Muskingum Flood routing method for the Titwala- Nashik reach ofKalu River

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Abstract: Flood routing is an important aspect of hydrology which progressively determines the timing and magnitude of flood wave along a river stream.For issuing a forecast to the down-stream areas of a river, flood routing isnecessary. The inflow and out flow discharge data of riverKalu at Titwala-Nashik reach has been recorded in the month of September 2015. This paper presents the results of a study of theTitbala-Nashik reach (124 kms) of the Kalu river. The Muskingurnmethod of flood routing has been adopted. The constants parameters of Muskingum method for the entirereach were found K =5.72hr. and x=0.1.

Introduction

Flood routing is the process of determining progressively the timing and shape of a flood wave at successive points along a river and is basic for flood forecasting.It plays an important role in the design and management of many environmental and water resource projects [1]. This communication presents some results of flood routing studies of the Titwala-Nashik reach of the river Kalu. The inflow and outflow data of the Titwala-Nashik reach has been recorded and presented in table1.

The storage in the reaches of stream channels is used extensively as an index of the timing and shape of flood waves at successive points along a river. Among the principal users of the technique are the Corps of Engineers who route hypothetical floods through river systems to determine the effects from proposed flood-control projects, the U.S [2]. Weather Bureau whose forecasts of river stages are based largely on flood routing, and the operators of hydroelectric power systems who schedule their operations according to the predicted progress of a flood wave. The storage index and the techniques of flood routing may also be used to advantage in computing and evaluating stream flowrecords [3]

The storage generated in a reach of channel by a uniformly progressive waveis completely different. The storage prism varies in shape and in volume. River stages and storage in a reach are conditioned by the inflow and the outflow rates. Hence,in the course of a flood that is controlled only by channel action, the storage increases rapidly in relation to outflow. Conversely, the storage decreases rapidly when the flood recedes. Storage is increasing when peak inflow occurs, and it continues to increase until outflow rises to equal the receding inflow. At this time the flood crest occupies a central position in the reach. At the instant of the maximum storage, the net change in storage equals zero and inflow equals outflow; the upstream stages are decreasing, the downstream stages are increasing and volume of storage in the reach at that instant is constant[4]. After this point is passed, outflow continues to increasepartly at the expense of storage in the reach, until the crest passes the lower end. The Hydrograph of the Titwala-Nashik reach of the Kalu river is shown in figure 1.

Table 1 Inflow and Outflow data for Titwala-Nashik reach of the Kalu River

Time (hr)	0	6	12	18	24	30	36	42	48	54	60	66	72
Inflow (m^3)	35	133	441	665	684	533	387	233	141	96	62	40	39
Outflow (m^3)	35	58	200	450	610	619	505	373	245	155	100	67	55

