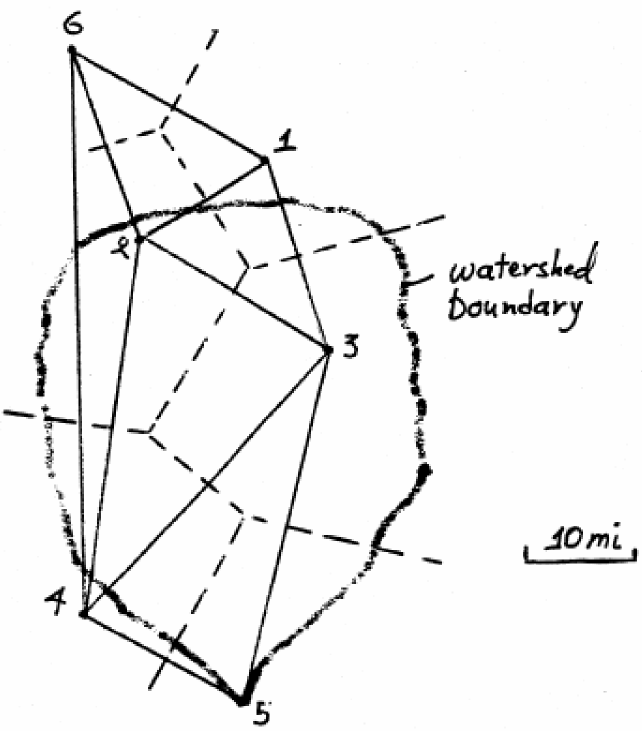
CIVL 3066 Engineering Hydrology
Spring 2009
Solution : Assignment Number 1

1.6. Mud Creek has the watershed boundaries shown in Fig. P1.6. There are six rain gages in and near the watershed, and the amount of rainfall at each one during a storm is given in the accompanying table. Using the Thiessen method and a scale of 1 in. = 10 mi, determine the mean rainfall of the given storm.



Gage	Area (mi^2)	Area (%)	Rainfall (cm)	Weighted Rainfall (cm)
1	55.6	5	5.5	0.275
2	266.7	23.5	4.5	1.058
3	466.7	41.2	4	1.648
4	200	17.6	6.2	1.091
5	144.4	12.7	7	0.889
6	0	0	2.1	0
SUM	1133.4	100		4.961

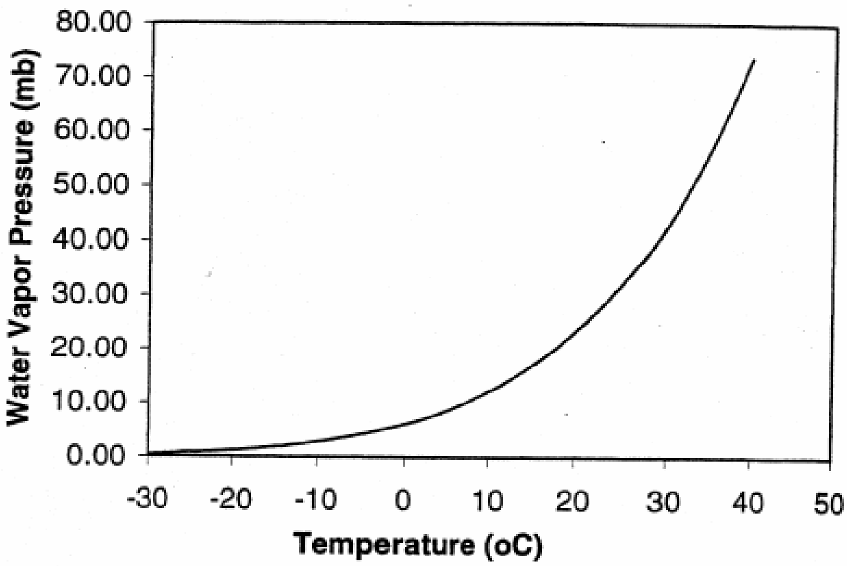
1.7. (cont.)

a) Saturated samples of air: $T = 10^\circ C$, $P = 20$ mb

$T = 10^\circ C$, $P = 30$ mb

Unsaturated samples of air: $T = 10^\circ C$, $P = 10$ mb

$T = 20^\circ C$, $P = 20$ mb



b) A = ($T = 30^\circ C$, $P = 25$ mb)

B = ($T = 30^\circ C$, $P = 30$ mb)

i) Saturation Vapor Pressure is a function of temperature.

