Flood Routing (Cont.),
Lecture 10, 05/02/2013

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Adapted from textbook and notes of Philip B. Bedient

Reservoir Routing
Storage Indication Method

Known — Un Known

$$I_1 + I_2 + \left(\frac{2S_1}{dt} - Q_1\right) = \left(\frac{2S_2}{dt} + Q_2\right)$$

1. LHS of Eqn is known
2. Known $2S/dt + Q$ as fcn of Q
3. Solve for Q_2 from $2S_2/dt + Q_2$

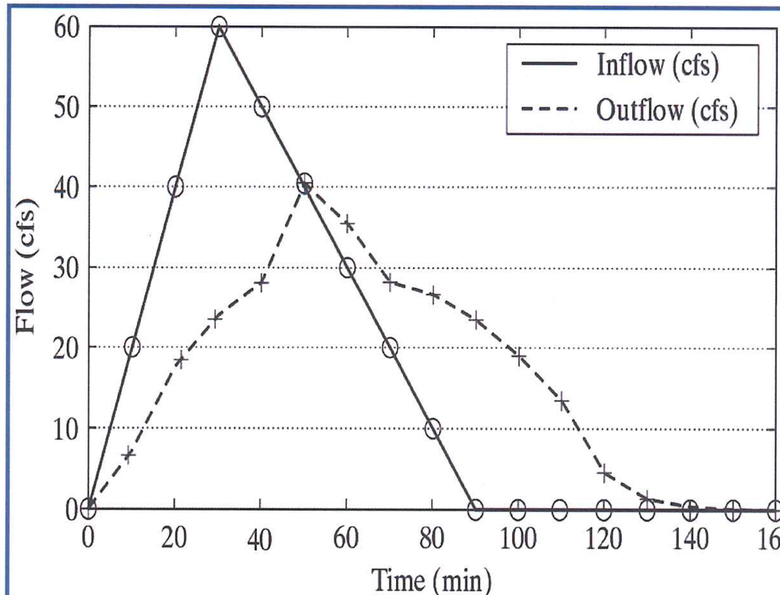


Figure E4.5(a)

Hydrographs.

Repeat each time step

(3)

$$\Sigma I - \Sigma O = \frac{\Delta S}{\Delta t}$$

$$\frac{I^n + I^{n+1}}{2} - \left(\frac{O^n + O^{n+1}}{2}\right) = \frac{S^{n+1} - S^n}{\Delta t}$$

$\times 2$

$$I^n + I^{n+1} - O^n - O^{n+1} = \frac{2S^{n+1}}{\Delta t} - \frac{2S^n}{\Delta t}$$

