Calculating the Coefficients of Muskingum and Muskingum-Cunge Methods for a reach from Shatt-Al-Hilla river

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Abstract

To rout the flow in a reach river need first finding the coefficients of the used method. By taking a reach from Shatt- Hilla the study calculates the coefficients of two methods of flow routing: 1- Muskingum method. 2- Muskingum-Cunge method. With the aid of historical data the study finds the different factors that each method depending on.

Key Word: Flood routing, flow routing, hydrologic routing, Muskingum method, Muskingum-Cunge method.

الخلاصة

الخطوة الاولى لاستتباع الجريان في أي نهر بطريقة معينة هي ايجاد معاملات تلك الطريقة. وباستتباع الجريان في شط الحلة باستخدام طريقتين هما: مسكنجم ومسكنجم كونج، وبالاستعانة بالبيانات الحقلية الخاصة بشط الحلة تم التوصل الى معاملات تلك الطرقتين.

الكلمات المفتاحية: توجيه الفيضانات، توجيه تدفق، توجيه هيدروليكي

Introduction

Many studies are deal with flood routing which means a procedure to determine the time and magnitude of flow (i.e., the flow hydrograph) at a point on the watercourse from known or assumed hydrographs at one or more points upstream.[chow:1988]

The importance of flood routing comes from it is used in predicting the characteristics of a flood wave and their change with time in the direction of flow. These characteristics include:[Abida:2005]

1. Maximum water surface elevation and its rate of rise or fall (considered to be an important factor in the planning and design of structures across or along streams and rivers).
2. Peak discharge, which is required in the design of spillways, culverts, bridges and channels sections.
3. Total volume of water resulting from a design flood to assist in the design of storage facilities for flood control, irrigation and water supply.

There are many classification of flood routing methods like flood and synthesis routing, reservoir and river routing. But the most importance classification are hydraulic and hydrologic routing. The main difference between these two types is that: the first class depending on the basic differential equation of flow moment equation and continuity equation. And by solving these equation and use the boundary conditions get equations called saint-venant equations which after solving them get mathematical model explain the wave progressive in the reach. While the hydrologic routing (some time called lumped routing) doesn't directly use the basic differential equation but it is use another equation like storage equation.

The current study find the coefficients of two method of hydrologic routing which are Muskingum and Muskingum-Cunge method for a reach from Shatt-Al-Hilla.

There are many studies introduced Muskingum and Muskingum-Cunge method here are some of these studies:

John D. Fenton steady the Muskingum-Cunge approach for computing the propagation of long waves. He found the corresponding linearised differential equation and he showed that the essential approximation required by the method is that diffusion be small. [Fenton:2011]

Ming- His Hsu use the dynamic wave theory of unsteady flow in open channels, to get a four- point implicit finite- difference method is employed to develop a flash flood routing model for the Tanshui River in Taiwan.[Hsu- 2003]

Mehdi Delphi consider Flood routing in a prismatic channel with solving simultaneous continuity and momentum equation which are known as Saint – Venant equations. If inertia terms in Saint – Venant equations is removed, flow equation with complete inertia terms will be converted to diffusive equation. In his study he has compared the results of full wave and diffusion wave flood routing methods in a reach of Karun river's between Mollasani and Ahvaz station.[Delphi:2010]

Yeou- Koung Tung developed a nonlinear Muskingum model to solve flood rousing in rivers by using the state variable modeling technique. [Tung:1985]

Habib Abida studied Released flows from the Sidi Salem Dam Reservoir on the Medjerda River (Northern Tunisia) were routed downstream along the river lower watercourse using both hydrologic and hydraulic flood Routing techniques. The hydrologic flood routing method used is that of Muskingum while the Hydraulic flood routing procedure used a numerical model RUFICC (Routing Unsteady Flows In Compound Channels). [Abida:2005]

Efrat Morin monitored The floods of the Kuiseb River in the Namib Desert for 46 Years, and provided a unique data set of flow hydrographs from one of the world’s hyperarid regions. The Study objectives were to: (1) subject the records to quality control; (2)model flood routing and transmission losses; and (3)study the relationships between flood characteristics, river characteristics and Recharge into the aquifers. [Morin:2009]

R. Peters found the model of the flood routing in the Lower reaches of the Freiberger Mulde river and its tributaries by using the one-dimensional hydrodynamic modeling system HEC- RAS. Furthermore, this model was used to generate a database to train multilayer feed forward networks. [Peters:2006]

Jan Szolgay studied the relationship between wave speed and discharge for a reach of the Morava River between Moravský Svätý Ján and Záhorská Ves. The modelling results showed that the inclusion of empirical information on the variability of the wave speed with discharge permits a satisfactory degree of accuracy of the prediction of the flood propagation process without needing to calibrate the model on input-output hydrographs. [Szolgay: 2006]

D. L. Fread investigated the range of applicability as governed by the accuracy for two simplified routing model. And determined the routing error for each simplified by systematic comparison with an accurate dynamic routing model (DAMPRK). And presented graphically the error properties of each simplified model as a functions of dominant channel and flood hydrograph parameters. [Fread:1993]

William H. Merkel used the Muskingum-Cunge flood routing procedure and the Natural Resources Conservation Service (NRCS) to make Technical Release 20 (TR-20) hydrologic model. The TR-20 model is an event watershed hydrologic model used to analyze impacts of watershed changes (land use, reservoir construction, channel modification, etc) on volume of runoff and peak discharge. [Merkel:2002]

Birkhead and James(1998) modified the traditional nonlinear Muskingum routing equations to synthesise the rating relationship(relationship between stage and discharge) based on a measured short-term local stage hydrograph at the site of interest, and a corresponding discharge hydrograph at a remote site along the river. Application of the procedures to a section of the Sabie River (South Africa) showed that neglecting bank storage resulted In poor optimization of the storage relationships and Unrealistic estimates of the storage weighting factor. The procedures were success fully modified to account for bank storage by assuming instantaneous response of seepage in the alluvial bank zone, this being justified by the high hydraulic.

