Student Name: SOLUTION

FALL 2024

NAME: 12
MULT GUESS 12
13: 18
14: 39
15: 16
JUST TRYING: 3
100

CE 3354 Engineering Hydrology
Exam 1, Fall 2024

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

1. Hydrology is

   VERBATIM FROM NOTES!

   a) Study of the atmosphere, ocean, and surface waters
   b) The study of the occurrence, distribution, and movement of water above, on, and below the surface of the earth
   c) A study of the processes of evaporation, infiltration, and storage
   d) The study of the relationship between rainfall and runoff

2. The fundamental unit of hydrology is ?

   a) The rainfall depth
   b) The main channel length
   c) The main channel slope
   d) The watershed

3. What is the relationship between the Annual Exceedance Probability (AEP) and the Annual Recurrence Interval (ARI)?

   a) The ARI is the average number of years between years containing one or more events exceeding a prescribed magnitude
   b) The AEP and ARI are the multiplicative inverse of one another
   c) The AEP is a plot of probability and magnitude
   d) The ARI is a plot of probability and magnitude

4. An annual recurrence interval of 100-years is equivalent to an AEP of what percent?

   a) 1-percent.
   b) 10-percent.
   c) 50-percent.
   d) 100-percent.

$$\frac{1}{100} = 0.01 \times 100 = 1\%$$

4

5. What is a flood frequency curve?

   a) A plot of the discharge magnitude and the Weibull plotting position

   b) A plot of the frequency and discharge

   c) A plot of estimated exceedance probability and discharge

   d) A plot of discharge and time

6. What is a plotting position?

   a) Location in a chart of a data pair

   b) The multiplicative inverse of relative frequency

   c) An estimate of probability associated with an observation based on its position within a ranked sample set

   d) An estimate of probability associated with an observation based on its magnitude relative to the arithmetic mean

7. To what type of data series would we apply the Bulletin 17C procedure ?

   a) Annual maximum rainfall

   b) Hourly rainfall

   c) Annual maximum discharge

   d) Instantaneous discharge

8. Rainfall behavior is expressed as a combination of

   a) depth and duration

   b) intensity and probability or frequency

   c) duration and probability or frequency

   d) depth or intensity, duration, and probability or frequency

9. Rainfall intensity is

   a) the ratio of accumulated depth to duration

   b) instantaneous rainfall rate

   c) slope of the depth duration curve at a duration of one hour

   d) integral of the depth duration curve from 0 to 24 hours

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10. Figure 1 is a depth-duration-frequency plot for precipitation.

