CE 3354 Engineering Hydrology
Exam 1

1. For a watershed with a size of 120 km^2, the following data on precipitation P, evaporation E and runoff Q are recorded in watershed mm.

Table 1: Monthly Precipitation (P), Evapotranspiration (E), and Runoff (Q)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
P (mm)	250	205	165	50	5	0	0	5	10	55	65	190
E (mm)	5	25	30	50	80	100	150	70	60	20	10	5
Q (mm)	150	110	80	5	0	0	0	0	0	10	15	120

Determine:

a) The month (end) when the amount of water stored in the basin is the largest.

b) The month (end) when the amount of water stored in the basin is the smallest.

c) The difference (in m^3) in the amount of water stored in the basin between these two extremes.

d) The likely climate type (arid, humid temperate or humid tropical) one would expect to find this catchment.

Solution(s): Items a,b, and c are determined using a water budget approach. An excel spreadsheet is shown in Figure(s) 1, and 2

	A	B	C	D	E	F	G	H	I	J
1	ce3354-ex1-2025-2-problem1					S_0(mm)	225	<= Changed until non-negative computed storage, one can answer questions on the change in storage terms as well		
2	**DATA SUPPLIED**									
3	Area (km^2)	120				**COMPUTED VALUES**				
4	MONTH	P(mm)	E(mm)	Q(mm)		ΔS(mm)	S(mm)		S(m^3)	
5	Jan	250	5	150		95	320		38400000	
6	Feb	205	25	110		70	390		46800000	
7	Mar	165	30	80		55	445	MAXIMUM VALUE	53400000	
8	Apr	50	50	5		-5	440		52800000	
9	May	5	80	0		-75	365		43800000	
10	Jun	0	100	0		-100	265		31800000	
11	Jul	0	150	0		-150	115		13800000	
12	Aug	5	70	0		-65	50		6000000	
13	Sep	10	60	0		-50	0	MINIMUM VALUE	0	
14	Oct	55	20	10		25	25		3000000	
15	Nov	65	10	15		40	65		7800000	
16	Dec	190	5	120		65	130		15600000	
17										
18								ΔS(m^3)	53400000	

Figure 1: PR1 Water Budget

	A	B	C	D	E	F	G	H	I
1	ce3354-ex:					S_0(mm)	225	<= Changed until non-negative computed storage, one can answer questions on the change in storage terms as well	
2	**DATA SUPI**								
3	Area (km^:	120				**COMPUTED VALUES**			
4	MONTH	P(mm)	E(mm)	Q(mm)		ΔS(mm)	S(mm)		S(m^3)
5	Jan	250	5	150		=B5-C5-D5	=G1+F5		=0.001*G5*$B$3*1000*1000
6	Feb	205	25	110		=B6-C6-D6	=F6+G5		=0.001*G6*$B$3*1000*1000
7	Mar	165	30	80		=B7-C7-D7	=F7+G6	MAXIMUM VALUE	=0.001*G7*$B$3*1000*1000
8	Apr	50	50	5		=B8-C8-D8	=F8+G7		=0.001*G8*$B$3*1000*1000
9	May	5	80	0		=B9-C9-D9	=F9+G8		=0.001*G9*$B$3*1000*1000
10	Jun	0	100	0		=B10-C10-D10	=F10+G9		=0.001*G10*$B$3*1000*1000
11	Jul	0	150	0		=B11-C11-D11	=F11+G10		=0.001*G11*$B$3*1000*1000
12	Aug	5	70	0		=B12-C12-D12	=F12+G11		=0.001*G12*$B$3*1000*1000
13	Sep	10	60	0		=B13-C13-D13	=F13+G12	MINIMUM VALUE	=0.001*G13*$B$3*1000*1000
14	Oct	55	20	10		=B14-C14-D14	=F14+G13		=0.001*G14*$B$3*1000*1000
15	Nov	65	10	15		=B15-C15-D15	=F15+G14		=0.001*G15*$B$3*1000*1000
16	Dec	190	5	120		=B16-C16-D16	=F16+G15		=0.001*G16*$B$3*1000*1000
17									
18								ΔS(m^3)	=MAX(I5:I16)-MIN(I5:I16)

Sheet1

Figure 2: PR1 Water Budget Formulas

Item d requires internet research to learn about climate classification. The model I used is *Köppen climate classification*, Gupta's classification(s), and Mays' classifications follow closely. A good starting place is Wikipedia `https://en.wikipedia.org/wiki/Kppen_climate_classification`.

For the supplied monthly values we can make the following assertions:

- Rainfall (P) is highly concentrated in Jan–Mar and Dec.
- Dry season from May–Sep (very low P, high E).
- E is high in May–Sep, reaching a peak in July (150 mm) when P is 0.

These data indicate a distinct wet/dry seasonality.

The Köppen classification scheme:

- Distinct wet and dry seasons
- Wet summer is not present — rainfall is in winter.
- Dry summer with high E
- Total annual precipitation is moderate (1000 mm)

This pattern is typical of a Mediterranean Climate (Köppen: Csa or Csb) Csa: Hot, dry summer; mild, wet winter (likely match)

Characteristics:

- Summer drought
- 3+ months with $P < 30$ mm and $E > 60$ mm (May–Sep fits)
- Wet winters ($P > E$ in Jan–Mar, Dec)

The catchment is most likely in a Mediterranean climate (Köppen Csa), common in:

- Coastal California
- Southern Europe (e.g., Spain, Italy)
- Western Australia
- Cape region of South Africa
- Parts of central Chile

2. A watershed with a catchment area of $1 mi^2$ converts about 60-percent of precipitation into streamflow, the remainder is lost. The watershed response equation is

$$k\frac{dQ}{dt} + Q(t) = P(t) \cdot A \cdot C \quad (1)$$

where $Q(t)$ is the streamflow leaving the catchment, $P(t)$ is the precipitation entering the catchment, A is the catchment area, C is the precipitation to streamflow conversion fraction, and k is the basin characteristic time constant.

