



Calculating the Parameters of Muskingum Methods for a Rectangular Channel

¹Asif Mazhar Ansari, ²S.K.Ukarande

¹M. H. Saboo Siddik College of Engineering, University of Mumbai

²Y.T. College of Engineering & Management, University of Mumbai

Abstract: Flood routing is an important aspect of hydrology which progressively determines the timing and magnitude of a flood wave along a river stream. For issuing a forecast to the down-stream areas of a river, flood routing is necessary. In flood routing the parameters of Muskingum method play very important role. In this paper a 5 km long and 60 m wide rectangular channel has been analyzed along with given inflow data. The outflow data obtained by HEC-RAS and Muskingum Cunge method separately. The parameters (K, x) of Muskingum method have been calculated using both outflow data. Results have been compared for K at different x values (x=0.3,0.2,0.1). The satisfactory values of K found at x=0.1.

Index Terms— Flood routing, hydrologic routing, Muskingum method, Muskingum-Cunge method, HEC-RAS

INTRODUCTION

Numbers of 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 point upstream[1,2]. 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[4,5]]. Simplified hydraulic

Table1 Inflow data for rectangular channel

Time (min)	0	12	24	36	48	60	72	84	96	108	120
Inflow (m ³ /s)	60	65	70	80	90	100	90	80	70	60	60

The Muskingum Method

The Muskingum method of flood routing was developed in the 1930s in connection with the design of flood protection schemes in the Muskingum River Basin, Ohio, USA. It is the most widely used method of hydrologic river routing, with numerous applications throughout the world.

flood routing methods which use linear system models with time invariant parameters are based on the assumption that the flow variations around a reference discharge which is used for estimating the model parameters are small [6]. For routing a given flood hydrograph in a channel reach with a linear model, this assumption implies that a reference discharge is used for the estimation of the parameters of the model irrespective of the magnitude of variation of the hydrograph about this reference value[7,8]. This limitation produces distortion in the computed outflow hydrograph when wide variations in flow variable are realized.

In this study, our objective is to develop a rectangular channel of 5 Km long 60 m wide having bed slope 0.01 , Manning's value 0.015. It is required to find the parameters of Muskingum method i.e. K and x. The inflow data of the channel is shown in table 1.. The outflow data has been calculated by HEC-RAS software and Muskingum Cunge method. Calculated outflow data by HEC-RAS and Muskingum Cunge method is used for the calculation of parameters K and x. The Muskingum method is used to calculate K at different values of x (x=0.3,0.2,0.1).

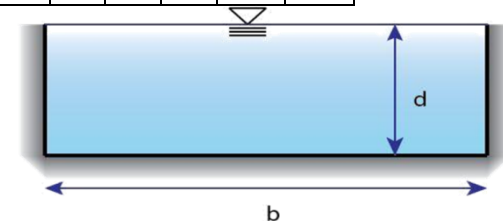


Fig. 1.1 Flow in rectangular channel

This method is based on conservation of mass which applied to storage, inflow and outflow within the reach.

Storage equation:

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

$$S = K(Ix + (1-x)O)$$

Where,

S = Absolute storage within the reach

I = Inflow discharge

O = Outflow discharge

x = Weighting factor

K = Gradient of the storage vs. the weighted flow curve, and K is related to time lag or travel time of the flood wave through the rectangular channel.

From the equations above, it seems that the Muskingum method is really a simple method. The difficulties are only how to determine proper values of K and x which lead to an accurate result or prediction. K and x could be determined graphically from the values of weighted flows vs. their pertinent storages[9]. If observed inflow and outflow hydrographs are available for a channel, the values of K and x can be determined [3,10]. 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 can be computed:

$$Q_{j+i} = C_1 I_{j+i} + C_2 I_j + C_3 Q_j$$

Where,

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

$$C_2 = \frac{\Delta t + 2Kx}{2K(1-x) + \Delta t}$$

$$C_3 = \frac{2K(1-x) - \Delta t}{2K(1-x) + \Delta t}$$

of x and using known values of the inflow and outflow, successive values of the numerator and denominator of the following expression can be computed:

$$K = \frac{0.5 \Delta t [(I_{i+j} + I_j) - (Q_{i+j} + Q_j)]}{x[(I_{i+j} - I_j) - (1-x)(Q_{i+j} + Q_j)]}$$

The computed values of the numerator and denominator are plotted for each time interval, with the numerator on the vertical axis and the denominator on the horizontal

axis. This usually produces a graph in the form of a loop. The value of x that produces a loop closest to a single line is taken to be the correct value for the reach, and K is equal to the slope of the line[11]. Note that 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. With K = Δt and x = 0.5, flow conditions are such that the outflow hydrograph retains the same shape as the inflow hydrograph, but it is translated downstream a time equal to K. For x = 0, Muskingum routing reduces to linear reservoir routing. One rule of thumb used in practice is that the ratio Δt / K be approximately 1 and x be in the range 0 to 0.5.