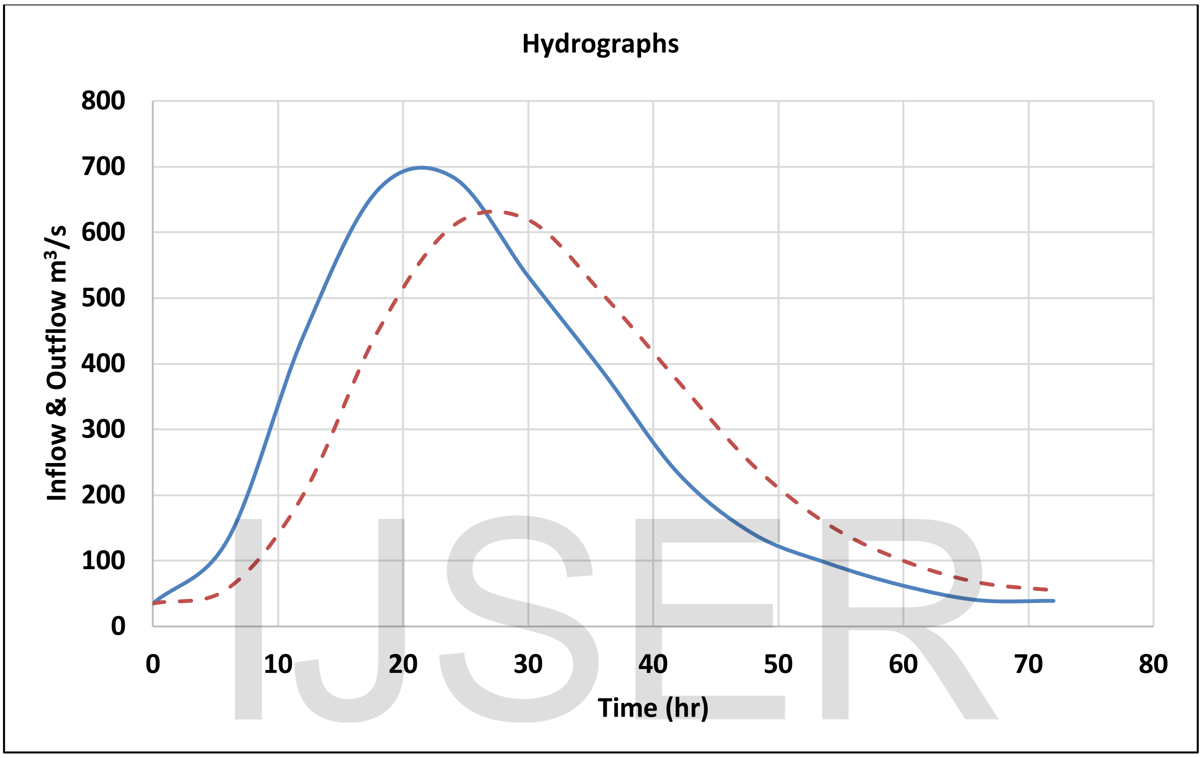

Fig. 1 Inflow and Out flow Hydrographs of Titwala-Nashik reach of the Kalu river

Muskingum Methods

One of standard methods of hydrological flood routing models is the well-known Muskingum method. This method is based on conservation of mass which applied to storage, inflow and outflow within the reach.Many les complicated methods have been developed for flood routing problems and have been found satisfactory in many practical applications.The Muskingum method, which was suggested by the U.S [2, 5]. Corps of Engineers for the study of the Muskingum river basin in Ohio, U.S.A., is one of the most frequent used.After much research even today the method is widely used by Scientists and Engineers, as it is simple and sufficiently accurate.

In the present study,the Muskingum liner method has been adopted. The storage equation is:

$$S = K(Ix + (1 - x)Q)\dots\dots\dots\dots (1)$$

Where,
S = absolute storage within the reach
I = inflow discharge
O = outflow discharge
x = a weighting factor

K = a 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 reach.

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.

To derive the values of *K* and *X* for the Kalu river reach Titwala-Nashik, several flood hydrographs during September 2015 were plotted and examined.From a preliminary examination of these twelve events were found suitable for further analysis. The suitability was judged on the basis on the steadiness of the flood hydrograph and its symmetry around the peak.When a pair of observed inflow and outflow hydrographs is available for a reach, the value of K and x of the reach can be determined using these hydrographs [6]. When these two graphs are plotted it will be seen thatboth will cross on the recession side of the inflow hydrograph.

The routing equation is

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

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

$$\frac{dS}{dt} = K\left[x\frac{dI}{dt} + (1-x)\frac{dQ}{dt}\right]$$

$$I - Q = K\left[x\frac{dI}{dt} + (1-x)\frac{dQ}{dt}\right] \text{............ (2)}$$

When the two hydrograph are crossing I=Q and I-Q=0, from above equation

$$x = \frac{\frac{dQ}{dt}}{\frac{dQ}{dt} - \frac{dI}{dt}}$$

Hence determination of x requires finding out the slope of inflow and outflow hydrographs at the point of crossing and substitute them in the above equation [7]. After the value of x is determined, the slopes of the hydrographs are not found at any other time, and these slopes along with known values of x are substituted in the equation (2) to give the value of K. The values of K and x are determined using the procedure are only of the outflow hydrograph at the point of crossing is very small.

Alternatively the values of K and x can be computed by applying equation (2) at two points on the Hydrographs and solving the resultingequation simultaneously.The K and x values from this procedure reflect the storage characteristics' of the reach only at those discharge conditions which are used in their determination. They may not represent the overall characteristics of the reach applicable for entire range of storage [8].

Assume a trial value of x the value of the expression $[\mathrm{K}(\mathrm{Ix} + (1-\mathrm{x})\mathrm{Q})]$ is evaluated at various points of time and these values are plotted against the corresponding storage. The plots which look like loop are plotted with different values of x till the plot is verynearly a straight line the slope of which gives an estimate of K and the best values of x is taken to be that which causes the plot to be straight line [9].