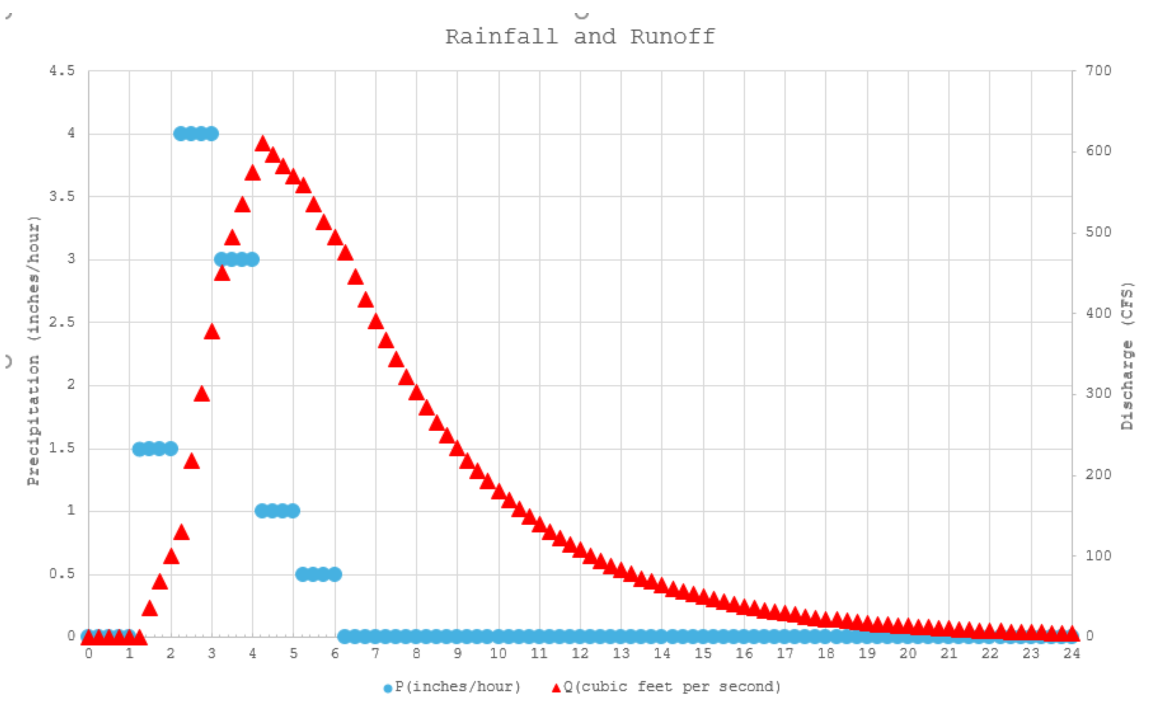


Figure 3: Rainfall-runoff plot for the catchment

Using the information in Figure 3 determine:

a) The maximum discharge rate in cubic feet per second.

b) The time when the maximum discharge occurs.

c) The value in hours of the of the basin time constant k.

d) The total volume in acre feet of precipitation entering the catchment (before any losses)

e) The total volume in acre feet of discharge leaving the catchment

Solution(s): Items a, and b can be read directly from the supplied plot. They are about 600 cfs and 4.25 hours. We can get more accurate estimates when we simulate the watershed using the supplied equation, and fit the simulated chart to the provided chart.

To fit fisrt build a finite-difference approximation as

$k\frac{dQ}{dt} + Q(t) = P(t) \cdot A \cdot C$

A should be supplied in acres assuming $P \cdot C$ is in inches per hour to produce output in CFS.

Move $Q(t)$ to RHS and divide by k

$\frac{dQ}{dt} = \frac{P(t) \cdot A \cdot C - Q(t)}{k}$

Then express the LHS as a difference quotient

$\frac{Q(t+\Delta t) - Q(t)}{\Delta t} = \frac{P(t) \cdot A \cdot C - Q(t)}{k}$

Isolate everything at the old time step to the RHS

$Q(t + \Delta t) = Q(t) + \frac{\Delta t}{k}(P(t) \cdot A \cdot C - Q(t))$

Code up into a spreadsheet, choose a small enough value of Δt and proceede.

Figure 4 is a screen capture of a portion of the spreadsheet.

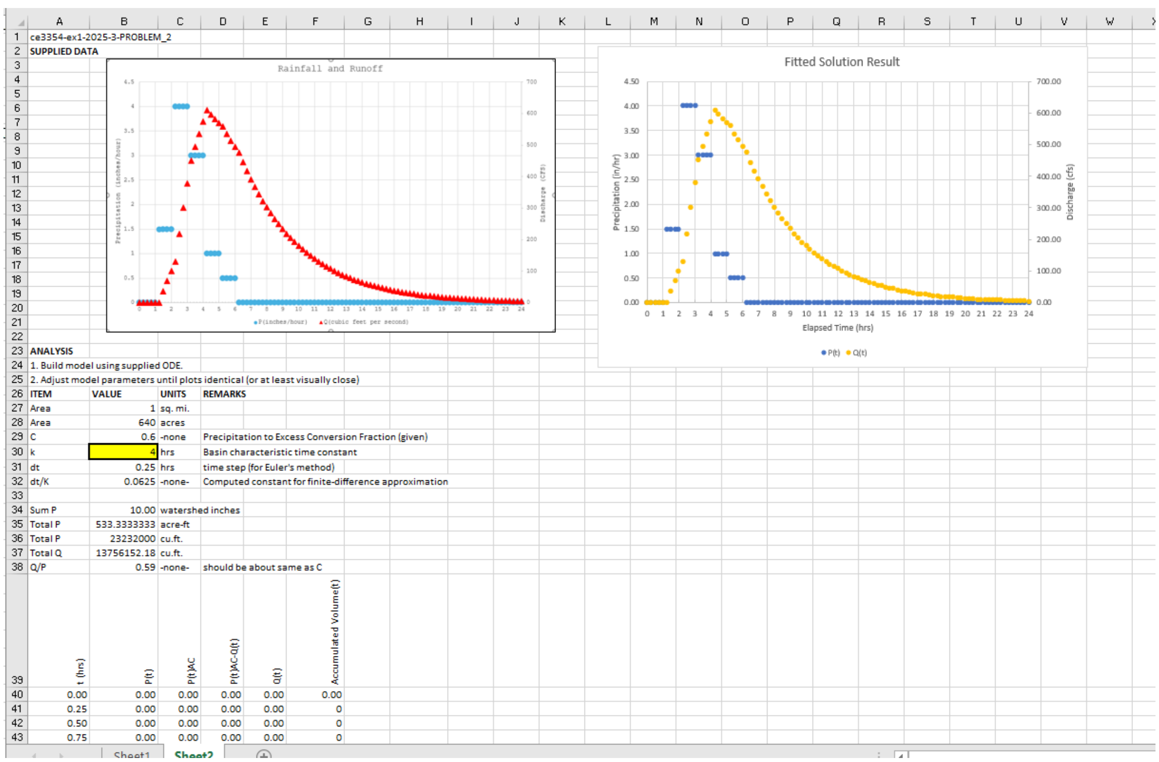


Figure 4: Rainfall-runoff plot for the catchment; supplied and computed charts side-by-side

Figure 5 is a screen capture of the computation portion of the spreadsheet.

