CE 374 K – Hydrology

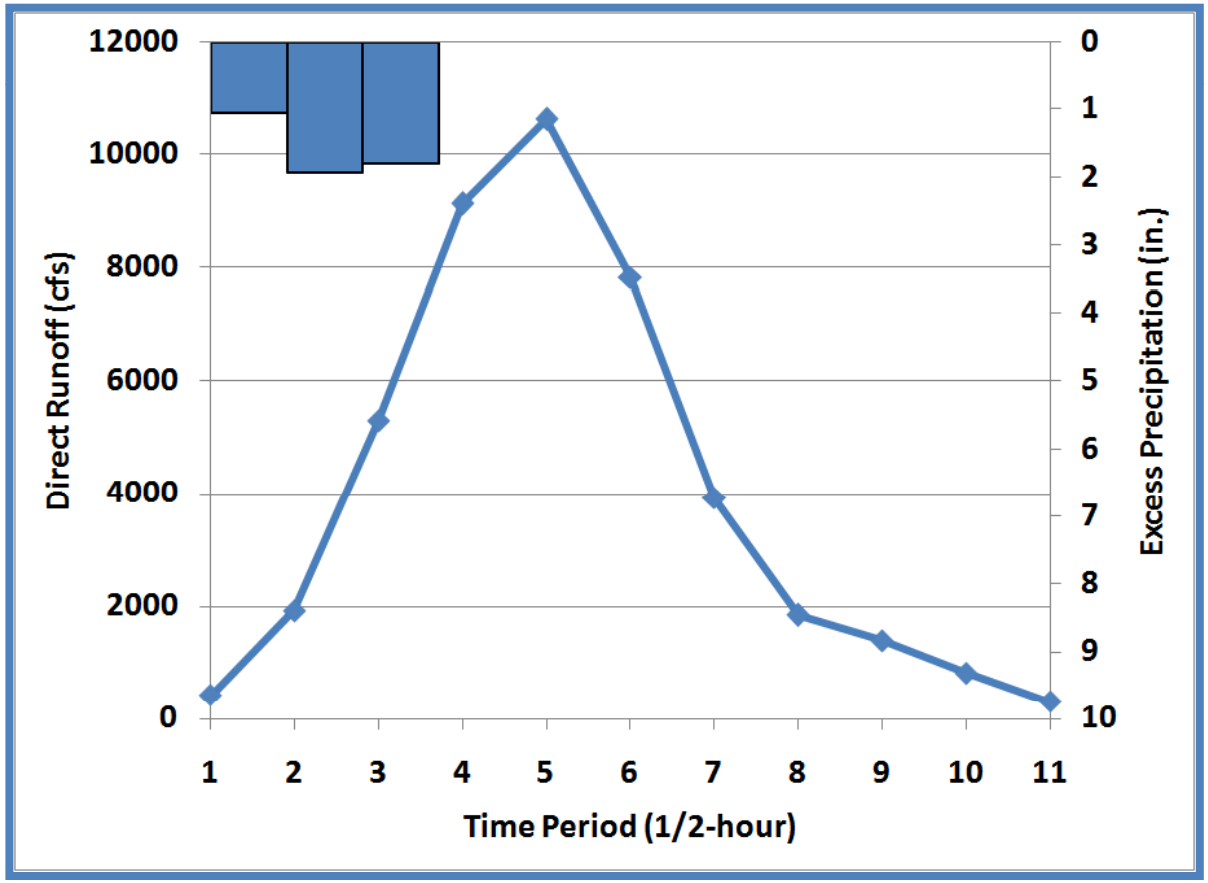
Runoff Hydrograph Computation

Daene C. McKinney

Example (7.4.1)

Recall: Shoal Creek Flood, May 24-25, 1981 (Example 5.3.1)
Find: ½-hr unit hydrograph

Time	Time	Direct Runoff	Excess Rainfall
	1/2 hr	cfs	in
10:00 PM	1	428	1.06
10:30 PM	2	1923	1.93
11:00 PM	3	5297	1.81
11:30 PM	4	9131	
12:00 AM	5	10625	
12:30 AM	6	7834	
1:00 AM	7	3921	
1:30 AM	8	1846	
2:00 AM	9	1402	
2:30 AM	10	830	
3:00 AM	11	313	



Example (Cont.)

