# Analysis of Flood Routing in Channels

[1]Rajat Pandey,[2]Vivek Kumar,[3]Rakesh Deo Pandey
Assistant Professor, Department of Civil Engineering
RajarshiRananjaySinh Institute of Management & Technology, Amethi, India

***Abstract* - The accuracy of flood routing is an important subject for research in hydrology andhydraulics. Accurate information of the flood peak attenuation and the duration of thehigh water levels obtained by channel routing are of most importance in floodforecasting operations and flood protection works. This studyimplements Muskingum method to estimate the inflow and outflow discharge at the river bank. The parameters of Muskingum method are determined using three methods i.e. graphical method, least square method and regression analysis approach. The assessment of results are compared from the above three methods.**

***Index Terms* - Flood routing, hydrological method, Muskingum method, least square method, graphical method, regression analysis.**

## I. INTRODUCTION

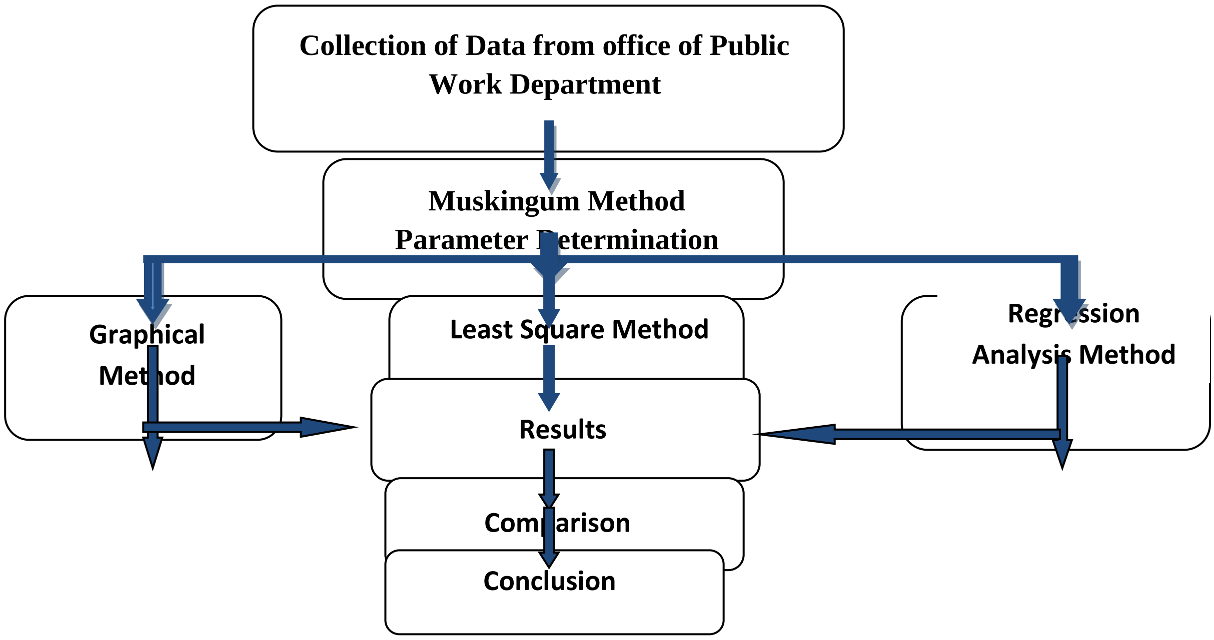
Flood routing is a tool acquiring or creating hydrograph at a specific downstream area of a waterway stream by use of the past information. Flood routing thinks about are valuable in outline of spillway, plan of store, surge determining and surge assurance (Subrmnaya). Surge directing related examinations are used to gauge highest water level streaming in waterway stream. This most extreme water level is profoundly concerned with settling greatest plan release for a spillway. Capacity stores are developed for powerful and dependable instruments of surge controlling measures. This is a flood control technique in which water discharge can be monitored at the downstream end in a given time duration without much effecting the banking areas of a river reach. With a specific end goal to complete above assignments surge directing investigations are required i.e., through reservoir and channel routing. Flood routing is used in (i) flood forecasting, (ii) flood protection, (iii) reservoir design, and (iv) design of spillway and outlet structures. The types of Food routing are (a) reservoir routing, and (b) channel routing. A variety of routing methods are available and they can be grouped into (1) hydrologic routing, and (2) hydraulic routing. Hydrologic routing methods employ essentially the equation of continuity, on the other hand hydraulic methods use continuity equation along with the equation of motion of unsteady flow (St. Venant equations) hence better than hydrologic methods.

