Journal of Geology and Mining Research Vol. 4(1), pp. 8-12, January 2012
Available online http://www.academicjournals.org/jgmr
DOI: 10.5897/JGMR11.015
ISSN 2006-9766 ©2012 Academic Journals

Full Length Research Paper

Application of characteristics method for flood routing (Case study: Karun River)

Mehdi Delphi

Department of Civil Engineering and water, Shoushtar Branch, Islamic Azad University, Shoushtar, Iran.
E-mail: delfi.mehdi@gmail.com

Accepted 29 September, 2011

Open channel flows often come in investigation and intervention scope of the environment engineering. Very often, the water layer depth is weak compared to the horizontal extension of the observed phenomena. This is the case for flows in rivers or channels and of the ground run off. The transition from turbulent Navier-Stokes equations tackled by using the Leibnitz formula. A series of approximation allowing to neglect one or several terms of the Saint-Venant equations is presented. In this study we used Characteristics method as a simplified from Kinematic wave equation for flood routing in the length 61 KM of Karun River. Moreover the process is carried out by MIKE 11 model for estimating the accuracy and agreement of the method together. The results showed that the Characteristics method is applied for this reach of river.

Key words: Navier stokes, saint-venant, flood, characteristics method, kinematic wave.

INTRODUCTION

One of the most important subjects in river engineering is flow routing analysis of rivers which passes through important areas. Flood routing analysis includes determination of flood hydrograph and water levels at different points of flow route. Flood routing in a prismatic open channel is obtained by solving simultaneous equations of continuity and momentum known as Saint Venant Equations (SVE). To solve these equations with analytical and semi analytical methods, some terms should be ignored. If inertia terms in Saint-Venant equations are removed, hydraulic equation with complete inertia will be converted to diffusive equation. Although, more hydrodynamic phenomena in rivers are the three-dimensional physical phenomena, but when the flow followed certain path, one-dimensional flow can be considered. Mathematical models are useful tools in analysis of river flow or Hydraulic structures. Flood routing is a problem of great importance particularly in view of increasing urbanization near river channels. In the unobstructed river channels, storage characteristics of the flood plain strongly influence the flood behavior. The storage characteristics in turn depend on the detailed geometry of the flood plain. In many cases, the characteristics cannot be directly determined. In such detailed topographical maps of the flood plain are not available so that the storage cases, it is attempted to establish a certain empirical relationship between the storage within the length of the river in which routing is to be performed, and the weighted flow determined from the inflow and outflow records. Such an empirical relationship is then used with the continuity equation to rout future floods. The classic method to solve nonlinear equation of partial differences equations with two variables is known as Characteristics Method. Using of this method was popular in the 60th decade A.D. for analysis of unstable flows. Although after that time the finite difference method was replaced instead of Characteristic, but still the characteristics method is used in finite differences schemes for simulating the boundary nodes (Shooshtari. 2008). Figure 1 show the Characteristics curve for the mentioned method.

MATERIALS AND METHODS

As it mentioned before two methods applied for Flood routing in this paper. The main method that we used it through MIKE11 as a numerical model is Dynamical and the second one is Characteristics which simplified and obtained from Kinematic wave solution. Continuation of paper we will mention the concept and scheme of the two mentioned methods.

