Flood Routing

Reservoir / River Routing

•In reservoir routing Storage is a unique function of the outflow discharge S= f(Q).

Reservoir routing

1. Continuity equation

$$I - Q = \frac{dS}{dt}$$

2. Storage equation

$$S = f(Q)$$

River Routing

•In channel routing the storage is a function of both inflow and outflow.

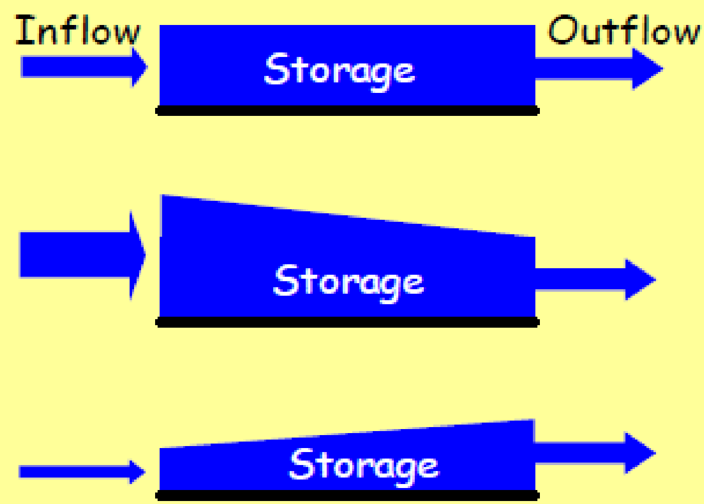
River routing

1. Continuity equation

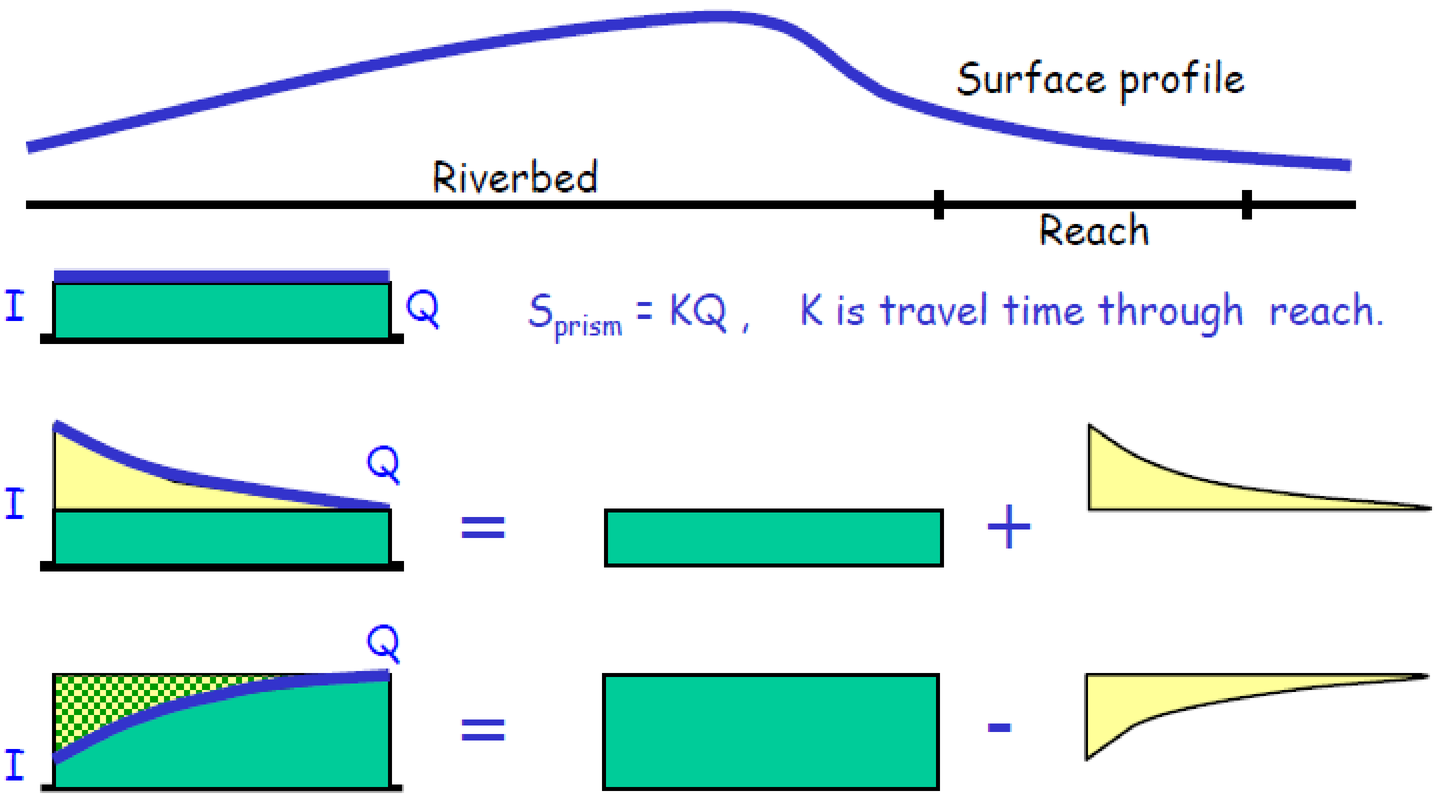
$$I - Q = \frac{dS}{dt}$$

2. Storage equation

$$S = f(I, Q)$$



Channel storage



$S_{prism} = KQ$, K is travel time through reach.

$S = S_{prism} + S_{wedge}$ $S_{prism} = KQ$ $S_{wedge} = xK(I-Q)$

$S=K*(x*I^m+(1-x)*Q^m$

$$S = K[xI + (1-x)Q]$$

$$S=K*(x*I^m+(1-x)*Q^m$$

S= Storage in the channel

I= Inflow

Q= out flow

K and x are constants

m= 0.6 to 1, 0.6 is for rectangular channel and 1.0 is for natural channels.

If m =1 , the above equation changes to

$$S = K[xI + (1-x)Q]$$