## II.OBJECTIVE

To study the newly generating techniques for flood routing and also to evaluate the old used methods. The objectives of this study are to assess the accuracy and reliability of the available flow data collected from the OPWD for modeling, and to check the results through basic flood routing methods.

## III.METHODOLOGY USED

This study focuses on the comparison of results calculated from hydrological methods. In this study we have compared results of flood routing inflow and outflow discharges using Muskingum method. Parameters of Muskingum method are determined using three methods namely graphical method, least square method and regression analysis. The reliability of above three methods depends on data availability and the time for calculation. The graphical method is the oldest method to compute the parameters of Muskingum method but the least square method and regression analysis is more fast and accurate in comparison to graphical method as we use mathematical and empirical formulae in least square and regression analysis method.



***Hydrologic Channel Routing***

The passage of a flood hydrograph through a reservoir or a channel reach is an example of unsteady –flow phenomenon. It is classified in open channel hydraulics as gradually varied unsteady flow phenomenon. The equation of continuity used in all hydrologic routing as the primary equation states that the difference between the inflow and outflow rate is equal ton the rate of change of storage, i.e.

$$I\text{-}Q = \frac{ds}{dt}$$

Where I= inflow rate, Q = outflow rate and S = storage.

In channel routing the storage is a function of both outflow and inflow discharges and hence a different routing method is needed. The flow in a river during a flood belongs to the category of gradually varied unsteady flow. The water surface in a channel reach is not only parallel to the channel bottom but also varies with time. Considering a channel reach having a flood flow, the total volume in storage can be considered under two categories as