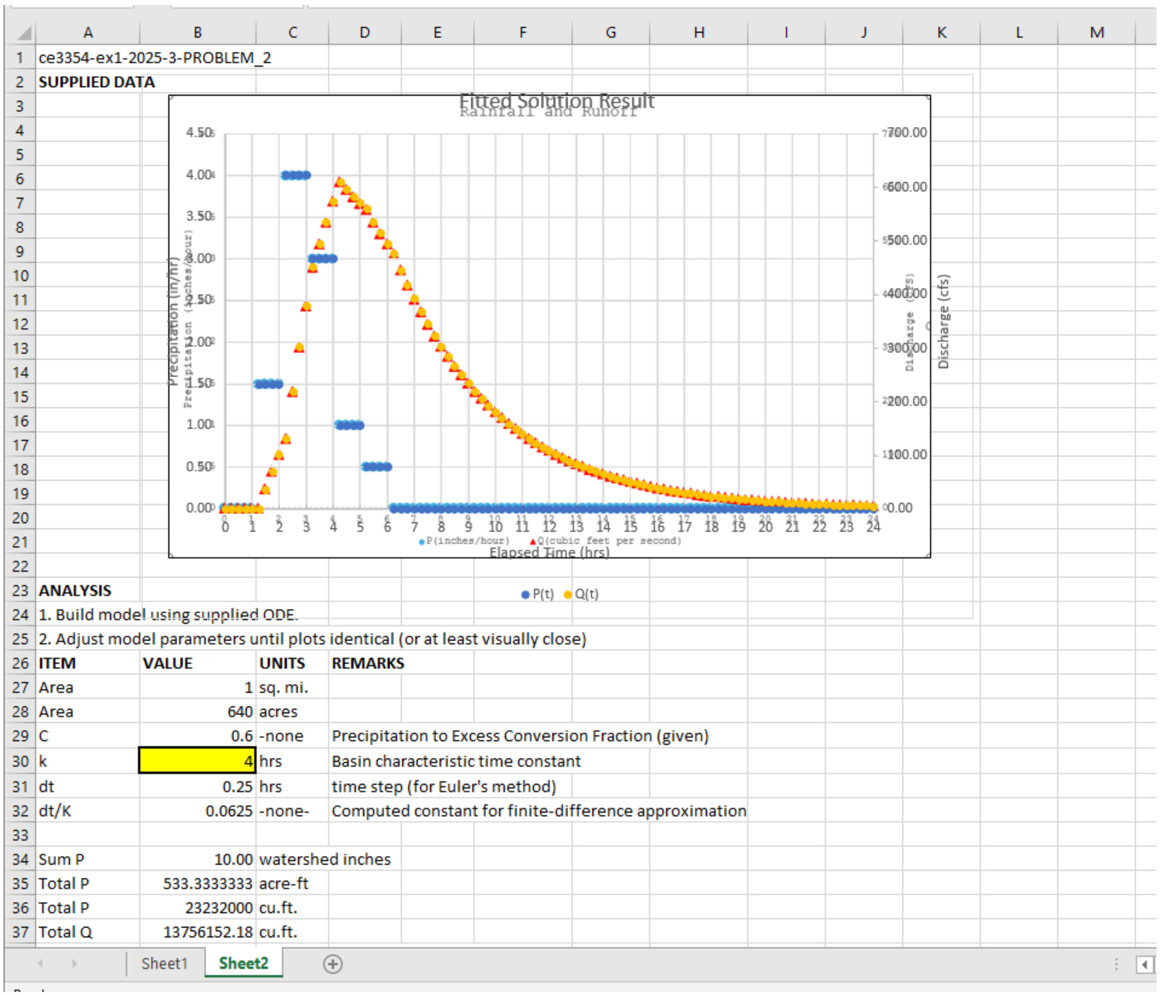
	A	B	C	D
22				
23	**ANALYSIS**			
24	1. Build model using supplied ODE.			
25	2. Adjust model parameters until plots identical (or at least visually close)			
26	**ITEM**	**VALUE**	**UNITS**	**REMARKS**
27	Area	1	sq. mi.	
28	Area	640	acres	
29	C	0.6	-none	Precipitation to Excess Conversion Fraction (given)
30	k	4	hrs	Basin characteristic time constant
31	dt	0.25	hrs	time step (for Euler's method)
32	dt/K	0.0625	-none-	Computed constant for finite-difference approximation
33				
34	Sum P	10.00	watershed inches	
35	Total P	533.3333333	acre-ft	
36	Total P	23232000	cu.ft.	
37	Total Q	13756152.18	cu.ft.	
38	Q/P	0.59	-none-	should be about same as C

39	t (hrs)	P(t)	P(t)AC	P(t)AC-Q(t)	Q(t)	Accumulated Volume(t)
40	0.00	0.00	0.00	0.00	0.00	0.00
41	0.25	0.00	0.00	0.00	0.00	0
42	0.50	0.00	0.00	0.00	0.00	0
43	0.75	0.00	0.00	0.00	0.00	0
44	1.00	0.00	0.00	0.00	0.00	0
45	1.25	1.50	576.00	576.00	0.00	0
46	1.50	1.50	576.00	540.00	36.00	16200
47	1.75	1.50	576.00	506.25	69.75	63787.5
48	2.00	1.50	576.00	474.61	101.39	140800.781
49	2.25	4.00	1536.00	1404.95	131.05	245400.732
50	2.50	4.00	1536.00	1317.14	218.86	402863.187
51	2.75	4.00	1536.00	1234.82	301.18	636884.237

Sheet1 Sheet2

Figure 5: Rainfall-runoff plot for the catchment; calculation portion. k is fit by trial-and-error updating

To demonstrate quality of the simulation, we change the computed chart background to transparent and overlay it onto the supplied graphic element. Figure 6 is the result. It is evident the fit is exact.