- Excess Rainfall: M = 3 pulses
- Streamflow: N = 11 pulses
- Unit Hydrograph: $N - M + 1$ = 9 pulses

Time	Time	Direct Runoff	Excess Rainfall
	1/2 hr	cfs	in
10:00 PM	1	428	1.06
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2:30 AM	10	830	
3:00 AM	11	313	

$$Q_n = \sum_{m=1}^{n<M} P_m U_{n-m+1}$$

$$Q_1 = P_1U_1$$
$$Q_2 = P_2U_1 + P_1U_2$$
$$Q_3 = P_3U_1 + P_2U_2 + P_1U_3$$
$$Q_4 = P_3U_2 + P_2U_3 + P_1U_4$$
$$Q_5 = P_3U_3 + P_2U_4 + P_1U_5$$
$$Q_6 = P_3U_4 + P_2U_5 + P_1U_6$$
$$Q_7 = P_3U_5 + P_2U_6 + P_1U_7$$
$$Q_8 = P_3U_6 + P_2U_7 + P_1U_8$$
$$Q_9 = P_3U_7 + P_2U_8 + P_1U_9$$

Example (Cont.)

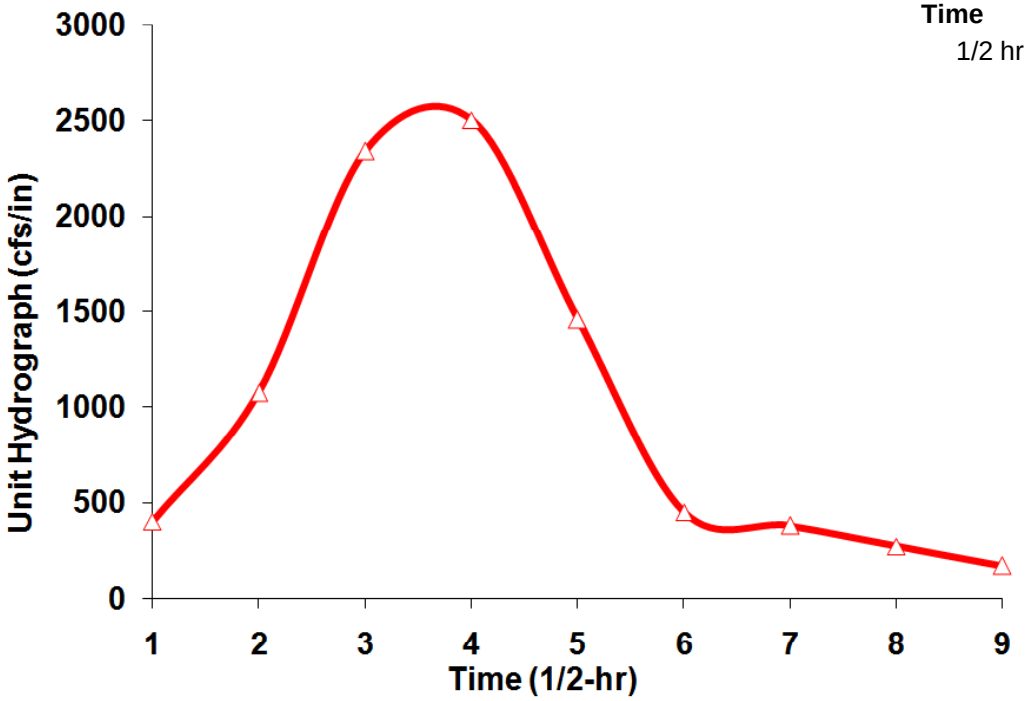
- Excess Rainfall: M = 3 pulses
- Streamflow: N = 11 pulses
- Unit Hydrograph: $N - M + 1$ = 9 pulses

