1) 5
2) 6
3) 12
4) 10
5) 12
6) ~~12~~ 9
7) 12
8) 8
9) 4
10) 10
11) 8
12) ~~12~~ 4

Student Name: ____________________ FALL 2024

CE 3354 Engineering Hydrology
Exam 2, Fall 2024

Students should write their name on **all sheets of paper**.
Students are permitted to use the internet, their own notes and the textbooks.
Students are **forbidden** to **communicate with other people** during the examination.

1. Figure 1 below shows a model of the water cycle. The arrows show the movement of water molecules through the water cycle. The circled numbers processes that dominate as the water molecules reach the different stages of the water cycle.

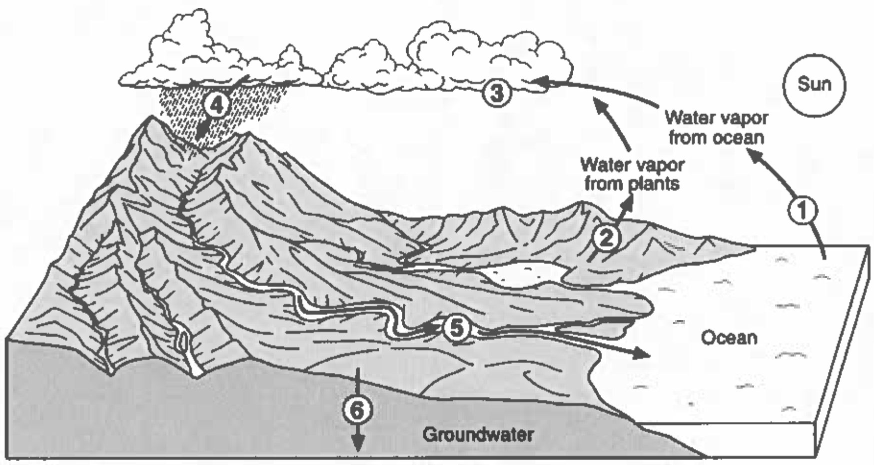

Figure 1: Water Cycle Diagram

Complete Table 1 by the water cycle process occurring at each number.

Table 1: Dominant Water Cycle Process

Item	: Water Cycle Process
1	: EVAPORATION
2	: TRANSPIRATION
3	: Condensation (into clouds)
4	: PRECIPATION
5	: STREAMFLOW (RUNOFF)
6	: INFILTRATION

5

2. Consider the two graphs in Figure 2, which show the relationship between the amount of rainfall during a storm and the amount of discharge in a nearby stream. Letter A represents the time when approximately 50% of the precipitation from the storm has fallen. Letter B represents the time when peak runoff from the storm is flowing in the stream. The delay is the difference in time between letters A and B on the graph. Graph I shows data before urbanization in an area. Graph II shows data after urbanization in the same area

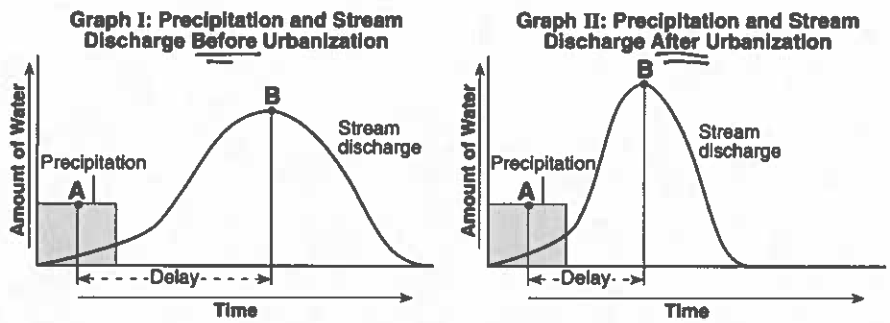

Figure 2: Hydrographs

a) What is a likely explaination for the delay time between points A and B?

TRAVEL TIME FROM VARIOUS POINTS IN WATERSHED TO OUTLET.

b) How did urbanization affect delay time between points A and B?