Muskingum Method

In this method the downstream outflow can be predicted by using the following equation:

$$O_{j+1} = C_1 I_{j+1} + C_2 I_j + C_3 O_j \qquad \ldots 1$$

Where:

$$C_1 = \frac{\Delta t - 2KX}{2K(1-X) + \Delta t} \quad ...2$$

$$C_2 = \frac{\Delta t + 2KX}{2K(1-X) + \Delta t} \quad ...3$$

$$C_3 = \frac{2K(1-X) - \Delta t}{2K(1-X) + \Delta t} \quad ...4$$

Note that:

$$C_1 + C_2 + C_3 = 1 \quad ...5$$

In which:

O_{j+1}: downstream outflow at time (j+1) (m^3/sec).

O_j: downstream outflow at time (j) (m^3/sec).

I_{j+1}: upstream inflow at time (j+1) (m^3/sec).

I_j: upstream inflow at time (j) (m^3/sec).

K: storage constant (hr).

X: weighting factor (show the relative importance of inflow and outflow in computing storage) (dimensionless).

Δt: time interval (hr).

If observed inflow and outflow hydrographs are available for a river reach, the values of K and X can be determined. Assuming various values of X and using known values of the inflow and outflow, successive values of the numerator and denominator of the following expression for K, can be computed:

$$K = \frac{0.5\Delta t\left[\left(I_{j+1} + I_j\right) - \left(O_{j+1} + O_j\right)\right]}{X\left(I_{j+1} - I_j\right) + (1-X)\left(O_{j+1} - O_j\right)} \quad ...6$$

The computed values of the numerator and the denominator are plotted for each time interval, with the numerator on the vertical axis and the denominator on the horizontal axis. This usually produced a graph in the form of a loop. The value of X that produced a loop closes to single line is taken to be the correct value for the reach, and K, according to equation(6), is equal to the slope of the reach. Since K is the time required for the incremental flood wave to traverse the reach, its value may also be estimated as the observed time of travel of peak flow through the reach.

If observed inflow and outflow hydrograph are not available for determining K and X, their values may be estimated using Muskingum-Cunge method.

Muskingum-Cunge Method

Cunge (1969; Miller and Cunge 1975) advanced the use of the Muskingum method when he explained how the coefficients K and X could be related to the hydraulic properties of a simplified, prismatic channel. This method use the following equations to predict the discharge:

$$Q_{i+1}^{j+1} = C_1 Q_i^{j+1} + C_2 Q_i^j + C_3 Q_{i+1}^j \quad ....7$$

where the flow discharge Q_i^j refers to position i in space and j in time. To solve this equation, the parameters k, and x, required in order to obtain C1, C2, and C3. Thus (k and x) are calculated from the following equations:

$$K = \frac{\Delta x}{C_k} = \frac{\Delta x}{\partial Q / \partial A} \quad ...8$$

$$X = \frac{1}{2}\left(1 - \frac{Q}{B C_k S_o \Delta x}\right) \quad ...9$$

Where:

C_k: is the celerity corresponding to Q and B (m/sec).

B: is the width of the water surface(m).

Q: is the discharge (m^3/sec).

A: is the cross sectional area (m^2).

So: is the bed slope (dimensionless).
Δx: is the increment in space (m).

In addition, Cunge also demonstrated that this solution constitutes an approximate solution of a modified diffusion equation if the parameters k and x are estimated as expressed above. (Ramírez: 2000)

For development of the Muskingum-Cunge method, the Courant number, C, and the cell Reynold's number, D, can be computed as defined and then used to compute C0, C1, and C2.

$C=c\ (\Delta t/\Delta x)$ ...10

$D=Q_{reference}/(\text{Reach Slope}*c*\text{TopWidth}*\Delta x)$ ...11

By substitution get the following equation:

$C_1=(-1+C+D)/(1+C+D)$ ...12

$C_2=(1+C-D)/(1+C+D)$ ...13

$C_3=(1-C+D)/(1+C+D)$ ...14

The right-hand side of equation (8) represents the time of propagation of a given discharge a long a reach of length Δx.

Cunge showed that for numerical stability it is required that (Cunge: 1969):

$$0 \le X \le 1/2 \qquad ...15$$

Flood wave velocity may be estimated by another means by multiplying the average velocity (V) by the ratio (C_k/V) shown in table(1).[U.S. Army Manual:1994]

For natural channel , an average ratio of 1.5 is suggested.[U.S. Army Manual:1994]

Application Case

A reach from Shatt-Al-Hilla is taken as a case study of the research. Shatt-Al-Hilla locates in Hilla city (100 km south of Baghdad city). It is the largest channel withdrawing water from the pool upstream of New Hindiya Barrage, and the main channel that branches from the left side of Euphrates river just the upstream of the New Hindiya Barrage.(SOD:1981)

The average bed slope range from (8-12 cm/km) and the maximum design discharge of Shatt-Al- Hilla is (250 m3/sec).[BWRD:2006]

The reach of Shatt- Al- Hilla that taken as a case study is located between the beginning of the river (0.000 km) to the section (8.600 km) that located before the Al Mahaweel sub canal which branches from Shatt-Al-Hilla at (9.080 km), as shown in figure (1).