X= is a weighing factor varying from 0 to 0.5

When x=0, the equation becomes

$$S=K * Q$$

When x=0.5, both input and output are important

Muskingum method

Continuity equation: $\frac{I_{n-1}+I_n}{2}-\frac{Q_{n-1}+Q_n}{2}=\frac{S_n-S_{n-1}}{\Delta t}$

$$S = K[xI + (1-x)Q]$$

Storage equation: $S_{n-1}=K[xI_{n-1}+(1-x)Q_{n-1}]$

$$S_n=K[xI_n+(1-x)Q_n]$$

$S1=K*(x*I_1+(1-x)*Q_1$

$S2=K*(x*I_2+(1-x)*Q_2$

$S2-S1=K(x*(I_2-I_1)+(1-x)(Q_2-Q_1)$

The above equation can be simplified as

$Q_2= Q_1+B_1*(I_1-Q_1)+B_2(I_2-I_1)$

$B_1= \Delta t/(K*(1-x)+\Delta t/2)$

$B_2= (\Delta t/2-K*x)/(K*(1-x)+\Delta t/2)$

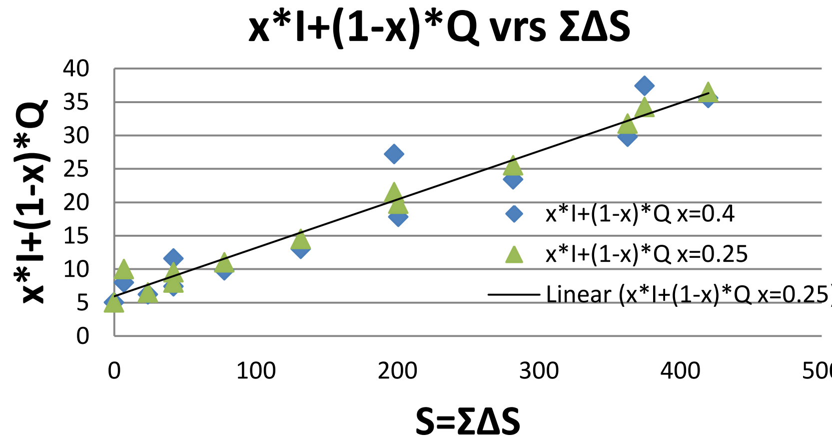
$Q2 =C_0*I_2+C_1*I_1+C_2*Q_1$

Estimation of K and x

$(I_1+I_2)/2*\Delta t-(Q1+Q2)/2*\Delta t=\Delta s$

Step1 : Plot S vrs (x*I+(1-x)*Q and by trial and error we can get x.

We should select x value so that the above curve obtained is far as possible as straight line.



