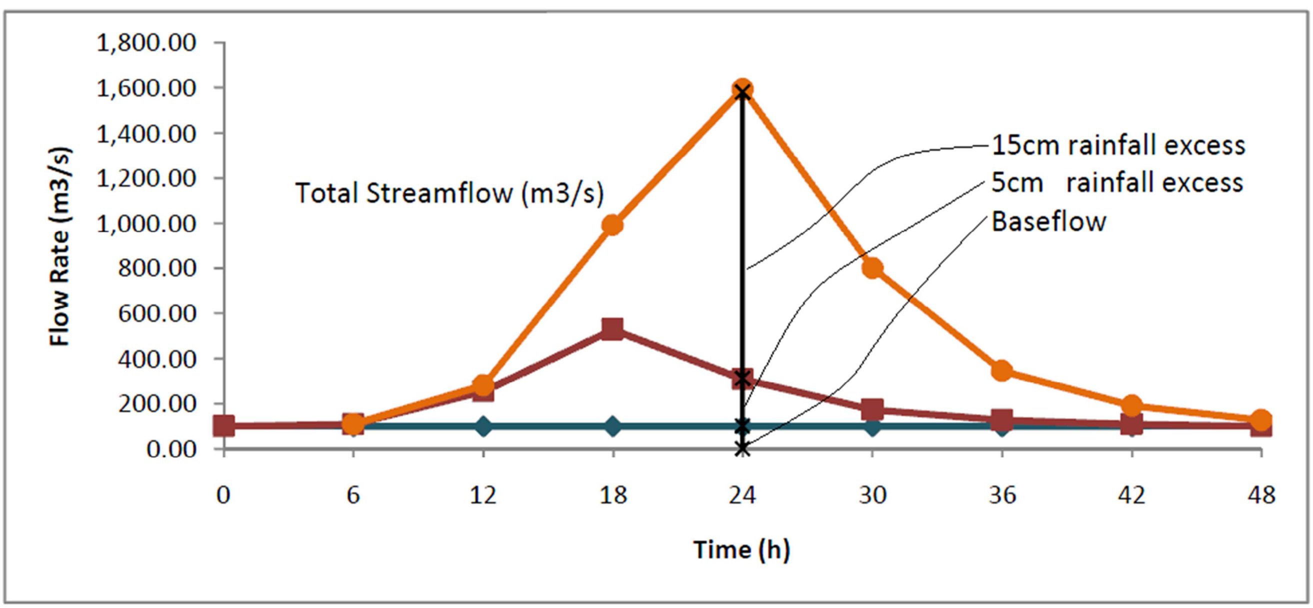
7.5.4 The six-hour unit hydrograph of a watershed having a drainage area equal to 393 km^2 is as follows:

Time (h)	**0**	**6**	**12**	**18**	**24**	**30**	**36**	**42**
Unit Hydrograph (m^3/s*cm)	**0**	**1.8**	**30.9**	**85.6**	**41.8**	**14.6**	**5.5**	**1.8**

For a storm over the watershed having excess rainfall of 5cm for the first six hours and 15 cm for the second six hours, compute the streamflow hydrograph, assuming a constant baseflow of 100 m^3/s.

Area=	393	km2	
Pe=	5	cm	(first six hours)
Pe=	15	cm	(second six hours)
Baseflow=	100	m3/s	

Time	Excess	Unit Hydrograph ordinates (m3/s*cm)							Direct	Streamflow
		1	2	3	4	5	6	7	Runoff	
(h)	Precipitation (cm)	1.8	30.9	85.6	41.8	14.6	5.5	1.8	(m3/s)	(m3/s)
6	5	9.0							9.0	109.0
12	15	27.0	154.5						181.5	281.5
18			463.5	428.0					891.5	991.5
24				1284.0	209.0				1493.0	1593.0
30					627.0	73.0			700.0	800.0
36						219.0	27.5		246.5	346.5
42							82.5	9.0	91.5	191.5
48								27.0	27.0	127.0
								Total	3,640	



7.7.11 A triangular synthetic unit hydrograph developed by the Soil Conservation Service method has $q_p = 2,900\, cfs/in$, $T_p = 50min$, and $t_r = 10min$. Compute the direct runoff hydrograph for a 20-minute storm, having $0.66in$ rainfall in the first 10 minutes and $1.70in$ in the second 10 minutes. The rainfall loss rate is $\phi = 0.6\, in/h$ throughout the storm.