REDUCED (SMALLER) TRAVEL TIME FROM VARIOUS POINTS IN WATERSHED TO OUTLET; CAUSED BY CHANNELIZATION; INCREASED IMPERVIOUS

c) How did urbanization affect the maximum stream discharge?

INCREASED PEAK VALUE.

6

3. Figure 3 shows the average monthly discharge, in cubic feet per second, for a stream in New England.

Data Table

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Discharge (ft^3/sec)	48	52	59	66	62	70	72	59	55	42	47	53

Figure 3: Tabular Data for New England Stream

a) On the grid on Figure 4, plot with an X the average stream discharge for each month shown in the data table.

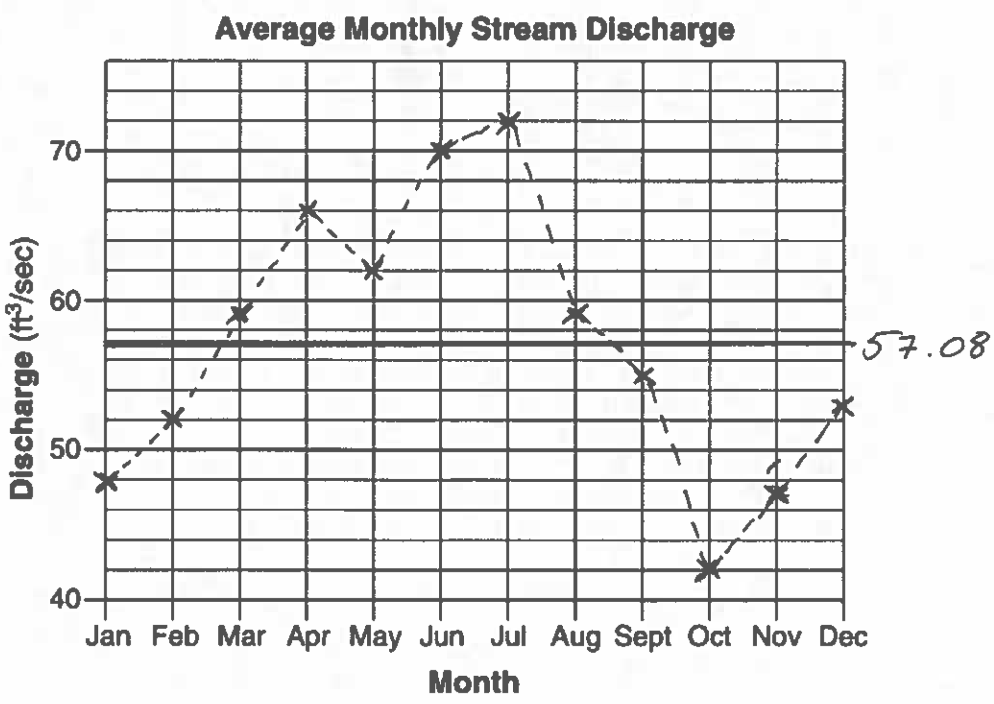

Figure 4: Monthly Average Discharge for New England Stream

/12

b) Explain one possible reason why this stream's discharge in April is greater than this stream's discharge in January.

NEW ENGLAND HAS "WINTER" SNOW.

APRIL ~~REPRE~~ INCLUDES SPRING SNOWMELT

2

c) What is the average streamflow for this stream?

$\bar{X} = \frac{1}{12}(48+52+59+66+62+70+59+55+42+47+53)$

$= 57.08\ ft^3/s \qquad SD = \left[(X_i - \bar{X})^2 \frac{1}{12-1}\right]^{1/2}$ 2

$S.D. = 9.336$ 2

d) How many standard deviations from this average is the maximum monthly streamflow?

$X_{MAX} = 72$

$\bar{X} = 57.08$

$\frac{X_{MAX} - \bar{X}}{SD} = \frac{72 - 57.08}{9.336} = 1.59$

SO X_{MAX} ABOUT 1.6 STANDARD DEVIATIONS ABOVE $\bar{X}$

2

e) How many standard deviations from this average is the minimum monthly streamflow?