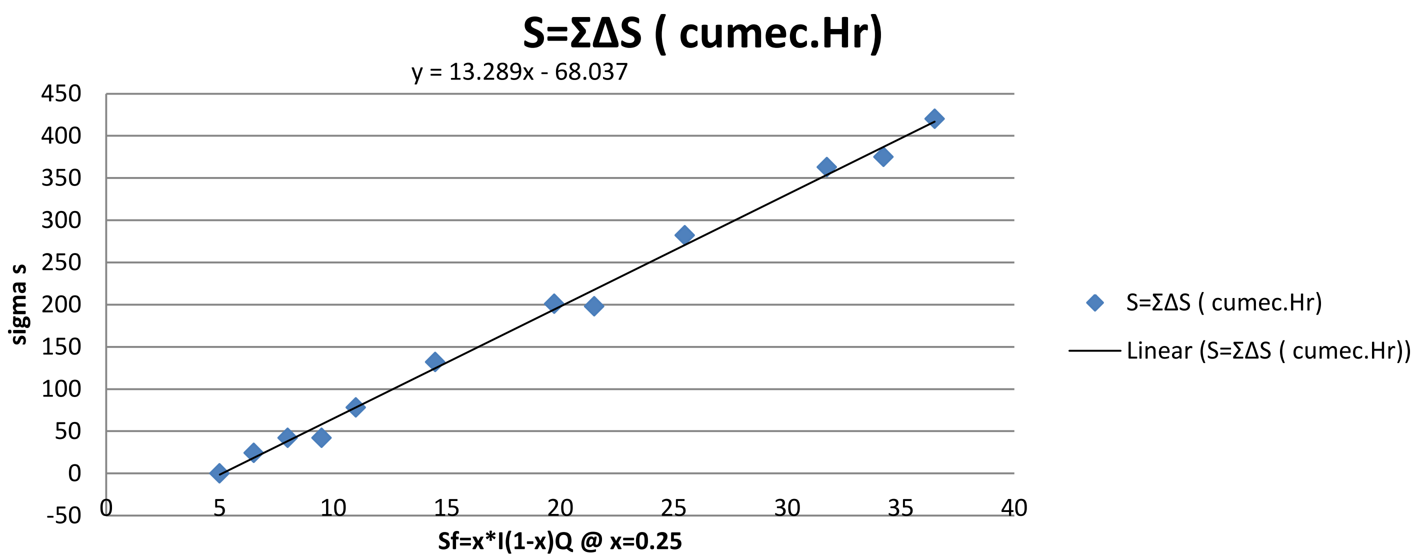
Muskingum routing equation:

$$Q_n = C_0 I_n + C_1 I_{n-1} + C_2 Q_{n-1}$$

$$C_0 = \frac{-Kx+\Delta t/2}{D} \qquad C_2 = \frac{K-Kx-\Delta t/2}{D}$$

$$C_1 = \frac{Kx+\Delta t/2}{D} \qquad D = K(1-x)+\Delta t/2$$

Step 2: Plot ΣΔS vrs (x*I+(1+x)*Q .
The slope of the equation is K



$$Q2 = C_0 * I_2 + C_1 * I_1 + C_2 * Q_1$$

Muskingum routing equation:

$$Q_n = C_0 I_n + C_1 I_{n-1} + C_2 Q_{n-1}$$

$$C_0 = \frac{-Kx + \Delta t/2}{D} \qquad C_2 = \frac{K - Kx - \Delta t/2}{D}$$

$$C_1 = \frac{Kx + \Delta t/2}{D} \qquad D = K(1-x) + \Delta t/2$$

$$Q_2 = Q_1 + B_1 * (I_1 - Q_1) + B_2 (I_2 - I_1)$$

$$B_1 = \Delta t / (K * (1-x) + \Delta t/2)$$

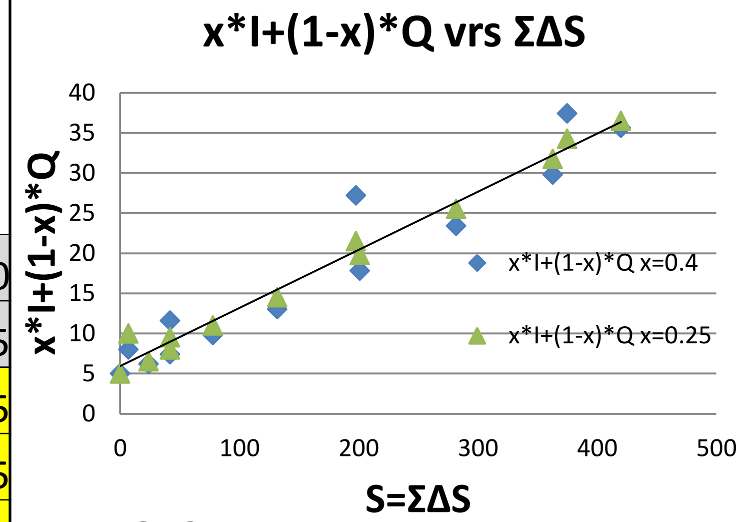
$$B_2 = (\Delta t/2 - K * x) / (K * (1-x) + \Delta t/2)$$