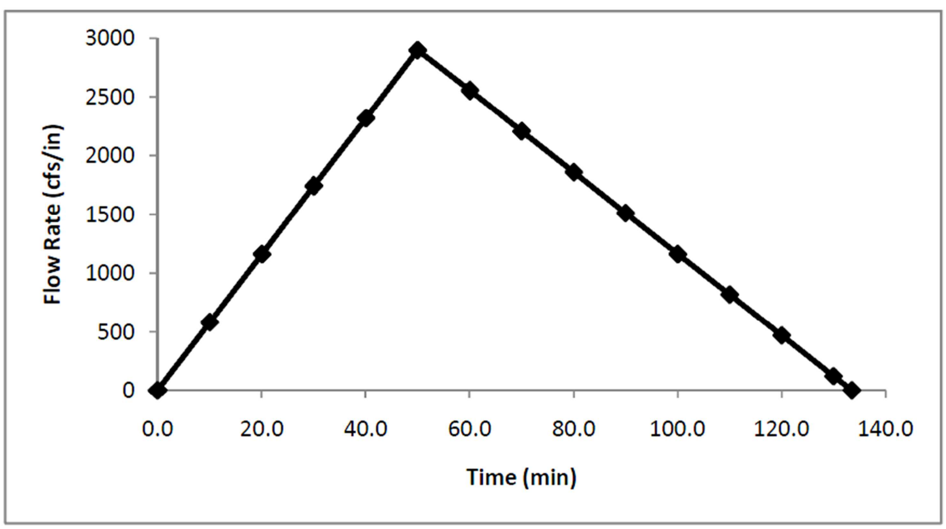
In this problem, what you need to do is to compute the triangular unit hydrograph by the SCS method, and then find the unit hydrograph flows at intervals of 10 minutes. Determine the excess rainfall amounts by subtracting ϕ = 0.6 in/hr = 0.1 in/10 min from the given rainfall values. Use the discrete convolution integral, Eq. (7.4.1) , to compute the direct runoff hydrograph.

$$q_p = 2{,}900\, cfs/in$$
$$T_p = 50min$$

$$t_b = 2.67T_p$$
$$t_b = 2.67(50min)$$
$$t_b = 133.5min$$

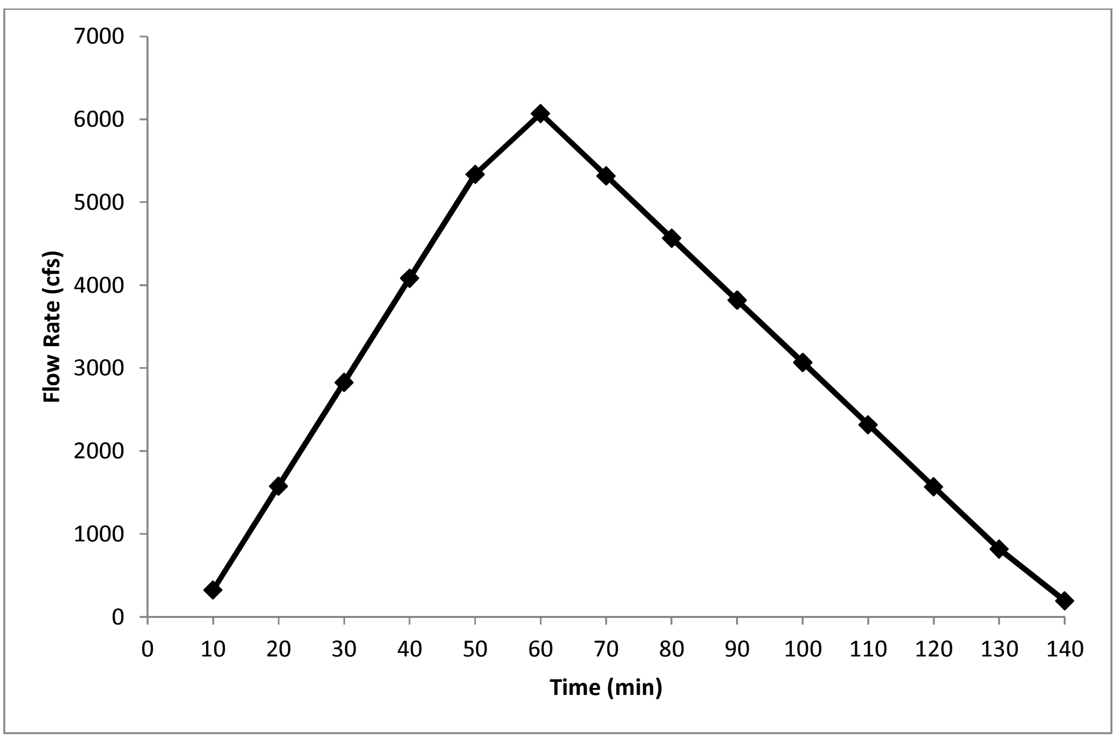
$$Flow\ Rate = \begin{cases} \frac{q_p}{T_p}(time) & if\ 0 \le time \le T_p \\ q_p - \frac{q_p}{1.67T_p}(time - T_p) & if\ T_p < time \le t_b \end{cases}$$

