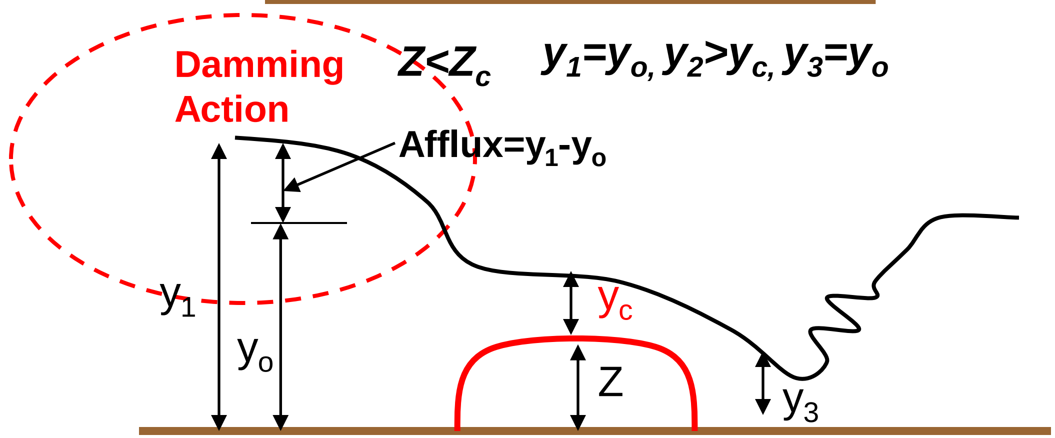


$Z>Z_c$ $y_1>y_o, y_2=y_c, y_3=y_o$

Flow Over Hump

- As it is explained with the help of E~y Diagram, a hump of any height "Z" would cause the lowering of the water surface over the hump in case of subcritical flow in channel. It is also clear that a gradual increase in the height of hump "Z" would cause a gradual reduction in y_2 value. That height of hump which is just causing the flow depth over hump equal to y_c is know as *critical height of hump* Z_c.

- Further increase in Z ($>Z_c$) would cause the flow depth y_2 remaining equal y_c , thus causing the water surface over the hump to rise. This would further cause an increase in the depth of water upstream of the hump which mean that water surface upstream of the hump would rise beyond the previous value i.e $y_1>y_o$. This phenomenon of rise in water surface upstream with $Z>Z_c$ is called *damming action* and the resulting increase in depth upstream of the hump i.e y_1-y_o is known as *Afflux*.

Flow Through Contraction

- When the width of the channel is reduced while the bed remains flat, the discharge per unit width increases. If losses are negligible, the specific energy remains constant and so for subcritical flow depth will decrease while for supercritical flow depth will increase in as the channel narrows.

Continuity Equation

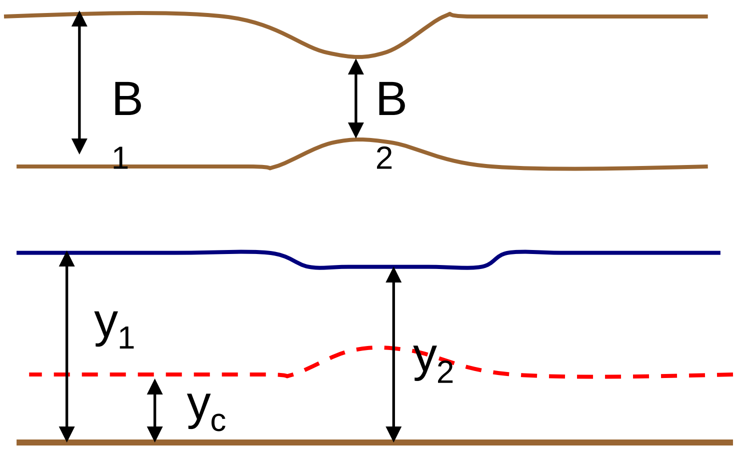
$$B_1 y_1 v_1 = B_2 y_2 v_2$$

Bernoulli's Equation

$$y_1 + \frac{v_1^2}{2g} = y_2 + \frac{v_2^2}{2g}$$

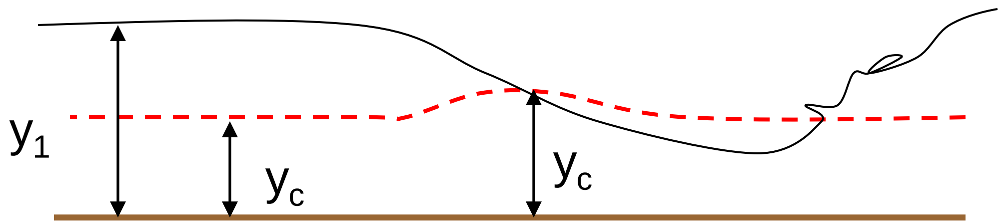
Using both equations, we get

$$Q = B_2 y_2 v_2 = B_2 y_2 \sqrt{\left[\frac{2g(y_1 - y_2)}{1 - \left(\frac{B_2 y_2}{B_1 y_1} \right)^2} \right]}$$