Estimation of X and K

Channel flow example

t(h)	I (inflow (cumec)	Q (Out flow) (cumec)	I-Q	average (I-Q)	ΔS= col5 * Δt (cumec. Hr)	S=ΣΔS (cumec .Hr)	x*I+(1-x)*Q x=0.4	x*I+(1-x)*Q x=0.25
1	2	3	4	5	6	7	8	10
							0.4	0.25
0	5	5	0			0	5	5
6	20	6	14	7	42	42	11.6	9.5
12	50	12	38	26	156	198	27.2	21.5
18	50	29	21	29.5	177	375	37.4	34.25
24	32	38	-6	7.5	45	420	35.6	36.5
30	22	35	-13	-9.5	-57	363	29.8	31.75
36	15	29	-14	-13.5	-81	282	23.4	25.5
42	10	23	-13	-13.5	-81	201	17.8	19.75
48	7	17	-10	-11.5	-69	132	13	14.5
54	5	13	-8	-9	-54	78	9.8	11
60	5	9	-4	-6	-36	42	7.4	8
66	5	7	-2	-3	-18	24	6.2	6.5
Δt	6							

Estimation of x

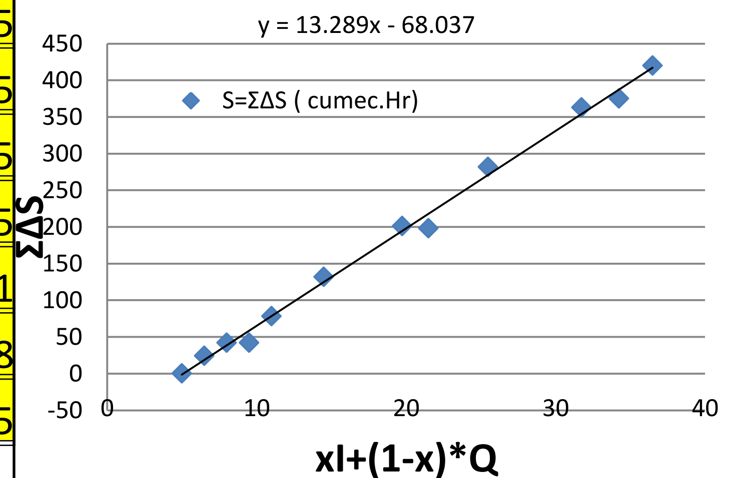


X=0.25

K= 13.28

$$S = K[xI + (1-x)Q]$$

Estimation of K



Time hrs	inflow(I) cumec	C0*I2	C1*I1	C2*Q1	O(cumec)
0	5				**5.00**
6	20	-0.49	2.44	2.69	4.63
12	50	-1.23	9.75	2.49	11.00
18	50	-1.23	24.38	5.91	29.06
24	32	-0.79	24.38	15.61	39.20
30	22	-0.54	15.60	21.05	36.11
36	15	-0.37	10.73	19.39	29.75
42	10	-0.25	7.31	15.98	23.05
48	7	-0.17	4.88	12.38	17.08
54	5	-0.12	3.41	9.17	12.46
x	0.25				
k	13.281				
2*k*x	6.64	C0=	**-0.025**		
		C1	**0.488**		
hrs	6	C2	**0.537**		
Numerator for (C0)		**-0.32**			
Numerator for (C1)		**6.32**			
Denominator (D)		**12.96**			

Muskingum routing equation:

$$Q_n = C_0 I_n + C_1 I_{n-1} + C_2 Q_{n-1}$$

$$C_0 = \frac{-Kx + \Delta t/2}{D} \qquad C_2 = \frac{K - Kx - \Delta t/2}{D}$$

$$C_1 = \frac{Kx + \Delta t/2}{D} \qquad D = K(1-x) + \Delta t/2$$

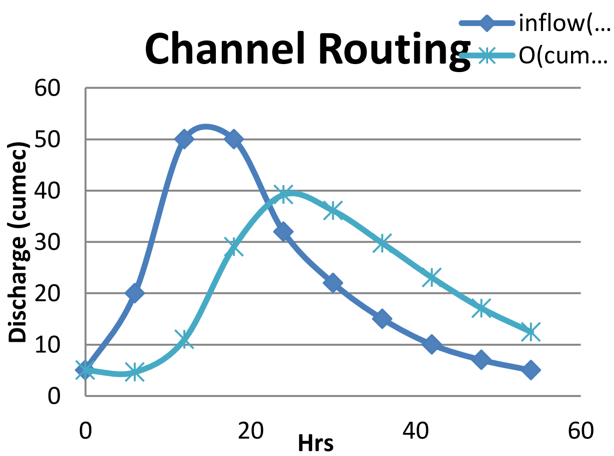
$$Q2 = C_0 * I_2 + C_1 * I_1 + C_2 * Q_1$$