$$Q_n = \sum_{m=1}^{n<M} P_m U_{n-m+1}$$

Time	Time	Q_n Direct Runoff	P_m Excess Rainfall
	1/2 hr	cfs	in
10:00 PM	1	428	1.06
10:30 PM	2	1923	1.93
11:00 PM	3	5297	1.81
11:30 PM	4	9131	
12:00 AM	5	10625	
12:30 AM	6	7834	
1:00 AM	7	3921	
1:30 AM	8	1846	
2:00 AM	9	1402	
2:30 AM	10	830	
3:00 AM	11	313	

$$428 = 1.06U_1$$
$$1923 = 1.93U_1 + 1.06U_2$$
$$5297 = 1.81U_1 + 1.93U_2 + 1.06U_3$$
$$9131 = 1.81U_2 + 1.93U_3 + 1.06U_4$$
$$10625 = 1.81U_3 + 1.93U_4 + 1.06U_5$$
$$7834 = 1.81U_4 + 1.93U_5 + 1.06U_6$$
$$3921 = 1.81U_5 + 1.93U_6 + 1.06U_7$$
$$1846 = 1.81U_6 + 1.93U_7 + 1.06U_8$$
$$1402 = 1.81U_7 + 1.93U_8 + 1.06U_9$$

Example (Cont.)

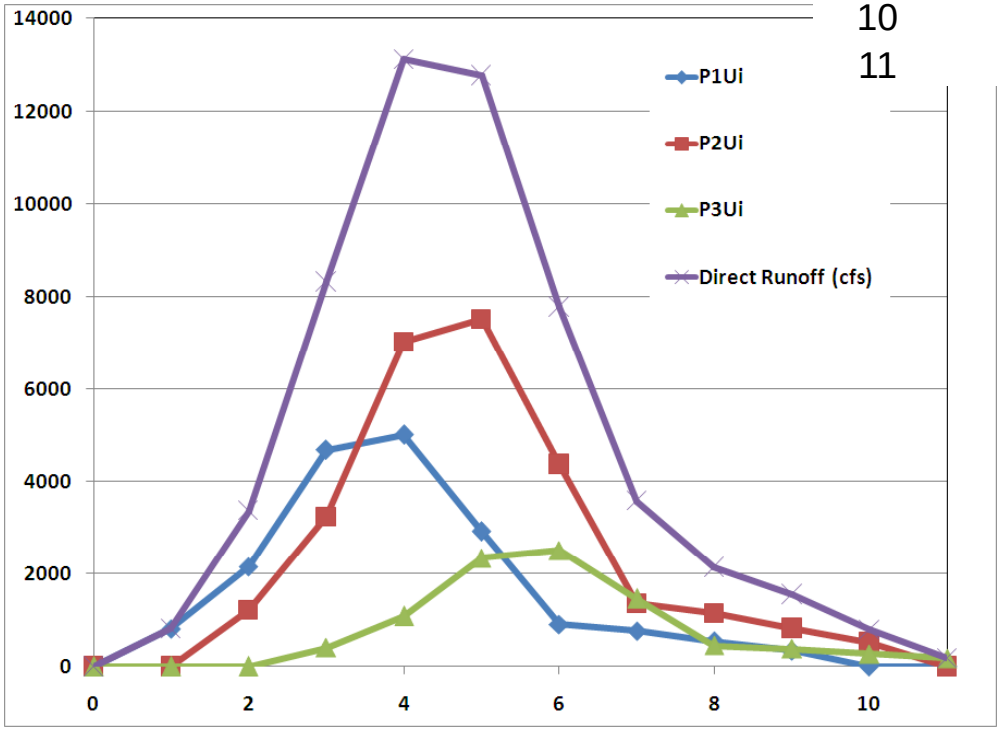


Time	Direct Runoff	Excess Rainfall	Unit Hydrograph
1/2 hr	cfs	in	cfs/in
1	428	1.06	404
2	1923	1.93	1079
3	5297	1.81	2343
4	9131		2506
5	10625		1460
6	7834		453
7	3921		381
8	1846		274
9	1402		173
10	830		
11	313		

Example

Three period storm:
1st period: 2 in rain
2nd period: 3 in rain
3rd period: 1 in rain
Find: DR using UH from last ex.

