

**SULTAN QABOOS UNIVERSITY**

**Department of Civil and Architectural Engineering  
B. Eng. Examination, Spring Semester 2006**

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**ENGINEERING HYDROLOGY**

**CIVL 3066**

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May 16, 2006

14:00-17:00

**Candidates are permitted to bring into the examination room:**

Calculator (programmable or non-programmable).

**Instructions to candidates:**

1. Answer all the questions
2. The paper consists of SIX questions.
3. Maximum allowed time is three hours.
4. Assume water density as  $1000 \text{ kg/m}^3$  wherever required.
5. Assume kinematic viscosity of the water as  $0.01 \text{ cm}^2/\text{s}$  wherever required.

**NAME:**

**ID #:**

<b>Question</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>Total</b>
<b>Marks</b>							

**1.**

From the hydrologic records of over 50 years on a drainage basin of area 500 square kilometres, the average annual rainfall is estimated as 90cm and the average annual runoff as 33cm. A reservoir in the basin, having an average surface area of 1700hectares, is planned at the basin outlet to collect available runoff for supplying water to a nearby community. The annual evaporation over the reservoir surface is estimated as 130cm. There is no groundwater leakage or inflow to the basin. Determine the available average annual withdrawal from the reservoir for water supply **[10%]**

**2.**

Four rain gages located within a rectangular area with four corners at (0,0), (8,0), (8,12) and (0,12) have the following coordinates and recorded rainfalls:

Station	Coordinates	Rainfall (cm)
1	(2,3)	1.5
2	(6,3)	1.0
3	(6,9)	1.5
4	(2,9)	2.0

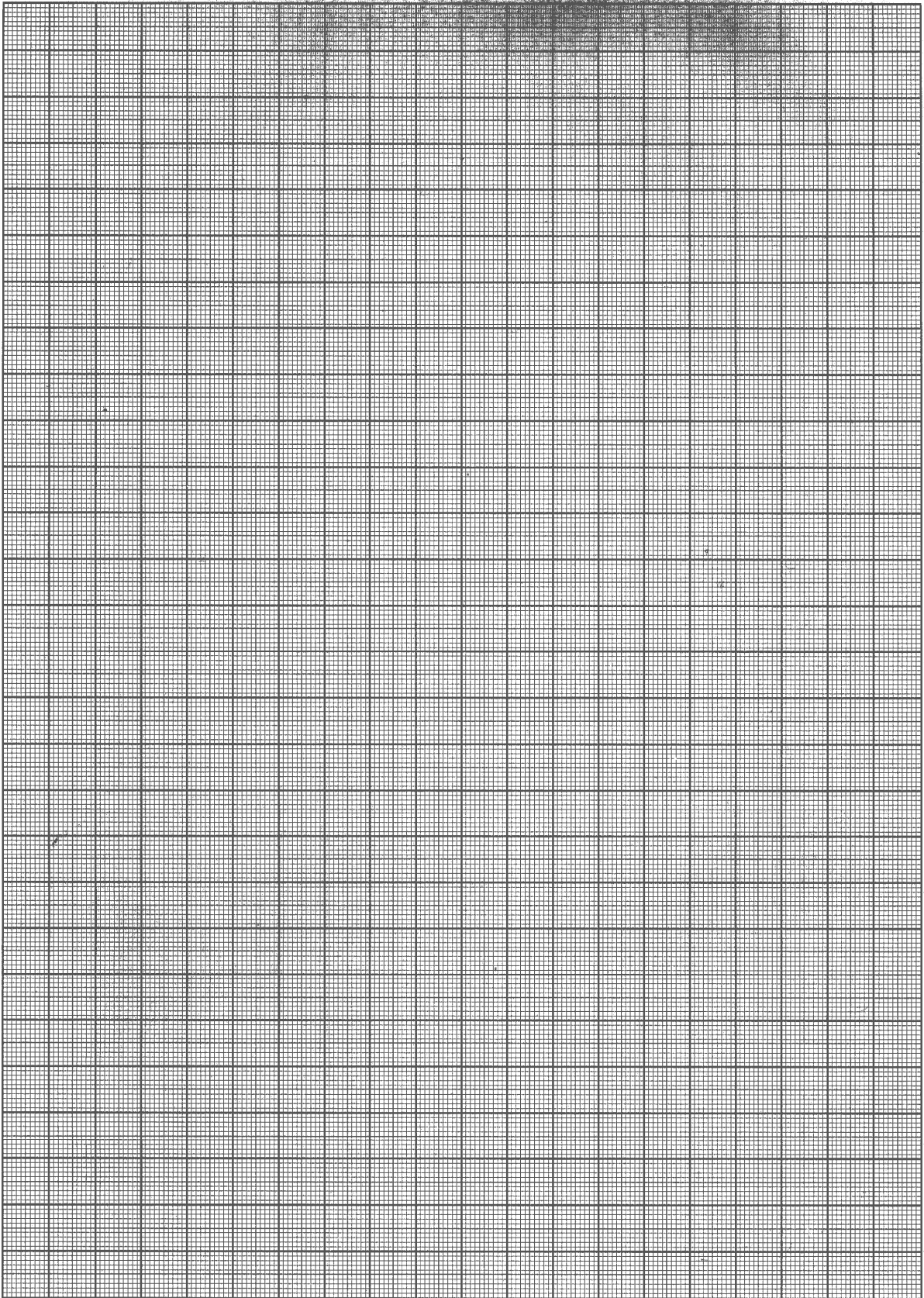
All coordinates are expressed in kilometers. Compute the average rainfall in the area by:

(a) Arithmetic mean method

**[5%]**

(b) Thiessen polygon method

**[10%]**



**3.**

A 100 ha watershed is 40% agricultural and 60% urban land. The agricultural area is 40% cultivated land without conservation treatment, 35% forest land with good cover and 25% pasture in poor condition.

The 60% of the urban area is residential, out of which 60% is 1/10 acre lots and 20% 1/8 acre lots and 20% is streets and roads with curbs and storm sewers. The remaining 40% of the urban area is commercial and business area. The hydrologic soil group of 25% of the watershed is Group A, 45% Group C and 35% Group D. Compute the volume of runoff (in cubic meters) from 15cm of rainfall on this watershed. Assume normal antecedent moisture conditions. **[20%]**



4.

- (a) Using the laws of conservation in a vertical column of soil having unit cross sectional area, prove that the cumulative infiltration  $F$  is given by the following relationship:

$$F = Kt + \psi\Delta\theta \ln\left(1 + \frac{F}{\psi\Delta\theta}\right)$$

Where,  $K$ = hydraulic conductivity of the soil,  $t$ =time,  $\psi$  =suction head and  $\Delta\theta$  is the change in moisture of the soil. **[10%]**

- (b) Write down the complete listing of VBA function to solve the relationship for cumulative infiltration given in Part (a). **[5%]**





5.

In a watershed with area of  $122 \text{ km}^2$ , the length of the main channel is 95km, and the main channel length from the watershed outlet to the point opposite to the centroid of the watershed is 30km. Using  $C_t = 2.0$  and  $C_p = 0.625$ , determine;

- (a) The standard synthetic unit hydrograph using Snyder's method, and [5%]
- (b) Two hour unit hydrograph for this watershed. Prove that the obtained unit hydrograph represents 1cm of depth of DRO. [15%]



6.