For both samples A & B, $T = 30^\circ C$

So $e_{sa} = e_{sb} = 42.41$ mb

ii) Dew point is a measure of the water vapor pressure.

For sample A, $e_a = 25$ mb $\longrightarrow T_d = 21.14^\circ C$

For sample B, $e_b = 30$ mb $\longrightarrow T_d = 24.14^\circ C$

iii) Relative humidity is the ratio of the actual vapor pressure to saturation vapor pressure

1.7 (cont.)

Sample A: $(25/42.41) \bullet 100 = 59\%$ Sample B: $(30/42.41) \bullet 100 = 71\%$

c) In 15°C, both samples have become saturated:

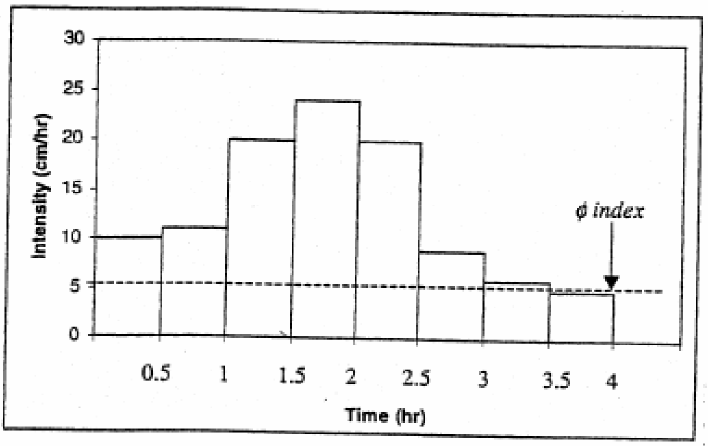
Their relative humidity is 100%.

After condensation begins, the temperature and the dew point are the same.

So, $T = T_d = 15^\circ C$

1.12. (cont.)

a) The hyetograph ordinates are found by dividing the incremental rainfall by the time interval



Time (hr)	Rainfall Intensity (cm/hr)
0 - 0.5	10
0.5 - 1	11
1 - 1.5	20
1.5 - 2	24
2 - 2.5	20
2.5 - 3	9
3 - 3.5	6
3.5 - 4	5
4 - 4.5	0

b) The total volume of rainfall is found by summing the incremental rainfall.

Volume = 52.5 cm over the watershed

c) $(10-\phi)\bullet 0.5+(11-\phi)\bullet 0.5+(20-\phi)0.5+(24-\phi)\bullet 0.5+(20-\phi)\bullet 0.5+(20-\phi)\bullet 0.5+(9-$

$\phi)\bullet 0.5+(6-\phi)\bullet 0.5+(5-\phi)\bullet 0.5=30.5$

$==>(10-\phi)+(11-\phi)+(20-\phi)+(24-\phi)+(20-\phi)+(9-\phi)+(6-\phi)+(5-\phi)=61$

