BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
SECOND SEMESTER 2022-2023
MID SEMESTER EXAMINATION-ENGINEERING HYDROLOGY (CLOSE BOOK)

Course No: CE F321 **Date: 17-03-2023 (Friday)**
Duration: 90 min (9:00 – 10:30 AM) **Max. Marks: 60**

Instructions:
1. Show all calculations/steps in detail. No marks will be awarded for correct answers without proper calculations
2. Read question carefully and express the answers only in the units you are instructed to use
3. Use graph paper wherever necessary and sharing of calculators is not allowed

Q.1. Answer the following in the form of a short paragraph/points: **[3 x 4 = 12 M]**

a. Please list four conditions required for the formation of precipitation.
b. Explain using the example of sponge, the concept of saturation, field capacity, gravitational water and unavailable water in the soil.
c. How different infiltration capacities can result in different flow pathways in a watershed ?
d. Why is evapotranspiration also known as consumptive use and how the knowledge of consumptive use is important?

Q.2. On a hot sunny day in the month of July (Avg. monthly temperature = 40°C), a 6-hr storm on a catchment (40°N) known for sugarcane production produces discharge in a river stream. The cumulated discharge measured in three equal time intervals during the storm accounts for 0.5 cm, 0.3 cm, and 0.1 cm. The precipitation intensity is approximated as ten times the infiltration rate. The infiltration rate for the catchment soil is given by $(1+e^{-0.5t})/10$ cm/hr., where 't' is in hours. Considering evapotranspiration losses as the only major component of initial losses (neglecting other losses) and averaging precipitation over three equal intervals, determine w-index for the storm (Use Blaney-Criddle for storm duration; also assume that average temperature and P_h values are same as in July during the all 4-month sugarcane cropping season (Jul-Oct)). **[12 M]**

Q.3. Mississippi river sub-watershed has an area of 4942.11 acres. Calculate the runoff (in mm) from the sub-watershed due to a rainfall of 5.9 inches in a day. Also, the sub-watershed has a mix of soils corresponding to groups B, C and D covering 30%, 30% and 40% area respectively. Land use consists of 60% residential (65% impervious) and 40% paved roads. Antecedent Moisture Conditions-II prevail across the sub-watershed. In case, the land was pastureland in poor condition before the commencement of any development, compute the runoff (in mm) under same rainfall conditions? Also, determine the percentage increase/decrease in runoff volume due to urbanization? **[12 M]**

Q.4. Watershed modeling practitioners are required to calculate the storage change (m^3) for a lake for the month of April using water-budget equation, where the lake is having a surface area of about 425 ha and monthly inflow, outflow and seepage given as 33 cusecs, 27 cusecs and 3.81 cm respectively. Calculate the storage change (m^3) if the total precipitation is 11.43 cm. It is decided to consider evapotranspiration to perform calculations for obtaining the storage change. Thus, practitioners used the following data of a nearby rice field to calculate consumptive use for the month of April:

Wind velocity measured at 200cm height = 0.58 m/s
Elevation of the area = 220 m
Relative humidity for April = 70%
Latitude = 35°N
Mean monthly temperature = 20°C

Nature of surface cover: Close-ground green crop
n= 7.2 h

Calculate the evapotranspiration (in mm). Mention necessary assumptions. **[12 M]**

Q.5. Which is more accurate for calculating infiltration capacity: Green Ampt's equation or Horton's equation? Please justify your answer. The infiltration data of a catchment is given as follows:

Time since start (min.)	**10**	**20**	**30**	**50**	**80**	**120**	**160**	**200**	**280**	**360**
Cumulative Infiltration (mm)	**9.8**	**18**	**25**	**38**	**55**	**76**	**94**	**110**	**137**	**163**

Establish Green-Ampt equation. While plotting, take units of infiltration capacity in cm/hr. Show all calculations in the form of a Table. **[12 M]**

Wish you all the best!

FORMULA AND TABLE SHEET

$$PET = \frac{AH_n + E_a\gamma}{A + \gamma}$$

$$H_n = H_a\,(1 - r)\left(a + b\,\frac{n}{N}\right) - \sigma T_a^4\left(0.56 - 0.092\sqrt{e}\right)\left(0.10 + 0.90\,\frac{n}{N}\right)$$

$$E_a = 0.35\left(1 + \frac{u_2}{160}\right)\left(e_w - e_a\right)$$

Values of r:

Surface	**Range of r values**
Close ground corps	0.20
Bare Lands	0.05 – 0.45
Water surface	0.05
Snow	0.45 – 0.95

Mean Monthly Solar Radiation at Top of Atmosphere, H_a in mm of Evaporable Water/Day

North latitude	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
0°	14.5	15.0	15.2	14.7	13.9	13.4	13.5	14.2	14.9	15.0	14.6	14.3
10°	12.8	13.9	14.8	15.2	15.0	14.8	14.8	15.0	14.9	14.1	13.1	12.4
20°	10.8	12.3	13.9	15.2	15.7	15.8	15.7	15.3	14.4	12.9	11.2	10.3
30°	8.5	10.5	12.7	14.8	16.0	16.5	16.2	15.3	13.5	11.3	9.1	7.9
40°	6.0	8.3	11.0	13.9	15.9	16.7	16.3	14.8	12.2	9.3	6.7	5.4
50°	3.6	5.9	9.1	12.7	15.4	16.7	16.1	13.9	10.5	7.1	4.3	3.0

Temperature (°C)	Saturation vapour pressure e_w (mm of Hg)	A (mm/°C)
0	4.58	0.30
5.0	6.54	0.45
7.5	7.78	0.54
10.0	9.21	0.60
12.5	10.87	0.71
15.0	12.79	0.80
17.5	15.00	0.95
20.0	17.54	1.05
22.5	20.44	1.24
25.0	23.76	1.40
27.5	27.54	1.61
30.0	31.82	1.85
32.5	36.68	2.07
35.0	42.81	2.35
37.5	48.36	2.62
40.0	55.32	2.95
45.0	71.20	3.66

$e_w = 4.584 \exp\left(\frac{17.27t}{237.3+t}\right)$ mm of Hg, where t = temperature in °C.

