CIVL3140 Introduction to Open Channel Hydraulics - TUTORIAL

1- Physical properties of fluids

+ Give the following fluid and physical properties(at 20 Celsius and standard pressure) with a 4-digit accuracy

	Value	Units
Air density :		
Water density :		
Air dynamic viscosity :		
Water dynamic viscosity :		
Gravity constant (in Brisbane) :		
Surface tension (air and water) :		

2- Uniform equilibrium flow

A rectangular (5.5 m width) concrete channel carries a discharge of 6 m^3/s. The longitudinal bed slope is 1.2 m per km. (a) What is the normal depth at uniform equilibrium ? (b) At uniform equilibrium what is the average boundary shear stress ? (c) At normal flow conditions, is the flow supercritical, super-critical or critical ? Would you characterise the channel as mild, critical or steep ?

For man-made channels, perform flow resistance calculations based upon the Darcy-Weisbach friction factor.

3- Flood plain calculations at uniform equilibrium (1)

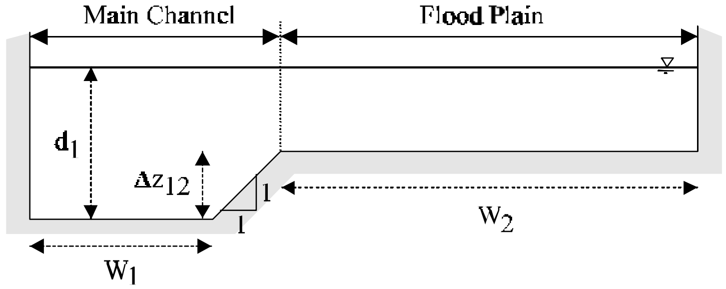
Considering the river channel and flood plain sketched below (Top Figure), the main dimensions of the channel and flood plain are :

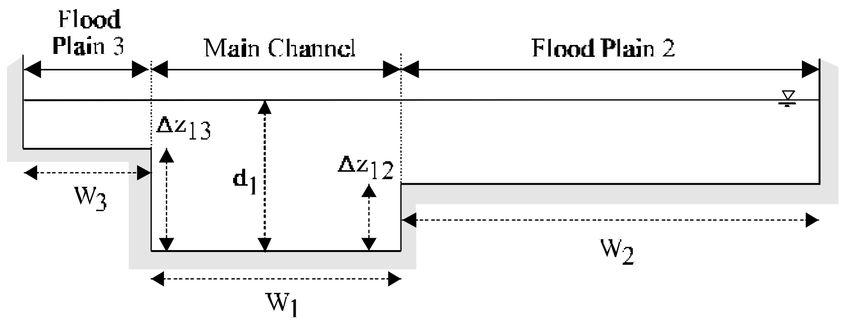
$$W_1 = 2.5 \text{ m}, W_2 = 25 \text{ m}, \Delta z_{12} = 1.2 \text{ m}$$

The main channel is lined with finished concrete. The flood plain is liable to flooding. (It is used as a flood water retention system). The flood retention plain consists of light bush. (Field observations suggested $n_{Manning}$ = 0.04 s/$m^{1/3}$). The longitudinal bed slope of the river is 1.5 m per km.

During a storm event, the observed water depth in the main (deeper) channel is 1.9 m. Assuming uniform equilibrium flow conditions, compute : (a) the flow rate in the main channel, (b) the flow rate in the flood water retention system and (c) the total flow rate. (d) What the flow Froude number in the deep channel and in the retention system ? (Assume energy loss at the interface between the river channel flow and the flood plain flows.)

For man-made channels, DO perform flow resistance calculations based upon the Darcy-Weisbach friction factor.





4- Flood plain calculations at uniform equilibrium (2)

Considering a river channel with a flood plain in each side (sketched above, Bottom Figure),

$W_1 = 5$ m, $W_2 = 14$ m, $\Delta z_{12} = 0.95$ m, $W_3 = 58$ m, $\Delta z_{13} = 1.35$ m

The river channel is lined with finished concrete. The lowest flood plain (Flood plain No. 2) is liable to flooding and its bed consists of gravel ($k_s = 20$ mm). The left bank plain (Flood plain No. 2) is a grassed area (centipede grass, $n_{Manning} \sim 0.06$ SI units).The longitudinal bed slope of the river is 3.2 m per km. For the 1-in-50-years flood ($Q = 150$ m^3/s), compute : (a) the flow depth in the main channel, (b) the flow depth in the right flood plain, (c) the flow rate in the main channel, (d) the flow rate in the flood water retention system and (e) the flow rate in the right flood plain.

Assume no friction (and no energy loss) at the interface between the river channel flow and the flood plain flows.

For man-made channels, DO perform flow resistance calculations based upon the Darcy-Weisbach friction factor.

