CVEN5313: Environmental Fluid Mechanics

Open Channel Flow: Uniform and Gradually Varied Flow
Due Friday, 10/1/10

1. Use the Buckingham-Pi theorem to formally show that if

$$\tau_0 = \phi(V, \rho, g, \nu, R_h, k)$$

where ϕ is some nondimensional function of :

- V is the flow velocity $[L\,T^{-1}]$
- ρ is the fluid density $[M\,L^{-3}]$
- g is the gravitational constant $[L\,T^{-2}]$
- ν is the fluid density $[L^2\,T^{-1}]$
- R_h is the channel hydraulic radius $[L]$
- k is the channel roughness scale $[L]$

then

$$\frac{V}{\sqrt{\tau_0/\rho}} = \phi\left(\frac{VR_h}{\nu}, \frac{V}{\sqrt{R_h g}}, \frac{k}{R_h}\right)$$

2. Consider the flow shown in Fig. 1. Flow passes under a gate, and then undergoes a hydraulic jump. You may assume that no energy is lost as the flow passes under the gate from station 1 to station 2. The volumetric discharge is $Q = 0.125$ m^3/s, the width of the channel is $B = 125$ cm, and the depth of the flow upstream of the gate is $d_1 = 50$ cm.

   (a) Determine the depth, velocity, and Froude number for all three sections of the flow.

   (b) Classify the jump based on its Froude number. What percentage energy loss would you expect for this type of jump?

   (c) Calculate the energy loss in the jump, and express it as a percentage of the upstream head.

   (d) Plot a specific energy diagram showing all three points of the flow.

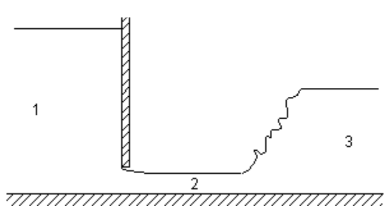

Figure 1: Hydraulic jump.

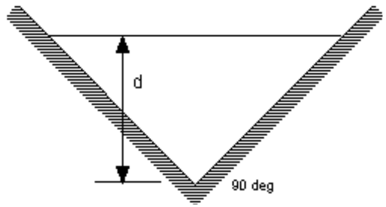

Figure 2: Concrete channel section.

3. Consider the triangular concrete channel section shown in Fig. 2. Assume Q = 20 m^3/s, and S_0 = 0.001.

   (a) Calculate the normal depth d_N.

   (b) Calculate the critical depth d_C.

   (c) Classify the channel slope (e.g. Mild, Critical, or Steep).

   (d) Calculate the Critical Slope.

4. Consider the following cases:

   (a) Case I:
   Trapezoidal Section
   B_0 = 5 m
   s = 1
   n = 0.013
   Q = 50 m^3/s
   S_0 = 0.0004
   A dam at x = 0 backs up the water to a depth of 6 m.
   ⇒ Compute the upstream profile. Note that this is the case shown in the notes.

   (b) Case II:
   Rectangular Section
   B = 2 m
   n = 0.010
   Q = 10 m^3/s
   S_0 = 0.005
   At x = 0 the flow passes under a gate, resulting in a depth of 0.5 m.
   ⇒ Compute the downstream profile.

   For each case, your solution should contain the following:

   i. Determine d_C, d_N, and the free-surface classification (e.g., M1, S2, etc.)
   ii. Plot depth vs. x. You should compute the profiles far enough in x so that the depth is within 1% of the normal depth.
   iii. Plot the free-surface elevation vs. x. The plot should also show the bed location, CDL, and NDL as a function of x. This plot should resemble the figure in the notes.
   iv. Determine the distance required for the flow to asymptote to within 1% of the normal depth.