1. Prism storage
2. Wedge storage

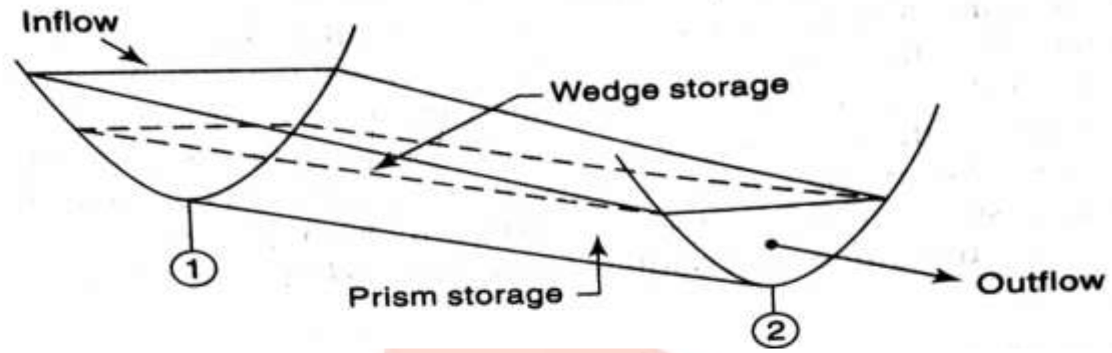



Fig.1. Prism and Wedge Storage In A Channel

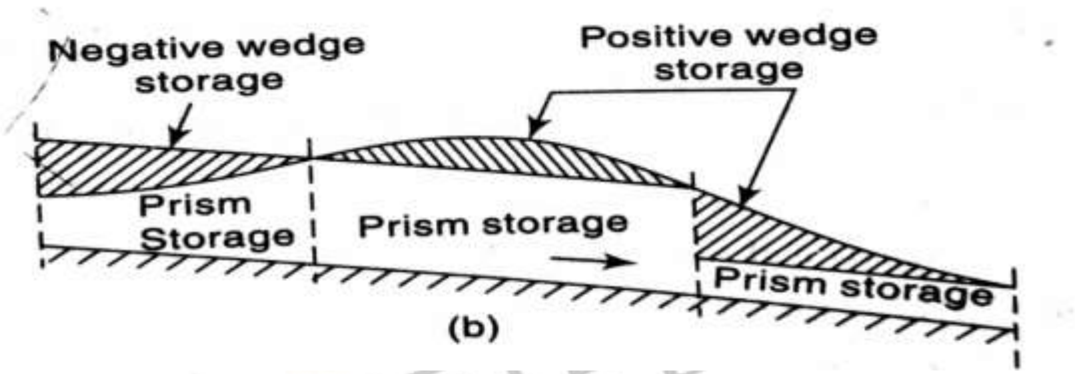



Fig.2. Channel Storage Reach

***Hydraulic Methods***

Hydraulic flow routing procedures are becoming popular for the purposes of flood routing. This is because hydraulic methods allow flow computation to be varied in both time and space. Hydraulic methods employ the continuity equation together with the equation of motion of unsteady flow (Subramanya, 2009: p280).

The equation of motion for a flood wave is derived from the application of the momentum equation as:

$$\frac{\partial y}{\partial x} + \frac{v}{g}\frac{\partial v}{\partial x} + \frac{1}{g}\frac{\partial v}{\partial t} = S_0 - S_f$$

Where,

v is the velocity of flow at any section in (m/s), $S_0$ is the channel bed slope and $S_f$ is the slope of the energy line in (m/m).

And the one dimensional continuity equation is given by:

$$\frac{\partial Q}{\partial x} + T\frac{\partial y}{\partial t} = 0$$

The one dimensional continuity and momentum equations mentioned above were first presented by and they are commonly called the Saint Venant equations. If all of the terms in the momentum equation are neglected except for the friction slope ($S_f$ ) and bed slope (So), the kinematic wave equation simplifies to:

The kinematic wave equation is sufficient for modelling flood waves on steep sloped rivers. When the pressure gradient term is considered, the diffusive wave equation is represented as:

$$S_0 - \frac{dy}{dx} = S_f$$

The shortcomings of these models are represented in the complexity of the methods which are used for solution. These often lead to a numerical instability and problems of 18 convergences. Besides a long running time is needed for the solution which is costly and expensive. Other simplified methods were developed to assist in the calculation, mainly referred to as Hydrological methods.

**IV. METHODOLOGIES**

***Muskingum Method***

For a given channel reach by selecting a routing interval Δt and using the Muskingum equation, the change in storage is

$$S_2 - S_1 = K [x (I_2 - I_1) + (1-x) (Q_2 - Q_1)]$$

Where suffixes 1 and 2 refer to the conditions before and after the time interval Δt.

The continuity equation for the reach is

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

$$Q_2 = C_0 I_2 + C_1 I_1 + C_2 Q_1$$

$$C_0 = \frac{-Kx + 0.5\,\Delta t}{K - Kx + 0.5\,\Delta t}$$

$$C_1 = \frac{Kx + 0.5\,\Delta t}{K - Kx + 0.5\,\Delta t}$$

$$C_2 = \frac{K - Kx - 0.5\,\Delta t}{K - Kx + 0.5\,\Delta t}$$

$C_0$, $C_1$, $C_2$, and $C_3$ are dimensionless

A brief review of the Muskingum method precedes the description of the Muskingum-Cunge method. The routing equation is similar for the methods. The Muskingum channel routing method is based on two equations.

The first is the continuity equation or conservation of mass.

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

The above Equation states that inflow to the reach minus outflow from the reach is equal to the change in storage. This are the same basic equation used in routing of reservoirs. Where the reservoir routing method assumes relation of storage and outflow discharge, the Muskingum method assumes the amount of storage is related to both inflow and outflow discharge. The Equal reservoir routing method assumes a level pool, and the Muskingum method assumes a sloping water surface.

$$S = K [XI + (1 - X) O]$$

where:

S = reach storage, $m^3$

K = storage constant, s

X = weighting factor, dimensionless

I = inflow discharge, $m^3/s$

O = outflow discharge, $m^3/s$

When X equals zero in the equation reduces to a simple relation of storage and outflow discharge: S is KO (reservoir routing assumption). The values in the equations are in units of meter and seconds. They may also be defined in any units of length and time as long as all values in the equation are consistent.

$$S = K [XI + (1-X) O]$$

$$O_2 = C_0 I_2 + C_1 I_1 + C_2 O_1$$

Coefficients with the sum of C1, C2, and C3 equal to 1.0.

