National Exams December 2005

98-Env-A1, Hydrology, Hydraulics & Groundwater

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an OPEN BOOK Exam. A Casio or Sharp approved model calculator is permitted.
3. FIVE (5) questions constitute a complete exam paper.
4. **Part A** of the exam consists of five problems. The candidate is asked to attempt **any four**.
5. **Part B** of the exam consists of two problems. The candidate is to attempt **only one** of the problems.
6. Each graded problem is of equal value.

Part A Attempt **four** of the five problems listed in Part A. If all problems are attempted, only the first four problems in the answer booklet will be graded

Problem 1 (20 marks)

A 2 hour unit (1 cm) hydrograph is provided below:

Time (hrs)	0	1	2	3	4	5	6	7
Q (m^3/s)	0	100	250	200	100	75	25	0

Compute the **peak discharge** resulting from the rainfall event provided below.

Time (hrs)	0 - 3	3 - 6
Rainfall (mm/hr)	15	10

Assume a ϕ index of 3 mm/hr and adopt a constant baseflow of 10 m^3/s.

Problem 2 (20 marks)

Flow is conveyed through a box culvert at a rate of 8.0 m^3/s. The backwater depth at the culvert entrance is exactly 2.0 m. The channel upstream of the culvert is rectangular in cross section having a constant width of 2.40 m and longitudinal slope of 0.002. The appropriate Manning's roughness for the upstream channel reach is 0.015.

a) Compute the normal depth and critical depth for the specified flow rate and classify the water surface profile upstream of the culvert.
b) Using one reach, compute the distance from the culvert entrance to the point where normal depth is established.

Problem 3 (20 marks)

You are employed with a local conservation authority. You are asked to verify the design for a flood control reservoir. The reservoir is initially empty and has a linear storage-outflow relationship

$$S = KO$$

where K = 1.3 hour. The design inflow hydrograph is provided below:

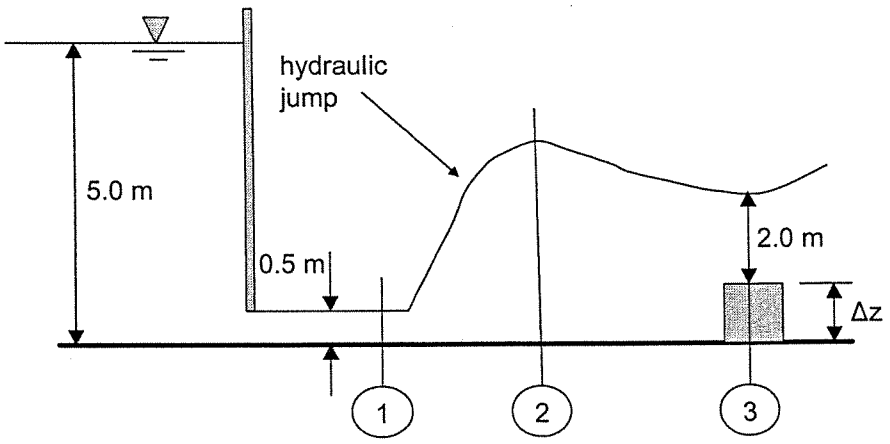
Time (hrs)	0	1	2	3	4	5	6	7	8
Q (m^3/s)	0	75	150	450	300	150	100	25	0

Using any method, route the inflow hydrograph through the reservoir (Δt = 1 hour). The maximum capacity of the downstream spillway is 280 m^3/s.

a) Is the storage-outflow design adequate?
b) What is the maximum utilized reservoir storage (m^3) during the routing event?

Problem 4 (20 marks)

A large reservoir 5.0 m deep discharges water through a sluice gate (1 m wide) into a 1 m wide horizontal rectangular channel as shown below. The flow discharging from the reservoir is forced into the subcritical flow regime by a step located downstream of the gate as shown.



a) If the flow depth immediately downstream of the gate (section 1) is 0.5 m, compute the rate of discharge from the reservoir. Neglect any energy losses through the gate.
b) Compute the critical depth and minimum specific energy associated with the channel discharge
c) Determine the step height (Δz) required to produce a hydraulic jump as indicated and a subcritical flow depth of 2.0 m on top of the step at section 3. Neglect any friction losses within the channel.

Problem 5 (20 marks)

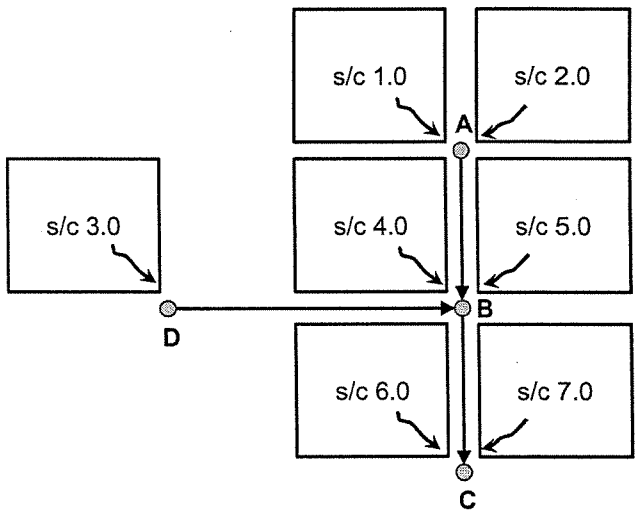
An urban drainage basin is comprised of 7 sub-catchments and 4 inlets as shown in the figure below. You are provided with the following information (Table 1 and Table 2)

Table 1.0
Characteristics of drainage subcatchments

Sub-catchment Number	Area (ha)	Runoff Coefficient	Inlet Time (min)
s/c 1	2	.7	5
s/c 2	3	.7	7
s/c 3	4	.6	12
s/c 4	4	.6	10
s/c 5	5	.5	15
s/c 6	4	.5	15
s/c 7	5	.5	15

Table 2.0
Pipe flow travel times

Pipe Segment	Flow Travel Time (min)
D-B	1.75
A-B	2.00
B-C	2.50



For this problem, you may adopt the following IDF relationship

$$i = \frac{4000}{t_d + 27}$$

where i represents the intensity (mm/hour) and t_d is the duration of rainfall (minutes). Determine the peak design flows at points **A**, **B** and **C**. Show all work for full marks.

Part B Answer Problem 6 **or** Problem 7. If both problems are attempted, the solution appearing first in the answer booklet will be graded.

Problem 6 (20 marks)

Use the Green-Ampt infiltration model to compute the **infiltration rate** and **cumulative infiltration volume** after one hour of infiltration into a silt loam soil. Assume water is ponded to a small but negligible depth on the surface over the entire hour. Adopt an initial soil moisture deficit of 0.340, a saturated hydraulic conductivity of 0.65 cm/hr and a suction head of 16.7 cm.

Problem 7 (20 marks)

a) A phreatic aquifer extends over 10 km^2. Initially, the water table was observed to be 10.0 m below the surface. Irrigation to a depth of 10 cm resulted in the water table rising to a depth of 9.8 m below the ground level. After 6×10^6 m^3 of water was pumped out, the water table was observed at a depth of 11.5 m below the ground level. Compute the specific yield (effective porosity) of the aquifer and the soil moisture deficit (below field capacity) prior to the irrigation event.

b) A well is constructed to pump water from a 25 m thick confined aquifer. Two observation wells are located at distances of 125 m and 1500 m. Water is pumped from the pumping well at a rate of 0.3 m^3/min. At steady state, draw-downs of 10 m and 5 m were observed in the observation wells. Determine the hydraulic conductivity (cm/sec) of the aquifer.