Time (min)	Flow (cfs/in)
0.0	0
10.0	580
20.0	1160
30.0	1740
40.0	2320
50.0	2900
60.0	2553
70.0	2205
80.0	1858
90.0	1511
100.0	1163
110.0	816
120.0	469
130.0	122
133.5	0



			Unit Hydrigraph ordinates (cfs/in)													Direct
			1	2	3	4	5	6	7	8	9	10	11	12	13	Runoff
Time (min)	Rainfall (in)	Excess Precipitation (in)	580	1160	1740	2320	2900	2553	2205	1858	1511	1163	816	469	122	(cfs)
10	0.66	0.56	324.8													325
20	1.70	1.60	928.0	649.6												1578
30				1856.0	974.4											2830
40					2784.0	1299.2										4083
50						3712.0	1624.0									5336
60							4640.0	1429.5								6070
70								4084.3	1235.0							5319
80									3528.6	1040.5						4569
90										2972.9	846.0					3819
100											2417.2	651.5				3069
110												1861.6	457.1			2319
120													1305.9	262.6		1568
130														750.2	68.1	818
140															194.5	194

Total 41,898



3. Exercise on “Introduction to HEC-HMS”

1. Verify with hand computation the amount of excess precipitation that results from a 2 inch rainfall in 1 hour falling on a basin with a curve number of 80 and 25% impervious cover.

The Results from HEC-HMS are shown in the following table.

Date	Time	Precip (IN)	Loss (IN)	Excess (IN)
01Jan2012	00:00			
01Jan2012	00:06	0.20	0.15	0.05
01Jan2012	00:12	0.20	0.15	0.05
01Jan2012	00:18	0.20	0.15	0.05
01Jan2012	00:24	0.20	0.13	0.07
01Jan2012	00:30	0.20	0.11	0.09
01Jan2012	00:36	0.20	0.10	0.10
01Jan2012	00:42	0.20	0.09	0.11
01Jan2012	00:48	0.20	0.08	0.12
01Jan2012	00:54	0.20	0.07	0.13
01Jan2012	01:00	0.20	0.06	0.14

Precipitation in 6 min intervals is: $\mathrm{P} = 6\mathrm{min}(2\mathrm{in}/60\mathrm{min}) = 0.2\mathrm{in}$. And $\mathrm{S} = \frac{1{,}000}{\mathrm{CN}} - 10 = \frac{1{,}000}{80} - 10 = 2.5\mathrm{in}$. The initial abstraction is $\mathrm{I_a} = 0.2\mathrm{S} = 0.2(2.5) = 0.5\ \mathrm{in}$. This means that precipitation for the first two periods and the half of the third period are absorbed as part of the losses.

Continuing Abstraction is computed with the equation: $\mathrm{F_a} = \mathrm{S}(\mathrm{P} - \mathrm{I_a})/(\mathrm{P} - \mathrm{I_a} + \mathrm{S})$. Where, $\mathrm{I_a}$ and P are cumulative values of initial abstraction and precipitation respectively .And the Cumulative Precipitation in excess is computed as $\mathrm{P_e} = \mathrm{P} - \mathrm{I_a} - \mathrm{F_a}$. The losses are the difference between Precipitation and Precipitation in excess.