Time	Pi	Ui	P1Ui	P2Ui	P3Ui	Direct Runoff (cfs)
0	**0**	0	**0**	**0**	**0**	**0**
1	2	404	808	0	0	808
2	3	1079	2158	1212	0	3370
3	1	2343	4686	3237	404	8327
4		2506	5012	7029	1079	13120
5		1460	2920	7518	2343	12781
6		453	906	4380	2506	7792
7		381	762	1359	1460	3581
8		274	548	1143	453	2144
9		173	346	822	381	1549
10		0	0	519	274	793
11		0	0	0	173	173

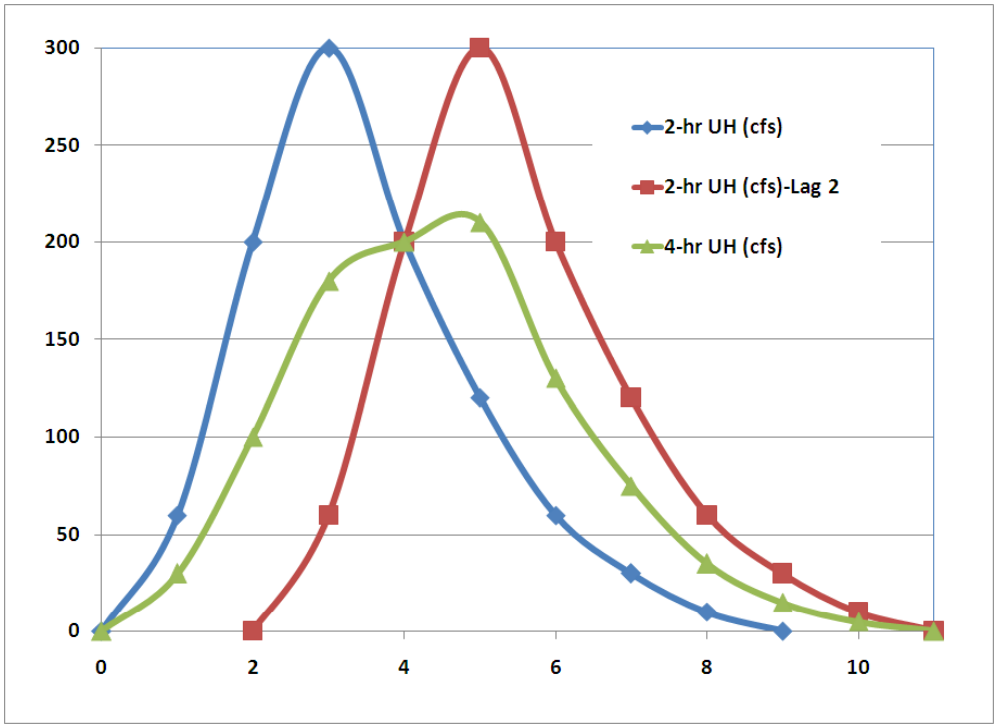


Unit Hydrographs

- 1 in. Excess Rainfall in 2 hr storm (0.5 in/hr) → 2-hr UH
- 1 in. Excess Rainfall in 12 hr storm (1/12 in/hr) → 12-hr UH
- 1 in. Excess Rainfall in 24 hr storm (1/24 in/hr) → 1-day UH
- 2 in. Excess Rainfall in 3-hr storm → 2*runoff of 3-hr UH
- 1/2 in. Excess Rainfall in 3-hr storm → 1/2*runoff of 3-hr UH