TRIAL AND ERROR

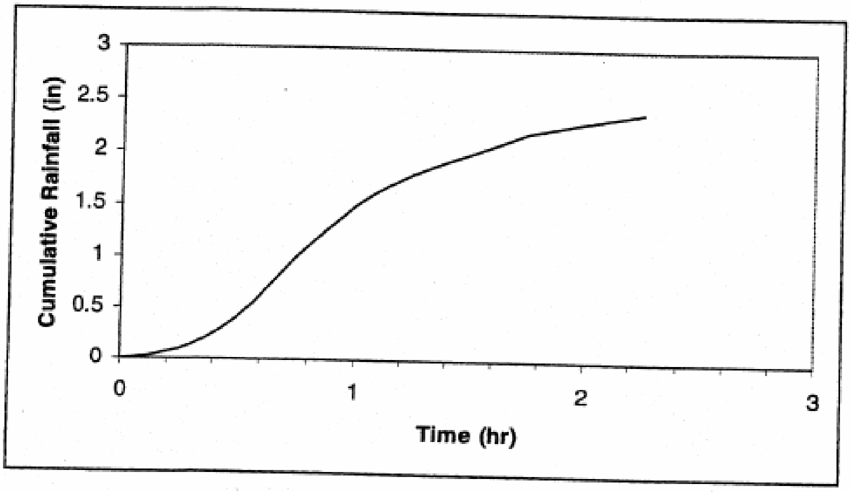
Assume $\phi=5 => 5+6+15+19+15+4+1=65>61$

Assume $\phi=5.57 => 4.45+5.43+14.43+18.43+14.43+3.43+0.43=61.01$

So ϕ index $=5.57$ cm/hr

1.13. (cont.)

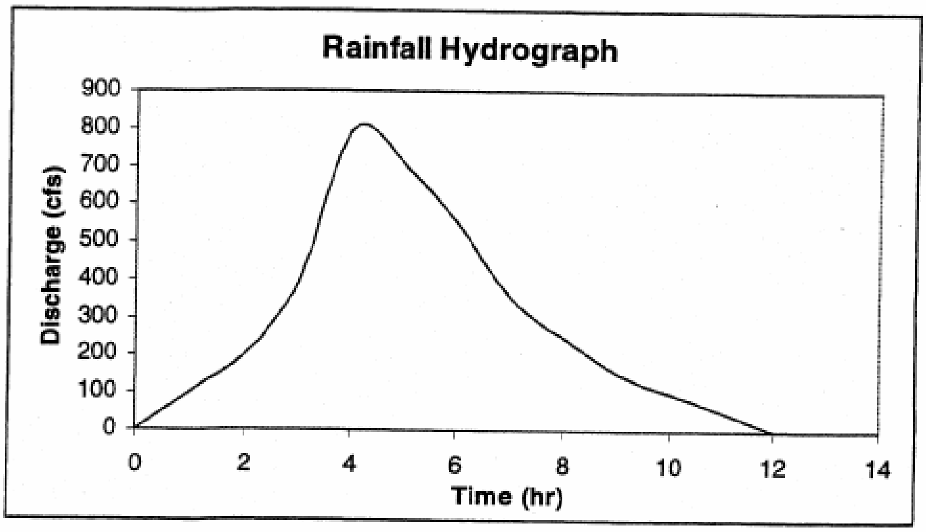
Time (hr)	Cumulative Rainfall (in)
0	0
0.25	0.1
0.5	0.4
0.75	1
1	1.5
1.25	1.8
1.5	2
1.75	2.2
2	2.3
2.25	2.4



1.13. (cont.)

Time (hr)	Gross Rainfall Intensity (in/hr)
0 - 0.25	(0.1-0) / 0.25 = 0.4
0.25 - 0.5	(0.4-0.1) / 0.25 = 1.2
0.5 -0.75	2.4
0.75 - 1	2
1 - 1.25	1.2
1.25 -1.5	0.8
1.5 - 1.75	0.8
1.75 - 2	0.4
2 -2.2.5	0.4

1.14. If the gross rainfall of problem 1.13 falls over a watershed with area of 1600 acres, find the volume that was left to infiltration (assume evaporation can be neglected) based on the volume under the hydrograph.



$$P_{NET} = \frac{\text{Direct Runoff (area under hydrograph)}}{\text{Area of Watershed}}$$

Direct Runoff = 0 +100 + 200 + 400 + 800 + 700 + 550 + 350 + 250 + 150 + 100 +50 + 0

= 3650 cfs –hr ~3650 ac – in.