An approximation for K is the travel time through the reach or the length of reach divided by the average flow velocity. Either water surface profiles or a solution of Manning's equation are needed for the reach to estimate the average flow velocity. The approximation of K is sensitive to the value of discharge at which velocity is selected. The approximation of K is also sensitive to whether the channel length, floodplain length, or some type of weighted reach length is used. The value of X is between 0.0 and 0.5. A value of 0.0 gives maximum attenuation from the procedure, and 0.5 provides the minimum attenuation.

The routing equation, is applied to a given inflow hydrograph, Ij (j=1, J),and initial outflow, O1, to calculate the outflow hydrograph, Oj (j=2, J), at a downstream section. The constants in the routing equation, $C_0$, $C_1$, and $C_2$are introduced in terms of the channel parameters K and X and the routing time step, t. Limiting the routing time step t within a reasonable range is very important to prevent instabilities in the routing procedure and also to prevent the negative value for coefficient $C_{1.}$

**V. Muskingum Method Parameters Determination by Graphical Method:**

In the basic Muskingum method, K and X can be graphically estimated from the available inflow and outflow data of the reach of interest. If S is plotted against XI+ (1-X) O, a straight line with a slope of K should result. Several values of X are tried; the value that gives the narrowest loop in the plotted relationship is taken as the correct X value and the slope of the plotted relationship is taken as the K value. K is taken as the slope of the straight line of the narrowest loop when X=0.15.

The Muskingum method assumes a single stage-discharge relationship. This assumption causes an effect known as hysteresis, which may introduce errors into the storage calculation. Thehysteresis effect between reach storage and discharge is due to the different flood wave speeds during the rising and falling limb of the hydrograph. For the same river stage, the flood wave moves faster during the rising limb of the hydrograph.

In spite of its simplicity and its wide applicability, the Muskingum method has the shortcoming of producing a negative initial outflow which is commonly referred to as 'dip' or 'reduced flow' at the beginning of the routed hydrograph. Additionally, the method is restricted to moderate to slow rising hydrographs being routed through mild.

A number of studies have been carried out to analyze flood wave propagation, and the results have shown that the time taken for the center of mass of the flood wave to travel from the upstream end of the reach to the downstream end is equal to K. Thus, K can be easily estimated from the observed inflow and outflow data.

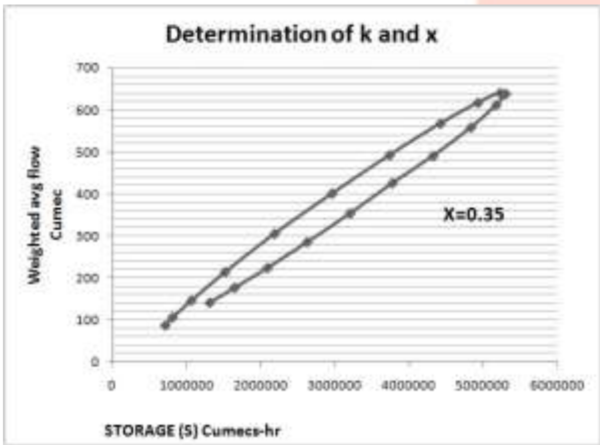
Some factors that are related to a catchment may also play an important role in defining the travel time K.
The surface geology, the soil type, the drainage pattern and the catchment shape may all have influences.
Finally, the Muskingum method also ignores variable backwater effects such as downstream dams, constrictions, bridges and tidal influences.
In small catchments, where measured inflow and outflow hydrographs are not available, or where a significant uncertainty and errors are reported for the outflow data, modeling the flow using this method is quite a source of errors, and the Muskingum method fails to simulate the flow hydrograph using this type of data. In this situation, an alternative procedure developed by Cunge (1967) has received widespread acceptance. This is due to its ability to estimate the model parameters without the observedhydrograph.
In the absence of observed flow data, the Muskingum-Cunge method may be used form parameter estimation. This concept is also applied when measured flow data are available, but with significant degree of uncertainty.