Table (2) (columns 2 and 3 and 4) shows the location (km), sub reach length (m), and bed slope of each sub reach in the considered reach.

It is required To find the coefficients of Muskingum and Muskingum-Cung methods for this reach.

Calculating Coefficients of Muskingum method

To find the coefficients of Muskingum method it is required finding the value of (X) and (K).To find these values, assume values for the value of (X), and draw the values of (cumulative storage) or {o.5Δt[(Ij+1+Ij)-(Oj+1+Oj)]} on the vertical axis verses values of (X I+ (1-X) O) or {X(Ij+1-Ij)+(1-X)(Oj+1-Oj)} on the horizontal axis. The resulting shape will be like a loop. Repeat this process for different values of X. The value of X is that which gives the closed loop to straight line, while the value of k represents the slope of that straight line.

For the given data which shown in table (5), the assumed values of X (0.18,0.19,0.20) plot the figures (2) and (3) and (4) with a regression factor on each plot. The closest loop to a straight line was shown in figure (3) with a regression factor (0.8776) and value of (k)(slope of the straight line) equal (31.6 hr) and value of X equal (0.19).

The second step find the values of (C1,C2, and C3) by substituting vales of (X and K) in equations (2,3,4), and use equation (5) for check. The value of (C1,C2, and C3) are (-0. 04,0.36,and0.68) respectively, and (C0+C1+C2=1).

Now for any given inflow hydrograph for the studied reach the outflow hydrograph can be predicated by using equation (1). For the given inflow hydrograph the predicated outflow hydrograph shown in figure(6). It is shown from figure (5) that the maximum inflow discharge is (224 cumics) occurs at time(8.8 day (211.2 hour)), while the maximum observed downstream discharge is (215 cumics) occurs time (10 day (240 hour)), while the maximum downstream discharge according to equatin (1) is (218.832 cumics) occurs at (9.2 day (220.8 hour)).

Calculating the Coefficients of Muskingum-Cung Method

Before use the Muskingum-Cunge method in routing the flow at any reach, the reach must satify the following condition:

$$T_r S_o \left(\frac{g}{d_o} \right) \geq 15 \qquad \ldots 16$$

By substitute the given data (8*24*3600*0.000085*9.81/5) found that this condition is satisfy.

After check the above condition, choose the value of Δt from the smallest value of these four criteria:

1. The user defined computation interval.
2. The time of rise of the inflow hydrograph divided by 20 (Tr/20 = 8*24/20 = 9.6 hr).
3. The travel time trough the channel reach (16 day * 24 hr =384 hr).
4. The value of Δt that satisfy the following criteria ($(T_r/\Delta t)>5$ by substitute the given data get (((8*24)/9.6) =20hr).

Then the value of Δt=9.6hr.

The taken reach can be divided into 13 sub reach according to longitudinal slope and bed level as shown in table (2). Then the next step is compare the each sub reach's length with the maximum allowable length

$$\Delta X \leq \frac{1}{2}\left(c\Delta t + \frac{Q_o}{BS_o c} \right) \qquad \ldots 17$$

To decrease number of calculations, this process may be done for the critical value of the sub reach's characters which is (3000 m) length, with (Q_o= $(Q_{max}+Q_{Normal})/2$= ((224+170)/2= 197), c= C_k/V*V= 1.67*0.677). So the allowable length is

$$\frac{1}{2}\left(1.6*0.677*9.6*3600 + \frac{197}{100*0.000085*1.6*0.67} \right) = 29527\text{m}$$

This length is much greater than 3000m so Misgingum-Cunge method is allowable to use.

The next step is to calculate the stage at each station for two values of discharge (170,224) m^3/s by using the following equation

h = 0.507 Q0.431 + ho …18

The value of ho can be taken from table(2) column (5).

This method required find the values of the stage (h), the discharge (Q), the cross sectional area (A), the top width (W), and the flow velocity (V)at the peak and ordinary conditions . these values are shown in table (6).

The next step find the values C and D by using equations (10 and 11). Then find the values of C1, C2, and C3 through the equations (12,13,14). The calculated values shown in table(7).

The downstream outflow from each sub reach can be calcutated by using equation (7). the results shown in table (8).

Figure (6) shows the Muskingum-Cunge downstream hydrograph.

Conclusions

1- The coefficients of Muskingum method were as follow C_1=-0.04, C_2=0.36, and C_3=0.68.
2- The coefficients of Muskingum-Cunge method were tabulated in table (7).
3- Thecoefficients of Muskingum method have three values for (C_1, C_2, and C_3), while the coefficients of Muskingum-Cunge method have a number of values for each (C_1, C_2, and C_3) equal to the number of sub reaches.
4- The coefficients of the two method should satisfy the condition ($C_1+C_2+C_3=1$)

Recommendations

1- Use actual data in the two method to find the method that gives the values close to the actual data.
2- Use another method of flow routing on the same reach till reach the most accurate method.
3- Apply the methods of flow routing opn the other main river.
4- Use the results that get by the methods of flow routing in design of structures on the river like weir, gates, and dams.