	A	B	C	D
1	ce3354-ex1-2025-3-PROBLEM_2			
2	**SUPPLIED DATA**			
23	**ANALYSIS**			
24	1. Build model using supplied ODE.			
25	2. Adjust model parameters until plots identical (or at least visually close)			
26	**ITEM**	**VALUE**	**UNITS**	**REMARKS**
27	Area	1	sq. mi.	
28	Area	640	acres	
29	C	0.6	-none	Precipitation to Excess Conversion Fraction (given)
30	k	4	hrs	Basin characteristic time constant
31	dt	0.25	hrs	time step (for Euler's method)
32	dt/K	0.0625	-none-	Computed constant for finite-difference approximation
33				
34	Sum P	10.00	watershed inches	
35	Total P	533.3333333	acre-ft	
36	Total P	23232000	cu.ft.	
37	Total Q	13756152.18	cu.ft.	

Figure 6: Rainfall-runoff plot for the catchment; Computed plot overlay and scaled so axes are same range.

Items c,d, and e appear directly or are computed from summary values in Figure 5.

c) value of k is 4 hours (to obtain the fitted chart)

d) Total volume in acre-feet of precipitation is **533.33 acre-feet**

e) Total volume in acre feet of runoff is 13,756,152 cu.ft. divided by 43560 sq. ft./acre-ft to obtain **315.80 acre-feet**.

Lastly Figure 7 is a portion of the spreadsheet showing the formulas employed.

	A	B	C	D	E	F
22						
23	**ANALYSIS**					P(t) Q(t)
24	1. Build model using supplie					
25	2. Adjust model parameters					
26	**ITEM**	**VALUE**	**UNITS**	**REMARKS**		
27	Area	1	sq. mi.			
28	Area	=640*B27	acres			
29	C	0.6	-none	Precipitation to Exc		
30	k	4	hrs	Basin characteristic		
31	dt	0.25	hrs	time step (for Euler		
32	dt/K	=B31/B30	-none-	Computed constan		
33						
34	Sum P	=SUM(B41:B137)*B31	watershed inches			
35	Total P	=(B34/12)*B28	acre-ft			
36	Total P	=B35*43560	cu.ft.			
37	Total Q	=F137	cu.ft.			
38	Total Q	=B37/43560	acre-feet			
39	Q/P	=B37/B36	-none-	should be about sa		
40	t (hrs)	P(t)	P(t)AC	P(t)AC-Q(t)	Q(t)	Accumulated Volume(t)
41	0	0	=B41*$B$28*$B$29	=C41-E41	0	=E41
42	=A41+$B$31	0	=B42*$B$28*$B$29	=C42-E42	=E41+$B$32*D41	=(0.5*(E42+E41)*(A42-A41)*3600)+F41
43	=A42+$B$31	0	=B43*$B$28*$B$29	=C43-E43	=E42+$B$32*D42	=(0.5*(E43+E42)*(A43-A42)*3600)+F42
44	=A43+$B$31	0	=B44*$B$28*$B$29	=C44-E44	=E43+$B$32*D43	=(0.5*(E44+E43)*(A44-A43)*3600)+F43
45	=A44+$B$31	0	=B45*$B$28*$B$29	=C45-E45	=E44+$B$32*D44	=(0.5*(E45+E44)*(A45-A44)*3600)+F44
46	=A45+$B$31	1.5	=B46*$B$28*$B$29	=C46-E46	=E45+$B$32*D45	=(0.5*(E46+E45)*(A46-A45)*3600)+F45
47	=A46+$B$31	1.5	=B47*$B$28*$B$29	=C47-E47	=E46+$B$32*D46	=(0.5*(E47+E46)*(A47-A46)*3600)+F46
48	=A47+$B$31	1.5	=B48*$B$28*$B$29	=C48-E48	=E47+$B$32*D47	=(0.5*(E48+E47)*(A48-A47)*3600)+F47
49	=A48+$B$31	1.5	=B49*$B$28*$B$29	=C49-E49	=E48+$B$32*D48	=(0.5*(E49+E48)*(A49-A48)*3600)+F48
50	=A49+$B$31	4	=B50*$B$28*$B$29	=C50-E50	=E49+$B$32*D49	=(0.5*(E50+E49)*(A50-A49)*3600)+F49
51	=A50+$B$31	4	=B51*$B$28*$B$29	=C51-E51	=E50+$B$32*D50	=(0.5*(E51+E50)*(A51-A50)*3600)+F50

Figure 7: Rainfall-runoff formulas for the catchment

3. Using an appropriate NRCS 24-hour rainfall distribution

   Determine:

   a) The cumulative rainfall depth (inches) for a 50-yr ARI storm in Lubbock, Texas.

   b) The rainfall intensity (inches/hour) for each half-hour increment of the storm.

   c) The maximum rainfall intensity (inches/hour) in any 30-minute interval.

   Solution(s): An apropriate NRCS distribution for Lubbock, Texas is a Type-II storm. Figure 8 is a screen capture of a map showing that Lubbock is best reperesented by Type II.