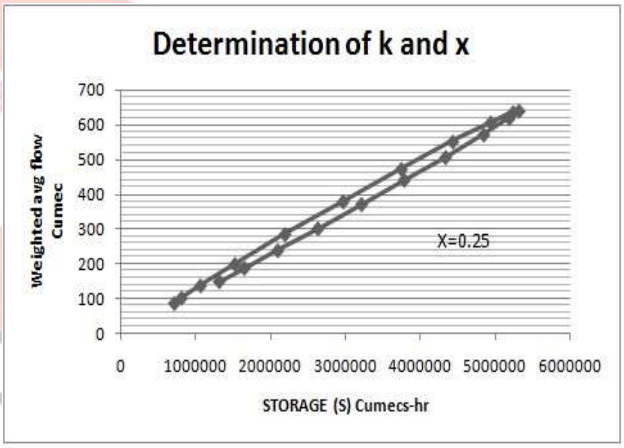
The Muskingum-Cunge parameters are calculated based on the flow and the channel characteristics. This method involves the use of a finite difference scheme for solving the Muskingum equation, where the parameters in the Muskingum equation are determined based on the grid spacing for the finite difference scheme and the channel geometry characteristics.
**Now Firstly we can determine parameter using graphical approach for the below data:**

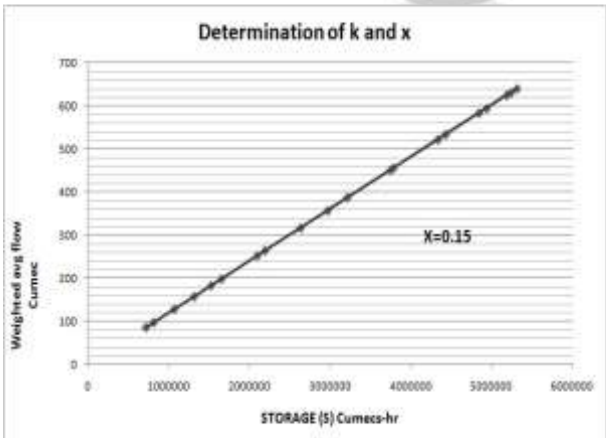
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| | | | | | ***X=0.25*** | ***X=0.35*** | ***X=0.1*** | ***X=0.15*** |
| ***Inflow, I ($m^3/s$)*** | ***Outflow, O ($m^3/s$)*** | ***Ave. Inflow ($m^3/s$)*** | ***Ave. Outflow ($m^3/s$)*** | ***Storage ($m^3$)*** | ***Weighted Average Flow XI + (1-X) O ($m^3/s$)*** | | | |
| 93 | 85 | | | 715000 | 87 | 87.8 | ***85.8*** | 86.21204 |
| 137 | 91 | 115 | 88 | 812200 | 102.5 | 107.1 | 95.6 | 97.96922 |
| 208 | 114 | 172.5 | 102.5 | 1064200 | 137.5 | 146.9 | 123.4 | 128.2414 |
| 320 | 159 | 264 | 136.5 | 1523200 | 199.25 | 215.35 | 175.1 | 183.3923 |
| 442 | 233 | 381 | 196 | 2189200 | 285.25 | 306.15 | 253.9 | 264.6645 |
| 546 | 324 | 494 | 278.5 | 2965000 | 379.5 | 401.7 | 346.2 | 357.634 |
| 630 | 420 | 588 | 372 | 3742600 | 472.5 | 493.5 | 441 | 451.816 |
| 678 | 509 | 654 | 464.5 | 4424800 | 551.25 | 568.15 | 525.9 | 534.6043 |
| 691 | 578 | 684.5 | 543.5 | 4932400 | 606.25 | 617.55 | 589.3 | 595.1201 |
| 675 | 623 | 683 | 600.5 | 5229400 | 636 | 641.2 | 628.2 | 630.8782 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 634 | 642 | 654.5 | 632.5 | 5308600 | 640 | 639.2 | 641.2 | 640.788 |
| 571 | 635 | 602.5 | 638.5 | 5179000 | 619 | 612.6 | 628.6 | 625.3037 |
| 477 | 603 | 524 | 619 | 4837000 | 571.5 | 558.9 | 590.4 | 583.9104 |
| 390 | 546 | 433.5 | 574.5 | 4329400 | 507 | 491.4 | 530.4 | 522.3653 |
| 329 | 479 | 359.5 | 512.5 | 3778600 | 441.5 | 426.5 | 464 | 456.2743 |
| 247 | 413 | 288 | 446 | 3209800 | 371.5 | 354.9 | 396.4 | 387.8502 |
| 184 | 341 | 215.5 | 377 | 2628400 | 301.75 | 286.05 | 325.3 | 317.2138 |
| 134 | 274 | 159 | 307.5 | 2093800 | 239 | 225 | 260 | 252.7894 |
| 108 | 215 | 121 | 244.5 | 1649200 | 188.25 | 177.55 | 204.3 | 198.789 |
| 90 | 170 | 99 | 192.5 | 1312600 | 150 | 142 | 162 | 157.8796 |