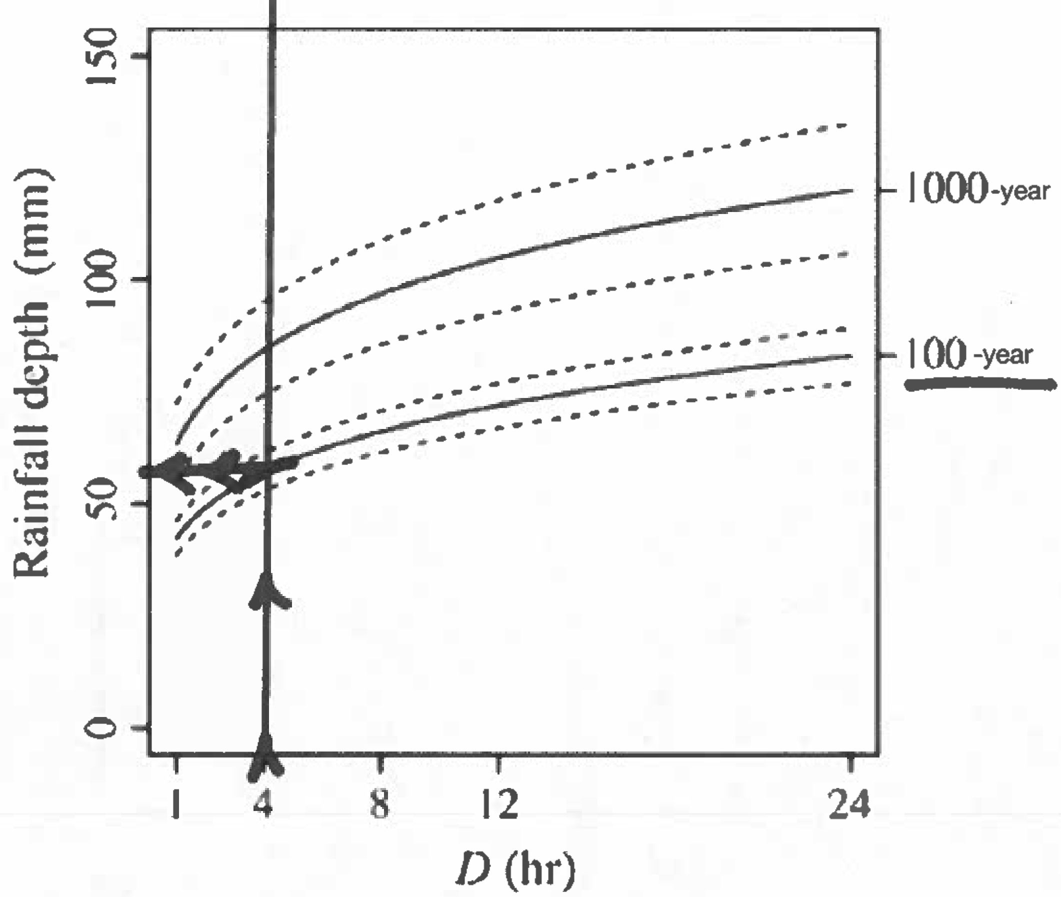


Figure 1: Depth-duration-frequency curve

The approximate depth, in millimeters, for a 4 hour, 100-yr (1% chance) storm is

a) 125 millimeters

b) 75 millimeters

c) 55 millimeters

d) 45 millimeters

(BIGGER THAN 50; SMALLER THAN 75 SO MUST BE 55)