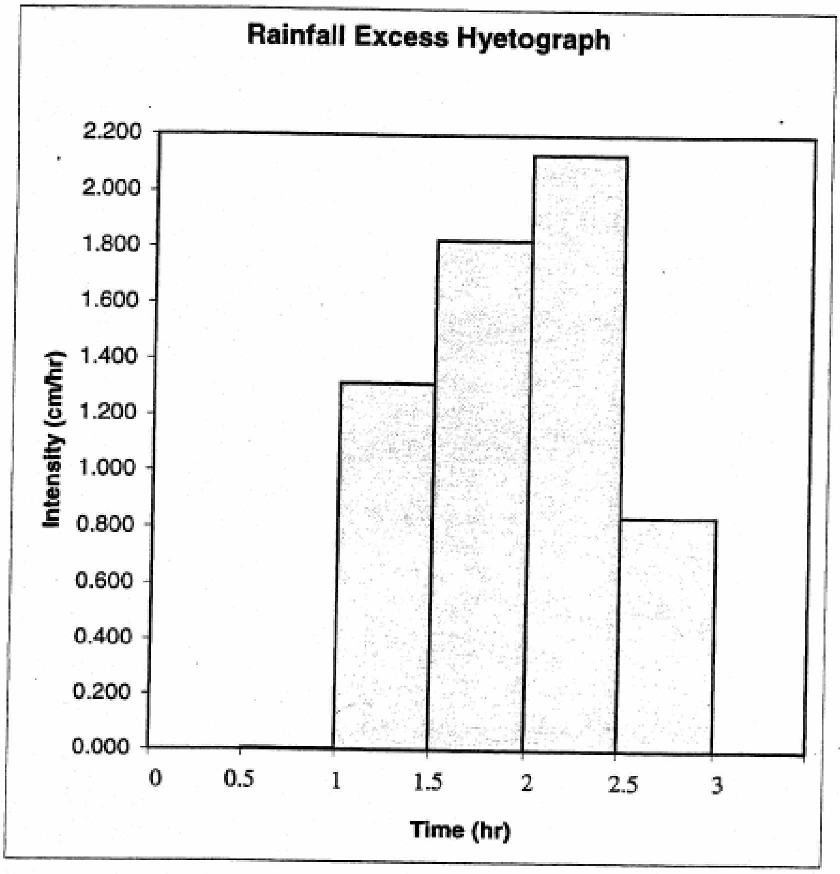
$$P_{NET} = \frac{3650 \text{ ac- in}}{1600 \text{ ac}} = 2.28 \text{ in.}$$

Volume of Infiltration = (2.4 – 2.28) in. = 0.12 in over the watershed

1.21. Using the rainfall below and a Horton infiltration curve with the parameters $k = 0.1\ \text{hr}^{-1}$, $f_c = 0.5$ cm/hr, and $f_o = 0.7$ cm/hr, determine and graph the excess rainfall that would occur. Assume that the initial loss for the watershed is 0.5 cm, calculate the excess rainfall as an average over half-hour intervals, and refer to Example 6.1 for guidance.

The volume of rainfall for the first half hour is 1 • ½ = 0.5 cm. This will fill the depression storage of the watershed. Thus infiltration begins at 30 min.

Time Interval (hr)	Rainfall (cm/hr)	Infiltration Capacity at the start of interval (cm/hr)	Average Infiltration Capacity (cm/hr)	Rainfall Excess (cm/hr)
0-0.5	1			0.000
0.5-1	0.7	0.700	0.695	0.005
1-1.5	2	0.690	0.686	1.314
1.5-2	2.5	0.681	0.677	1.823
2-2.5	2.8	0.672	0.668	2.132
2.5-3	1.5	0.664	0.660	0.840
3-3.5	0.5	0.656	0.652	0.000



1.29. Compute the ϕ index for the rainfall of problem 1.13 using the results from problem 1.14 and plot the rainfall excess hyetograph.

