THE UNIVERSITY OF ADELAIDE
AUSTRALIA

Student ID:	
Family Name:	
Other Name(s):	
Desk and Row No.:	
Date:	
Exam Mark:	

Examination for the Bachelor of Engineering

School of Civil, Environmental & Mining Engineering

Third Year Examination

Semester 1, 2009

Course ID 2393	**Water Engineering and Design III A** **C&ENVENG 3013**

Official Reading Time:	10 mins
Writing Time:	180 mins
Total Duration:	190 mins
Total Marks available	60

Instructions

- This is a closed book examination.
- Write your name, Student ID, desk and row number and date in the top right hand corner of this page.
- Answer any or all questions on the question paper answer book.
- You must show all workings if your answer is to be considered.
- Examination materials must not be removed from the examination room.
- Show all calculations and assumptions.

Materials

- Question paper answer book
- Formulae sheet and useful data
- The use of calculators is permitted, this equipment to be supplied by the candidate. No pre-recorded material nor calculator instruction book is permitted, and calculators with remote communication links will be barred from the examination room.
- Dictionaries are **not** permitted

QUESTION 1 – 8 marks

(a) Figure 1 shows a sluice gate. If the water depth upstream is 3.0 metres and the downstream depth is 0.25 metres, determine the flow rate per unit width if losses are ignored. [3 marks]

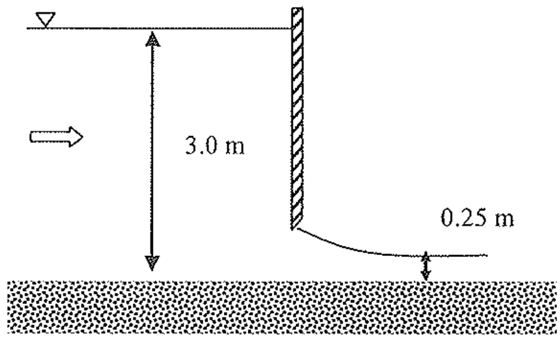

Figure 1 – Sluice gate and flows.

Flow rate =

(b) What is the force per unit width on the gate? Is this the value that would be calculated assuming a hydrostatic pressure distribution? Explain your answer. [5 marks]

Force =

QUESTION 2 – 8 marks

(a) A rectangular channel is 4.0 m wide and carries a discharge of 20 m^3/s at a depth of 2.0 m. At a certain section it is proposed to build a hump. Calculate the water surface elevations at upstream of the hump and over the hump if the hump height is 0.33 m. [4 marks]

Water depth upstream =

Water depth over hump =

(b) Using appropriate hydraulics theory and relevant sketches of key diagrams, explain the flow behaviour in this situation. [4 marks]

QUESTION 3 – 8 marks

(a) The specific energy in a 2.0 m wide rectangular channel is not to exceed 1.2 m. What maximum discharge can be carried in such a channel? What longitudinal slope is required to sustain such a flow? Assume Manning's $n = 0.015$. [5 marks]

Discharge =

Longitudinal slope =

(b) The Manning's n and Chezy C are both coefficients of roughness. Determine a relationship of one in terms of the other. [3 marks]

QUESTION 4 – 8 marks

(a) Water from a low dam is released through a sluice gate on a horizontal rectangular channel. The depth of water upstream of the sluice gate is 16.0 metres above the channel bed and the gate opening is 1.5 metres. The sluice gate can be assumed to be sharp-edged. If a free hydraulic jump is formed just downstream of the gate, find the sequent depths and the percentage of the initial energy lost in the jump. Assume that the discharge from the sluice gate can be calculated as: $q = C_d a \sqrt{2g\Delta H}$ where $C_d = 0.60$, a is the gate opening and ΔH is the difference in height between the upstream and downstream depth.

[5 marks]

Sequent depths =

Percentage energy loss =

(b) Is the depth downstream of a jump less than the alternate depth? Please use a schematic of the specific energy diagram as part of the answer.