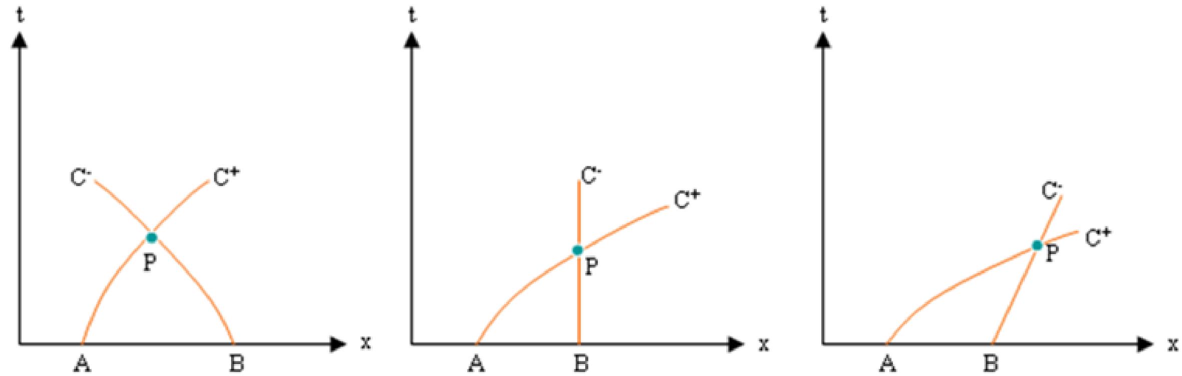

Figure 1. The characteristic curves for Sub-Critical, Critical and Super Critical flows.

Solution scheme in characteristics method

In this method the partial differential equations of Saint-Venant converted to pair ordinary differential equations and finally solve by using finite difference scheme. This method help to better understand the physics of shallow water. Moreover the initial and boundary conditions in this way could be better obtained (Delphi, 2010).The governing equations of Characteristics Method are shown as below:

$$\left[\frac{dV}{dt}\right]+\frac{g}{c}\left[\frac{dy}{dt}\right]=g(S_0-S_f) \quad \frac{dx}{dt}=V+C \tag{1}$$

$$\left[\frac{dV}{dt}\right]-\frac{g}{c}\left[\frac{dy}{dt}\right]=g(S_0-S_f) \quad \frac{dx}{dt}=V-C \tag{2}$$

This method is derived from kinematic wave theory. In this method routing coefficients are determined by using graphical scheme.

MIKE11 Model

Implicit method as a numerical one with usage of Abbott and Ionesco schemes defines to sever Partial Differential Dynamic Wave Equations in MIKE11 software. Commencing the project, we perused and analyzed recorded time series of water level data in two hydrometric Stations for 246000 hours, overall. Ahwaz and Mollasani stations are located in downstream and upstream of the Karun River, respectively. Using aforesaid statistics, we collected discharge time series during 40 years up to now; and consequently, we used 4 acceptable of flood events with suitable historical scattering. Later on, we performed and optimized MIKE11 flood routing model with definition of aforesaid statistics as input boundary conditions. Needless to say that although we used Manning coefficient (n) as the meaning of optimization parameter in MIKE11 hydrodynamic model; we estimated it through the main of Karun River with territorial reconnaissance, (Figure 2 and 3).

Initial and boundary conditions

As we mentioned before flood routing bases on two partial differential equations which named Dynamic Wave Equations and contain Mass continuity and Momentum equation:

$$T\frac{\partial y}{\partial t}+A\frac{\partial v}{\partial x}+V\frac{\partial A}{\partial x}=0 \tag{3}$$

$$\frac{\partial v}{\partial t}+V\frac{\partial v}{\partial x}+g\frac{\partial y}{\partial x}=g\left(s_0-s_f\right) \tag{4}$$

Because of water viscosity property, flood movement in open channels occurs continually. Consequently, in each cross section through the channel, initial and boundary discharge conditions impress flood condition in next time steps. On the other hand, most of the numerical methods (finite difference and finite element methods) which are used to solve Dynamic Wave Equations for flood routing description contain schemes with two or three time steps (i-1, i, i+1). Furthermore, based on Courant Equation (R. Courant, K. Friedrichs and H. Lewy, 1928), there is some limitation in range of Δt and Δx definition. To wrap it up, it could be said that time range of input statistics definition; and also, sensitivity of each case study flood routing modeling to input discharge statistics have to be calculated. The upstream boundary condition for Mollasani station that was used in the model was flood hydrograph related to January 6th, 1996. The downstream boundary condition for Ahwaz stations that introduced to the model is rating curve (Delphi et al., 2010). According to upstream hydrograph, the model will calculate this curve at downstream. In the simulation process, MIKE11 was performed with approximate hydrodynamic conditions (Manning's n), after which the model was calibrated by the changing value of Manning's n so long as the observed and measured data reached the agreed result. Thus, the average resistance factor in the entire reach obtained a value of 0.028. In Figures 4, the results of model calibration are shown. Obviously before calibration of the model, it was observed and calculated that hydrograph don't match very well, this means that Manning's n is incorrectly introduced to the model, but after calibration the mentioned hydrographs had more accurate status. After this step flood routing was repeated by Characteristics method as shown in Figure 5.