Mean Monthly Values of Possible Sunshine Hours, N

North latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0°	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
10°	11.6	11.8	12.1	12.4	12.6	12.7	12.6	12.4	12.9	11.9	11.7	11.5
20°	11.1	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
30°	10.4	11.1	12.0	12.9	13.7	14.1	13.9	13.2	12.4	11.5	10.6	10.2
40°	9.6	10.7	11.9	13.2	14.4	15.0	14.7	13.8	12.5	11.2	10.0	9.4
50°	8.6	10.1	11.8	13.8	15.4	16.4	16.0	14.5	12.7	10.8	9.1	8.1

Monthly Daytime Hours Percentages P_h for use in Blaney- Criddle Formula

North latitude (deg)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	8.50	7.66	8.49	8.21	8.50	8.22	8.50	8.49	8.21	8.50	8.22	8.50
10	8.13	7.47	8.45	8.37	8.81	8.60	8.86	8.71	8.25	8.34	7.91	8.10
15	7.94	7.36	8.43	8.44	8.98	8.80	9.05	8.83	8.28	8.26	7.75	7.88
20	7.74	7.25	8.41	8.52	9.15	9.00	9.25	8.96	8.30	8.18	7.58	7.66
25	7.53	7.14	8.39	8.61	9.33	9.23	9.45	9.09	8.32	8.09	7.40	7.42
30	7.30	7.03	8.38	8.72	9.53	9.49	9.67	9.22	8.33	7.99	7.19	7.15
35	7.05	6.88	8.35	8.83	9.76	9.77	9.93	9.37	8.36	7.87	6.97	6.86
40	6.76	6.72	8.33	8.95	10.02	10.08	10.22	9.54	8.39	7.75	6.72	6.52

Values of K for selected crops

Crop	Average value of K	Range of monthly values
Rice	1.10	0.85–1.30
Wheat	0.65	0.50–0.75
Maize	0.65	0.50–0.80
Sugarcane	0.90	0.75–1.00
Cotton	0.65	0.50–0.90
Potatoes	0.70	0.65–0.75
Natural Vegetation:		
(a) Very dense	1.30	
(b) Dense	1.20	
(c) Medium	1.00	
(d) Light	0.80	

$CN_I = \frac{CN_{II}}{2.281 - 0.01281\, CN_{II}}$	$CN_{III} = \frac{CN_{II}}{0.427 + 0.00573\, CN_{II}}$

AMC for determining the value of CN

AMC Type	Total Rain in Previous 5 days	
	Dormant Season	Growing Season
I	Less than 13 mm	Less than 36 mm
II	13 to 28 mm	36 to 53 mm
III	More than 28 mm	More than 53 mm

Runoff Curve Numbers [CN_{II}] for Hydrologic Soil Cover Complexes [Under AMC-II Conditions]

Land Use	Cover		Hydrologic soil group			
	Treatment or practice	Hydrologic condition	A	B	C	D
Cultivated	Straight row		76	86	90	93
Cultivated	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
Cultivated	Contoured &	Poor	66	74	80	82
	Terraced	Good	62	71	77	81
Cultivated	Bunded	Poor	67	75	81	83
		Good	59	69	76	79
Cultivated	Paddy		95	95	95	95
Orchards	With understory cover		39	53	67	71
	Without understory cover		41	55	69	73
Forest	Dense		26	40	58	61
	Open		28	44	60	64
	Scrub		33	47	64	67
Pasture	Poor		68	79	86	89
	Fair		49	69	79	84
	Good		39	61	74	80
Wasteland			71	80	85	88
Roads (dirt)			73	83	88	90
Hard surface areas			77	86	91	93

CN_{II} values for Sugarcane

Cover and treatment	Hydrologic soil group			
	A	B	C	D
Limited cover, Straight Row	67	78	85	89
Partial cover, Straight row	49	69	79	84
Complete cover, Straight row	39	61	74	80
Limited cover, Contoured	65	75	82	86
Partial cover, Contoured	25	59	45	83
Complete cover, Contoured	6	35	70	79

CN_{II} values for Suburban and Urban Land Uses

Cover and treatment	Hydrologic soil group			
	A	B	C	D
Open spaces, lawns, parks etc				
(i) In good condition, grass cover in more than 75% area	39	61	74	80
(ii) In fair condition, grass cover on 50 to 75% area	49	69	79	84
Commercial and business areas (85% impervious)	89	92	94	95
Industrial Districts (72% impervious)	81	88	91	93
Residential, average 65% impervious	77	85	90	92
Paved parking lots, paved roads with curbs, roofs, driveways, etc	98	98	98	98
Streets and roads				
Gravel	76	85	89	91
Dirt	72	82	87	89

Thornthwaite Formula

$$E_T = 1.6\, L_a \left(\frac{10\,\overline{T}}{I_t} \right)^a$$

a = an empirical constant

$$= 6.75 \times 10^{-7}\, I_t^3 - 7.71 \times 10^{-5}\, I_t^2 + 1.792 \times 10^{-2} I_t + 0.49239$$