Table(1) Ratio(C_k/V)

Channel shape	Ratio C_k/V
Wide rectangular	1.67
Wide parabolic	1.44
Triangular	1.33

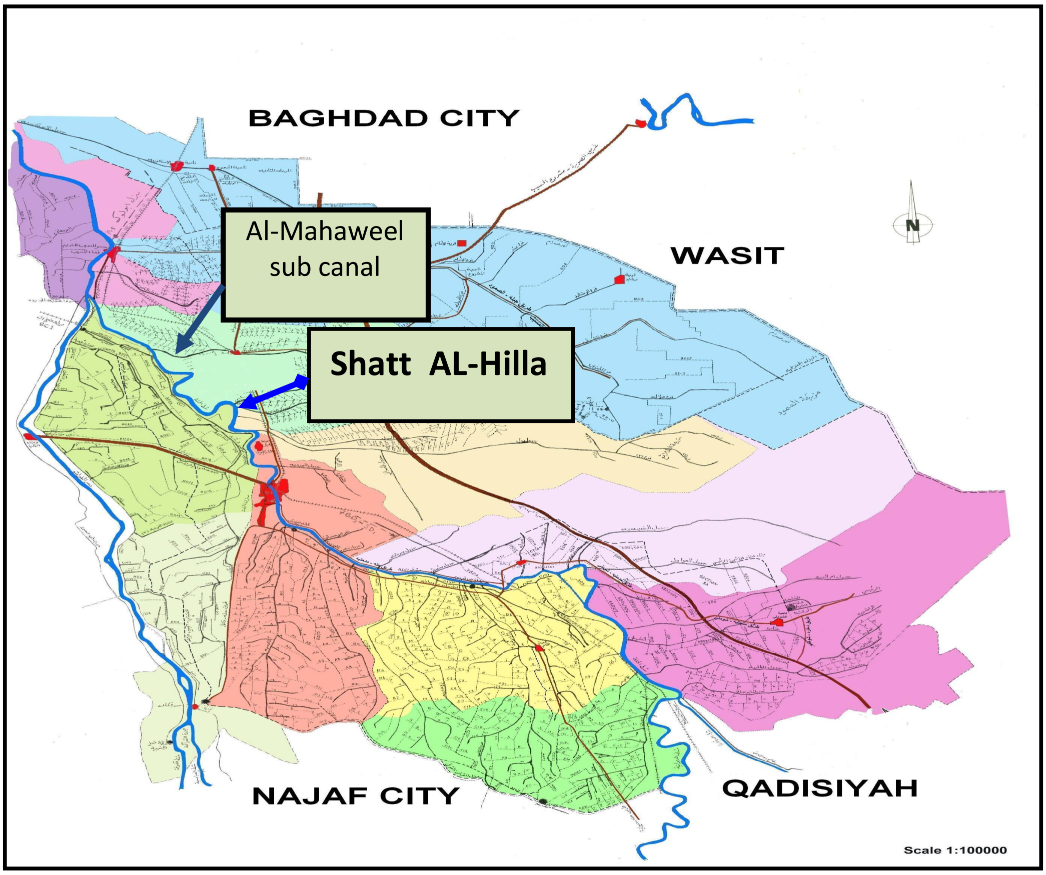


Figure (1): Location of the studied reach of Shatt-Al-Hilla.

Table (2): Cross sectional information for the sub reaches in the considered reach.

River station No.	Location (km)	Sub reach length (m)	Bed slope	Stage(m), h0
1	0+00			26.200
		200	0.000080	
2	0+200			26.180
		200	0.000085	
3	0+400			26.160
		3000	0.000087	
4	3+400			25.860
		2200	0.000081	
5	5+600			25.640
		200	0.000085	
6	5+800			25.620
		200	0.000090	
7	6+000			25.600
		80	0.000100	
8	6+080			25.590
		13.6	0.000090	
9	6+0936			25.585
		106.4	0.000087	
10	6+200			25.575
		200	0.000085	
11	6+400			25.555
		200	0.000095	
12	6+600			25.535
		2000	0.000087	
13	8+600			25.335

Table (3): Regression coefficients for (*A*) versus (*h*) relationship of Shatt Al-Hilla.[Kadhum:2010]

River Section No.	a0	a1	a2	a3	a4	R2
1	30834	-3228.4	110.78	-1.24	0	0.991
2	100847	-10395	354.6	-3.99	0	0.988
3	-12562	1645.3	-70.85	1.006	0	0.999
4	2239.6	-211.38	4.781	0	0	0.993
5	93034	-9558.3	325.18	-3.658	0	0.987
6	589.45	-116.48	3.477	0	0	0.980
7	93979	-9700.2	331.15	-3.733	0	0.997
8	-683387	96323	-5077.7	118.59	-1.034	0.977
9	588.95	-116.48	3.477	0	0	0.987
10	5985.5	-478.56	9.888	0	0	0.996
11	35323	-3504.8	112.86	-1.166	0	0.996
12	37741	-3633.3	113.19	-1.125	0	0.978
13	189458	-19459	662.83	-7.48	0	0.980

Table (4): Coefficients for (*W*) versus (*h*)relationship of Shatt Al-Hilla.[Kadhum:2010]