[3 marks]

QUESTION 5 – 8 marks

(a) A sharp-crested weir is 1.5 metres long. Calculate the height of the weir required to pass a flow of 0.75 m^3/s while maintaining an upstream depth of flow of 1.5 metres. [4 marks]

Height of weir =

(b) Describe some of the weir layouts that are used for conditions that might include a range of flows from very low to high. Why are sharp-crested weirs not suitable in these situations? [4 marks]

QUESTION 6 – 8 marks

(a) Describe in detail the generation of a shock wave in supercritical flow and the implications in the design of open channel systems. [3 marks]

(b) A wide stream has a sediment bed of median size 0.35 mm. The slope of the channel is 1.5×10^{-4}. If the depth of flow in the channel is 0.25 m, determine the shear velocity and whether the bed particles will be in motion or not using the Shields diagram. Check your answer using an appropriate approximate method if possible. [5 marks]

Shear velocity =

Are particles in motion?

QUESTION 7 – 6 marks

In a paper by Samani and Magallanez (2000) entitled "Simple Flume for Flow Measurement in Open Channel" the authors describe a device that consists of two semi-cylinders that are fixed to opposite walls of the flume to form a flow contraction as shown in Figure 2.

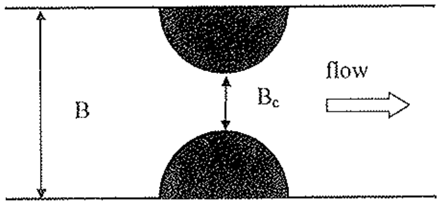

Figure 2 Simple flow measurement device.

(a) Describe the basic hydraulic principles of such as device and discuss how it is similar to a Parshall flume. What is the key feature of this device and a Parshall flume that make them suitable for flow measurement in rectangular irrigation channels? [4 marks]

(b) The authors go on to give details of gauges that could be fitted inside the semi-circular cylinders to reduce the fluctuations. What would the gauges measure and why would this be important for estimating the flow? [2 marks]

QUESTION 8 – 6 marks

The Method of Characteristics can be applied to the solution of unsteady flow in an open channel. The method solves the continuity and momentum equations:

$$A\frac{\partial V}{\partial x}+V\frac{\partial A}{\partial x}+T\frac{\partial y}{\partial t}=0 \qquad \frac{\partial y}{\partial x}+\frac{V}{g}\frac{\partial V}{\partial x}+\frac{1}{g}\frac{\partial V}{\partial t}=S_0-S_f \qquad (1,2)$$

by transforming them into a pair of differential equations:

$$\frac{d}{dt}(V\pm 2C)=g(S_0-S_f) \qquad (3,4)$$

that are only valid if:

$$\frac{dx}{dt}=V\pm C \qquad (5,6)$$

where the terms are defined as usual. Without showing the full derivations, explain:

- how Equations 1 and 2 are transformed into Equations 3 and 4;
- how Equations 5 and 6 limit the solutions that can be obtained;
- what the four unknowns are that the four equations (3,4,5,6) are used to solve for;
- how the solution proceeds; and
- what information is needed to start and continue the solution.

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END OF EXAM

FORMULA SHEET

Chapter 1

$$H = Z + y + \alpha \frac{V^2}{2g}$$

$$\sum F = F_1 - F_2 - F_3 + F_4 = M_2 - M_1$$

$$M_1 = \beta_1 \rho Q V_1$$

$$F_1 = \frac{1}{2}\gamma y_1^2$$

$$P_s = \frac{1}{\gamma}(F + M)$$

Chapter 2

$$E = y + \frac{V^2}{2g}$$

$$F = \frac{V}{\sqrt{gy}}$$

$$y_c = \left(\frac{q^2}{g}\right)^{1/3} \text{(rectangular)}$$

$$E_c = \frac{3}{2} y_c$$

$$Z = A\sqrt{A/T}$$

$$Q_c = \sqrt{g}Z$$

Chapter 3

$$V = C\sqrt{RS_0}$$

$$h_f = f\frac{L}{D}\frac{V^2}{2g}$$

$$C = \sqrt{8g/f}$$

$$V = \frac{1}{n} R^{2/3} S_0^{1/2}$$

$$n = \frac{\left(\sum n_i^{3/2} P_i\right)^{2/3}}{P^{2/3}}$$

$$Q = KS_0^{1/2}$$

Chapter 4

$$S_f = \frac{n^2 V^2}{R^{4/3}}$$

$$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - \frac{\alpha Q^2 T}{gA^3}}$$

More on other side ...