1

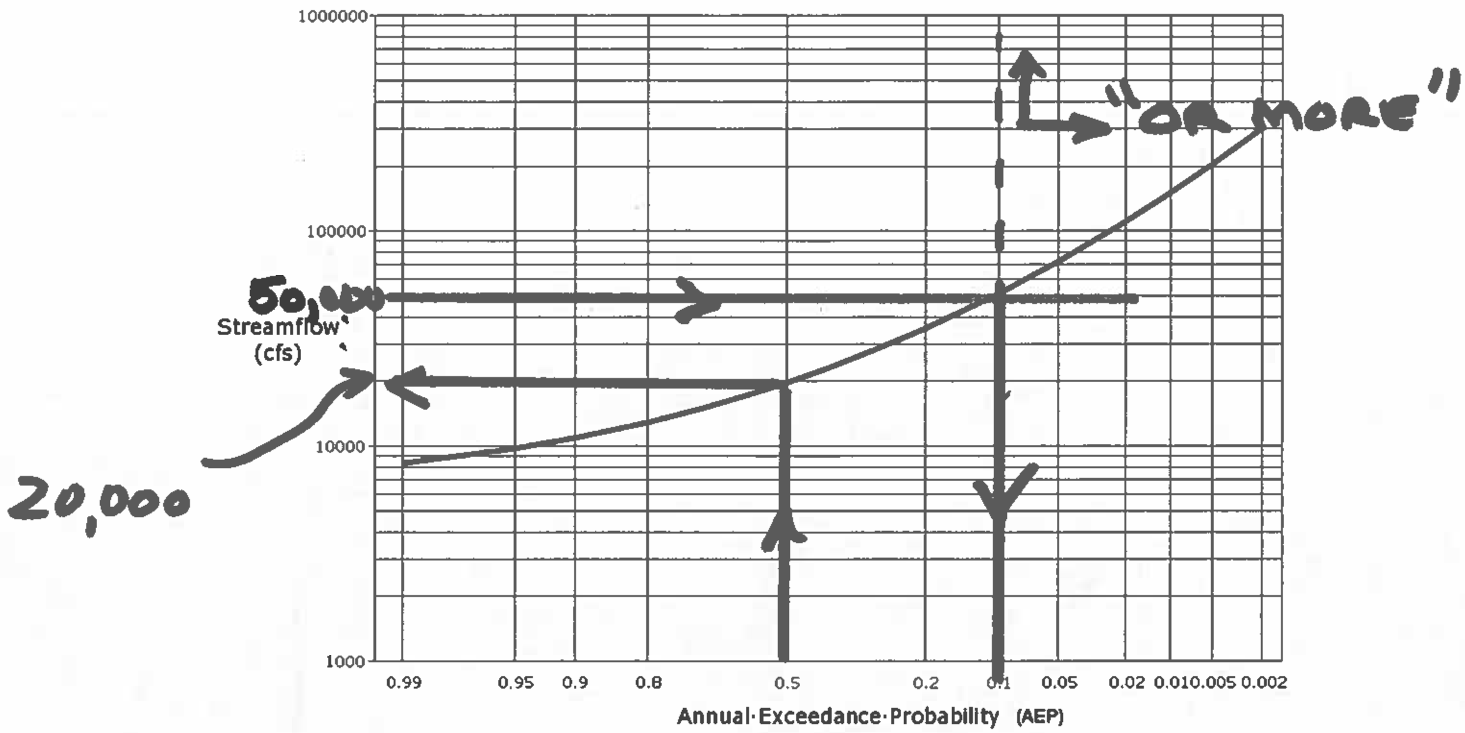


Figure 2: Flood frequency curve for a gaging station

11. Figure 2 is a flood frequency curve. The probability of observing a discharge of magnitude of 50,000 CFS or more is

    (a) 0.01

    (b) 0.05

    (c) 0.10

    (d) 0.50

12. The median discharge from Figure 2 is

    (a) 10,000 CFS

    (b) 20,000 CFS

    (c) 50,000 CFS

    (d) 90,000 CFS

MEDIAN MEANS AEP = 0.5

2

13. The equation $k\frac{dQ}{dt} + Q(t) = I(t)$ is used to describe the response of streamflow to a constant rate of precipitation applied indefinitely on some watershed. Suppose that $Q(t) = 0$ for $t = 0$, the watershed characteristic time constant is $k = 2\ hrs$, and $I(t) = 2$ for $t = [0, 12)\ hrs$ and then $I(t) = 0$ for $t = [12, 24]\ hrs$.

Determine:

(a) The necessary equation(s) to predict the response $Q(t)$ over the 24-hour period.

(b) Plot the values of $Q(t)$ over the 24-hour period (i.e. complete Figure 3 below, showing the discharge $Q(t)$).