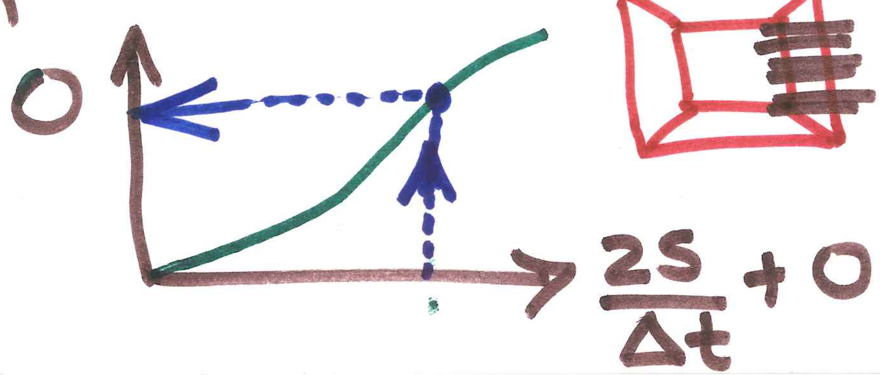
n: current time (known) step

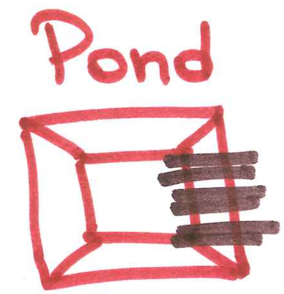
$n+1$: New or next time (unknown) step

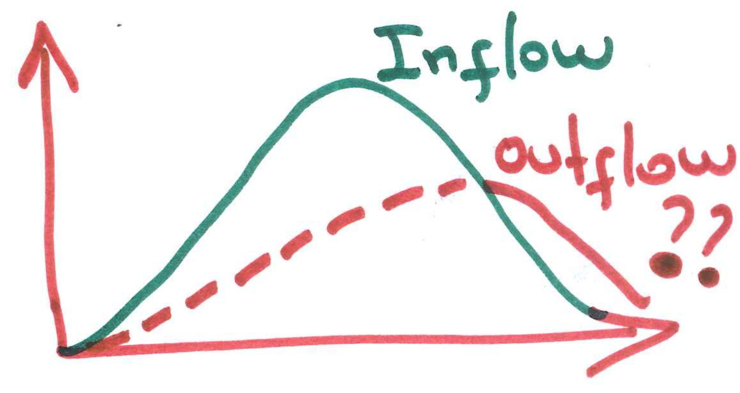
$$I^n + I^{n+1} + \frac{2S^n}{\Delta t} - O^n = \frac{2S^{n+1}}{\Delta t} + O^{n+1}$$

Known

We need to know this







Storage Indication Curve

- Relates *Q* and storage indication, *(2S / dt + Q)*
- Developed from topography and outlet data
- Pipe flow + weir flow combine to produce Q (out)