$X_{MIN} = 42$

$\bar{X} = 57.08$

$\frac{\bar{X} - X_{MIN}}{SD} = \frac{57.08 - 42}{9.336} = 1.615$

SO X_{MIN} ABOUT 1.6 STANDARD DEVIATIONS BELOW $\bar{X}$

2

10

4. Figure 5 is a small watershed comprised of two distinct land cover types.

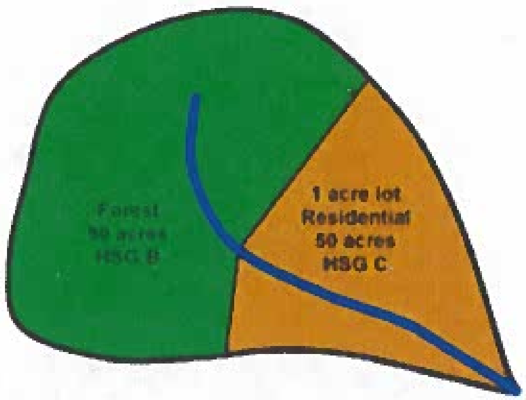

Figure 5: A watershed

The forest portion has a flow path length of 360 feet, at an average slope of 0.01 (1%) until it reaches the residential portion whose path length is 430 feet, at an average slope of 0.005 (0.5%).

a) Determine the composite CN value for the watershed.

LOOKUP CN FOR DIFFERENT LAND USE 6

HSG-B; WOODS = 60

HSG-C; RESIDENTIAL = 79

$$CN = \frac{60(90) + 79(50)}{90+50} = 66.78$$ (FRACTIONAL CN · NEVER USED SO) 67

b) Estimate the time of concentration for the entire watershed using the NRCS-Upland method (Gupta pp. 718-720).

UPLAND:

FOREST SLOPE: 1%
FOREST VELOCITY: 0.25 ft/s

$$T_{FOREST} = \frac{360 ft}{0.25 ft/s} = 1440 sec$$

RESIDENTIAL SLOPE: 0.5%
RESIDENTIAL VELOCITY: 1.5 ft/s

$$T_{RES.} = \frac{430 ft}{1.5 ft/s} = 287 sec$$

$$T_c = \frac{1727 sec}{60 sec} = 28.7 min$$

FROM DRAWING

FOREST → RESIDENCE → OUTLET

12

5. A tabulation of an observed storm and associated runoff for the drainage area are listed below in Table 2. The runoff was measured at the culvert system and indicated by the blue circle on the map in Figure 6.