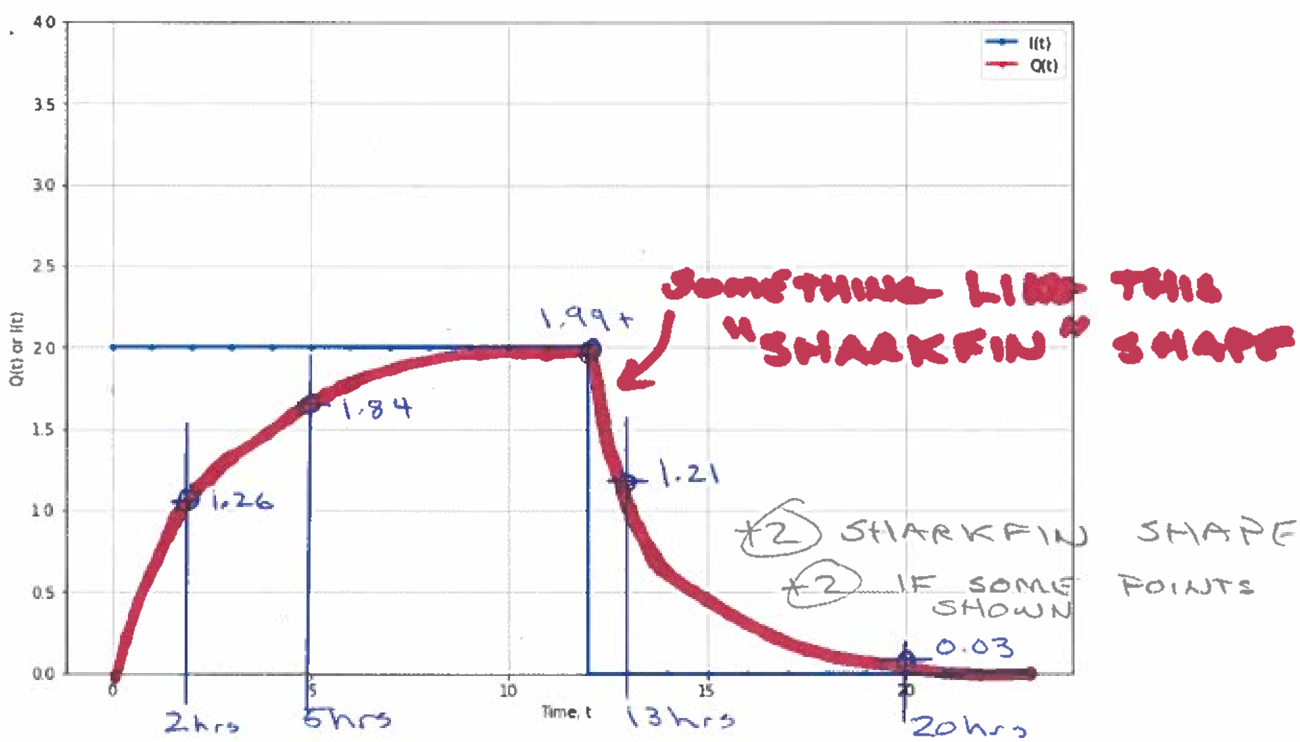


Figure 3: Plot of Runoff for Watershed described by $k\frac{dQ}{dt} + Q(t) = I(t)$, where $I(t)$ is as shown (in blue)

Show your work below (and on next page) +6 (FORMULAS & TIME SHIFTS)

$k=2$

$T=12$

For $t<0$; $Q(t)=0$

$0 \le t \le T=12$; $Q(t) = 2[1-e^{-\frac{1}{k}t}]$

$T_{12} \le t < +\infty$; $Q(t) = 2[1-e^{-\frac{1}{k}t}] - 2[1-e^{-\frac{1}{k}(t-T)}]$