The ordinates of a 1-hour unit hydrograph are given as follows;

Time(hr)	0	1	2	3	4	5
$q$ ( $m^3/s.cm$ )	0	17	22	8	3	0

- (a) Calculate the watershed area. [5%]  
(b) Determine S-hydrograph ordinates, and [10%]  
(c) Derive 2-hour unit hydrograph [5%]



The following information may be useful in solving the problems.

$$f(t) = f_c + (f_0 - f_c)e^{-kt}, \quad F(t) = S\sqrt{t} + Kt$$

$$f(t) = \frac{1}{2} \frac{S}{\sqrt{t}} + K, \quad F(t) - \psi\Delta\theta \ln\left(1 + \frac{F(t)}{\psi\Delta\theta}\right) = Kt$$

$$f = K\left(\frac{\psi\Delta\theta + F}{F}\right) = \frac{dF}{dt}, \quad \Delta\theta = (1 - s_e)\theta_e$$

$$e_s = 611 \exp\left(\frac{17.3T}{T + 237.3}\right),$$

$$E_t = \frac{\Delta SM}{\Delta t} = \frac{\sum_{i=1}^n (\theta_1 - \theta_2) \Delta S_i + I - D}{\Delta t}$$

$$Q = \frac{1}{n} AR^{2/3} S_f^{1/2}$$

$$Q_n = \sum_{m=1}^{n \leq M} P_m U_{n-m+1}$$

$$t_p = 5.5t_r$$

$$t_p = C_1 C_t (LL_c)^{0.3} \quad \{ C_1 = 0.75 \text{ (SI), } 1 \text{ (English)} \}$$

$$q_p = \frac{C_2 C_p}{t_p} \quad \{ C_2 = 2.75 \text{ (SI), } 640 \text{ (English)} \}$$

$$t_p = t_{pR} + \frac{t_r - t_R}{4} \quad t_b = \frac{C_3}{q_{pR}} \quad \{ C_3 = 5.56 \text{ (SI), } 1290 \text{ (English)} \}$$

$$W = C_w q_{pR}^{-1.08} \quad \{ 75\% \text{ width: } C_w = 1.22 \text{ (SI), } 440 \text{ (English)} \}$$

$$50\% \text{ width: } C_w = 2.14 \text{ (SI), } 770 \text{ (English)} \}$$

$$q_p = \frac{2.08A}{T_p} \quad T_p = \frac{t_r}{2} + t_p \quad t_p = 0.6T_c$$

$$n^6 \sqrt{RS_f} \geq 1.1 \times 10^{-13} \quad \text{(SI units)}$$

$$\geq 1.9 \times 10^{-13} \quad \text{(British units)}$$

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S} \quad CN = \frac{1000}{10 + S}$$

**TABLE 5.5.2**  
**Runoff curve numbers for selected agricultural, suburban, and urban land uses (antecedent moisture condition II,  $I_a = 0.2S$ )**

Land Use Description	Hydrologic Soil Group			
	A	B	C	D
Cultivated land <sup>1</sup> : without conservation treatment	72	81	88	91
with conservation treatment	62	71	78	81
Pasture or range land: poor condition	68	79	86	89
good condition	39	61	74	80
Meadow: good condition	30	58	71	78
Wood or forest land: thin stand, poor cover, no mulch	45	66	77	83
good cover <sup>2</sup>	25	55	70	77
Open Spaces, lawns, parks, golf courses, cemeteries, etc.				
good condition: grass cover on 75% or more of the area	39	61	74	80
fair condition: grass cover on 50% to 75% of the area	49	69	79	84
Commercial and business areas (85% impervious)	89	92	94	95
Industrial districts (72% impervious)	81	88	91	93
Residential <sup>3</sup> :				
Average lot size	Average % impervious <sup>4</sup>			
1/8 acre or less	65	77	85	90
1/4 acre	38	61	75	83
1/3 acre	30	57	72	81
1/2 acre	25	54	70	80
1 acre	20	51	68	79
Paved parking lots, roofs, driveways, etc. <sup>5</sup>	98	98	98	98
Streets and roads:				
paved with curbs and storm sewers <sup>5</sup>	98	98	98	98
gravel	76	85	89	91
dirt	72	82	87	89

<sup>1</sup>For a more detailed description of agricultural land use curve numbers, refer to Soil Conservation Service, 1972, Chap. 9

<sup>2</sup>Good cover is protected from grazing and litter and brush cover soil.

<sup>3</sup>Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.

<sup>4</sup>The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.

<sup>5</sup>In some warmer climates of the country a curve number of 95 may be used.