Cross Section No.	w0	w1	w2	w3
1	-3228.4	221.56	-3.72	0
2	-10395	709.2	-11.97	0
3	1645.3	-141.7	3.018	0
4	-211.38	9.562	0	0
5	-9558.3	650.36	-10.974	0
6	-116.48	6.954	0	0
7	-9700.2	662.3	-11.199	0
8	96323	-10155.4	355.77	-4.136
9	-116.48	6.954	0	0
10	-478.56	19.776	0	0
11	-3504.8	225.72	-3.498	0
12	-3633.3	226.38	-3.375	0
13	-19459	1325.66	-22.44	0

Table (5): Muskingum Method

Time (day)	Upstream discharge (cumics))(I)	Observed downstream discharge (cumics) (O)	I-O	s	cum s	0.2i+0.8d	0.19I+0.81o	0.18I+0.82O
0.0	170.0	170.0	0.0	0.0	0.0	170.0	170.0	170.0
0.4	170.0	170.0	0.0	0.0	0.0	170.0	170.0	170.0
0.8	170.0	170.0	0.0	0.0	0.0	170.0	170.0	170.0
1.2	170.0	170.0	0.0	0.0	0.0	170.0	170.0	170.0
1.6	173.0	170.0	3.0	1.5	1.5	170.6	170.6	170.5
2.0	175.0	172.0	3.0	3.0	4.5	172.6	172.6	172.5
2.4	178.0	177.0	1.0	2.0	6.5	177.2	177.2	177.2
2.8	186.0	182.0	4.0	2.5	9.0	182.8	182.8	182.7
3.2	195.0	188.0	7.0	5.5	14.5	189.4	189.3	189.3
3.6	203.0	192.0	11.0	9.0	23.5	194.2	194.1	194.0
4.0	210.0	196.0	14.0	12.5	36.0	198.8	198.7	198.5
4.4	211.0	198.0	13.0	13.5	49.5	200.6	200.5	200.3
4.8	210.5	200.0	10.5	11.8	61.3	202.1	202.0	201.9
5.2	210.0	200.3	9.8	10.1	71.4	202.2	202.1	202.0
5.6	210.5	200.5	10.0	9.9	81.3	202.5	202.4	202.3
6.0	211.0	201.0	10.0	10.0	91.3	203.0	202.9	202.8
6.4	211.0	201.5	9.5	9.8	101.0	203.4	203.3	203.2
6.8	211.0	202.0	9.0	9.3	110.3	203.8	203.7	203.6
7.2	212.0	202.5	9.5	9.3	119.5	204.4	204.3	204.2
7.6	214.0	204.0	10.0	9.8	129.3	206.0	205.9	205.8
8.0	218.0	205.0	13.0	11.5	140.8	207.6	207.5	207.3
8.4	222.0	207.0	15.0	14.0	154.8	210.0	209.9	209.7
8.8	224.0	209.0	15.0	15.0	169.8	212.0	211.9	211.7
9.2	215.0	211.0	4.0	9.5	179.3	211.8	211.8	211.7
9.6	207.0	214.0	-7.0	-1.5	177.8	212.6	212.7	212.7
10.0	198.0	215.0	-17.0	-12.0	165.8	211.6	211.8	211.9
10.4	192.0	212.0	-20.0	-18.5	147.3	208.0	208.2	208.4
10.8	188.0	207.0	-19.0	-19.5	127.8	203.2	203.4	203.6
11.2	186.0	204.0	-18.0	-18.5	109.3	200.4	200.6	200.8
11.6	184.0	202.0	-18.0	-18.0	91.3	198.4	198.6	198.8

12.0	180.0	200.0	-20.0	-19.0	72.3	196.0	196.2	196.4
12.4	177.0	196.0	-19.0	-19.5	52.8	192.2	192.4	192.6
12.8	173.5	192.0	-18.5	-18.8	34.0	188.3	188.5	188.7
13.2	172.0	185.0	-13.0	-15.8	18.3	182.4	182.5	182.7
13.6	171.0	176.0	-5.0	-9.0	9.3	175.0	175.1	175.1
14.0	170.0	172.0	-2.0	-3.5	5.8	171.6	171.6	171.6
14.4	169.5	171.0	-1.5	-1.8	4.0	170.7	170.7	170.7
14.8	169.0	170.5	-1.5	-1.5	2.5	170.2	170.2	170.2
15.0	169.0	170.0	-1.0	-1.3	1.3	169.8	169.8	169.8
15.4	169.0	169.5	-0.5	-0.8	0.5	169.4	169.4	169.4
15.8	169.0	169.0	0.0	-0.3	0.3	169.0	169.0	169.0
16.0	169.0	169.0	0.0	0.0	0.3	169.0	169.0	169.0