Table 2 Determination of Muskingum Parameters for the Titwala-Nashik reach of Kalu River

Time (h)	Inflow (m^3/s)	Outflow (m^3/s)	(I-Q)	$(I-Q)_{avg}$	ΔS cum-day	S=ΣΔS Cum-day	[xI+(1-x)Q]		
							x=0.3	x=0.2	x=0.1
0	35	35	0	-	-	-	-	-	-
6	133	58	75	37.5	9.375	9.375	80.5	73	65.5
12	441	200	241	158	39.5	48.875	272.3	248.2	224.1
18	665	450	215	228	57	105.87	514.5	493	471.5
24	684	610	74	144.5	36.125	142	632.2	624.8	617.4
30	533	619	-86	-6	-1.5	140.5	593.2	601.8	610.4
36	387	505	-118	-102	-25.5	115	469.6	481.4	493.2
42	233	373	-140	-129	-32.25	82.75	331	345	359
48	141	245	-104	-122	-30.5	52.25	213.8	224.2	234.6
54	96	155	-59	-81.5	-20.37	31.875	137.3	143.2	149.1
60	62	100	-38	-48.5	-12.12	19.75	88.6	92.4	96.2
66	40	67	-27	-32.5	-8.125	11.625	58.9	61.6	64.3
72	39	55	-16	-21.5	-5.375	6.25	50.2	51.8	53.4