$P_{NET} = 2.28$ in

$2.28 = [(0.4 - \phi) + (1.2 - \phi) + (2.4 - \phi) + (2 - \phi) + (1.2 - \phi) + (0.8 - \phi) + (0.8 + \phi) + (0.4 - \phi) + (0.4 - \phi)] \cdot 0.25$

⇨ $9.12 = [(0.4 - \phi)+(1.2-\phi)+(2.4-\phi)+(2-\phi)+(1.2-\phi)+(0.8-\phi)+(0.8-\phi)+(0.4-\phi)+(0.4-\phi)]$
(Equation 1)

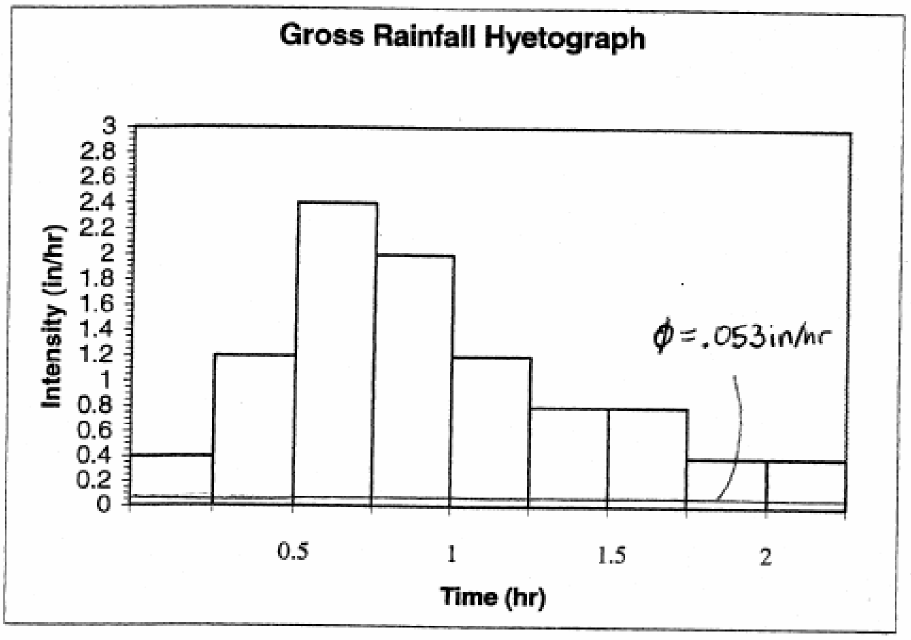
Trial and Error Method

For $\phi = 0.1$: $0.3 + 1.1 + 2.3 + 1.9 + 1.1 + 0.7 + 0.7 + 0.3 + 0.3 =$

$= 8.7 < 9.12 \Rightarrow \phi < 0.1$

Since ϕ is less than 0.4 in/hr (where 0.4 in/hr is the smallest rainfall intensity,) we can solve Equation 1 as a regular equation:

$9.12 = 9.6 - 9\phi$ $\qquad \phi = 0.053$ in/hr



1.30. A sandy loam has an initital moisture content of 0.18, hydraulic conductivity of 7.8 mm/hr, and average capillary suction of 100 mm. Rain falls at 2.9 cm/hr and the final moisture content is measured to be 0.45. Plot the infiltration rate vs. the infiltration volume, using the Green and Ampt method of infiltration.

$\theta_i = 0.18$, $\theta_f = 0.45$

$K_s = 78$ mm/hr

$S_{av} = 100\text{mm} = -\Psi_F$ Avg Capillary Suction

Rain Intensity = 2.9 cm/hr (For 6 hours)

$M_D = \theta_f - \theta_i = 0.45 - 0.18 = 0.27$

$F_s = (S_{av} \cdot M_D) / ((I/K_s) - 1) = 100 \bullet (0.27) / (2.9/0.78 - 1)$ mm/ (cm/cm) = 9.93 mm

Until 9.93 mm has infiltrated, the rate of infiltration equals the rainfall intensity = 2.9 cm/ hr

$t = (1/2.9) \bullet (.993) = 0.34$ hr.