10

USING SOLUTION ES-I

Continued

$$k\frac{dQ}{dt} = I - Q$$

$$\frac{k\,dQ}{I-Q} = dt$$

$$\frac{dQ}{I-Q} = \frac{1}{k}dt$$

let $u = I - Q$; $du = -dQ$

ALSO SET $I = 1$

$$\therefore \frac{-(-dQ)}{1-Q} = -\frac{du}{u} = \frac{1}{k}dt$$

$$\int -\frac{du}{u} = \int \frac{1}{k}dt$$

$$\ln|u| = -\frac{1}{k}t + c$$

Evaluate C @ t=0

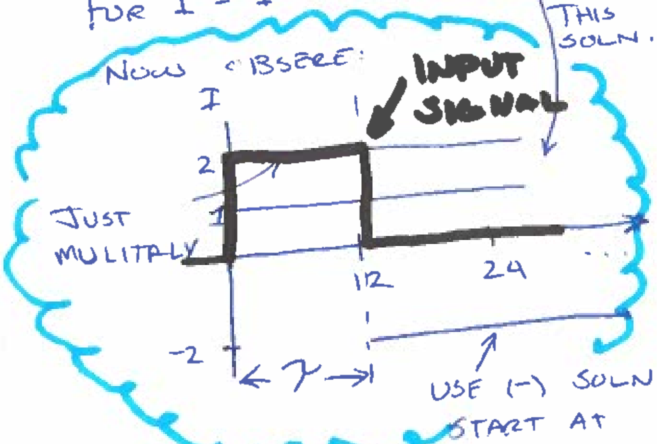
$$\ln|u| = -\frac{1}{k}t$$

$$u = e^{-\frac{1}{k}t}$$

$$1 - Q = e^{-\frac{1}{k}t}$$

$$Q = 1 - e^{-\frac{1}{k}t}$$

FOR $I = 1$



NOW THE "MATH"

FOR $0 \le t \le \tau$

$$\boxed{Q(t) = 2\left[1 - e^{-\frac{1}{k}t}\right]}$$

FOR $\tau \le t < +\infty$

$$\boxed{Q(t) = 2\left[1 - e^{-\frac{1}{k}t}\right] - 2\left[1 - e^{-\frac{1}{k}(t-\tau)}\right]}$$

FOR $t < 0$

$$\boxed{Q(t) = 0}$$

IN THIS CASE

$\tau = 12$ hrs (given)

$k = 2$ hrs (given)

$I = 2$ (implied; given)

(8) ANALYSIS (ES-I OK) THEN ADDITIONS & TIME SHIFTS

① START AT POUR POINT

② MARK HIGH SPOTS SEVERAL DIRECTIONS FROM POUR POINT

Student Name: FROM POUR POINT FALL 2024

③ DRAW DRAINAGE PATHS USING TOPOGRAPHY

④ DRAW BOUNDARY
- JOIN HIGH POINTS &
- FOLLOW DRAINAGE PATTERN

14. Figure 4 is a topographic map of a small drainage basin. The contours show elevation in meters. [illegible] the contours [illegible]. A culvert structure is located on the Eastern portion of the basin, near the outlet shown on Figure 4. The red line is a proposed impoundment alignment, beneath which the culvert structure is placed.

⑤ COUNT SQUARES TO FIND AREA

BNDRY
1) METHOD + DRAINS
1) LINE
1) SQUARES
1) TOTAL

WEST BNDRY NOT OBVIOUS

COUNTS
100
20
25
34
10
100
100
100
71
= 560

Figure 4: Topographic Map of a portion of the Earth. Elevations are in *meters*. Each square is 150 *meters* on a side. North (by convention) is up.

Figure 5 is a photograph of a representative culvert system comprised of 4-parallel , 4-foot diameter, 100-foot long culverts. The lowest portion of the proposed impoundment structure directly above the culverts is at elevation 810 meters. The culverts are to be laid on a dimensionless slope of 0.02.

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Figure 5: Multiple-barrel outlet structure

a) Delineate the drainage area to the culverts using the 810 meter elevation as the pour point elevation (located at the blue marker in the drawing). Pg 7 ✓

b) Determine the area of each small square.

3 $A_i = (150m)(150m) = \boxed{22{,}500\,m^2}$

c) Estimate the drainage area in square meters of the drainage basin.

3 $DA = (560\,\text{squares})\left(22{,}500\,\frac{m^2}{sq.}\right) = 12{,}600{,}000\,m^2$ $\boxed{12.6\cdot 10^6\,m^2}$

d) Convert the drainage area from square meters into acres.

3 $12.6\cdot 10^6\,m^2\left(\frac{3.28\,ft}{1\,m}\right)^2\left(\frac{1\,acre}{43560\,ft^2}\right) = \boxed{3{,}111.94\,ac}$

e) Convert the drainage area from acres into square miles.