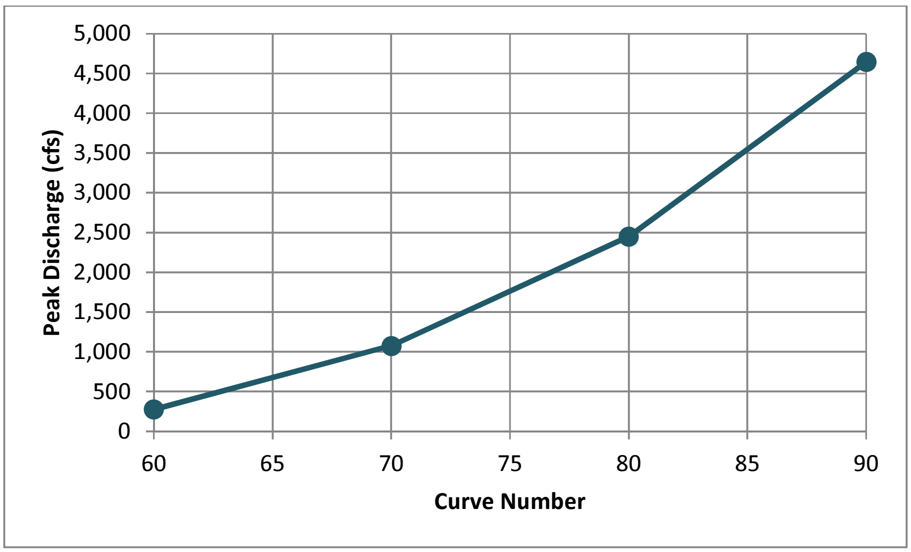
We consider 25% of terrain with impervious cover. The losses will be 75% of the original value. Precipitation in Excess is obtained subtracting the Losses from Precipitation. The values are shown in the following table; notice that they match the values from HEC-HMS.

Time	Precip. [in]	Cumul. P. [in]	Cumul. Abst. [in] Ia	Fa	Cumul. P. in excess [in]	P. in excess [in]	Loss [in]	25% impervious Loss [in]	P. in excess [in]
0:00		0.00							
0:06	0.20	0.20	0.20	0.00	0.00	0.00	0.20	0.15	0.05
0:12	0.20	0.40	0.40	0.00	0.00	0.00	0.20	0.15	0.05
0:18	0.20	0.60	0.50	0.10	0.00	0.00	0.20	0.15	0.05
0:24	0.20	0.80	0.50	0.27	0.03	0.03	0.17	0.13	0.07
0:30	0.20	1.00	0.50	0.42	0.08	0.05	0.15	0.11	0.09
0:36	0.20	1.20	0.50	0.55	0.15	0.07	0.13	0.10	0.10
0:42	0.20	1.40	0.50	0.66	0.24	0.09	0.11	0.09	0.11
0:48	0.20	1.60	0.50	0.76	0.34	0.10	0.10	0.08	0.12
0:54	0.20	1.80	0.50	0.86	0.44	0.11	0.09	0.07	0.13
1:00	0.20	2.00	0.50	0.94	0.56	0.12	0.08	0.06	0.14

2. Prepare a graph that shows the relation between the peak discharge and curve number for increments of the curve number of 10 from 60 to 90. Assume zero impervious cover and a lag time of 60 min.

For each curve number a simulation is run. The peak discharge can be accessed in the summary table.

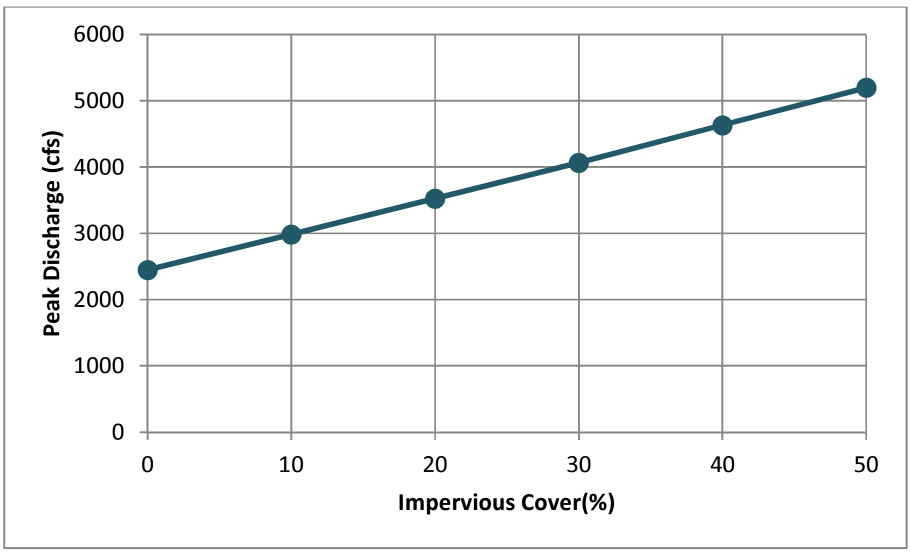
Curve Number	Peak Discharge (cfs)
60	276
70	1,076
80	2,448
90	4,643



3. For a curve number of 80, prepare a graph that shows the relation between the peak discharge and the % impervious cover for impervious cover 0 to 50% in 10% increments. Assume a lag time of 60 min.

Similar to the previous point, for each impervious value a simulation is run. The peak discharge can be accessed in the summary table.