$Q_2 = Q_1 + B_1 * (I_1 - Q_1) + B_2 (I_2 - I_1)$

$B_1 = \Delta t / (K * (1-x) + 0.5 * \Delta t)$

$B_2 = (0.5 * \Delta t - K * x) / (K * (1-x) + 0.5 * \Delta t)$

B1=	0.462963
B2=	-0.02469



Reservoir Routing

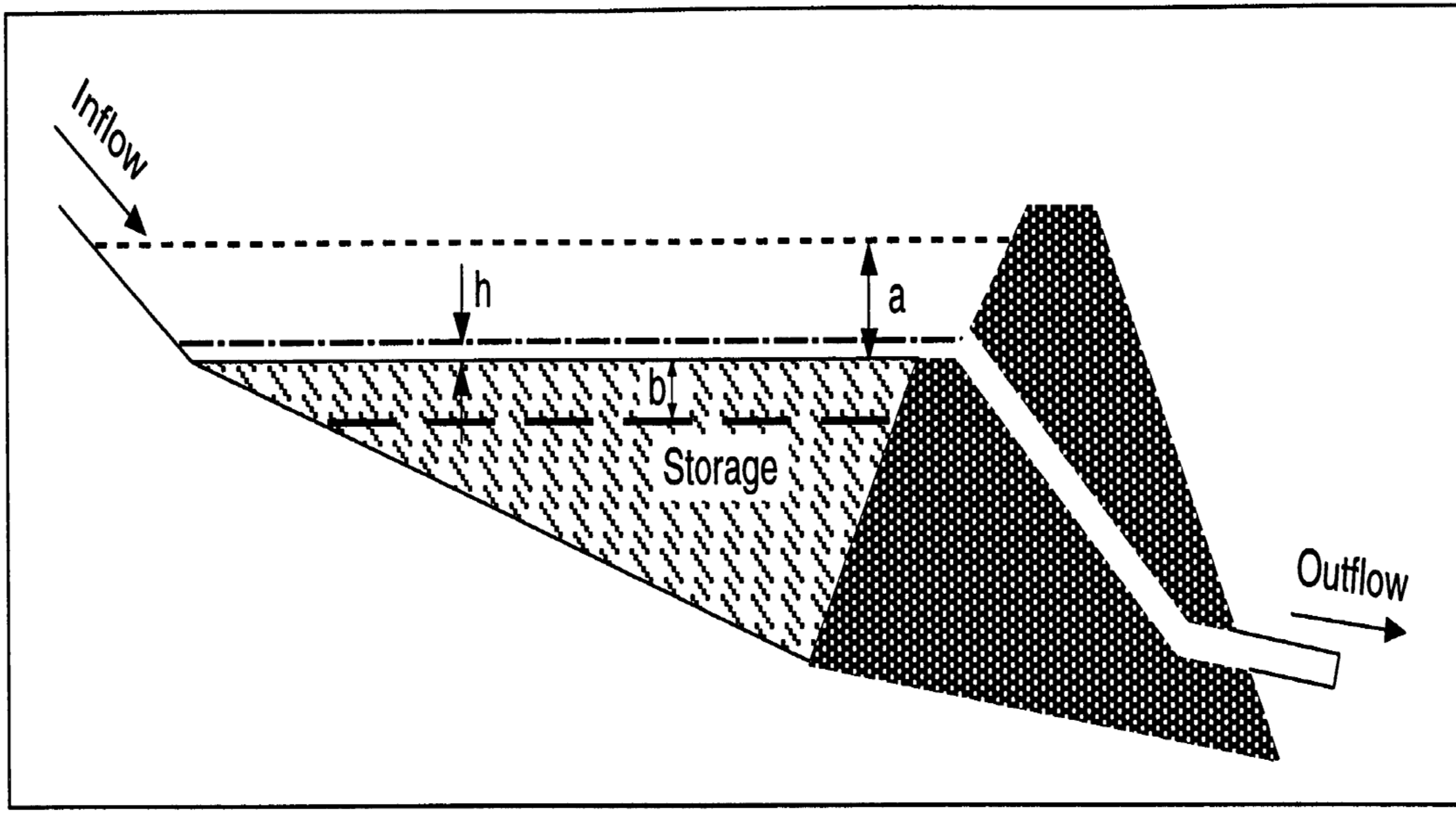


Figure 3. Reservoir Operations: (a) reservoir level after large rain; (b) reservoir level after prolonged drought; (h) reservoir level in typical case just after inflow begins so h is slightly more than zero.

Reservoir routing

Objective:

Determination of outflow hydrograph from given inflow hydrograph.

Outflow hydrograph is determined by:

- Reservoir form, shape
- Hydraulic properties of outlet

Modified Pulse Method

Goodrich Method

Goodrich Method

$$\frac{I_1 + I_2}{2} - \frac{(O_1 + O_2}{2} = \frac{S_2 - S_1}{\Delta t}$$

Continuity Equation

Rewritten

$$2S_2/\Delta t+Q_2=(I_1+I_2)+((2S_1/\Delta t)-Q_1)$$

$$(2S_1/\Delta t)-Q_1= [(2S/\Delta t)+Q) -2Q]$$

Basic Data

Elevation	Storage mcm	Outflow (cumec) Q
100	3.35	0
100.5	3.472	10
101	3.88	26
101.5	4.383	46
102	4.882	72
102.5	5.37	100
102.75	5.527	116
103	5.856	130

Actual Data

Time hrs	inflow(I) cumec
0	10
6	30
12	85
18	140
24	125
30	96
36	75
42	60
48	46
54	35
60	25
66	20