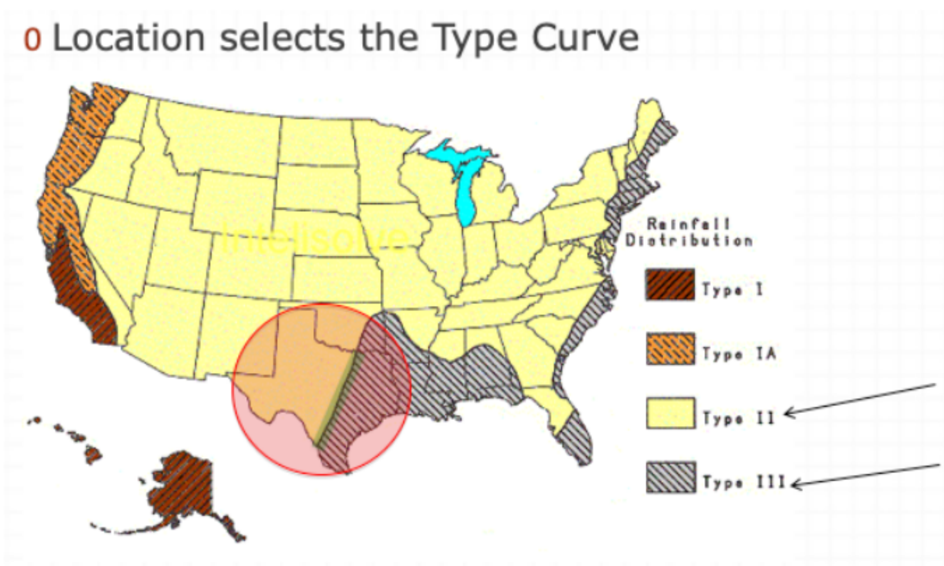


Figure 8: NRCS Type Curve Map

Item a) use NRCS PFDS to look up 24-hr storm depth. Using Partial Duration Series for Lubbock, TX value is **6.09 inches**. Figure 9 is a screen capture of the NRCS server access.