HEC-RAS Software

HEC-RAS is a computer program that models the hydraulics of water flow through natural rivers and other channels. The HEC-RAS system contains four one-dimensional river analysis components for: (1) Steady flow water surface profile computations (2) Unsteady flow simulation (3) Movable boundary sediment transport computations and (4) Water quality analysis. The component of software modeling system is capable of simulating one dimensional unsteady flow through a full network of open channels.

The cross section of the rectangular channel has been developed (5 Km long, 60 m wide) using cross section options in which coordinates of X-Y axes, downstream length of the channel, Manning's values and location of main channels bank stations data are entered. The interface of HEC-RAS Software is shown in figure 2. In this paper HEC-RAS Software has been used to calculate the outflow data of the given inflow data as shown in table 2. Further, Muskingum method is used in order to calculate the parameter K and x by out flow data.

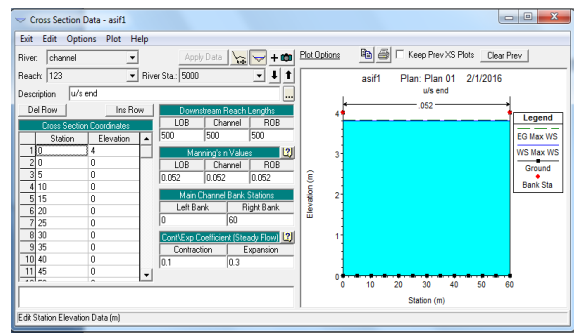


Figure2. Interface of HEC-RAS Software

Table 2 Outflow data Calculated by HEC-RAS Software

Time (min)	Time (Hr)	Inflow cumec	Outflow cumec	I-Q cumec	(I-Q)Avg cumec	ΔS cumec-hr	[XI+(1-X)Q] x=0.1	S=∑S cumec-hr
0	0	60	60	0	-	-	-	-
12	0.5	65	64	1	0.5	0.25	64.1	0.25
24	1	70	65	5	3	3	65.5	3.25
36	1.5	80	68.51	11.49	8.245	12.3675	69.659	15.6175

48	2	90	73.33	16.67	14.08	28.16	74.997	43.7775
60	2.5	100	75	25	20.835	52.0875	77.5	95.865
72	3	90	83.06	6.94	15.97	47.91	83.754	143.775
84	3.5	80	83.11	-3.11	1.915	6.7025	82.799	150.477
96	4	70	80.44	-10.44	-6.775	-27.1	79.396	123.377
108	4.5	60	75.86	-15.86	-13.15	-59.175	74.274	64.2025
120	5	60	68	-8	-11.93	-59.65	67.2	4.5525

Muskingum Cunge method

The Muskingum Cunge method is an efficient technique often applied to solve flood routing problems. The Muskingum Cunge method assumes that water surface in the reach is a uniform unbroken surface profile

between upstream and downstream ends of the channel [4,8]. Out flow data has been calculated by Muskingum Cunge method of a given inflow data as shown in table 2. Further, parameters K and x calculated by Muskingum method.

Table 3 Outflow data Calculated by Muskingum Cunge Method

Time interval	Time (hr)	Time (days)	Inflow	C_0I_2	C_1I_1	C_2O_1	Outflow
0	0	0	60	-	-	-	60
1	0.2	0.008	65	36.776	-36.766	59.99	63
2	0.4	0.017	70	42.905	-36.766	59.99	65.12
3	0.6	0.025	80	49.035	-42.894	66.118	68.34
4	0.8	0.033	90	55.164	-49.021	72.247	73.45
5	1	0.042	100	61.294	-55.149	78.377	78.23
6	1.2	0.05	90	55.164	-61.277	84.507	84.97
7	1.4	0.058	80	49.035	-55.149	78.381	80
8	1.6	0.067	70	42.905	-49.021	72.255	80.12
9	1.8	0.075	60	36.776	-42.894	66.128	74.22
10	2	0.083	60	36.776	-36.766	60	67.3

Results

In our study, a rectangular channel has been developed and the outflow hydrographs calculated by HEC-RAS and Muskingum Cunge method. The obtained outflow hydrographs from both the methods are showing approximately same behavior as shown in table 2 and table 3 respectively.