After Saturation:

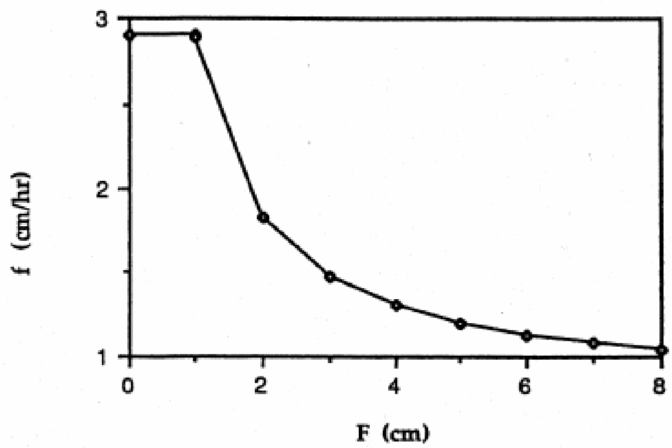
$f = K_s (1 + S_{av} \bullet (M_d/F))$

$= 0.78 (1 + 10 \bullet (0.27 /F))$

$= 0.78 (1 + (2.7/F))$

F (cm)	F (cm/hr)
1	2.89
2	1.83
3	1.48
4	1.31
5	1.20
6	1.13
7	1.08
8	1.04

Infiltration Rate vs. Infiltration Volume



1.31. Use the parameters given to graph the infiltration rate vs. the infiltration volume for the same storm for both types of soil. Prepare a graph using the Green-Ampt method, comparing all the curves calculated with both the lower- and upper-bound porosity parameters. The rainfall intensity of the storm was 1.5 cm/hr for several hours and the initial moisture content of all the soils was 0.15.

SOIL	POROSITY	CAPILLARY SUCTION (cm)	HYDRAULIC CONDUCTIVITY (cm/hr)
Silt loam	0.42–0.58	16.75	0.65
Sandy clay	0.37–0.49	23.95	0.10

$\theta_i = 0.15$ $S_{AV} = -\Psi_F$ Capillary Suction

Rain Intensity = 1.5 cm/hr

	SL	SC
K_S	0.65	0.10 cm/hr
S_{AV}	16.75	23.95 cm
θ_f	0.42- 0.58	0.37- 0.49

$M_d = \theta_f - \theta_i$

<u>-Silty Loam: (SL)</u>

$F_S = (S_{AV} \bullet M_d) / ((I/K_s) - 1) = (16.75 \bullet M_d) / ((1.5 \text{ cm/hr} / 0.65 \text{ cm/hr}) - 1) = 16.75 \bullet M_d / 1.308$

With a Low Porosity,

$M_d = 0.42 - 0.15 = 0.27$

$F_s = 3.46$ cm

Saturation Time = Fs/I = 3.46 cm/ 1.5 cm/hr = 2.31 hr

With a High Porosity:

$M_d = 0.58 - 0.15 = 0.43$

$F_s = 5.51$ cm

Saturation Time = 5.51 cm/ 1.5 cm/hr = 3.67 hr

1.31. (cont.)

Sandy Clay:

$F_s = (S_{AV} \bullet M_d) / ((I / K_s) - 1) = (23.95 \bullet M_d) / ((1.5/0.1) - 1) = 23.95 \bullet M_d / 14$

With a Low Porosity,

$M_d = 0.37 - 0.15 = 0.22$

$F_s = 0.38$ cm

Saturation Time = 0.38 cm / 1.5 cm/hr = 0.25 hr

With a High Porosity,

$M_d = 0.49 - 0.15 = 0.34$

$F_s = 0.58$ cm

Saturation Time = 0.58 cm/ 1.5 cm/hr = 0.39 hr

Plot the Infiltration Volume –vs.– The Infiltration Rate: $f = k_s (1 + S_{av} \bullet (M_d/F))$