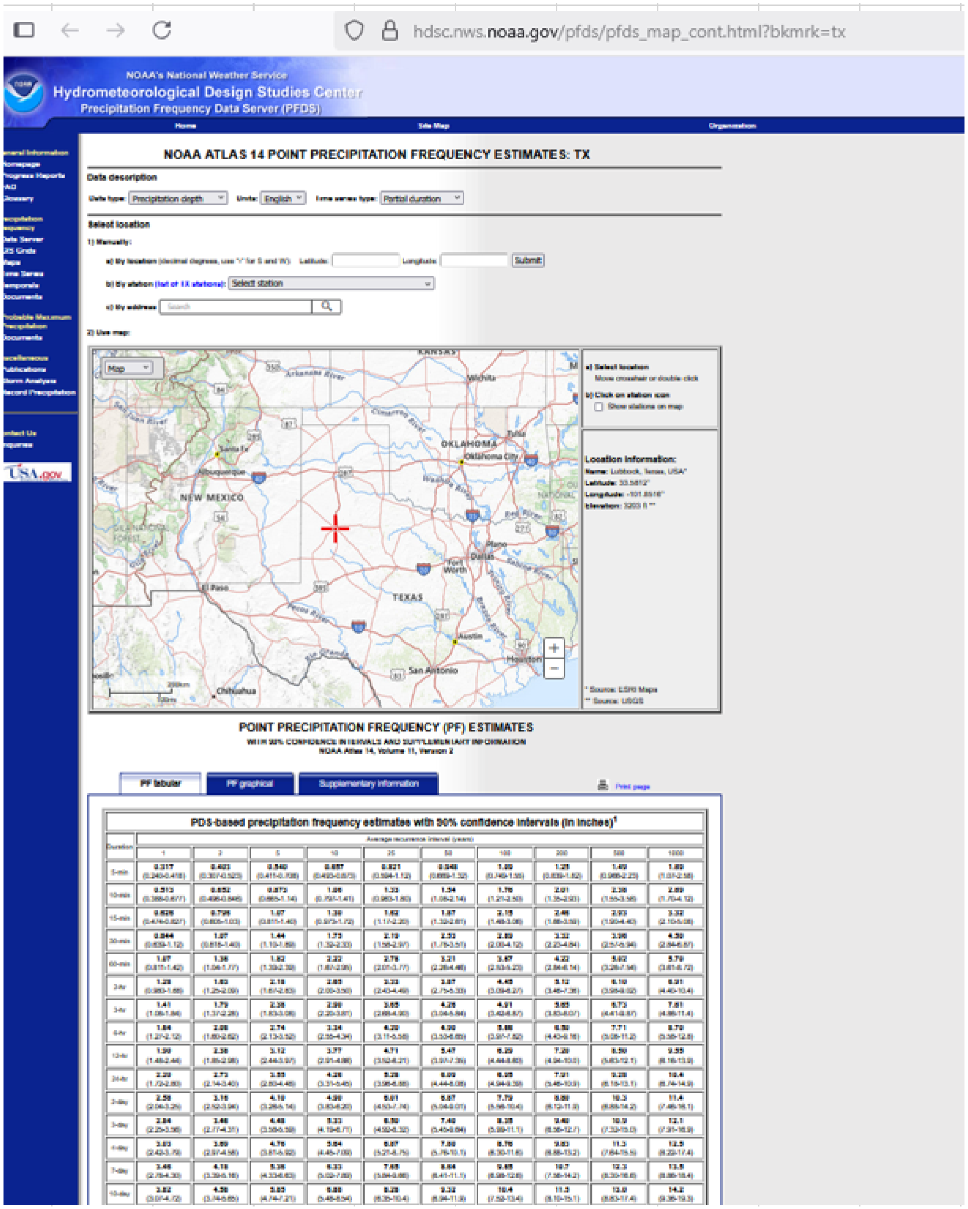


Figure 9: PFDS lookup for Lubbock, Texas

Item b) Use Script in notes, or spreadsheet implementation to obtain cumulative depth estimates each 1/2 hour. Backward difference to obtain intensity. Figure 10 is a screen capture of the python script for processing design storms (provided in course notes, and es2 solution file).

```
[6]: # Script to generate 1-minute hyetographs
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.interpolate import interp1d
hyetType = 'type2'
PT = 1.0 # total depth
#######################################
hour = [0,2,4,6,7,8,8.5,9,9.5,9.75,10,10.5,11,11.5,11.75,12,12.5,13.0,13.6,14,16,20,24,48]
minutes = [i*60 for i in hour]
hyets = {
        'type1': [0,0.035,0.076,0.125,0.156,0.194,0.219,0.254,0.303,0.362,0.515,0.583,0.624,0.654,0.669,0.682,0.706,0.727,0.748,0.767,0.83,0.926,1,1],
        'type1A': [0,0.05,0.116,0.206,0.268,0.425,0.48,0.52,0.55,0.564,0.577,0.601,0.624,0.645,0.655,0.664,0.683,0.701,0.719,0.736,0.8,0.906,1,1],
        'type2': [0,0.022,0.048,0.08,0.098,0.12,0.133,0.147,0.163,0.172,0.181,0.204,0.235,0.283,0.357,0.663,0.735,0.772,0.799,0.82,0.88,0.952,1,1],
        'type3': [0,0.02,0.043,0.072,0.089,0.115,0.13,0.148,0.167,0.178,0.189,0.216,0.25,0.298,0.339,0.5,0.702,0.751,0.785,0.811,0.886,0.957,1,1],
        'user': [0,0,0.4285,0.8571,1.0,1.0,1.0,1.0]  # Adjust time scaling below if needed
    }
if hyetType == 'user':
    user_time = [0,7,8,9,9.3333,10,24,48]
    minutes = [i*60 for i in user_time]
    hyet = hyets['user']
else:
    hyet = hyets.get(hyetType)
f = interp1d(minutes, hyet, kind='linear')
t24 = np.arange(0, 1455)  # 48 hours in minutes
depth = PT * f(t24)  # Scaled cumulative rainfall depth
intensity = np.diff(np.insert(depth, 0, 0)) * 60  # in/hr
# Build DataFrame #######################################
df = pd.DataFrame({
    "Time (min)": t24,
    "Cumulative Depth (in)": depth,
    "Intensity (in/hr)": intensity
})
# Optionally, write every nth row (e.g., every 15 minutes)
n = 15
df_thinned = df.iloc[::n]
# Save to CSV ##########################################################
df_thinned.to_csv(f"interpolated_output_{hyetType.upper()}.csv", index=False)
##########################################################################
```

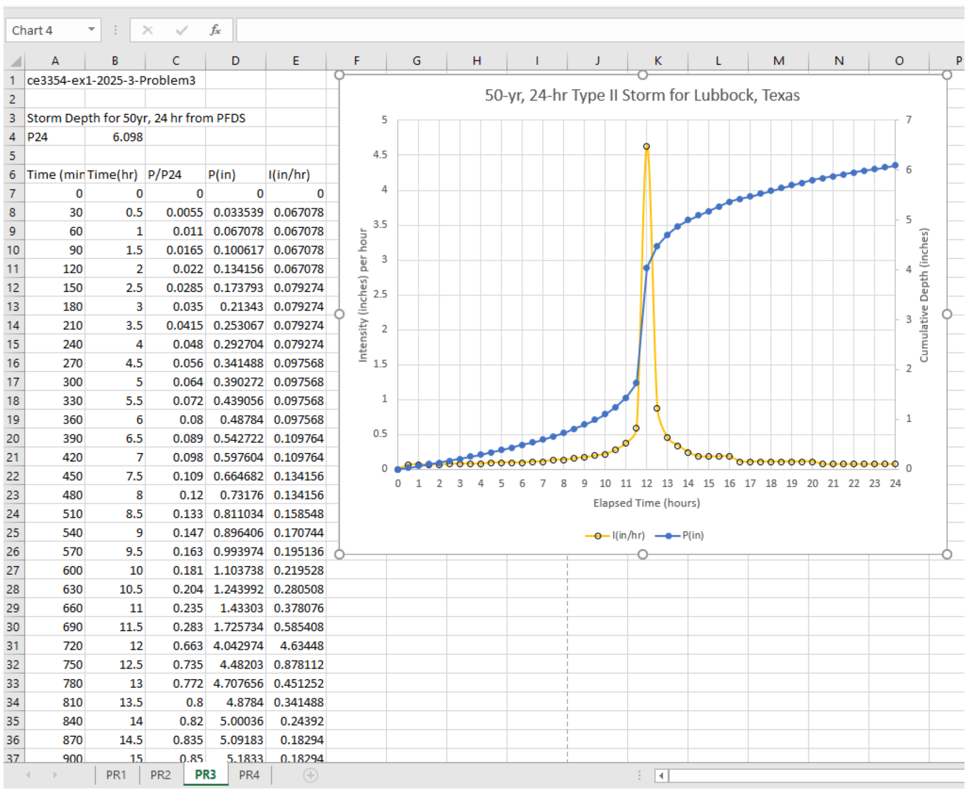
Figure 10: Script to generate Type II storm weights every 15 minutes

The output of the script is loaded into a spreadsheet to make the necessary computations to answer the remaining items. Figure 11 is a screen capture of such a spreadsheet.

Item b) based on differencing an interpolated NRCS storm, the intensity for each 1/2 hour is the column labeled I(in/hr) (rightmost in the figure), the maximum value in the spreadsheet, Item c) is 4.63 in/hr.[1]

Figure 11 is a screen capture of the spreadsheet as formulas.

[1] If you did not actually make the calculations and instead just reported the 30-min intensity from the PFDS, that value is 5.04 in/hour – partial credit for reporting this value



	A	B	C	D	E
1	ce3354-ex1-2025-3-Problem3				
2					
3	Storm Depth for 50yr, 24 hr from PFDS				
4	P24	6.098			
5					
6	Time (min	Time(hr)	P/P24	P(in)	I(in/hr)
7	0	0	0	0	0
8	30	0.5	0.0055	0.033539	0.067078
9	60	1	0.011	0.067078	0.067078
10	90	1.5	0.0165	0.100617	0.067078
11	120	2	0.022	0.134156	0.067078
12	150	2.5	0.0285	0.173793	0.079274
13	180	3	0.035	0.21343	0.079274
14	210	3.5	0.0415	0.253067	0.079274
15	240	4	0.048	0.292704	0.079274
16	270	4.5	0.056	0.341488	0.097568
17	300	5	0.064	0.390272	0.097568
18	330	5.5	0.072	0.439056	0.097568
19	360	6	0.08	0.48784	0.097568
20	390	6.5	0.089	0.542722	0.109764
21	420	7	0.098	0.597604	0.109764
22	450	7.5	0.109	0.664682	0.134156
23	480	8	0.12	0.73176	0.134156
24	510	8.5	0.133	0.811034	0.158548
25	540	9	0.147	0.896406	0.170744
26	570	9.5	0.163	0.993974	0.195136
27	600	10	0.181	1.103738	0.219528
28	630	10.5	0.204	1.243992	0.280508
29	660	11	0.235	1.43303	0.378076
30	690	11.5	0.283	1.725734	0.585408
31	720	12	0.663	4.042974	4.63448
32	750	12.5	0.735	4.48203	0.878112
33	780	13	0.772	4.707656	0.451252
34	810	13.5	0.8	4.8784	0.341488
35	840	14	0.82	5.00036	0.24392
36	870	14.5	0.835	5.09183	0.18294
37	900	15	0.85	5.1833	0.18294

Figure 11: Spreadsheet showing scaled storm depths and intensities (backward differences) for Type II storm. The differencing was performed in the python pre-processing script - all the spreadsheet does is rescale the results.