Flow Through Contraction

- If the degree of contraction and the flow conditions are such that upstream flow is subcritical and free surface passes through the ***critical depth y_c*** in the throat.



$$Q = B_c y_c v_c = B_c y_c \sqrt{2g\left(E - y_c\right)}$$

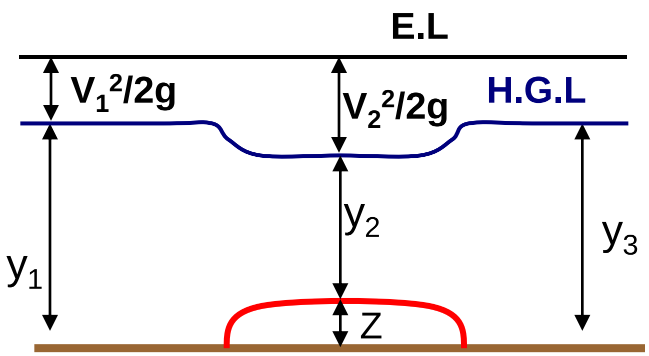
$$\sin ce \qquad y_c = \frac{2}{3}E$$

$$Therefore \qquad Q = B_c \frac{2}{3}E\sqrt{\left(2g\frac{1}{3}E\right)}$$

$$Q = 1.705BE^{3/2} \qquad in\ SI\ Units$$

Example # 11.3

- In the accompanying figure, uniform flow of water occurs at 0.75 m^3/sec in a 1.2m wide rectangular flume at a depth of 0.6m.
- (a). Is the flow sub-critical or super-critical.
- (b). If a hump height of Z=0.1 m is placed in the bottom of flume, calculate the water depth over the hump. Neglect the head loss in flow over the hump.
- (c). If the hump height is raised to Z=0.2m, what then are the water depths upstream and downstream of hump. Neglect head loss over hump.



$Q = 0.75$ m^3/sec

$B = 1.2$ m

$y = 0.6$ m

$q = Q/B = 0.625$ m^3/sec/m

Example # 11.3
Solution

- (a)

$$y_c = \sqrt[3]{\frac{q^2}{g}} = \sqrt[3]{\frac{0.625^2}{9.81}}$$

$$= 0.341m < y$$

$$\therefore Flow \ is \quad subcritical$$

Problem 11.54

- A rectangular channel 1.2 m wide carries 1.1 m^3/sec of water in uniform flow at a depth of 0.85m. If a bridge pier 0.3m wide is placed in the middle of this channel, find the local change in water surface elevation. What is the minimum width of the constricted channel which will not cause a rise in water surface upstream.

- Given that

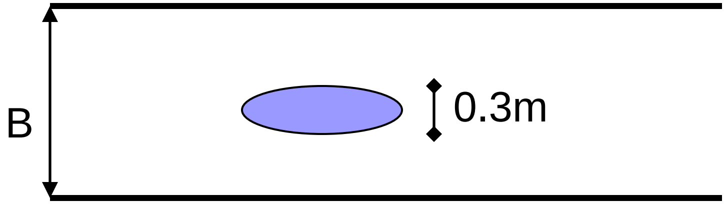
  $Q = 1.1\ m^3/sec$

  $B_1 = 1.2\ m$

  $q_1 = 0.92\ m^3/sec/m$

  $y_o = 0.85\ m$

  $B_2 = B_1 - 0.3 = 0.9\ m$



Problem 11.54

$$\sin ce \quad E = y_o + \frac{q_1^{\;2}}{2gy_o} = 0.91m$$

$$y_c = \frac{2}{3}E = 0.606m$$

$$V_c = \sqrt{gy_c} = 2.473m/\sec$$

$$Therefore$$

$$Q = B_c y_c v_c = 1.1$$

$$B_c = 0.744m$$

$$y_o + \frac{q_1^{\;2}}{2gy_o} = y_2 + \frac{q_2^{\;2}}{2gy_2}$$

$$y_2 + \frac{q_2^{\;2}}{2gy_2} = 0.91$$

$$y_2 = o.38m \qquad \& \qquad 0.785m$$

Assignment

- Problem:
  - 11.50 to 11.58

- Date of Submission:

Questions