Δt	6 hrs	0.0216

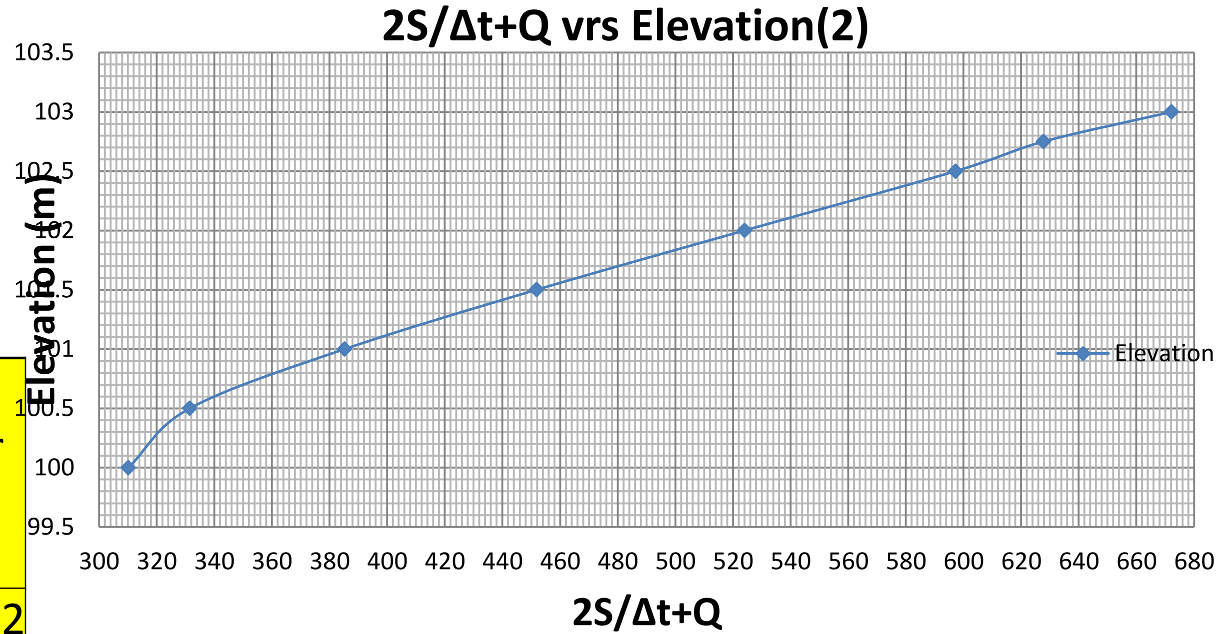
For t=0, reservoir level is 100.6

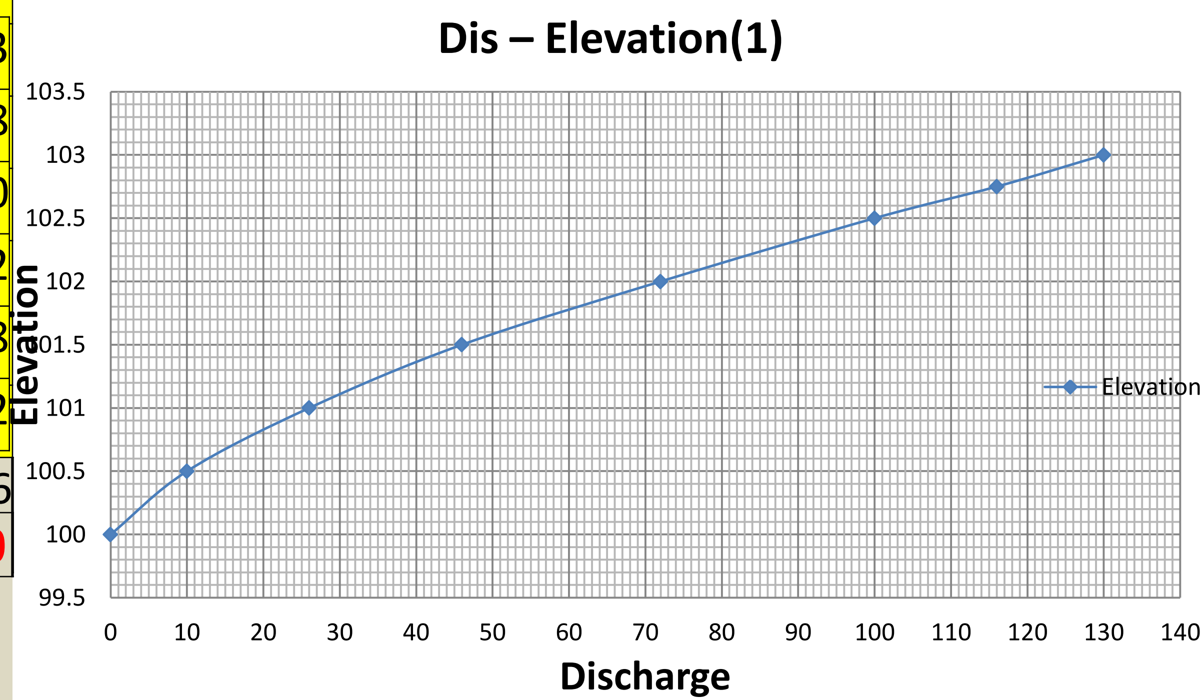
- Plot Elevation vrs to [2S/Δt + O].
- Plot Discharge vrs to Elevation

Basic Data

Elevation	Storage mcm	Outflow (cumec) Q	2S/Δt+Q Cumec_hr
100	3.35	0	310.2
100.5	3.472	10	331.5
101	3.88	26	385.3
101.5	4.383	46	451.8
102	4.882	72	524.0
102.5	5.37	100	597.2
102.75	5.527	116	627.8
103	5.856	130	672.2
	Δt	6 hrs	0.0216
		,=6*60*60/1000000	