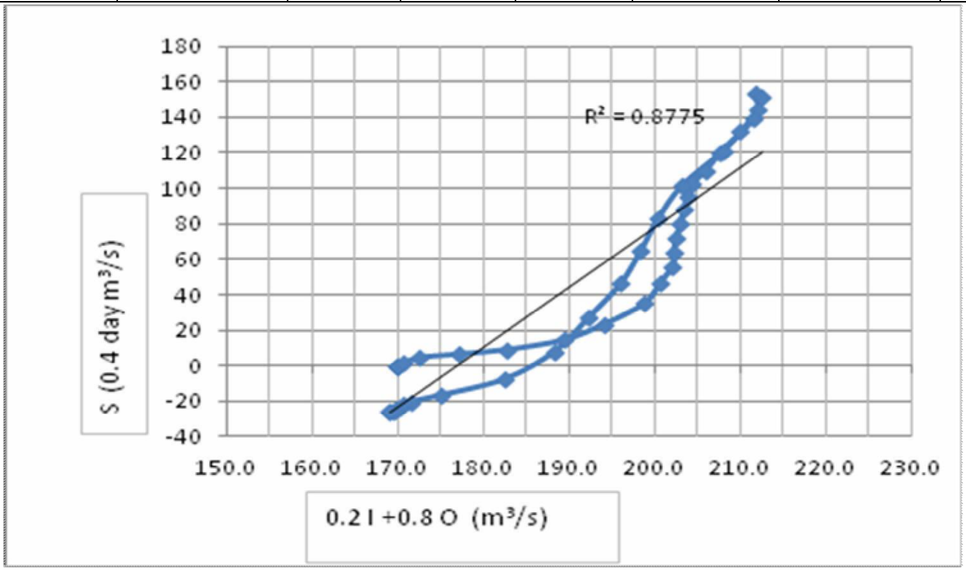


Figure (2): River routing storage loop for X=0.2

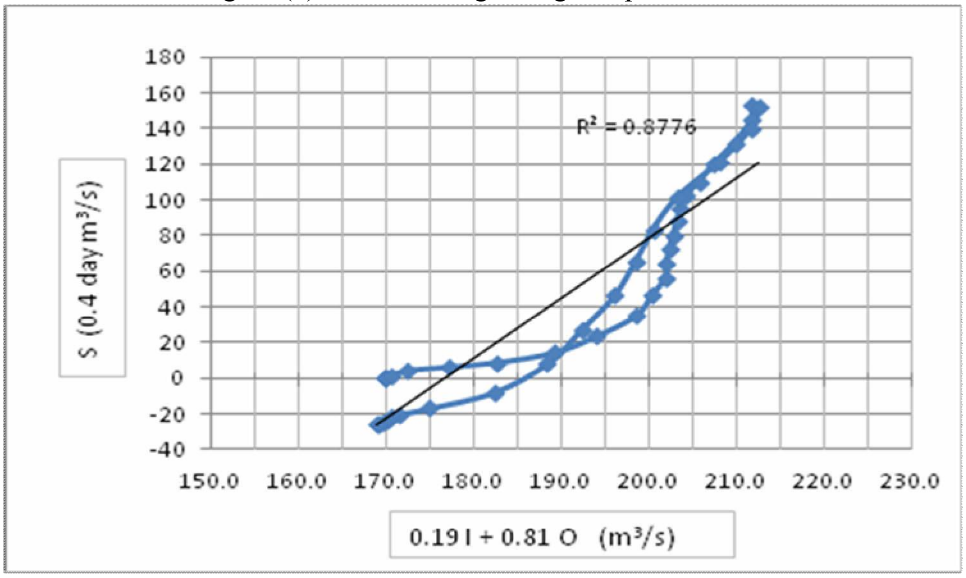


Figure (3): River routing storage loop for X=0.19

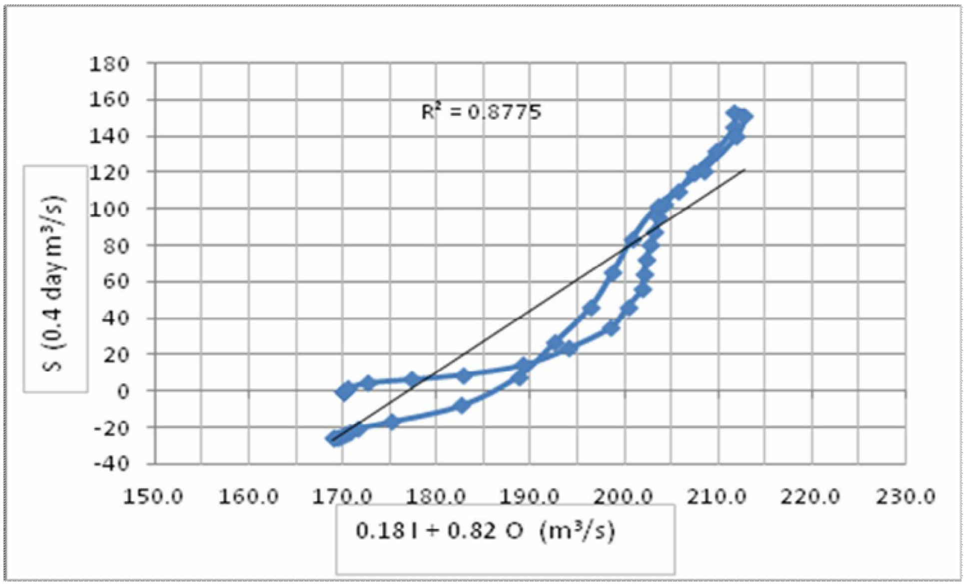


Figure (4): River routing storage loop for X=0.21

Table (6): Data Required to Muskingum Cunge Method

Station no.	Q=170 m³/s				Q=224 m³/s				ß
	h (m)	A (m²)	W (m)	V(m/s)	h (m)	A (m²)	W (m)	V(m/s)	
1	30.84	261.69	66.41	0.650	31.42	298.98	60.53	0.749	1.152
2	30.81	490.15	92.63	0.347	31.40	538.69	71.79	0.416	1.199
3	30.80	295.23	143.85	0.576	31.38	387.24	170.76	0.578	1.003
4	30.50	239.87	80.24	0.709	31.08	288.50	85.84	0.776	1.095
5	30.28	201.71	72.81	0.843	30.86	241.17	60.74	0.929	1.102
6	30.26	248.35	93.93	0.685	30.84	304.55	98.01	0.736	1.075
7	30.24	238.03	86.77	0.714	30.82	285.52	74.17	0.785	1.099
8	30.23	805.04	186.48	0.211	30.81	915.46	188.07	0.245	1.161