Lagged Hydrograph

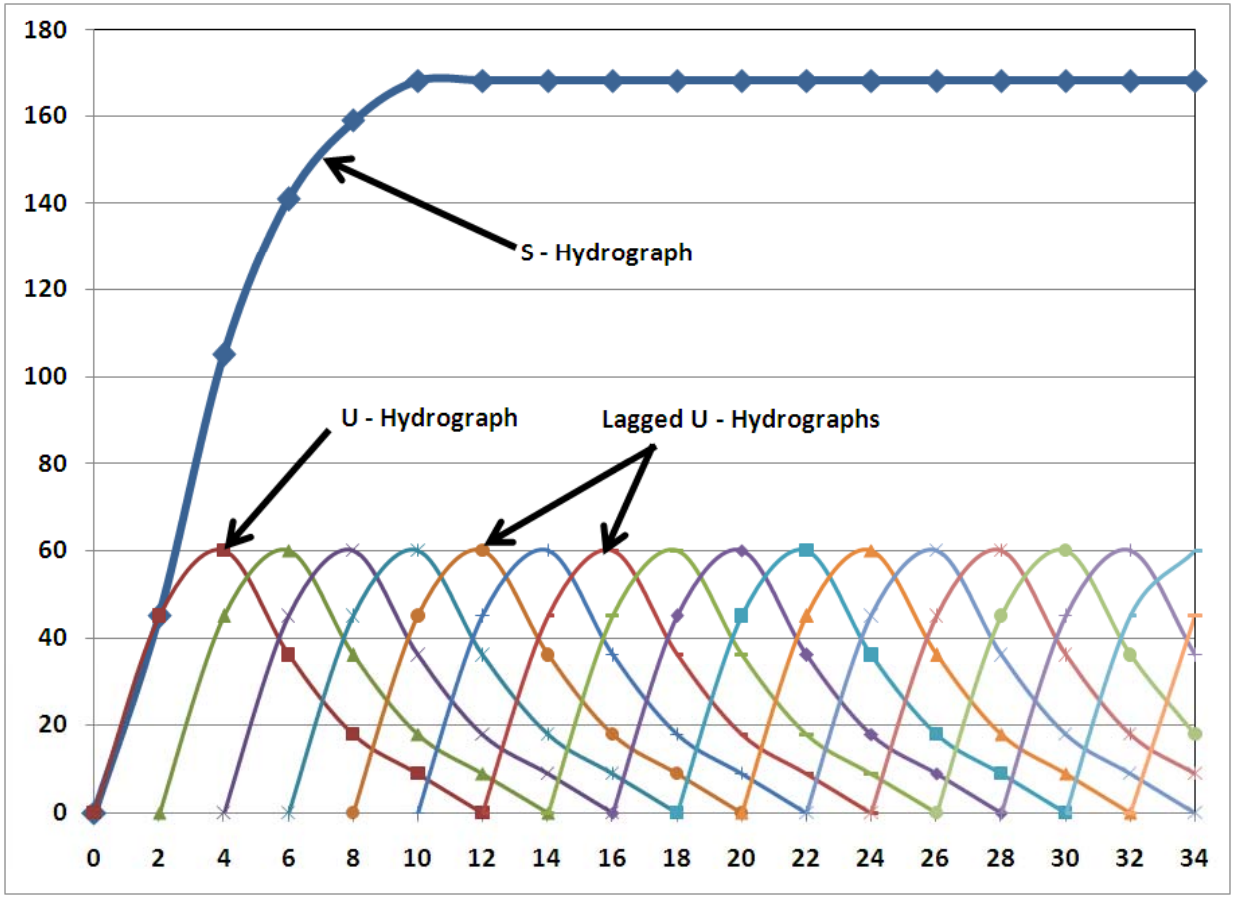
- **Given a 2-hr UH, a 4-hr UH can be derived.**
  - **Plot the 2-hr UH**
  - **Plot another 2-hr UH, lagged 2 hrs**
  - **Add the ordinates of the UHs and divide by 2to get 4-hr UH**



Time (hr)	2-hr UH (cfs)	2-hr UH (cfs)-Lag2	4-hr UH (cfs)
0	0		0
1	60		30
2	200	0	100
3	300	60	180
4	200	200	200
5	120	300	210
6	60	200	130
7	30	120	75
8	10	60	35
9	0	30	15
10		10	5
11		0	0