The plots have been drawn between S and $[xI+(1-x)Q]$ and the Muskingum parameter K has been calculated at different values of x for both obtained outflow hydrographs. The satisfactory result of Muskingum parameter K was found at $x=0.1$ in both cases. The regression values at $x=0.1$ were found 0.937 and 0.900 for HEC-RAS and Muskingum Cunge method respectively.

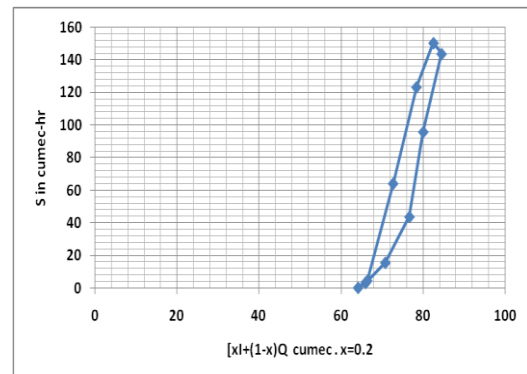
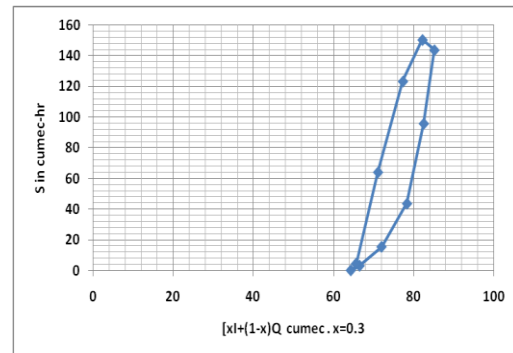


Fig.3 Determination of Muskingum parameters at $x=0.2,0.3$.

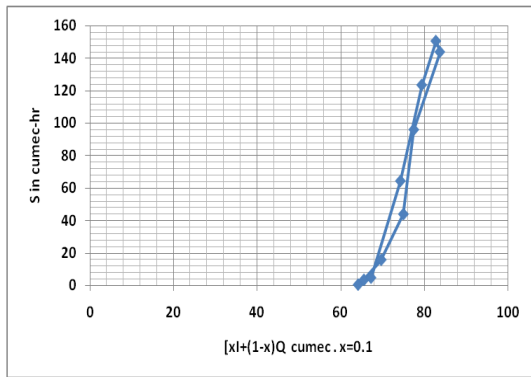


Fig.4 Determination of Muskingum parameters at x=0.1

Table 4 Regressions Values Vs Slope(K) for HEC-RAS

x	Slope K (hr.)	R ²
0.3	6.998	0.751
0.2	7.802	0.867
0.1	8.161	0.937

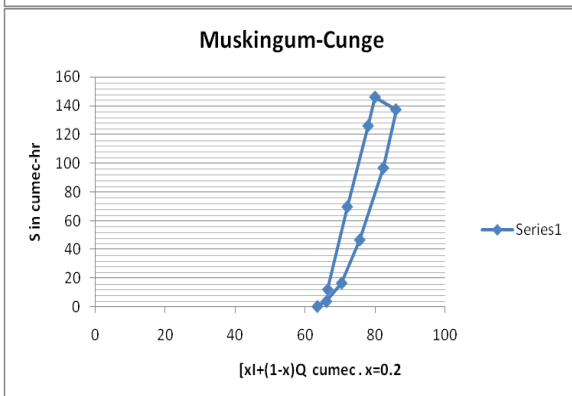
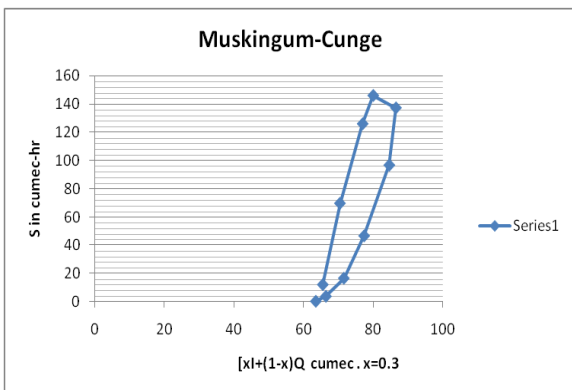


Fig.5 Determination of Muskingum parameters at x=0.2,0.3.