Δt : time step

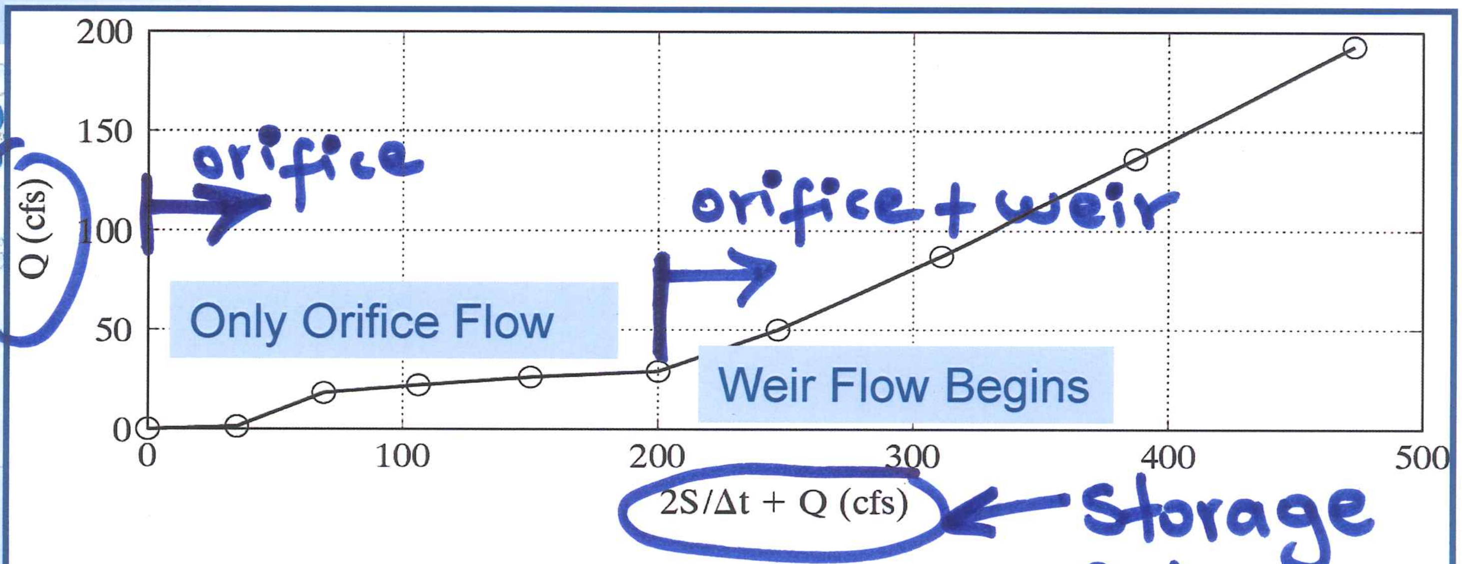


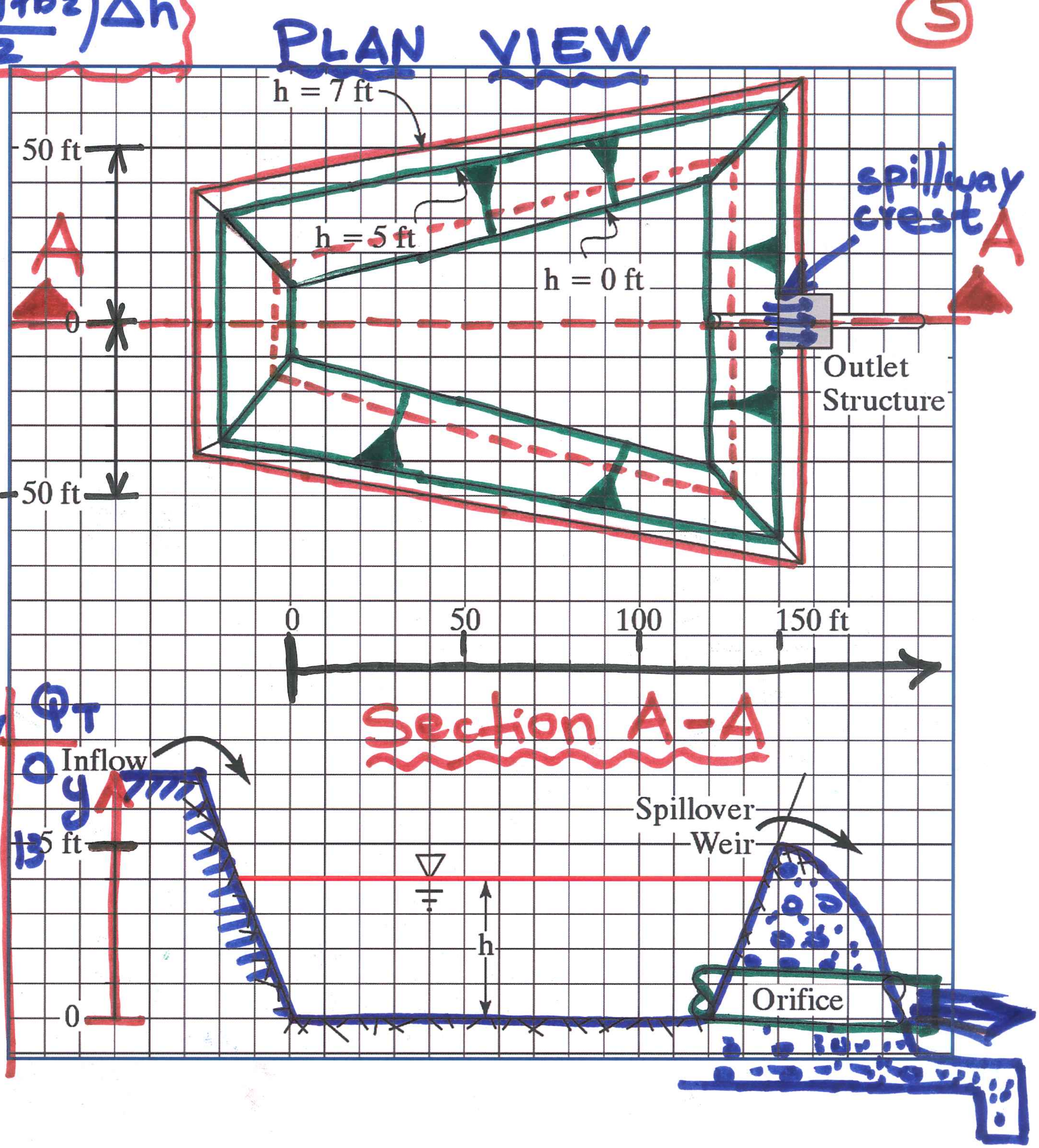
Figure E4.5(c)

Storage indication curve.

Example Reservoir Routing

Storage Indication Method

$A = \left(\frac{b_1 + b_2}{2}\right)\Delta h$



y	A (ft²)	ΔS (ft³)	S (ft³)	Q_o	Q_w	Q_T
0	6000	0	0	0	0	0
1	7500	6750	6750	13	0	13
2	⋮	⋮	⋮	⋮	⋮	
⋮	↓	↓	↓	↓	↓	

(6)

C_0 = 0.9 (for this problem)

$$Q_o = C_o A \sqrt{2gh}$$

D = 1.5 ft

$$Q_o = 0.9 \times \pi \times \frac{1.5^2}{4} \sqrt{2 \times 32.2 \times 1}$$

$$\boxed{Q_o = 13 \text{ cfs}}$$

7a

Storage Indication Method

- Initial reservoir is empty
- dt = 10 minutes
- Note that outlet consists of weir and orifice.
- Weir crest at h = 5.0 ft
- Orifice centerline is assumed to be at h = 0 ft
- Area (6000 to 17,416 ft^2)
- Volume ranges from 6772 to 84006 ft^3

STEPS

- Develop Q (orifice) vs h
- Develop Q (weir) vs h
- Develop A and Vol (or S) vs h
- $2S/dt + Q$ *vs* Q where **Q is sum of weir and orifice flow rates**