***Now graph between storage (S) in $m^3/s*h$ & $XI+(1-X)\ O\ m^3/s$***




From the above graph best fit line for least square is for X=0.15
Slope of the line for X =0.15 is K & given by K=2.3h.

**VI. Muskingum Method Parameters Determination by Least Square Method:**

It consisting in generating graph of [XI+(1-X) O] vs storage (S) for different value of X arbitrarily selected such that 0<X<0.5.the optimal value of X is selected as that which produce narrowest and straightest loop graph of [XI+(1-X)O] vs X. the slope of the least square fit to resulting point is the estimate of K.

$$A=\frac{\sum_{i=1}^{n}O_i^2\sum_{i=1}^{n}S_iI_i-\sum_{i=1}^{n}O_iI_i\sum_{i=1}^{n}S_iO_i}{\sum_{i=1}^{n}I_i^2\sum_{i=1}^{n}O_i^2-[\sum_{i=1}^{n}O_iI_i]^2} \qquad B=\frac{\sum_{i=1}^{n}I_i^2\sum_{i=1}^{n}S_iO_i-\sum_{i=1}^{n}O_iI_i\sum_{i=1}^{n}S_iI_i}{\sum_{i=1}^{n}I_i^2\sum_{i=1}^{n}O_i^2-[\sum_{i=1}^{n}O_iI_i]^2}$$

Now using least square method we find out the value of K & X

| ***Inflow* ($m^3/s$)** | ***Outflow* ($m^3/s$)** | ***Storage* (S)** | ***$O^2$*** ($(m^3/s)^2$) | ***$I^2$*** ($(m^3/s)^2$) | ***OI*** ($(m^3/s)^2$) | ***SO*** ($m^6/s$) | ***SI*** ($m^6/s$) |
|---|---|---|---|---|---|---|---|
| 93 | 85 | 715000 | 7225 | 8649 | 7905 | 60775000 | 66495000 |
| 137 | 91 | 812200 | 8281 | 18769 | 12467 | 73910200 | 111271400 |
| 208 | 114 | 1064200 | 12996 | 43264 | 23712 | 121318800 | 221353600 |
| 320 | 159 | 1523200 | 25281 | 102400 | 50880 | 242188800 | 487424000 |
| 442 | 233 | 2189200 | 54289 | 195364 | 102986 | 510083600 | 967626400 |
| 546 | 324 | 2965000 | 104976 | 298116 | 176904 | 960660000 | 1618890000 |
| 630 | 420 | 3742600 | 176400 | 396900 | 264600 | 1571892000 | 2357838000 |
| 678 | 509 | 4424800 | 259081 | 459684 | 345102 | 2252223200 | 3000014400 |
| 691 | 578 | 4932400 | 334084 | 477481 | 399398 | 2850927200 | 3408288400 |
| 675 | 623 | 5229400 | 388129 | 455625 | 420525 | 3257916200 | 3529845000 |
| 634 | 642 | 5308600 | 412164 | 401956 | 407028 | 3408121200 | 3365652400 |
| 571 | 635 | 5179000 | 403225 | 326041 | 362585 | 3288665000 | 2957209000 |
| 477 | 603 | 4837000 | 363609 | 227529 | 287631 | 2916711000 | 2307249000 |
| 390 | 546 | 4329400 | 298116 | 152100 | 212940 | 2363852400 | 1688466000 |
| 329 | 479 | 3778600 | 229441 | 108241 | 157591 | 1809949400 | 1243159400 |
| 247 | 413 | 3209800 | 170569 | 61009 | 102011 | 1325647400 | 792820600 |
| 184 | 341 | 2628400 | 116281 | 33856 | 62744 | 896284400 | 483625600 |
| 134 | 274 | 2093800 | 75076 | 17956 | 36716 | 573701200 | 280569200 |
| 108 | 215 | 1649200 | 46225 | 11664 | 23220 | 354578000 | 178113600 |
| 90 | 170 | 1312600 | 28900 | 8100 | 15300 | 223142000 | 118134000 |
| | | | $SO^2$ = 3514348 | $SI^2$ = 3804704 | SIO = 3472245 | SSO = 29062547000 | SSI = 29184045000 |