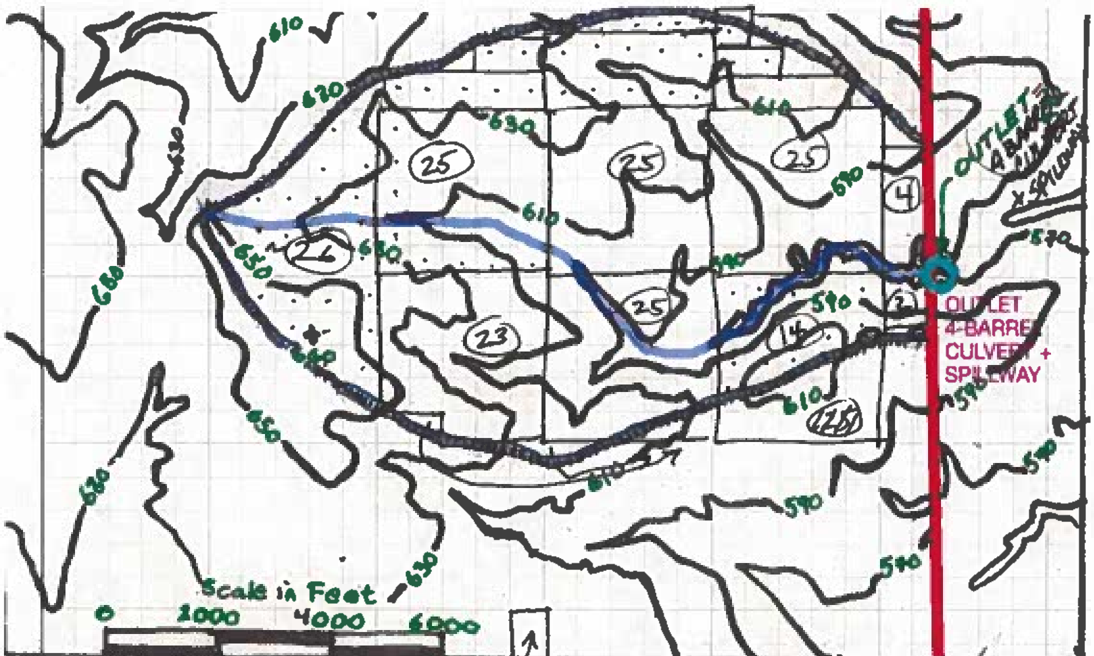

Figure 6: Plan view of a small watershed draining to a culvert under a roadway

EACH CELL 666×666 = ~~111,111~~ 443556 ft^2

Determine

a) The approximate drainage area in ft^2

CELL COUNT

26 + 25 + 25 + 25 + 4
+ 23 + 25 + 14 + 2
+ 20
= 187 (~~111,111~~ 443556) = ~~20,777,778~~ ft^2 82,944,972 ft^2

9

b) Complete Table 2

Table 2: Tabulated Rainfall and Runoff for Watershed

Time (hrs)	Accumulated Rain (inches)	Observed Discharge (cfs)	Incremental Volume (ft^3)	Cumulative Volume (ft^3)
0	0.000	0.00	∅	∅
1	0.000	0.00		
2	0.000	0.00		
3	0.000	0.00		
4	0.000	0.00		
5	0.000	0.00		
6	0.000	0.00		
7	0.000	0.00	∅	∅
8	0.101	0.20 · 3600 sec	720	720
9	0.106	0.31 · 3600 sec	1,116	1836
10	0.111	0.31	1,116	2952
11	0.115	0.31	1,116	4068
12	0.120	0.31	1,116	5184
13	0.120	0.40	1,424	6608
14	0.150	0.40	1,424	8032
15	0.750	24.66	88,768	96800
16	2.750	588.23	2,119,634	2216434
17	2.940	808.70	2,911,331	5127765
18	3.030	154.28	555,398	5683163
19	3.030	94.68	340,834	6023997
20	3.030	27.56	99,212	6123209
21	3.030	36.13	130,067	6253276
22	3.210	19.65	70,730	6324006
23	3.300	7.00	25,206	6349212
24	3.300	0.00 · 3600 sec	∅	6349212

↑ CONVERT TO WS inches

c) The loss from the raw precipitation input to the watershed. 5

$P = 3.30\ in$

$Q = \frac{6,349,212\ ft^3}{82,944,972\ ft^2} \times 12 = 0.918\ in$ 3

$LOSS = P - Q = 3.30 - 0.918 = 2.381\ in.\ LOSS$ 4

OR $16.45 \cdot 10^6\ ft^3$ (16 million) for total — Yuck! refuse to report at useful scale!

12

d) An appropriate CN for the watershed supported by the tabular data.

$$Q = \frac{(P-0.2S)^2}{P+0.8S}$$, SOLVE FOR S

P	S	Q
3.30	3.3	1.17
	3.5	1.108
	3.7	1.047
	3.9	0.989
	4.0	0.961
3.30	4.1	0.934
	4.2	0.908
	4.16	0.918

CLOSE ENOUGH

$$S = \frac{1000}{CN} - 10$$

SOLVE FOR CN

$$S + 10 = \frac{1000}{CN}$$

$$\frac{1000}{S+10} = CN$$

$$\frac{1000}{14.16} = CN = 70.62$$

USE INTEGER RESULT 70

e) The maximum retention S for the watershed supported by the tabular data.

$S_{MAX} = 4.16$ in

COULD SUBSTITUTE CN INTO $Q = \cdots$

BUT STILL HAVE TO FIND

S

8

6. Figure 7 is the unit hydrograph response for a watershed to a 1-hour long **excess rainfall** event of intensity equal to 1-inch/hour.