3 $3{,}111.94\,ac\left(\frac{1\,mi^2}{640\,ac}\right) = \boxed{4.86\,mi^2}$

- ARITHMETIC 1
- ANSWER 1
- UNITS 1

f) The water surface area when the culvert system (like a dam, with 4 holes in the wall) impounds water to a water surface elevation of 760 *meters* is essentially zero. Complete the elevation (side) view sketch of the embankment and culvert system in Figure 6 by indicating the elevations on the sketch of the roadway crest, the culvert inlet elevation (also the upstream base of the embankment), and culvert outlet elevation.

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OUTLET ELEV.

760 0.02 (30.48) 1

760 − 0.6096

(2) ARITHMETIC + RESULT

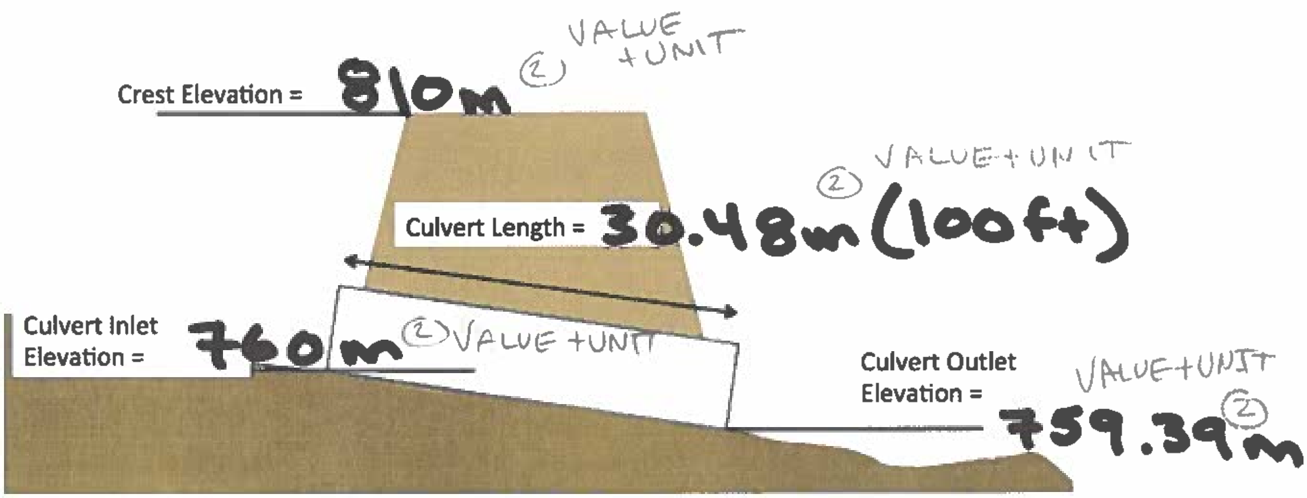

Figure 6: Culvert system elevation view sketch

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g) Estimate the water surface area (area of the pool on the upstream side of the embankment) when the embankment impounds water to a water surface elevation of 780 *meters*. Describe how you made the estimate.

FIND 790 CONTOUR (1) METHOD

COUNT SQUARES ~49 (1) RESULT

$$\frac{(49)(22{,}500)(3.28)(3.28)}{43560} = 272.3 \text{ ac.}$$

(2) VALUE + UNIT

h) Estimate the water surface area when the embankment impounds water to a water surface elevation of 790 *meters*. Describe how you made the estimate.

FIND 790 CONTOUR (1)

COUNT SQUARES ~60 (1)

$$\frac{(60)(22{,}500)(3.28)(3.28)}{43560} = 333.42 \text{ ac.}$$

(2)

i) Estimate the water surface area when the embankment impounds water to a water surface elevation of 810 *meters*. Describe how you made the estimate.