**Example Problem Using Least Square Method:-**
Formulas used generally for estimating storage are:
$S_{i+1}=S_i+\Delta t/2(Ii+1-Ii)-\Delta t/2(Oi+1+Oi)$
Formulas for least Square Approach:
From above we can determine the parameter 'K' as

***K=A+B or X=A/A+B***
***A=1255.626164sec. B=7079.100513sec***
***K=A+B***
***K=8284.726677/3600***
***K=2.3h***
***X= A/ (A + B) = 0.151559154***

**VII. MuskingumMethod Parameters Determination By Regression Analysis:**

This method is used for rainfall runoff correlation because of several factors effecting runoff resulting from a given rainfall. The relationship between these two is quite complex, in case of flood routing through Muskingum method, the parameters determined are through relation between storage and wetted average flow the coefficient of correlation is found. The coefficient of correlation whose value is minimum, will give the best correlation, however we may use straightlinear regression for small and medium size catchments and exponential form of regression for large catchments.

The general formulae used in linear regression analysis are as follows:

R=aP+b

Where a and b are constants representing abstractions. The values of a and b are given by the following equations:

$$a=\frac{N(\sum P.R)-(\sum P)(\sum R)}{N(\sum P^2)-(\sum P)^2}$$

$$b=\frac{\sum R-a(\sum P)}{N}$$

$$r=\frac{N(\sum P.R)-(\sum P)(\sum R)}{\sqrt{\{[N(\sum P^2)-(\sum P)^2]\times[N(\sum R^2)-(\sum R)^2]\}}}$$

**From Data GivenTable1.3**

| ***P*** (storage) | ***$P^2$*** (storage) | ***X=0.25 $R_1^2$*** | ***$PR_1$*** | ***X=0.35 $R_2^2$*** | ***$PR_2$*** | ***X=0.15 $PR_3$*** | ***$R_3^2$*** |
|---|---|---|---|---|---|---|---|
| 715000 | $5.1122*10^{13}$ | 7569 | 62205000 | 7708.84 | 62777000 | 61641608.6 | 7432.515 |
| 812200 | $6.5966*10^{11}$ | 10506.25 | 83250500 | 11470.41 | 86986620 | 79570600.48 | 9597.92 |
| 1064200 | $1.132*10^{12}$ | 18906.25 | 146327500 | 21579.61 | 156330980 | 136474497.9 | 16445.856 |
| 1523200 | $2.32*10^{12}$ | 39700.562 | 303497600 | 46375.622 | 328021120 | 279343151.4 | 33632.7357 |
| 2189200 | $4.7925*10^{12}$ | 81367.5625 | 624469300 | 9372.8225 | 670223580 | 579403523.4 | 70047.297 |
| 2965000 | $8.7912*10^{12}$ | 144020.25 | 1125217500 | 161362.89 | 1191040500 | 1060384810 | 127902.078 |
| 37426000 | $1.4007*10^{13}$ | 223253.25 | 1768378500 | 243542.25 | 1846973100 | 1690966562 | 204137.6979 |
| 4424800 | $1.9578*10^{13}$ | 303876.562 | 2429171000 | 322794.4225 | 2513950120 | 236551.7107 | 285801.7576 |
| 4932400 | $2.432*10^{13}$ | 367539.0625 | 2990267500 | 381368.0025 | 3046003620 | 2935370381 | 354167.93 |
| 5229400 | $2.7346*10^{13}$ | 404496 | 3325898400 | 411137.64 | 3353091280 | 329914459 | 398007.3032 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5308600 | $2.81812*10^{13}$ | 409600 | 33975040000 | 408576.64 | 3393257120 | 3401687177 | 410609.2609 |
| 5179000 | $2.6822*10^{13}$ | 383161 | 3205801000 | 375278.76 | 3172650400 | 3238447862 | 391004.7172 |
| 4837000 | $2.3396*10^{13}$ | 194922.25 | 2135535500 | 213906.25 | 2237112500 | 2206998789 | 208186.23 |
| 4329400 | $1.8743*10^{13}$ | 138012.25 | 1608372100 | 125954.01 | 1536504060 | 1679158656 | 150427.77 |
| 37789600 | $1.4277*10^{13}$ | 91053.0625 | 1140192550 | 8182.6025 | 1080868530 | 1198624065 | 100624.594 |
| 3209800 | $1.0302*10^{13}$ | 57121 | 767142200 | 50625 | 722205000 | 811403416.1 | 63902.48075 |
| 1312600 | $1.7229*10^{13}$ | 22500 | 196890000 | 20164 | 186389200 | 207232763 | 24925.9681 |
| $\sum P=55553000$ | $\sum p^2=24.2407*10^{13}$ | $\sum R_1^2=2897607.312$ | $\sum PR_1=2.532*10^{10}$ | $\sum R_2^2=2977396.572$ | $\sum PR_2=2.55843*10^{10}$ | $\sum PR_3=2.52313*10^{10}$ | $\sum R_3^2=2856854.111$ |