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Storage Indication Curve

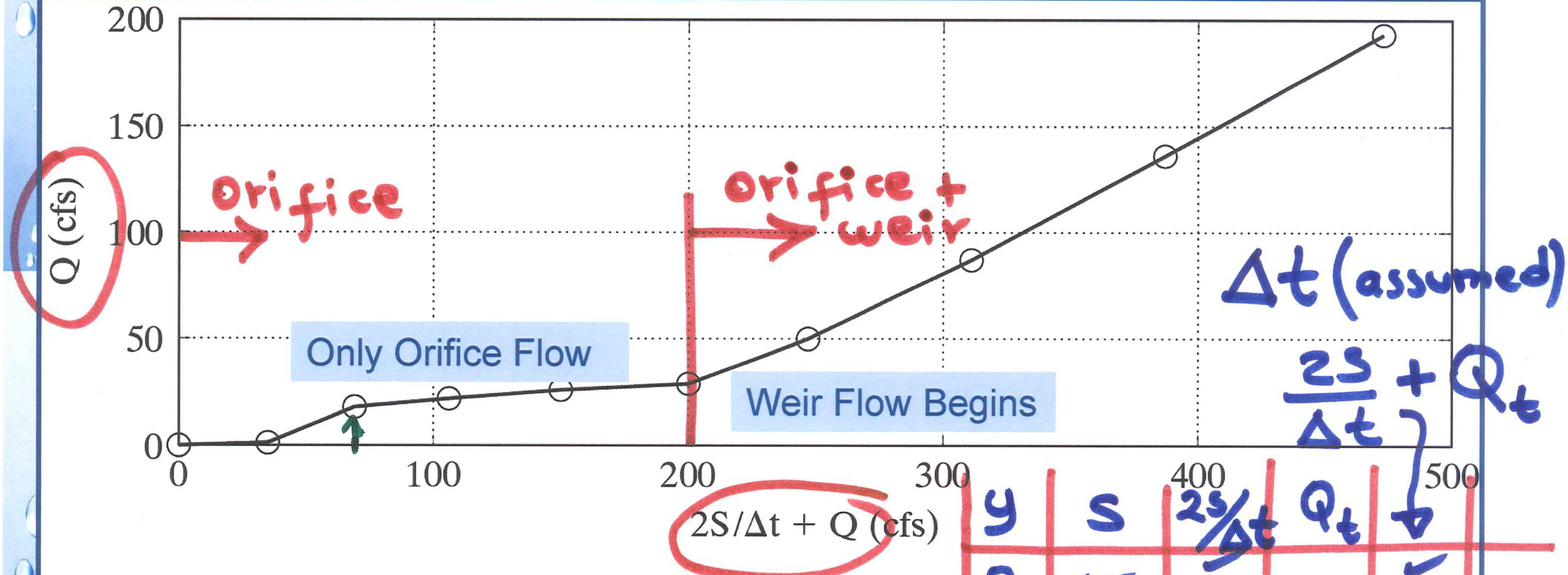

Figure E4.5(c)

Storage indication curve.

y	S	2S/Δt	Q_t	↓
0	✓	✓		✓
1	✓	✓		✓
2	✓	✓		✓
3	✓	✓		✓
4	✓	✓		✓
5...	✓	✓		✓

$\Delta t = 10$ min (8)

Storage Indication Inputs

height h - ft	Area 10^3 ft^2	Cum Vol (S) 10^3 ft^3	Q total cfs	$2S/dt + Q_n$ cfs
0	6	0	0	0
1	7.5	6.8	13	35
2	9.2	15.1	18	69
3	11.0	25.3	22	106
4	13.0	37.4	26	150
5	15.1	51.5	29	200
7	17.4	84.0	159	473

Storage-Indication

Note that: $\frac{2S}{\Delta t} - Q = \frac{2S}{\Delta t} + Q - 2Q$

(9)

Storage Indication Tabulation

initial condition

from storage indication curve

Time (min)	I_n	$I_n + I_{n+1}$	$(2S/dt - Q)_n$	$(2S/dt + Q)_{n+1}$	Q_{n+1}
0	0	0	0	0	0
10	20	20	0	20	7.2
20	40	60	5.6	65.6	17.6
30	60	100	30.4	130.4	24.0
40	50	110	82.4	192.4	28.1
50	40	90	136.3	226.3	40.4
60	30	70	145.5	215.5	35.5