FIND 810 CONTOUR (1)

COUNT SQUARES ~92 (1)

$$\frac{(92)(22{,}500)(3.28)(3.28)}{43560} = 511.25 \text{ ac.}$$

(2)

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14. Figure 4 is a topographic map of a small drainage basin. The contours show elevation in meters. Some of the contours are labeled. A culvert structure is located on the Eastern portion of the basin, near the outlet shown on Figure 4. The red line is a proposed impoundment alignment beneath which the culvert structure is placed.

IMPOUNDMENT AREAS; PLOT REPRODUCED FOR CLARITY

Figure 4: Topographic Map of a portion of the Earth. Elevations are in *meters*. Each square is 150 *meters* on a side. North (by convention) is up.

Figure 5 is a photograph of a representative culvert system comprised of 4-parallel , 4-foot diameter, 100-foot long culverts. The lowest portion of the proposed impoundment structure directly above the culverts is at elevation 810 meters. The culverts are to be laid on a dimensionless slope of 0.02.

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15. Figure 7 is a tabulation of an observed storm and runoff for the drainage area depicted by the map in Figure 4. The runoff was measured before the installation of the roadway, at the location indicated by the blue circle on the map.

TIME-HOURS	ACC-RAIN-INCHES	OBSERVED-FLOW-CFS	MULTIPLY BY 3600 TO GET FT3	ACCUMULATE
0	0.000	0	0	0
1	0.000	0		
2	0.000	0		
3	0.000	0		
4	0.000	0		
5	0.000	0		
6	0.000	0		
7	0.000	0	0	0
8	0.091	1.42466349	5126	5126
9	0.096	0.31660086	1136	6266
10	0.101	0.3165874	1139	7405
11	0.105	0.31660086	1139	8545
12	0.110	0.3165874	1139	9685
13	0.110	0.403656	1453	11138
14	0.140	0.403656	1453	12591
15	0.740	25.161224	90576	103167
16	2.740	600.236472	2160828	2263996
17	2.930	825.207416	2970720	5234716
18	3.020	157.42584	566712	5801428
19	3.020	96.608336	347760	6149188
20	3.020	28.121368	101232	6250420
21	3.080	36.867248	132696	6383116
22	3.200	20.048248	72144	6455260
23	3.259	7.1447112	25720	6480981
24	3.259	0	0	6480981

PEAK RAIN

PEAK FLOW

Σ TOTAL INCHES FT3

Figure 7: Cumulative rainfall for a 24-hour period on watershed determined for Figure 4

(1)+(1) (1)+(1)

5

a) Estimate the total **volume** of runoff in cubic feet from the storm. Describe how you made your estimate.

ACCUMULATE OBS FLOW PER EACH HOUR (COLUM 3 & 4) Pg 11

$\boxed{6{,}480{,}981 \text{ ft}^3}$ (ASSUMING ARITHMETIC OK)

2 VALUE + UNIT + EXPLAIN

b) Convert the estimate of runoff volume from cubic feet into watershed inches.

$$\text{WS IN.} = \frac{\text{TOTAL VOLUME}}{\text{WS AREA}}$$

$$\frac{6{,}480{,}981 \text{ ft}^3}{3{,}111.94(43560 \text{ ft}^2)} = 0.0478 \text{ ft} \times 12 = \boxed{0.574 \text{ in}}$$

4 VALUE + UNIT + EXPLAIN + EQ.

c) How long (in hours) from the beginning of rainfall until the peak discharge occurs?

PEAK RAIN: HR 15 → 16

PEAK FLOW HR 16 → 17

$\boxed{\text{ABOUT 1 HR}}$

2 LOGIC + VALUE

d) What is the fraction of rainfall that becomes runoff?

TOTAL RAIN: 3.259 in

TOTAL RUNOFF: 0.574 in

$$\text{FRACTION } \frac{0.574 \text{ in}}{3.259 \text{ in}} = 0.176$$

VALUE + LOGIC 2

$\boxed{\sim 17.6\% \text{ OF RAIN BECOMES RUNOFF}}$

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