Now,
Coefficient of correlation,
for X=0.25, $r_1$=0.81177
For X=0.35, $r_2$=0.7985
For X=0.15, $r_3$=0.8329
Hence, from the above calculation, the best correlation found from the value of X=0.15, $r_3$=0.8329.

**VIII. Results and Analysis:**

In above data analysis, we have found that all the three methods are equally liable for exact calculation of parameters of Muskingum method. Thereby we can use anyone of the method for the calculation of Muskingum method.

**In graphical method**, we have found that linear shape of the graph is coming from the value of x=0.15 and slope of the line for x= 0.15 gives value of k as K=2.3 hour.

**Also in least square method**, we have found that the value of X for which the best relationship is found is for x =0.1515, value of K=2.3 hour.

***K=A+B and X=A/(A+B)***

Where A=1255.626164 sec
B=7079.100513 sec

**From regression analysis**, we have found coefficient of correlation for different values of X=0.25,0.15,0.10
The coefficient of correlation which is nearly equal to 1 found for x=0.15, which is $r_3$=0.8329.
Hence, we have found that all the three method gives the same result for x=0.15.
Therefore, we can apply any of the above mentioned methods which is suitable condition of given data.

**IX. Acknowledgement**

The authors wish to thank Dr. Pande B.B Lal Director General, NIET Greater Noida, UP for providing a conductive environment and facilities for study and research. Authors are also thankful to Mr. Nishant Kumar Srivastava, Head of Department, Civil Engineering, RRSIMT, Amethi, UP, for his continuous guidance, patient advice and encouragement at all stages of this work.

**[REFERENCES]**

[1]. Akan, A. (2006) Open Channel Hydraulics, Oxford: Elsevier Ltd.
[ 2]. American Society of Civil Engineers (ed.) (1992) Design and construction of urban irrigation system.
[3]. Storm-water management systems, New York: American Society of Civil Engineers.
[4]. A Textbook of Engineering Hydrology by K. Subramanya, TMH Publication.
[5]. A Textbook of Irrigation and Water Power Engineering by Dr. Pande B B Lal, Laxmi Publication.
[6]. Kumar, Nagesh, Baliarsingh Falguni, Raju Srinivasa.K, 2010, Extended Muskingum Method for Flood Routing.
[7]. Carter. W. R, Godfrey. G.R, 1960, Storage and FloodRouting, Manual of Hydrology.
[8]. Elnbashir. T Safa, 2011, Flood Routing in natural channels using Muskingum methods, Dublin Institute of Technology