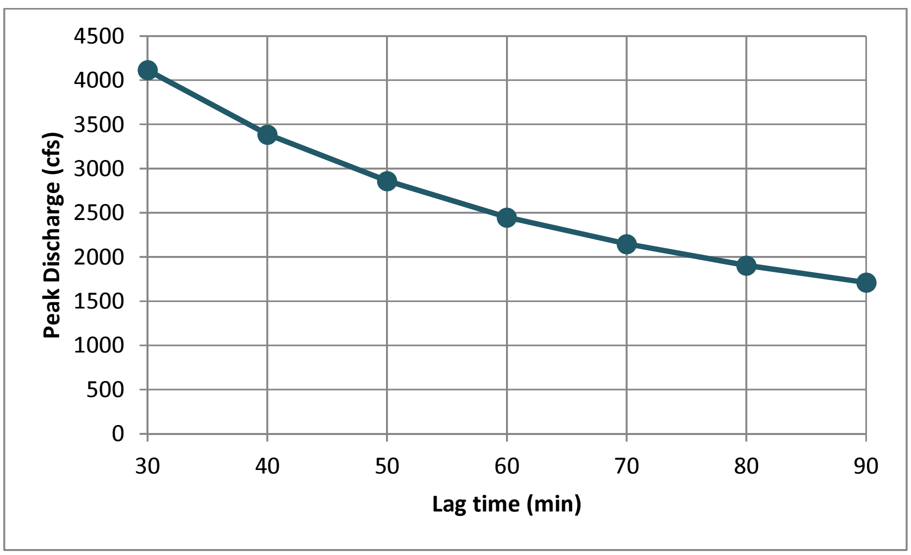
Impervious Cover (%)	Peak Discharge (cfs)
0	2,448
10	2,982
20	3,522
30	4,064
40	4,630
50	5,196



4. For a curve number of 80 and zero impervious cover, prepare a graph that shows the relation between peak discharge and lag time for lag times in the range 30 min to 90 min in 10 min increments.

Similar to the previous two points, for each lag time value a simulation is run. The peak discharge can be accessed in the summary table.

Lag time (min)	Peak Discharge (cfs)
30	4,115
40	3,388
50	2,860
60	2,448
70	2,150
80	1,904
90	1,712



5. How long (min) does it take the peak to traverse the reach? Change the slope to 0.0001 (typical of slopes in Houston). What effect does this have on the outflow?

The peak is 2441.1 cfs. The time can be 8acquired in the Time-series table.

Time	Outflow (CFS)
0:00	0
0:06	0
0:12	0
0:18	0
0:24	0
0:30	0.1
0:36	0.1
0:42	0.2
0:48	0.2
0:54	0.7
1:00	11.6

Time	Outflow (CFS)
1:06	102
1:12	313.5
1:18	631.8
1:24	1015
1:30	1408.4
1:36	1780.3
1:42	2097.8
1:48	2315.1
1:54	2426.3
2:00	**2441.4**
2:06	2380.5

The peak takes **18 minutes** to transverse the reach. If we change the slope to 0.0001 (next table) , the peak takes only **6 minutes** but it magnitude its reduced significantly to 1267.2 cfs.

Time	Outflow (CFS)
0:00	0
0:06	0
0:12	0
0:18	0
0:24	0
0:30	0
0:36	0
0:42	0
0:48	3.6
0:54	16.9
1:00	87.1

Time	Outflow (CFS)
1:06	218.8
1:12	397.6
1:18	607.5
1:24	827.9
1:30	1022.1
1:36	1165
1:42	1251.5
1:48	1283.6
1:54	**1267.2**
2:00	1208.3

6. By how much does Dam 7 reduce the outflow from the basin? Suppose that you change the rainfall from 2 inches in the first hour to 10 inches, with 5 inches in the first hour and 5 inches in the second hour (this is the "rain bomb" that happened in Tropical Storm Hermine). What is the outflow from the Routing Reach then? By how much does Dam-7 then reduce the outflow? Does water start going over the Emergency Spillway in this case?

The peak inflow in the reservoir is 2,441.4 cfs and the outflow is 99.9 cfs. The flow is reduced in 96%.

If we consider 5 inches of precipitation in the first hour and another 5 inches in the second hour, the peak outflow from the routing reach is 24,055.3 cfs. The outflow from the reservoir is 1,549.1cfs. The flow is reduced in 94%.

The peak storage is 3,780 AC-FT, that correspond to an elevation of 831m. The water starts going to emergency spillway at 829 ft; the emergency spillway was used.