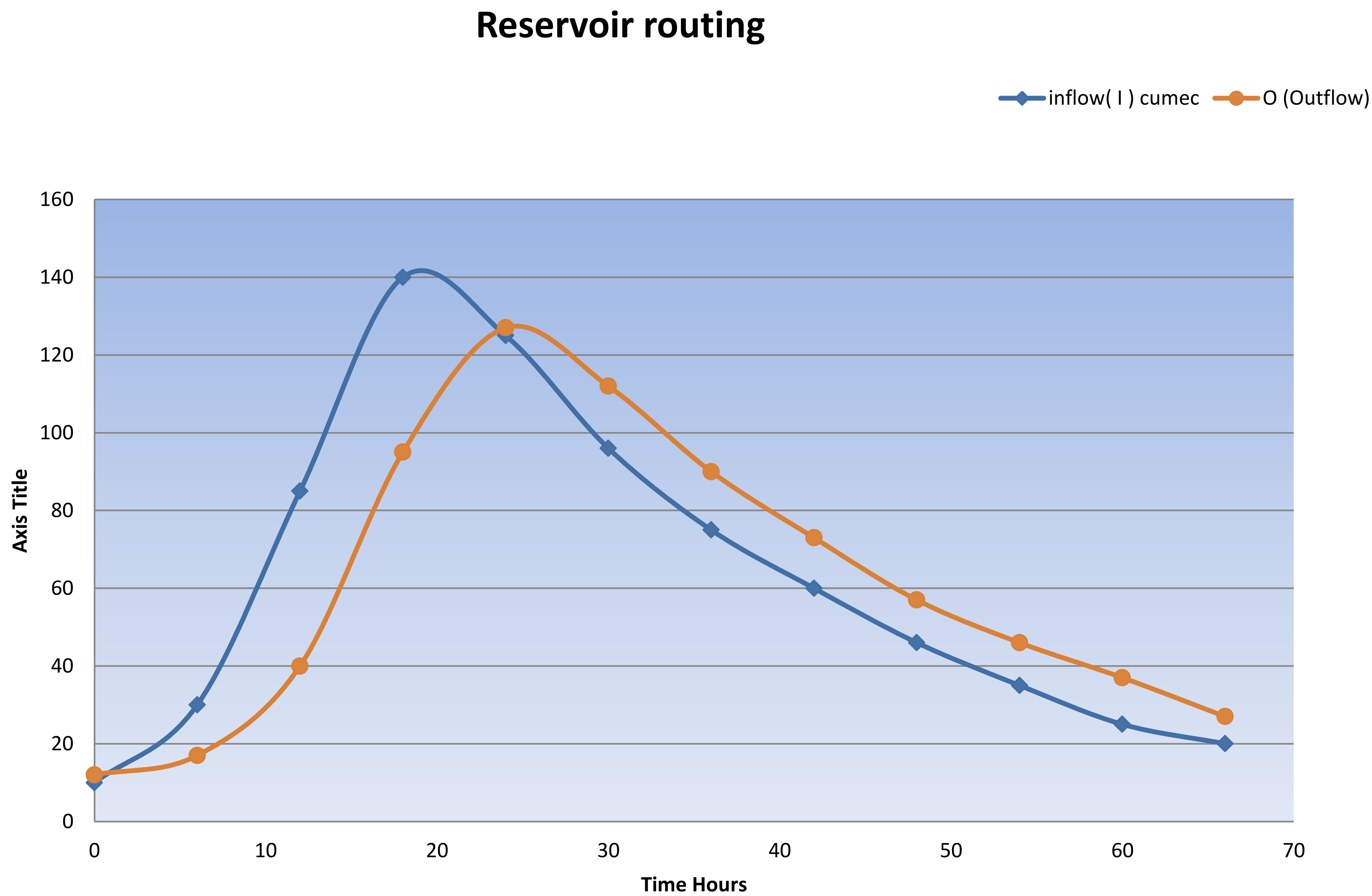
For t=0, reservoir level is 100.6





Time hrs	inflow(I) cumec	I1+I2	(2S/Δt)-Q (col5 (pre)- 2*col7 (pre))	(2S/Δt)+Q (col3+col4)	elevation	O (Outflow)		
1	2	3	4	5	6	7		
0	10			**340.**	100.6	**12**	From Graph(1)	**From Graph (2)**
6	30	40	316	356	**100.75**	**17**	**1. Col 6 and read from graph 2**	
12	85	115	322	437	**101.35**	**40**	2. Col 7 and read from graph 1	
18	140	225	357	582	**102.5**	**95**		
24	125	265	392	657	**102.92**	**127**		
30	96	221	403	624	**102.7**	**112**		
36	75	171	400	571	**102.32**	**90**		
42	60	135	391	526	**102.02**	**73**		
48	46	106	380	486	**101.74**	**57**		
54	35	81	372	453	**101.51**	**46**		
60	25	60	361	421	**101.28**	**37**		
66	20	45	347	392	**101.02**	**27**		
			338					

$(2S_1/\Delta t)-Q_1= [(2S/\Delta t)+Q) -2Q]$ $2S_2/\Delta t+Q_2=(I_1+I_2)+((2S_1/\Delta t)-Q_1)$


Reservoir routing
inflow(I) cumec
O (Outflow)
Axis Title
Time Hours
0
20
40
60
80
100
120
140
160
0
10
20
30
40
50
60
70

Modified Pulse Method

$$\frac{I_1 + I_2}{2} - \frac{(O_1 + O_2}{2} = \frac{S_2 - S_1}{\Delta t}$$

Re arranging the above equation, we get

$$(I_1+I_2)\ \Delta t/2+S_1-(Q_1*\Delta t)/2= S_2+(Q_2*\Delta t)/2$$

End