Karun River

Karun River is only navigated River in the past that contain wide area of Iran. Its basin has been covered by provinces of Khouzestan, Lorestan, Charmahal Bakhtiari and Boyer Ahmad, respectively. Karun basin is located at middle Zagros folding and south of Karkheh river basin. Karun river length is about 890 KM and its basin included 66930 Sq. KM and only a little part of it including plain and foothill regions. This river has a large content of permanent flow. The annual water volume of this river is more than 24 milliard cubic meters and its instantaneous

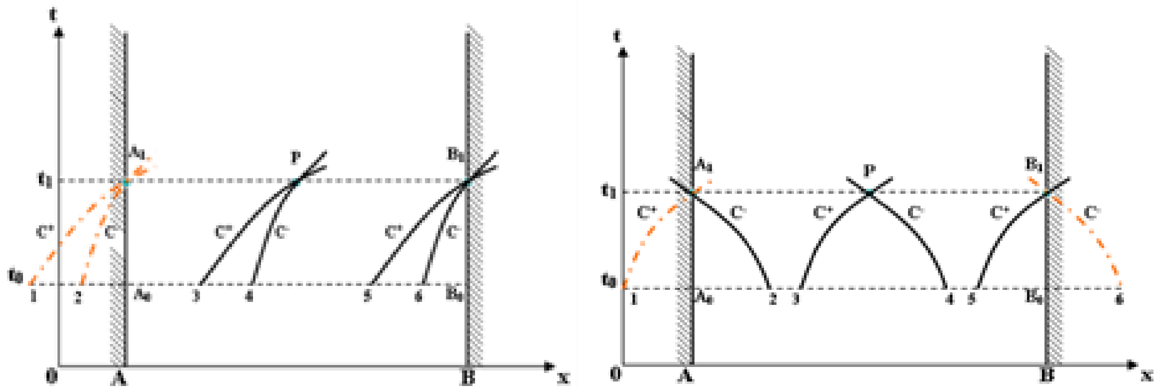

Figure 2. Effective range of initial and boundary conditions in numerical modeling utilization.

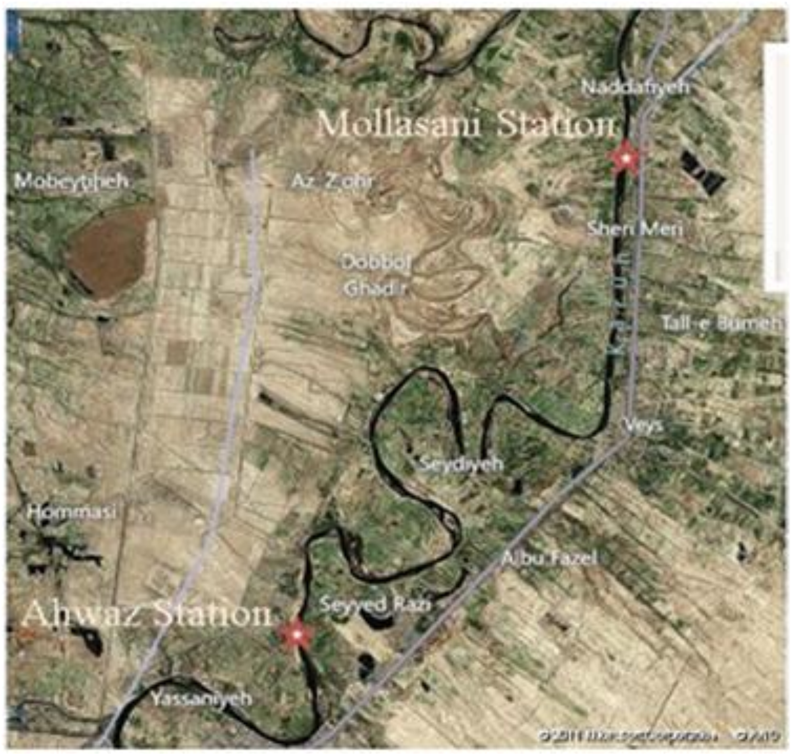

Figure 3. Satellite picture from the case study zone showing Mollasani and Ahwaz stations

average discharge value is 736 cubic meters per second in measured data. The sedimentations of this river form Khouzestan plain and expand it (Delphi, 2010). One useful satellite picture from the case study zone is taken as follow as below:

Model Run

After gathering the information of river net work and cross sections in the reach between Mollasani and Ahvaz stations, about 61 KM in length and 70 cross sections imported to MIKE11 software. The upstream boundary condition for Mollasani station that used in the model was flood hydrograph related to January First 1997. The downstream boundary condition for Ahwaz stations that introduced to the model is rating curve (Delphi, 2010).]. According to upstream hydrograph the model will calculate this curve at downstream. In the simulation process MIKE11 performed with approximate hydrodynamic conditions (Manning's n), after that the model calibrated by changing value of Manning's n insofar as observed and measured data reached to good agreement. Thus the average resistance factor in whole of reach was obtained 0.028 in value. The calibration process applied by using shuffled algorithm that automatically improves the accuracy of choosing the manning coefficient for each time step. In

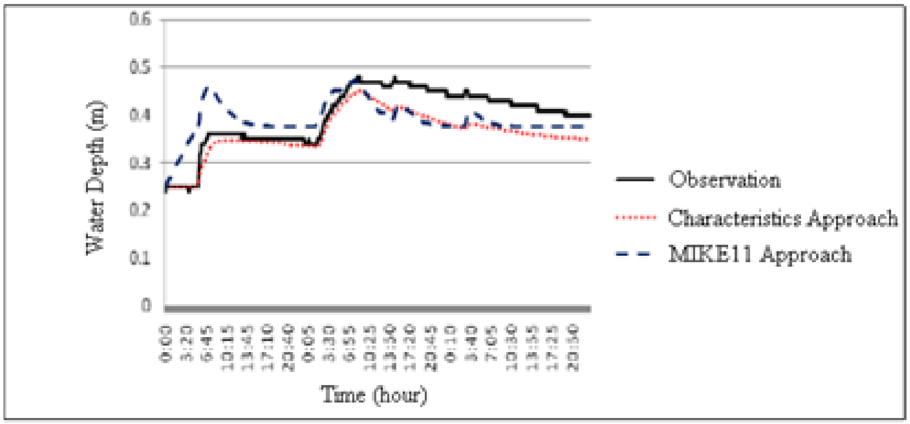

Figure 4. Calibration of MIKE11 Model and Characteristics Method .