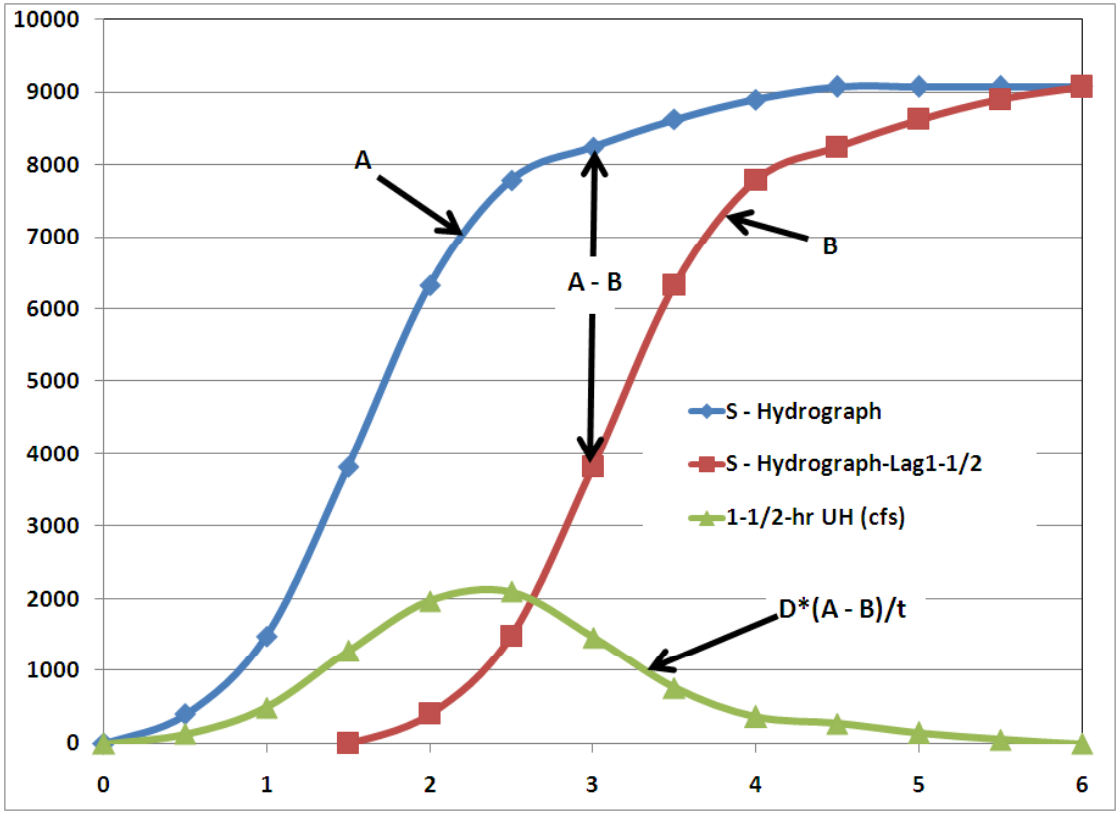
S - Hydrograph

- Continuously lagging a 1-hr UH represents the direct runoff from a continuous excess rainfall of 1 in./hr.
- This is an S - Hydrograph



UH of Different Duration from SH

- Lagging to obtain UH of a different duration is restricted to multiples of the original duration
- To obtain a non-multiple duration UH, use the S-Hydrograph method
- Plot an S – Hydrograph
- Plot another S – Hydrograph, lagged by a time interval equal to the desired duration
- Take the difference between the two to get new UH



Hydrographs of Different Duration

- **S - Hydrograph**

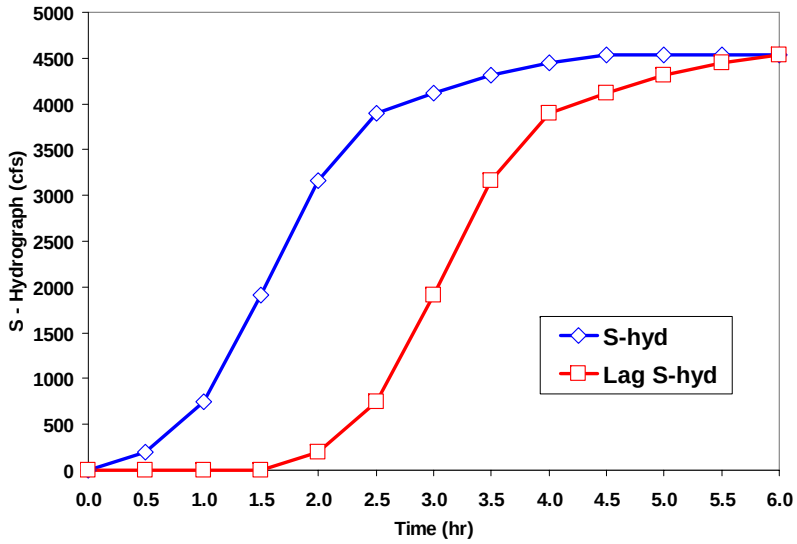
$$SH(0.5) = \Delta t[UH(t)] = 0.5[404]$$