5- **2001 examination** paper

An artificial canal carries a discharge of 25 m^3/s. The channel cross-section is trapezoidal and symmetrical, with a 0.5-m bottom width and 1V:2.5H sidewall slopes. The longitudinal bed slope is 8.5 m per km. The channel bottom and sidewall consist of a mixture of fine sands ($k_s = 0.3$ mm).

(a) What is the normal depth at uniform equilibrium ?(b) At uniform equilibrium what is the average boundary shear stress ? (c) At uniform equilibrium what is the shear velocity ?

A gauging station is set at a bridge crossing the waterway. The observed flow depth, at the gauging station, is 2.2 m.

(c) Compute the flow velocity at the gauging station. (d) Calculate the Darcy friction factor (at the gauging station). (e) What is the boundary shear stress (at the gauging station) ? (f) How would you describe the flow at the gauging station ? (g) At the gauging station, from where is the flow controlled ? Why ?

6- Backwater calculations (1)

Considering the outflow from a reservoir of constant free-surface elevation into a long channel (200-m length). The channel ends by a free overfall (at the downstream end) (Textbook, fig. 15-2). The channel has a rectangular cross-section (width : 3.5 m). The channel bed is made of smooth concrete and the equivalent roughness height of bed and sidewalls is $k_s = 2$ mm.

(a) Assuming that the flow rate in the channel is 5 m^3/s, sketch the composite profile for each of the following channel slopes :

(a1) Case 1 : $\theta = 0.02$ degrees

(a2) Case 2 : $\theta = 1.4$ degrees

(b) Assuming that the flow rate in the channel is 5 m^3/s, compute the backwater profile for the following two different channel slopes :

(b1) Case 1 : $\theta = 0.02$ degrees

(b2) Case 2 : $\theta = 1.4$ degrees

(c) In each case, what is the reservoir free-surface elevation above the channel intake (crest) ?

7- Backwater calculations (2)

Write a calculation sheet to integrate the backwater equation in the form :

$$\frac{\partial H}{\partial s} = -S_f$$

using the standard step method ('distance calculated from depth'). In order to limit the task, use the following specifications : [1] Cross section shape limited to symmetrical trapezoidal and specified bottom width, angle of side slope, elevation of bed level above datum and distance of section from a reference location (positive in downstream direction); [2] In the iterative procedure required to calculate the correct total head and distance which constitute the result of the integration, you may use any depth increment provided that the changes in friction slope remain small. (For engineering purposes, agreement would be satisfactory if $\Delta S_f/(S_o - S_f) < 5\%$ and $\Delta S_f/S_f < 5\%$.)

In order to validate your calculation sheet, use it to compute the following backwater profile : trapezoidal channel : 6-m bottom width, 1V:1.5H side slope, bed slope $S_o = 0.001$, $k_s = 25$ mm, Q = 3.84 m3/s.

Calculate the free-surface elevation upstream of a gauging station, where the known depth is 1.05 m and the bed elevation is R.L. 779.8 m, at the following locations : s = 0 m, s = - 20 m, s = -89 m, s = -142 m.

The following summary sheet may be used to regroup your results.

Summary sheet :

Q =

s (m)	Free-surface elevation (m R.L.)	V (m/s)
0		
-20 m		
-89 m		
-142 m		

Uniform equilibrium flow conditions in the channel :

d_o =

Fr_o =

Type of free-surface profile observed :

More exercises in textbook pp. 88-89, 91-97, 103-105, 113-115.

"The Hydraulics of Open Channel Flow: An Introduction", *Butterworth-Heinemann Publ.*, Oxford, UK, 1999.

More Exercises at : {http://www.bh.com/companions/0340740671/}

Go to Exercises, Part 1 : {http://www.bh.com/companions/0340740671/exercises/exercisesP1.htm}

Tutorial - Solutions

Exercise No. 2- Uniform equilibrium flow
(a) d = 0.64 m (c) Fr = 0.68 : near-critical flow, although sub-critical (hence mild slope)
(See discussion in textbook page 100)

Exercise No. 3 - Flood plain flow
(a) 18.4 m^3/s (b) 13.1 m^3/s (c) 31.5 m^3/s (d) Fr = 0.7 and 0.3 respectively (see textbook page 40)

Exercise No. 4 - Flood plain flow
(a) d_1 = 2.17 m (d) Q_2 = 53.2 m^3/s (e) Q_3 = 39.2 m^3/s

Exercise No. 5
(a) d_o = 1.23 m (c) V_* = 0.226 m/s
(d) f = 0.0115 (e) τ_o = 5.2 Pa (f) Turbulent, transition between smooth-turbulent to rough-turbulent (textbook p. 75)
(g) Downstream because $Q/\sqrt{g*A^3/B}$ = 0.56 (subcritical flow) (see textbook p. 40)

Exercise No. 6
See textbook pp. 290-293.

Exercise No. 7
See {http://www.bh.com/companions/0340740671/exercises/exercisesP3-15.htm}.