$\frac{2S}{\Delta t} + Q - 2Q = \frac{2S}{\Delta t} - Q$

Time 2

Note that **20 - 2(7.2) = 5.6** and is repeated for each one

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S-I Routing Results

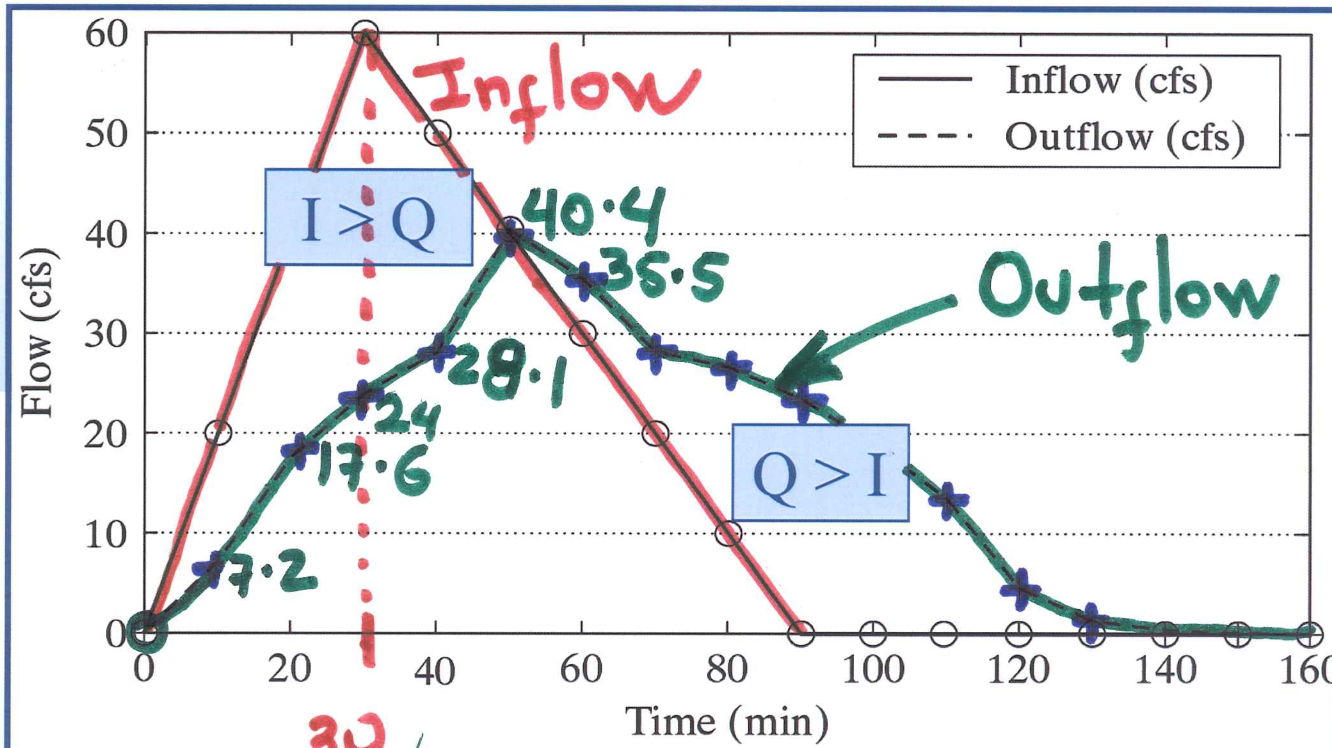


Figure E4.5(a)

Hydrographs.

Show Excel Spreadsheet

11a

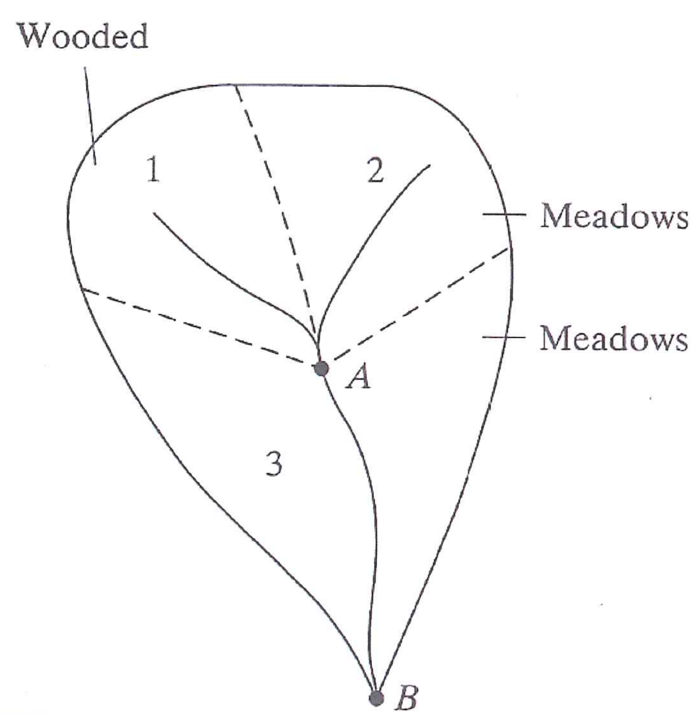
Review on Unit Hydrographs (Solve in class problems 2.18-2.20)