9	30.22	244.57	93.69	0.695	30.81	300.62	97.76	0.745	1.072
10	30.21	552.78	118.93	0.31	30.80	625.81	130.51	0.358	1.155
11	30.19	294.18	121.53	0.578	30.78	367.59	128.81	0.609	1.054
12	30.17	259.22	124.63	0.656	30.76	335.86	136.77	0.667	1.017
13	29.97	271.89	115.34	0.625	30.56	334.58	96.21	0.669	1.070

Table (7): Coefficients of Muskingum-Cunge method

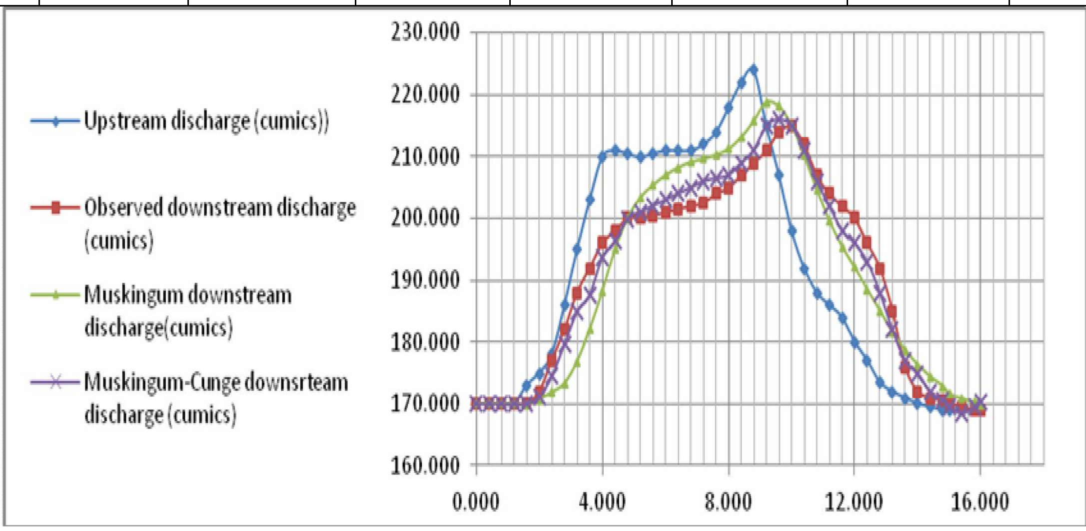
subreach	C	D	C1	C2	C3	C1+C2+C3
1	149	267	0.995	-0.281	0.286	1.000
2	86.1	368	0.996	-0.619	0.623	1.000
3	6.68	8.66	0.878	-0.064	0.186	1.000
4	13.3	17.2	0.937	-0.095	0.159	1.000
5	176	211	0.995	-0.088	0.093	1.000
6	136	160	0.993	-0.078	0.084	1.000
7	275	591	0.998	-0.364	0.366	1.000
8	721	3421	1.000	-0.652	0.652	1.000
9	258	309	0.996	-0.088	0.092	1.000
10	71.2	244	0.994	-0.545	0.550	1.000
11	110	142	0.992	-0.123	0.130	1.000
12	11.6	13.8	0.924	-0.047	0.123	1.000
13	51.3	77.8	0.985	-0.198	0.213	1.000