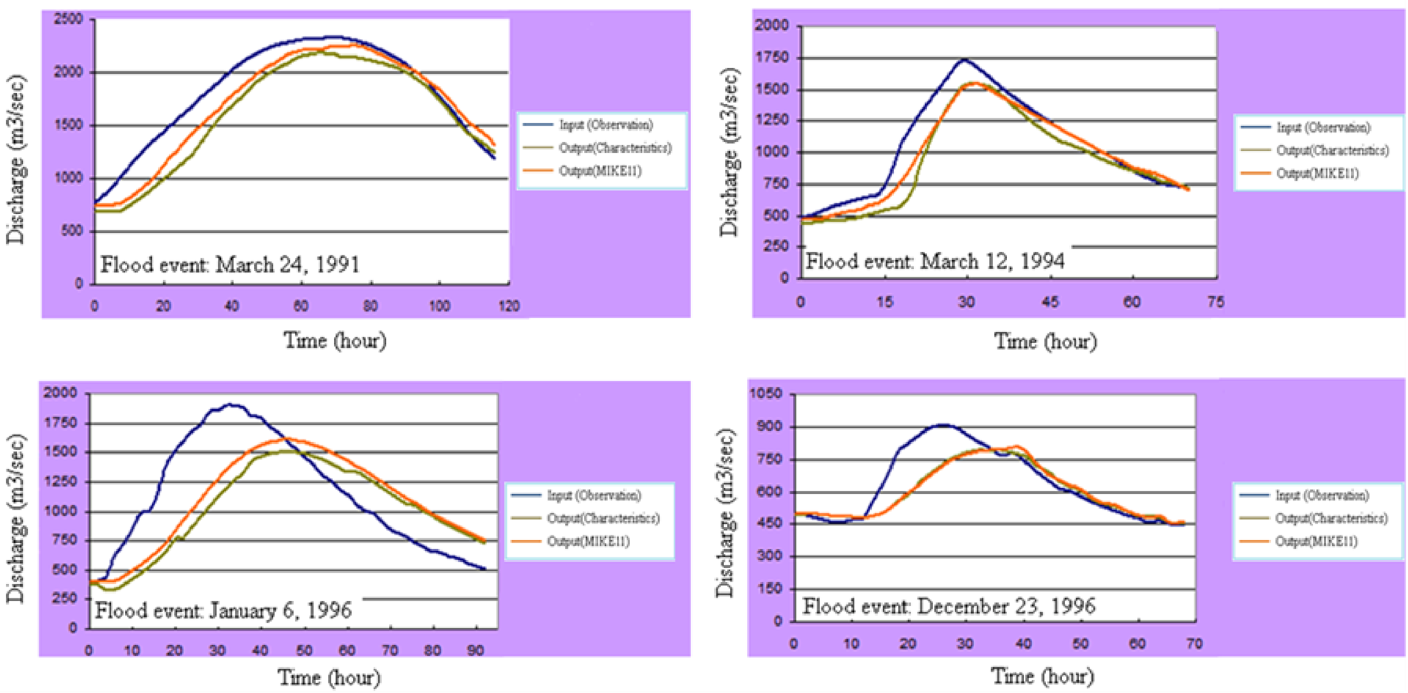

Figure 5. Results of flood routing by MIKE11 and Characteristics Method after choosing the correct manning coefficient.

Figure 4 results of model calibration has been shown. As seen in Figure 5, the observed and calculated data has a good agreement in the Characteristics method. The statistical analysis of MIKE11 model and Characteristics results were done and have been showed in Table 1. As seen in the Table 1, Characteristics results are very close to MIKE11 model. Thus for this reach of Karun river we can use both of these methods with high accuracy.

RESULTS AND DISCUSSION

As seen in Figure 5 and Table 1, there is a good accuracy by using Characteristics method and MIKE11 model for simulating the propagation of flood in this river reach. Obviously, the calculated error of this method in this reach is acceptable. Moreover, usage of Characteristics method as simplified derived from Kinematic wave method can be useful when observational data are insufficient or inaccurate. So we can say Ignoring inertia terms in saint – venant equations at the case study zone seem not to be an unreasonable approximation. Thus, Characteristics method can be used for flood routing between the reach of Mollasani to Ahwaz stations of Karun river with high accuracy. However, numerical solution, semi analytical and analytical schemes of this

Table 1. Comparison of statistical analysis results of MIKE11 model and Characteristics Method.

Performance criteria	Statistical Analysis Results	
	MIKE11	Characteristics Method
STD	0.041	0.562
R2	0.986	0.926
MSE	0.0021	0.00721
RMSE	0.046	0.085
MAD	0.019	0.039
SSE	0.132	0.729
Min absolute error	0.0003	0.00015
Max absolute error	0.854	0.219

method are usable. According to Table 1, performance of MIKE11 as a numerical model is higher than Characteristics method, because this model uses high order fully dynamic method for solving saint-venant equations. So we recommend High order Fully Dynamic method for this reach of the river. It is tentatively suggested that the simplest and best way of solving flood propagation problems is to use the full equations with an explicit forward- time centred- space scheme (Ferrick, 2005).

ACKNOWLEDGEMENTS

The extensive support of Islamic Azad University, Shoushtar Branch throughout the research by providing the field for doing this work is highly appreciated. Also the authors wish to thanks Dr. Mahmoodian Shooshtari about his useful recommendations.

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