11 b

2.18. Develop storm hydrographs from UHs of subareas 1 and 2 shown in Figure P2–18 for the given rainfall and infiltration.

t (hr)	*i* (in./hr)	*f* (in./hr)
1	0.5	0.4
2	1.1	0.2
3	3	0.2
4	0.9	0.2

Time (hr)	0	1	2	3	4	5	6	7	8	9
UH_1 (cfs)	0	200	450	650	450	300	150	0		
UH_2 (cfs)	0	150	300	500	350	250	125	100	50	0



There is one missing information in this problem. The duration of both UHs is one hour.

Solution

P

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Time (hr)	*i* (in/hr)	*f* (in/hr)	Net Rainfall Intensity (in/hr)	Net Rainfall depth (in)
1	0.5	0.4	0.1	**0.1**
2	1.1	0.2	0.9	**0.9**
3	3	0.2	2.8	**2.8**
4	0.9	0.2	0.7	**0.7**

Sub area 1

Time (hr)	UH1	P1*UH1 (cfs)	P2*UH1 (cfs)	P3*UH1 (cfs)	P4*UH1 (cfs)	Q1
0	0	0				0
1	200	20	0			20
2	450	45	180	0		225
3	650	65	405	560	0	1030
4	450	45	585	1260	140	2030
5	300	30	405	1820	315	2570
6	150	15	270	1260	455	2000
7	0	0	135	840	315	1290
8			0	420	210	630
9				0	105	105
10					0	0

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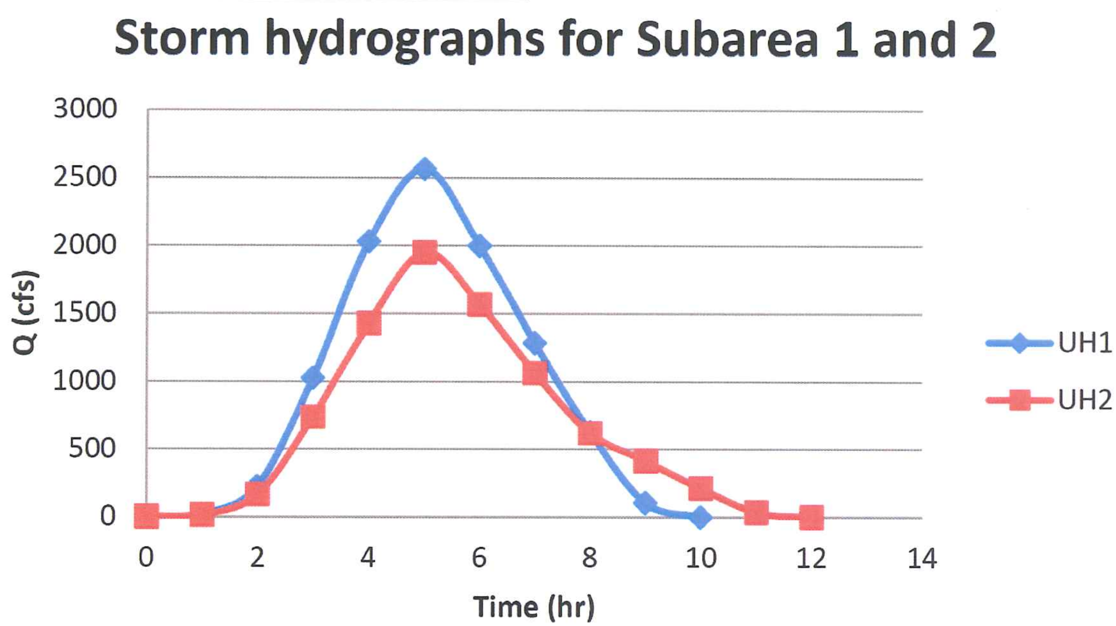
Solution (Cont.)