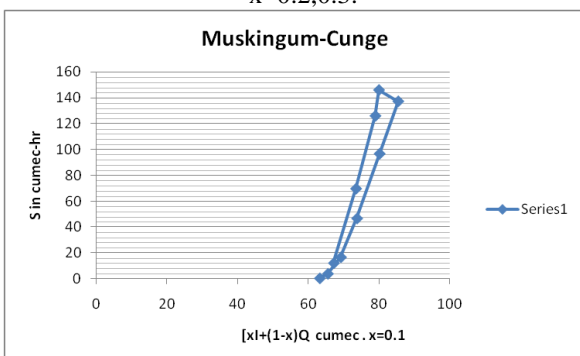


Fig.6 Determination of Muskingum parameters at x=0.1

Table 5 Regressions Values Vs Slope(K) for Muskingum method

x	Slope K (hr.)	R ²
0.3	6.091	0.717
0.2	6.856	0.821
0.1	7.412	0.900

CONCLUSION

In the present study the HEC-RAS Software found slighter better than Muskingum Cunge method in order to calculate the Outflow hydrographs of a channel. HEC-RAS shown more accuracy then Muskingum Cunge method for unsteady flow analysis as regression value in case of HEC-RAS more closer to one .In HEC-RAS assumptions are also very less as compared to Muskingum Cunge method.

REFERENCES

- [1] M. Perumal. Comparison of two variable parameter Muskingum methods. Extreme Hydrological Events: Precipitation, Floods and Droughts (Proceedings of the Yokohama Symposium, July 1993). IAHS Publ. no. 213, 1993.
- [2]. D. A. Barry and K. Bajracharya. On the Muskingum-Cunge Flood Routing Method. Environment International, Vol. 21, No. 5, 1995, pp. 485-490,
- [3]. V.M. Ponce, a, A.K. Lohanib, C. Scheyhing. Analytical verification of Muskingum-Cunge routing. Journal of Hydrology 174 (1996), pp 235-241.
- [4]. Kuniyoshi Takeuchi, Tianqiao & Hiroshiishidaira. Introduction of block-wise use of TOPMODEL and Muskingum-Cunge method for the hydroenvironmental simulation of a large ungauged basin. Hydrological Sciences—Journal—des Sciences Hydrologiques, August 1999, 44(4) .
- [5] Xiao-meng SONG, Fan-zhe KONG, Zhao-xia ZHU3. Application of Muskingum routing method with variable parameters in ungauged basin. Water Science and Engineering, 2011, 4(1), pp 1-12.
- [6] D. Nagesh Kumar a, Falguni Baliarsingh b , K. Srinivasa Raju. Extended Muskingum method for flood routing. Journal of Hydro-environment Research 5 (2011) pp 127-135.
- [7]. safa taha elbashir. Flood Routing in Natural Channels Using Muskingum Methods. School of Civil and Building Services Engineering,2012.
- [8]. Muthiah Perumal , Roland K. Price. A fully mass conservative variable parameter McCarthy–Muskingum method: Theory and verification. Journal of Hydrology 502 (2013) pp 89–102.

- [9]. Paolo Reggiani , Ezio Todini , Dennis Meisner . A conservative flow routing formulation: Déjà vu and the variable-parameter Muskingum method revisited. *Journal of Hydrology* 519 (2014) pp 1506–1515.
- [10] Sajikumar Na, Gyncy Ib , Sumam K.Sa. Modelling of Nonlinear Muskingum Method using Control System Concept. *Aquatic Procedia* 4 (2015) pp 979 – 985.
- [11] Ratnakar Swain , Bhabagrahi Sahoo. Variable parameter McCarthy–Muskingum flow transport model for compound channels accounting for distributed non-uniform lateral flow. *Journal of Hydrology* 530 (2015) pp 698–715.