	A	B	C	D	E	F
1	ce3354-ex1-2025-3-P					
2						
3	Storm Depth for 50yr					
4	P24	6.098				
5						
6	Time (min)	Time(hr)	P/P24	I/I24	P(in)	I(in/hr)
7	0	=A7*24/1440	0	0	=$B$4*C7	=$B$4*D7
8	30	=A8*24/1440	0.0055	0.0109999999999999	=$B$4*C8	=$B$4*D8
9	60	=A9*24/1440	0.011	0.0109999999999999	=$B$4*C9	=$B$4*D9
10	90	=A10*24/1440	0.0165	0.011	=$B$4*C10	=$B$4*D10
11	120	=A11*24/1440	0.022	0.0109999999999998	=$B$4*C11	=$B$4*D11
12	150	=A12*24/1440	0.0284999999999999	0.0129999999999998	=$B$4*C12	=$B$4*D12
13	180	=A13*24/1440	0.035	0.0130000000000002	=$B$4*C13	=$B$4*D13
14	210	=A14*24/1440	0.0414999999999999	0.0129999999999994	=$B$4*C14	=$B$4*D14
15	240	=A15*24/1440	0.048	0.0130000000000002	=$B$4*C15	=$B$4*D15
16	270	=A16*24/1440	0.056	0.0159999999999999	=$B$4*C16	=$B$4*D16
17	300	=A17*24/1440	0.064	0.0159999999999999	=$B$4*C17	=$B$4*D17
18	330	=A18*24/1440	0.072	0.0159999999999999	=$B$4*C18	=$B$4*D18
19	360	=A19*24/1440	0.08	0.0159999999999999	=$B$4*C19	=$B$4*D19
20	390	=A20*24/1440	0.089	0.0179999999999996	=$B$4*C20	=$B$4*D20
21	420	=A21*24/1440	0.098	0.0179999999999996	=$B$4*C21	=$B$4*D21
22	450	=A22*24/1440	0.109	0.022	=$B$4*C22	=$B$4*D22
23	480	=A23*24/1440	0.12	0.022	=$B$4*C23	=$B$4*D23
24	510	=A24*24/1440	0.133	0.0260000000000004	=$B$4*C24	=$B$4*D24
25	540	=A25*24/1440	0.147	0.0280000000000002	=$B$4*C25	=$B$4*D25
26	570	=A26*24/1440	0.163	0.0319999999999998	=$B$4*C26	=$B$4*D26
27	600	=A27*24/1440	0.181	0.0359999999999993	=$B$4*C27	=$B$4*D27
28	630	=A28*24/1440	0.204	0.0459999999999999	=$B$4*C28	=$B$4*D28
29	660	=A29*24/1440	0.235	0.0619999999999998	=$B$4*C29	=$B$4*D29
30	690	=A30*24/1440	0.283	0.0959999999999994	=$B$4*C30	=$B$4*D30
31	720	=A31*24/1440	0.663	1.22399999999999	=$B$4*C31	=$B$4*D31
32	750	=A32*24/1440	0.735	0.143999999999997	=$B$4*C32	=$B$4*D32
33	780	=A33*24/1440	0.772	0.0739999999999985	=$B$4*C33	=$B$4*D33
34	810	=A34*24/1440	0.7945	0.044999999999995	=$B$4*C34	=$B$4*D34
35	840	=A35*24/1440	0.82	0.0524999999999975	=$B$4*C35	=$B$4*D35
36	870	=A36*24/1440	0.835	0.0299999999999966	=$B$4*C36	=$B$4*D36
37	900	=A37*24/1440	0.85	0.0300000000000033	=$B$4*C37	=$B$4*D37
38	930	=A38*24/1440	0.865	0.0299999999999966	=$B$4*C38	=$B$4*D38

PR1 PR2 PR3

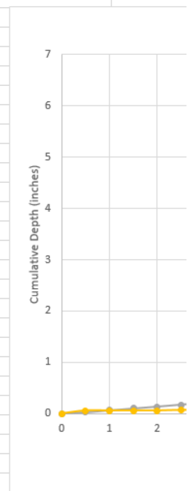


Figure 12: Spreadsheet showing scaled storm depths and intensities formulas for Type II storm

4. The relation between infiltration capacity in mm/hour and the time (in hours) since the start of the experiment as measured with an infiltrometer is depicted in Figure 13.

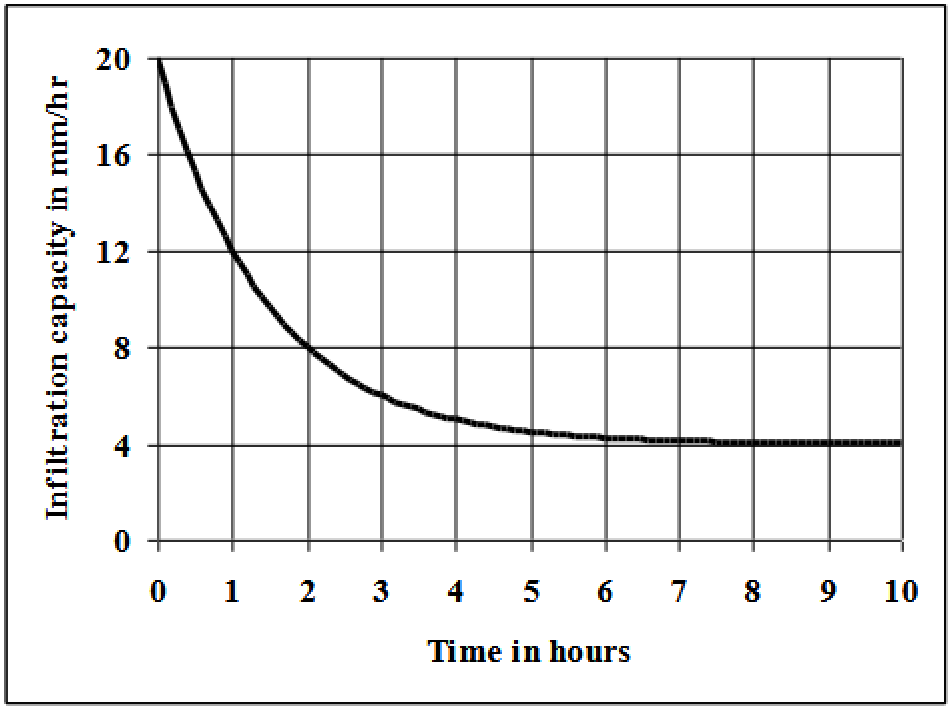


Figure 13: Infiltrometer data for some soil

The relationship is to be described with the Horton infiltration model

$$q(t) = f_c + (f_o - f_c)e^{-kt} \tag{2}$$

Determine:

a) The equilibrium infiltration rate, f_c, in mm/hr.