Chapter 5

$$\frac{dE}{dx} = S_0 - S_f$$

$$(x_2 - x_1) = \Delta x = \frac{(E_2 - E_1)}{S_0 - \frac{1}{2}(S_{f1} + S_{f2})}$$

$$S_f = \frac{n^2 Q^2}{2}\left[\frac{1}{A_{i+1}^2 R_{i+1}^{4/3}} + \frac{1}{A_i^2 R_i^{4/3}}\right]$$

$$h_f = \overline{S_f}\Delta x$$

$$H_2 = H_1 + h_f + h_e$$

Chapter 6

$$\frac{y_2}{y_1} = \frac{1}{2}\left(-1 + \sqrt{1 + 8F_1^2}\right)$$

$$E_L = \frac{(y_2 - y_1)^3}{4 y_1 y_2}$$

$$\frac{E_L}{E_1} = \frac{\left(\frac{y_2}{y_1} - 1\right)^3}{4\left(\frac{y_2}{y_1}\right)\left(1 + \frac{F_1^2}{2}\right)}$$

$$\frac{E_L}{E_1} = \frac{\left(-3 + \sqrt{1 + 8F_1^2}\right)^3}{8\left(2 + F_1^2\right)\left(-1 + \sqrt{1 + 8F_1^2}\right)}$$

$$L_j = 6.9(y_2 - y_1)$$

$$\frac{y_2}{y_1}\left(1 + \frac{y_2}{y_1}\right) = \frac{2q^2}{g y_1^3} = 2F_1^2$$

Chapter 7

$$Q = \frac{2}{3} C_d \sqrt{2g} L H_1^{3/2}$$

$$C_d = 0.611 + 0.08\frac{H_1}{P}$$

$$C_d = 1.06\left(1 + \frac{P}{H_1}\right)^{3/2} \text{(sill)}$$

$$L_e = L - 0.1nH_1$$

$$Q = \frac{2}{3} C_{dc} \sqrt{2g} L_e H_{1e}^{3/2}$$

$$L_e = L + K_L$$

$$H_{1e} = H_1 + K_H$$

Chapter 10

$$A\frac{\partial V}{\partial x} + V\frac{\partial A}{\partial x} + T\frac{\partial y}{\partial t} = 0$$

$$\frac{\partial y}{\partial x} + \frac{V}{g}\frac{\partial V}{\partial x} + \frac{1}{g}\frac{\partial V}{\partial t} = S_0 - S_f$$

$$\frac{d}{dt}(V \pm 2C) = g(S_0 - S_f)$$

$$\frac{dx}{dt} = V \pm C$$

Chapter 11

$$\tau_0 = \gamma R S_0 = \rho u_*^2$$

$$u_* = \sqrt{\frac{\gamma R S_0}{\rho}} = \sqrt{gRS_0}$$

$$\tau_c = \tau_{*c}(\gamma_s - \gamma)d$$

$$R_{*c} = \frac{u_{*c} d}{\nu}$$

$$\tau_c = 0.155 + \frac{0.409 d_{mm}^2}{\left[1 + 0.177 d_{mm}^2\right]^{1/2}} \quad (\mathrm{d}_{mm} \le 5.5)$$

$$\tau_c = 0.905 d_{mm} \quad (\mathrm{d}_{mm} > 6.0)$$

$$d_c = \frac{\tau_0}{0.056(\gamma_s - \gamma)} = \frac{\gamma R S_0}{0.056(\gamma_s - \gamma)} \approx 11RS$$

$$n_s = \frac{d^{1/6}}{21.1}$$

$$q_B = \phi_B \gamma_s \sqrt{gd^3}\sqrt{\frac{\gamma_s}{\gamma} - 1}$$

$$\phi_B = 8\left(\tau_*' - 0.047\right)^{3/2}$$

$$\tau_*' = \left[\frac{n_s}{n}\right]^{3/2} \frac{\gamma R S_0}{(\gamma_s - \gamma)d}$$

$$q_T = \phi_T \gamma_s \sqrt{gd^3}\sqrt{\frac{\gamma_s}{\gamma} - 1}$$

$$\phi_T f = 0.4\tau_*^{5/2}$$

$$\tau_* = \frac{\tau_0}{(\gamma_s - \gamma)d}$$

$$f = \frac{8gRS_0}{V^2}$$