Sub area 2

Time (hr)	UH2	P1*UH2 (cfs)	P2*UH2 (cfs)	P3*UH2 (cfs)	P4*UH2 (cfs)	Q2
0	0	0				0
1	150	15	0			15
2	300	30	135	0		165
3	500	50	270	420	0	740
4	350	35	450	840	105	1430
5	250	25	315	1400	210	1950
6	125	12.5	225	980	350	1567.5
7	100	10	112.5	700	245	1067.5
8	50	5	90	350	175	620
9	0	0	45	280	87.5	412.5
10			0	140	70	210
11				0	35	35
12					0	0



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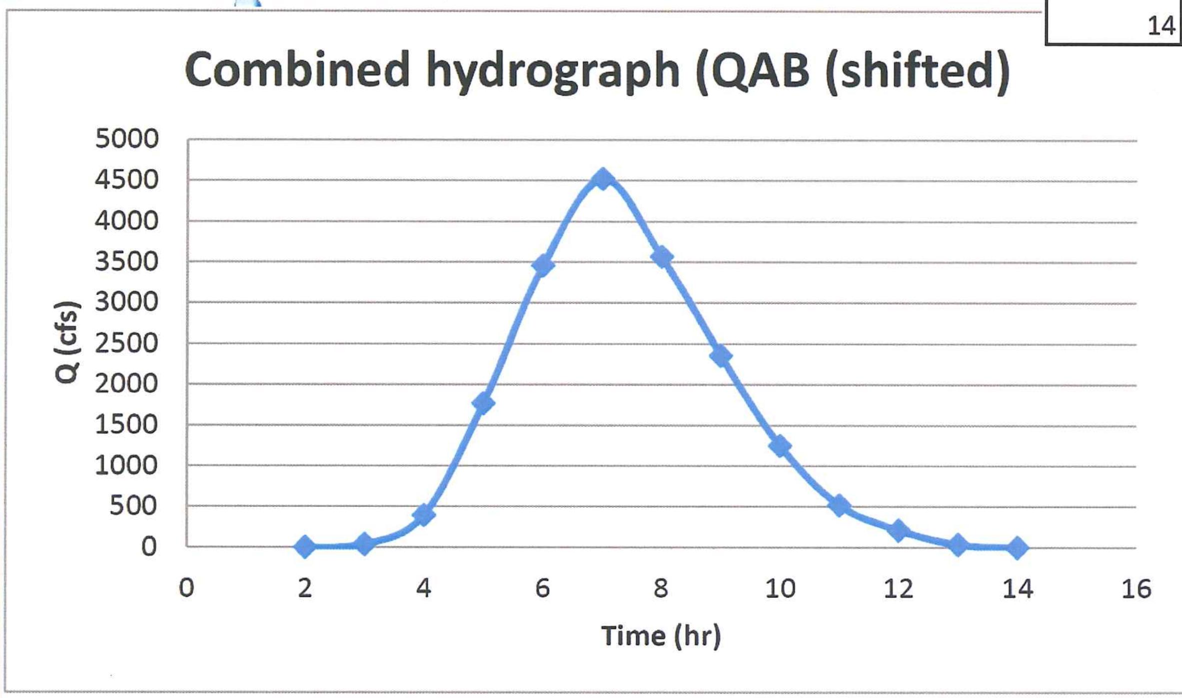
2.19. Develop a combined storm hydrograph at point A in the watershed (Fig. P2–18) and lag route (shift in time only) assuming that travel time from point A to B is exactly 2 hr.

Solution

We add the ordinates Q1 and Q2 from problem 2.18 to develop the combined storm hydrograph at point A. We then account for a 2-hr lag between points A and B to create a combined hydrograph.

Time (hr)	Q1 (cfs)	Q2 (cfs)	QA (cfs)	QAB (shifted) (cfs)
0	0	0	0	
1	20	15	35	
2	225	165	390	0
3	1030	740	1770	35
4	2030	1430	3460	390
5	2570	1950	4520	1770
6	2000	1567.5	3567.5	3460
7	1290	1067.5	2357.5	4520
8	630	620	1250	3567.5
9	105	412.5	517.5	2357.5
10	0	210	210	1250
11		35	35	517.5
12		0	0	210
13				35
14				0



(15)

2.20. Develop a storm hydrograph for subarea 3 from the given UH, add to the combined hydrograph from Problem 2.19, and produce a final storm hydrograph at the outlet of the watershed, *B*.