Table(8): Application of Muskingum-Cunge Method

Time (day)	Inflow	Outflow(1) C149D267	Outflow(2) C86.1D368	Outflow(3) C6.68D8.66	Outflow(4) C13.3D17.2	Outflow(5) C176D211	Outflow(6) C136D160
0	170	170	170	170	170	170	170
0.4	170	170	170	170	170	170	170
0.8	170	170	170	170	170	170	170
1.2	170	170	170	170	170	170	170
1.6	173	172.986	172.972	172.609	172.444	172.431	172.415
2	175	174.986	174.969	174.659	174.503	174.491	174.476
2.4	178	177.982	177.957	177.536	177.33	177.314	177.294
2.8	186	185.956	185.905	184.857	184.361	184.323	184.274
3.2	195	194.944	194.874	193.586	192.956	192.908	192.846
3.6	203	202.946	202.867	201.654	201.045	200.999	200.939
4	210	209.951	209.871	208.793	208.246	208.205	208.152
4.4	211	210.981	210.928	210.601	210.402	210.387	210.368
4.8	210.5	210.497	210.466	210.458	210.429	210.427	210.418
5.2	210	210.002	209.985	210.043	210.065	210.067	210.069
5.6	210.5	210.498	210.485	210.434	210.413	210.411	210.409
6	211	210.997	210.987	210.916	210.882	210.879	210.876
6.4	211	210.999	210.993	210.979	210.97	210.969	210.968
6.8	211	211	210.996	210.993	210.991	210.991	210.991
7.2	212	211.995	211.989	211.866	211.81	211.806	211.801
7.6	214	213.989	213.977	213.711	213.585	213.575	213.563
8	218	217.978	217.952	217.417	217.163	217.144	217.119
8.4	222	221.974	221.941	221.355	221.066	221.044	221.016
8.8	224	223.983	223.951	223.6	223.413	223.399	223.381
9.2	215	215.038	215.061	216.075	216.523	216.557	216.594
9.6	207	207.05	207.098	208.257	208.822	208.865	208.92
10	198	198.058	198.127	199.435	200.082	200.131	200.194
10.4	192	192.045	192.115	193.089	193.591	193.629	193.678
10.8	188	188.032	188.091	188.76	189.112	189.139	189.173
11.2	186	186.018	186.065	186.436	186.638	186.653	186.673
11.6	184	184.015	184.053	184.367	184.529	184.541	184.557
12	180	180.024	180.065	180.609	180.872	180.892	180.916
12.4	177	177.021	177.059	177.527	177.763	177.781	177.803
12.8	173.5	173.523	173.559	174.073	174.329	174.348	174.373
13.2	172	172.013	172.041	172.311	172.462	172.473	172.485
13.6	171	171.008	171.032	171.204	171.298	171.297	171.299
14	170	170.007	170.026	170.18	170.259	170.265	170.273
14.4	169.5	169.504	169.518	169.608	169.657	169.661	169.665
14.8	169	169.004	169.015	169.093	169.13	169.103	169.107
15.2	169	169.001	169.008	169.023	169.031	169.031	169.032
15.6	169	169	169.004	169.004	169.003	169	169
16	169	169	169.003	169.001	169	169	169
16.4	169	169	169.002	169	169	169	169

Time (day)	Outflow(7) C275D591	Outflow(8) C721D3421	Outflow(9) C258D309	Outflow(10) C71.2D244	Outflow(11) C110D142	Outflow(12) C11.6D13.8	Outflow(13) C51.3D77.8
0	170	170	170	170	170	170	170
0.4	170	170	170	170	170	170	170
0.8	170	170	170	170	170	170	170
1.2	170	170	170	170	170	170	170
1.6	172.409	172.408	172.4	172.385	172.366	172.188	172.154
2	174.469	174.467	174.459	174.438	174.419	174.243	174.204
2.4	177.285	177.282	177.271	177.241	177.217	176.985	176.935
2.8	184.255	184.25	184.225	184.165	184.107	183.56	183.448
3.2	192.819	192.812	192.78	192.693	192.618	191.911	191.759
3.6	200.911	200.902	200.871	200.772	200.699	200.006	199.85
4	208.125	208.116	208.088	207.988	207.914	207.284	207.139
4.4	210.353	210.346	210.336	210.267	210.24	209.989	209.917
4.8	210.404	210.395	210.394	210.356	210.352	210.313	210.293
5.2	210.068	210.065	210.066	210.047	210.049	210.067	210.067
5.6	210.408	210.406	210.405	210.392	210.39	210.367	210.362
6	210.874	210.872	210.87	210.86	210.856	210.818	210.81
6.4	210.967	210.966	210.966	210.96	210.899	210.891	210.888
6.8	210.991	210.99	210.99	210.987	210.986	210.979	210.977
7.2	211.799	211.798	211.795	211.788	211.782	211.721	211.709
7.6	213.558	213.557	213.551	213.536	213.521	213.383	213.352

8	217.109	217.106	217.093	217.062	217.03	216.749	216.691
8.4	221.003	220.999	220.984	220.943	220.909	220.583	220.512
8.8	223.371	223.367	223.357	223.319	223.296	223.072	223.017
9.2	216.602	216.601	216.624	216.646	216.696	217.166	217.245
9.6	208.942	208.944	208.973	209.033	209.099	209.728	209.859
10	200.222	200.229	200.262	200.35	200.427	201.156	201.315
10.4	193.703	193.711	193.736	193.826	193.887	194.467	194.603
10.8	189.193	189.2	189.218	189.296	189.34	189.715	189.812
11.2	186.686	186.692	186.7	186.759	186.785	187.024	187.063
11.6	184.567	184.572	184.58	184.626	184.646	184.836	184.883
12	180.928	180.933	180.944	180.992	181.021	181.316	181.38
12.4	177.815	177.82	177.812	177.858	177.887	178.158	178.22
12.8	174.382	174.387	174.4	174.447	174.478	174.767	174.832
13.2	172.494	172.498	172.506	172.544	172.559	172.738	172.783
13.6	171.305	171.303	171.308	171.336	171.342	171.453	171.482
14	170.275	170.278	170.282	170.304	170.314	170.405	170.422
14.4	169.668	169.67	169.673	169.689	169.695	169.753	169.768
14.8	169.109	169.111	169.113	169.125	169.105	169.152	169.162
15.2	169.031	169.031	169.03	169.037	169.038	169.049	169.053
15.6	169	169.001	169.001	169.005	169.005	169.009	169.01
16	169	169	169	169.002	169	169.001	169
16.4	169	169	169	169.001	169	169	169



Figure(5):Upstream discharge and downstream discharge for the reach(0.000km)to(8.600Km) of Shatt-Al-Hilla.

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