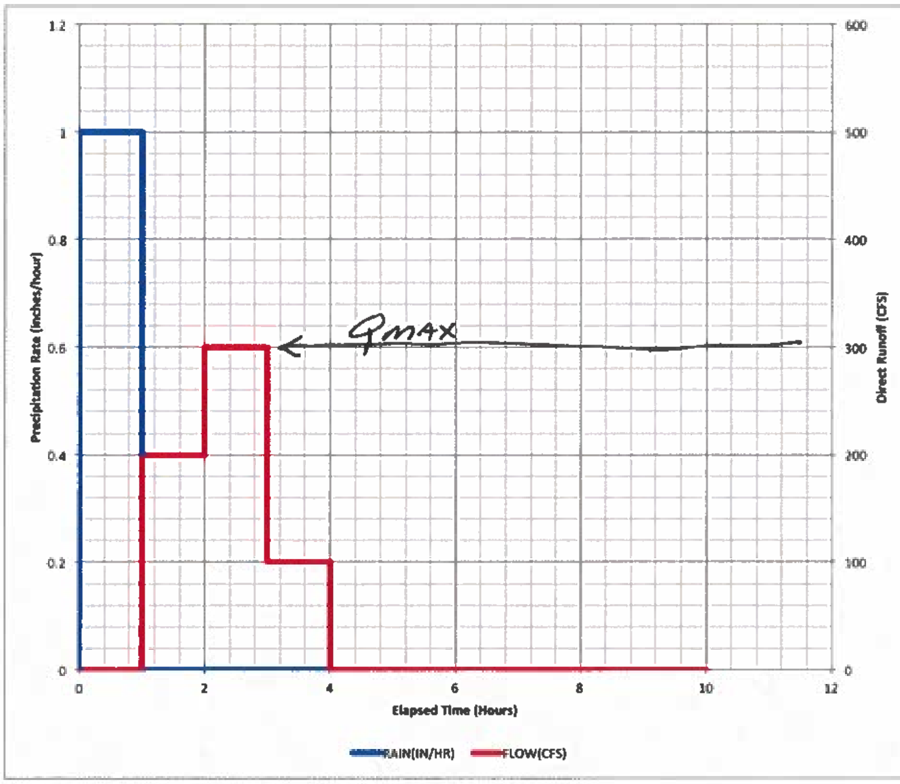

Figure 7: Unit hydrograph response (red) to a 1-inch per hour constant intensity precipitation (blue) input.

a) What is the meaning of **excess rainfall**?

PRECIPITATION AFTER LOSSES ARE REMOVED; ITS THE PROPORTION THAT CAN BECOME RUNOFF

b) How many non-zero intervals of (including the hour zero to hour one interval) direct runoff are indicated by the unit hydrograph?

HOURS 0 → 1
1 → 2
2 → 3
3 → 4

4 INTERVALS

4

c) What is the maximum discharge in CFS indicated by the unit hydrograph?

300 cfs

d) What is the total volume (in ft^3) of runoff depicted by the unit hydrograph?

(200 + 300 + 100 cfs)(3600 sec) = 2,160,000 ft^3

OR

200 cfs * 3600 sec (2ND interval)
+ 300 cfs * 3600 sec (3RD interval)
+ 100 cfs * 3600 sec (4th interval)

2,160,000 ft^3

e) Compute the watershed area (in mi^2) of the watershed?

INPUT = OUTPUT

1 in * AREA = 2,160,000 ft^3

$$\text{AREA} = \frac{2{,}160{,}000\ ft^3}{\frac{1}{12}\ ft} = 25{,}920{,}000\ ft^2 * \left(\frac{1\ acre}{43560\ ft^2}\right)\left(\frac{1\ mi^2}{640\ acre}\right) = 0.929\ mi^2$$