b) The initial (dry soil) infiltration rate, f_o, in mm/hr.

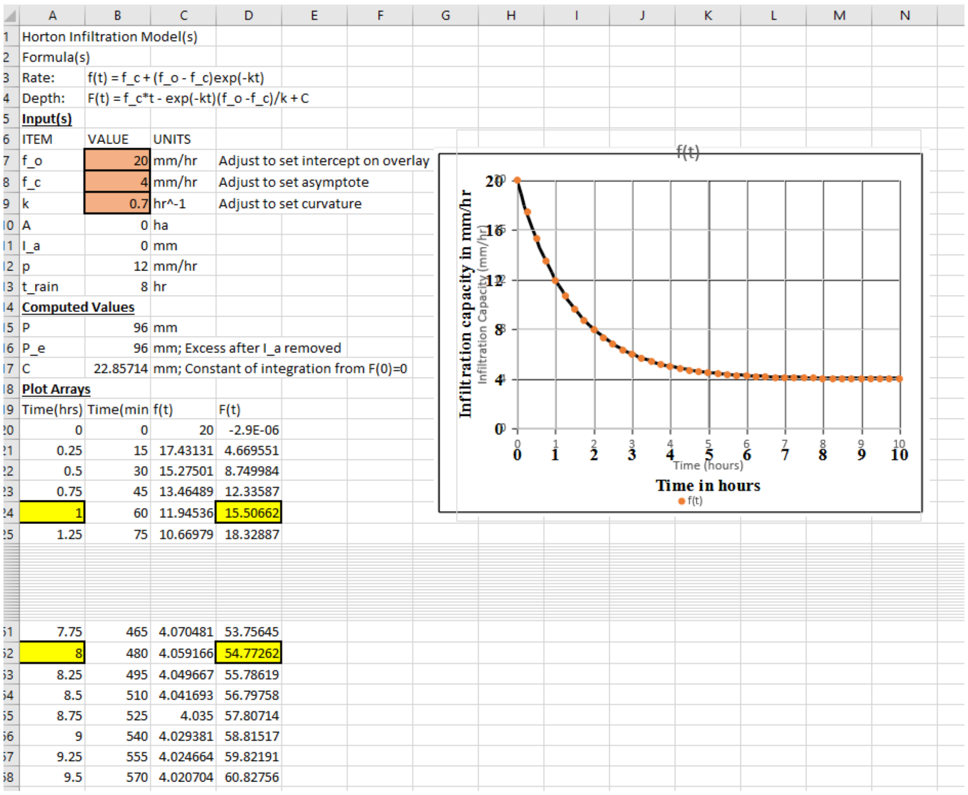
c) The soil constant k.

d) The total amount of water that will infiltrate into an initially dry soil during a rainstorm with a duration 60 minutes and a constant intensity of 20 mm/h.

e) The total amount of water that will infiltrate into an initially dry soil during a rainstorm with a duration 480 minutes and a constant intensity of 12 mm/h.

Solution(s):

Use ES3 solution to construct a spreadsheet and fit infiltration curve as shown in Figure 14



	A	B	C	D	E
1	Horton Infiltration Model(s)				
2	Formula(s)				
3	Rate:	f(t) = f_c + (f_o - f_c)exp(-kt)			
4	Depth:	F(t) = f_c*t - exp(-kt)(f_o -f_c)/k + C			
5	**Input(s)**				
6	ITEM	VALUE	UNITS		
7	f_o	20	mm/hr	Adjust to set intercept on overlay	
8	f_c	4	mm/hr	Adjust to set asymptote	
9	k	0.7	hr^-1	Adjust to set curvature	
10	A	0	ha		
11	I_a	0	mm		
12	p	12	mm/hr		
13	t_rain	8	hr		
14	**Computed Values**				
15	P	96	mm		
16	P_e	96	mm; Excess after I_a removed		
17	C	22.85714	mm; Constant of integration from F(0)=0		
18	**Plot Arrays**				
19	Time(hrs)	Time(min	f(t)	F(t)	
20	0	0	20	-2.9E-06	
21	0.25	15	17.43131	4.669551	
22	0.5	30	15.27501	8.749984	
23	0.75	45	13.46489	12.33587	
24	1	60	11.94536	15.50662	
25	1.25	75	10.66979	18.32887	
51	7.75	465	4.070481	53.75645	
52	8	480	4.059166	54.77262	
53	8.25	495	4.049667	55.78619	
54	8.5	510	4.041693	56.79758	
55	8.75	525	4.035	57.80714	
56	9	540	4.029381	58.81517	
57	9.25	555	4.024664	59.82191	
58	9.5	570	4.020704	60.82756	

Figure 14: Fitted Infiltrometer data for some soil on es3 solution spreadsheet tool. Change chart background to transparent, and overlay, resize to fit provided curve.

Results are:

a) The equilibrium infiltration rate, f_c, is 4.0 mm/hr.

b) The initial (dry soil) infiltration rate, f_o, is 20.0 mm/hr.

c) The soil constant k, is 0.7 $\frac{1}{hr}$.

d) The total amount of water that will infiltrate into an initially dry soil during a rainstorm with a duration 60 minutes and a constant intensity of 20 mm/h is 15.5 mm.

e) The total amount of water that will infiltrate into an initially dry soil during a rainstorm with a duration 480 minutes and a constant intensity of 12 mm/h is 54.7 mm