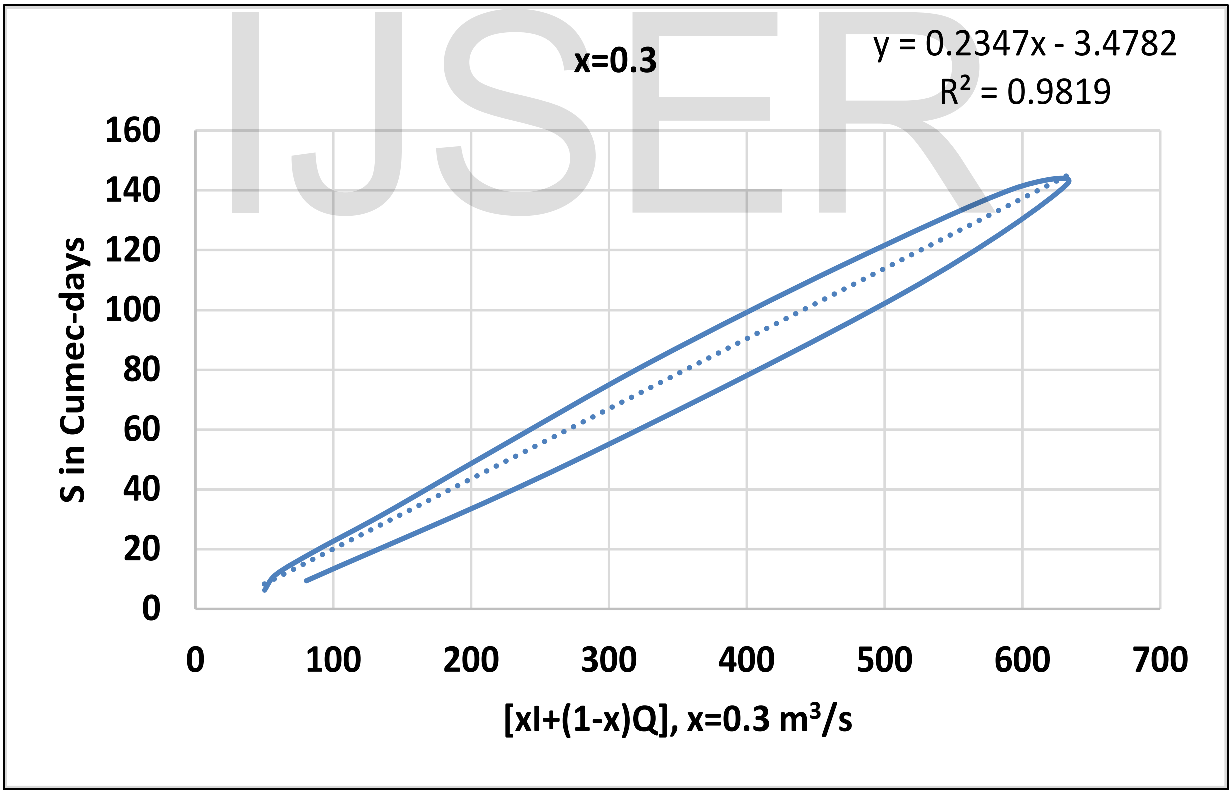

Fig.2 Muskingum Parameters at x =0.3

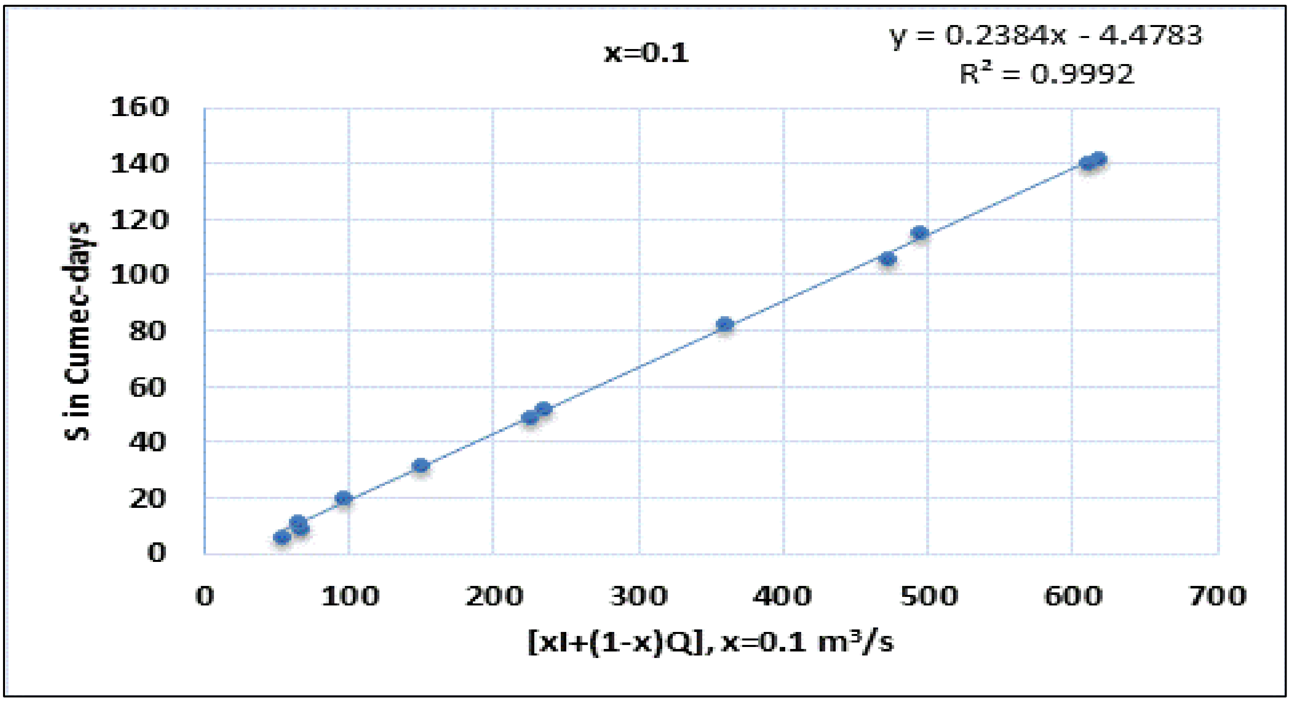

Fig.3 Muskingum Parameters at x =0.1

Table 3 Calculated Muskingum Parameters with R^2

Trial	x	K(hr.)	R^2
1	0.3	5.61	0.9819
2	0.2	5.69	0.9939
3	0.1	5.72	0.9992

Results and Discussion

The Muskingum Parameters for the Titwala-Nashik reach of Kalu River at varying x calculated as shown in table 2 and graph is plotted with $[K(Ix + (1 - x)Q)]$ on x-axis and the Storage S on y-axis as shown in figure 2 and 3 respectively. The points indicate the formation of a loop and there is improvement when x tends to zero. In the beginning the loop was narrower at x= 0.3 but in the third trial at x= 0.1 is computed, found satisfactory. Therefore the correct value of x can be taken as 0.1 for the Titwala-Nashik reach of the Kalu River.

The slope of the line in figure 3 at x=0.1 is found 0.2384 Cumec-days which is equal to 5.72 hour. This value of slope K tallies the peak to peak time of 6 hour in the inflow and outflow Hydrographs as shown in figure 1.The R square values also calculated for each trail is shown in table 3, to know the accuracy and in third trail at x=0.1 was found 0.9992, which is representing the best result. Therefore for the Titwala-Nashik reach of the Kalu river,the value of x=0.1 and K=5.72 hour can be adopted. This implies that a flood wave Titwala would take about 6 hour to reach Nashik. This result will be useful for engineers for making remedial action at the downstream points, as and when necessary.

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