$$SH(1) = 0.5[UH(1) + UH(0.5)]$$

$$SH(t) = \Delta t\left[\sum_{j=0}^{N-M+1} UH(t - j\Delta t)\right]$$

$$= \Delta t[UH(t) + UH(t - \Delta t) + \ldots + UH(t - (N - M + 1)\Delta t)]$$

Time hr	1/2-hr UH cfs/in	S-hyd cfs
0.0	0	0.0
0.5	404	202
1.0	1079	742
1.5	2343	1913
2.0	2506	3166
2.5	1460	3896
3.0	453	4123
3.5	381	4313
4.0	274	4450
4.5	173	4537
5.0	0	4537
5.5	0	4537
6.0	0	4537

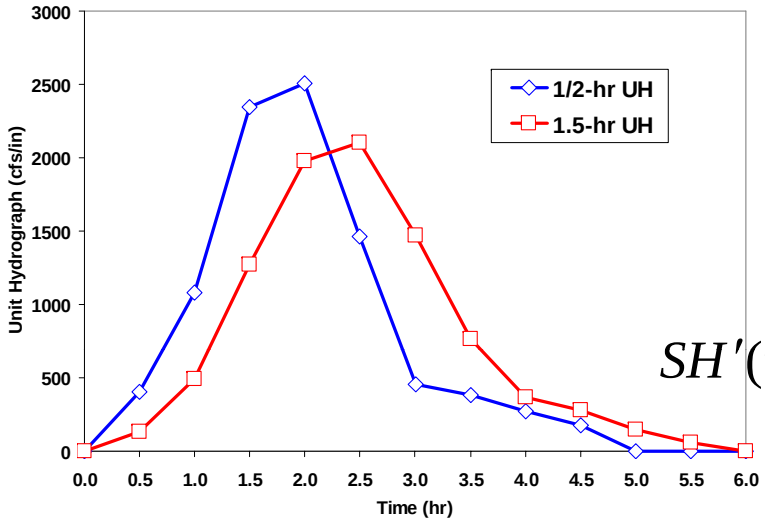


Hydrographs of Different Duration

- Advance (lag) the *S – Hydrograph* by a time equal to the new desired duration $\Delta t'$
- Subtract this *Lagged S – Hydrograph* $SH'(t-\Delta t')$ from the original *S – Hydrograph* to get the *new Unit Hydrograph* with duration $\Delta t'$

$$UH'(t) = \frac{1}{\Delta t'}\left[SH(t) - SH(t-\Delta t')\right]$$

Hydrograph of Different Duration



Find: 1.5-hr UH from ½-hr UH

$$SH'(t-\Delta t')\quad UH'(t)=\frac{1}{\Delta t'}\left[SH(t)-SH(t-\Delta t')\right]$$

Time	1/2-hr UH	S-hyd	Lagged S-hyd	1.5-hr UH
hr	cfs/in	cfs	cfs	cfs/in
0.0	0.0	0.0	0.0	0.0
0.5	404	202	0	135
1.0	1079	742	0	494
1.5	2343	1913	0	1275
2.0	2506	3166	202	1976
2.5	1460	3896	742	2103
3.0	453	4123	1913	1473
3.5	381	4313	3166	765
4.0	274	4450	3896	369
4.5	173	4537	4123	276
5.0	0	4537	4313	149
5.5	0	4537	4450	58
6.0	0	4537	4537	0