Time (hr)	UH_3 (cfs)	*t* (hr)	*i* (in./hr)	*F* (in./hr)
0	0	1	0.5	0.4
1	140	2	1.1	0.2
2	420	3	3	0.2
3	630	4	0.9	0.2
4	490			
5	350			
6	210			
7	130			
8	70			
9	0			

Solution

The net rainfall depth was obtained in problem 2.18.

Time (hr)	*i* (in/hr)	*f* (in/hr)	Net Rainfall Intensity (in/hr)	Net Rainfall depth (in)
1	0.5	0.4	0.1	**0.1**
2	1.1	0.2	0.9	**0.9**
3	3	0.2	2.8	**2.8**
4	0.9	0.2	0.7	**0.7**

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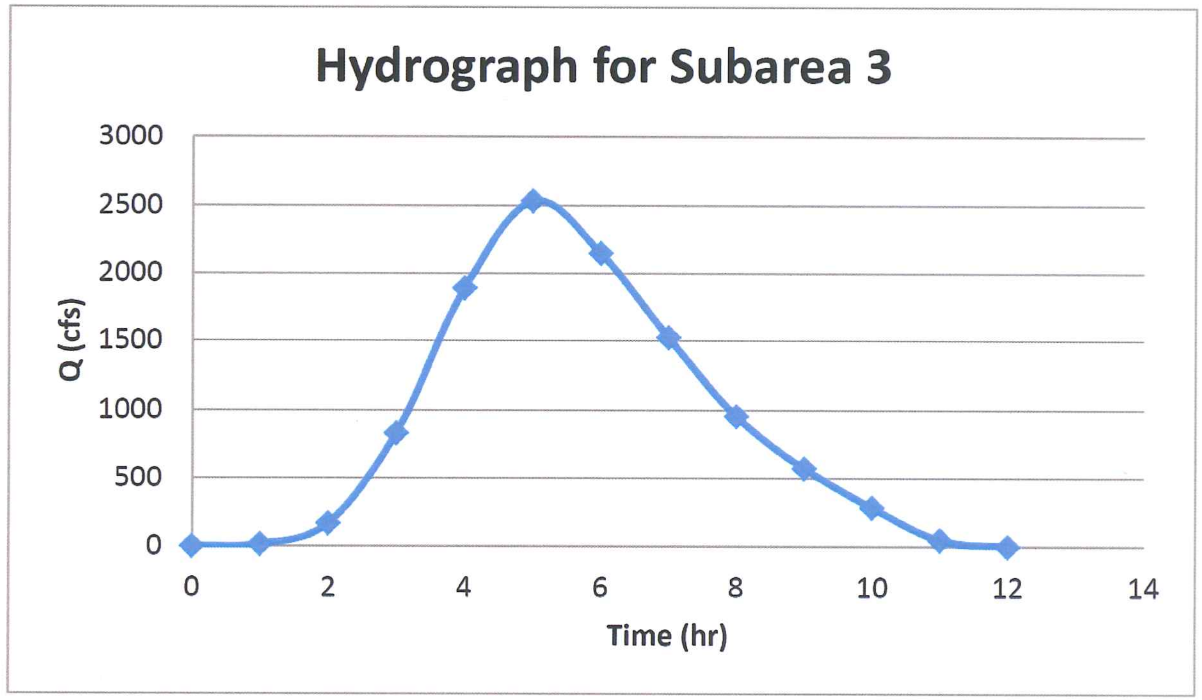
Hydrograph for Subarea 3

Time (hr)	UH1	P1*UH3 (cfs)	P2*UH3 (cfs)	P3*UH3 (cfs)	P4*UH3 (cfs)	Q3
0	0	0				0
1	140	14	0			14
2	420	42	126	0		168
3	630	63	378	392	0	833
4	490	49	567	1176	98	1890
5	350	35	441	1764	294	2534
6	210	21	315	1372	441	2149
7	130	13	189	980	343	1525
8	70	7	117	588	245	957
9	0	0	63	364	147	574
10			0	196	91	287
11				0	49	49
12					0	0



Hydrograph for Subareas 1, 2 and 3

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Time (hr)	QAB (shifted) (cfs)	Q3 (cfs)	Qtotal (cfs)
0	0	0	0
1	0	14	14
2	0	168	168
3	35	833	868
4	390	1890	2280
5	1770	2534	4304
6	3460	2149	5609
7	4520	1525	6045
8	3567.5	957	4524.5
9	2357.5	574	2931.5
10	1250	287	1537
11	517.5	49	566.5
12	210	0	210
13	35	0	35
14	0	0	0

Final hydrograph (Subareas 1, 2 and 3)