10

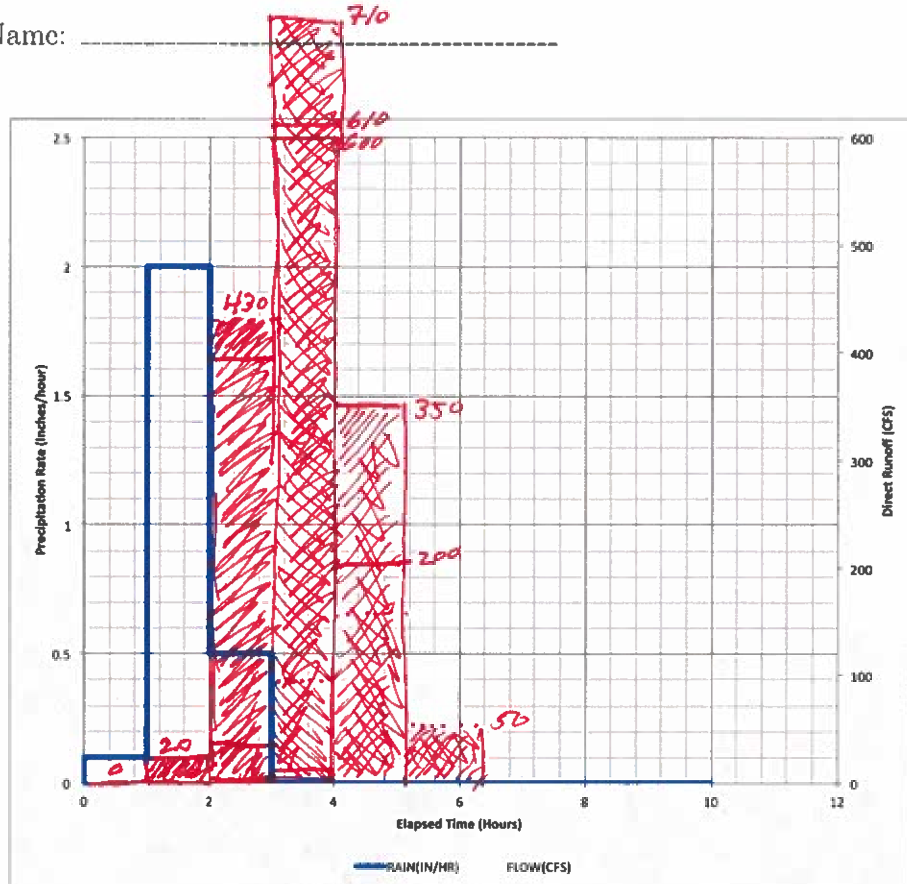

Figure 8: 3-hour event comprised of 3 consecutive 1-hour events.

f) What is the total volume (in ft^3) of runoff anticipated for the storm depicted in Figure 8?

TOTAL P_e = 2,6in

TOTAL Q = (2,160,000)(2.6) = 5,616,000 ft^3

g) Plot the response to the 3 consecutive 1-hour events with the intensities indicated in Figure 8.

8

7. What is a synthetic unit hydrograph?

    a) A unit hydrograph derived directly from observed rainfall-runoff data.

    b) A unit hydrograph estimated using empirical equations and watershed characteristics.

    c) A hydrograph that measures both rainfall and runoff over a synthetic watershed.

    d) A hydrograph that uses only temperature and humidity data to predict runoff.

8. Which of the following parameters is typically used to construct a synthetic unit hydrograph?

    a) Soil moisture and groundwater levels.

    b) Watershed area, time of concentration, and peak discharge.

    c) Evaporation rates and relative humidity.

    d) Daily rainfall totals for the region.

9. In Snyder's Synthetic Unit Hydrograph method, which factor represents the lag time between the centroid of rainfall and the peak of the hydrograph?

    a) Time of concentration. (1/2 point if choose T_c, which is WRONG for Snyder, but on right track)

    b) Basin lag coefficient.

    c) Peak discharge coefficient.

    d) Runoff coefficient.

10. What is one advantage of using a synthetic unit hydrograph over an observed unit hydrograph?

    a) It requires extensive streamflow data from multiple storm events.

    b) It can be applied to ungauged watersheds where no direct runoff data is available.

    c) It eliminates the need for watershed parameterization.

    d) It provides a more accurate prediction of runoff for every storm event.

4