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ORIGINAL ARTICLE

NUMERICAL EVALUATION OF ROUTING OF DAM RESERVOIR TO DISCUSS THE FLOOD PLAIN

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ABSTRACT: Flood is a complex natural disaster and destroying phenomenon that causes considerable annual damage. In addition, floodplain and lands alongside river beds are always in expose of flood hazards, while most of economic and social activities are conducted in these areas. Therefore, in these regions, flood zoning is necessary. In hydrology, routing is a technique used to predict the changes in shape of water as it moves through a river channel or a reservoir. In flood forecasting, hydrologists may want to know how a short burst of intense rain in an area upstream of a city will change as it reaches the city. Routing can be used to determine whether the pulse of rain reaches the city as a deluge or a trickle. Other uses of routing include reservoir and channel design, floodplain studies and watershed simulations. In this research, the map of flood zoning with different return periods for a part of Gorgan Rood River, Iran was provided. Hydrological data and information were collected and analyzed. Flood routing by using Muskingum-Cunge method in different reaches was conducted.
KEYWORDS: Flood Routing, Hydrologic Model, Iran.

INTRODUCTION

Unsteady open channel flow modeling is important in flood routing and prediction, stream flow modeling, river regulation and in the analysis of estuarine flows. Flood routing is the activity of mathematically modeling the progress of a flood wave (or hydrograph) while it moves downstream. It is an integral component in any hydrologic model and is the most important activity in predicting flood stages and discharges as functions of time and space along a river reach. Flood routing is employed in practice for the solution of a wide variety of problems associated with water use. Some of these include:

Predicting flood hydrographs for given or assumed initial conditions;

Determining hydrographs modified by reservoir storage;

Evaluating past floods for which records are incomplete;

Studying the effects of water resources development on the downstream flow conditions Flood routing is used in predicting the characteristics of a flood wave and their change with time in the direction of flow. These characteristics include:

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), peak discharge, which is required in the design of spillways, culverts, bridges and channels sections, and total volume of water resulting from a design flood to assist in the design of storage facilities for flood control, irrigation and water supply.

Unlike the hydrologic routing method, which is based on the solution of the continuity of mass equation alone, the hydraulic routing approach is based on both continuity and momentum equations. The numerical model used for this exercise is RUFICC (Routing Unsteady Flows In Compound Channels), which is a one-dimensional model for routing floods in channels of composite sections (Wu *et al.*, 2001).

RECENT FLOOD DISASTERS

Reinsurance companies, due to their worldwide activities, are among the best sources for natural disaster statistics (Kron, 2000; Munich, 2000). Their analyses focus on three aspects: the number of people affected (fatalities, injured, homeless), the overall economic damage to the country hit, and the losses covered by the insurance industry.

Natural disasters with thousands of deaths almost always hit poor countries and are mainly caused by earthquakes. The poverty aspect is related to the higher vulnerability in less developed countries (poorer quality of structures, more people), the cause (earthquakes) to the sudden onset of such

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events, which strike without warning. In the past (more than 10 years ago), floods were also responsible for a huge number of deaths. This is not so anymore today, because early warning has become more operational, more reliable and hence more effective.

In the statistics of economic losses floods take a leading position. While two earthquakes (Kobe: US$ 100bn; Northridge: US$ 44bn) still have been the costliest natural disasters so far, floods, which usually affect much larger areas than earthquakes and occur much more frequently, have at least the same importance. Not only the great disasters, but also the vast number of small and medium-sized events cause tens of billions of dollars of losses every year for economies and severe distress to people.

Probably, floods are responsible for more damage than all other destructive natural events together. Additionally, the financial means societies all over the world spend on flood control (sea dikes, levees, reservoirs, etc.) is a multiple of the costs they devote to protection against other impacts from nature.

Table 1 shows the greatest flood losses in recent years. It is apparent that China is the country whose economy suffers most and most regularly from such disasters. It also becomes clear that great flood losses can occur in practically any region of the world.

Table 1: The costliest floods of the past 10 years (original values, not adjusted for inflation)

Rank	Year	Country/countries (mainly affected regions)	Economic losses US$ bn	Insured (%)
1	1998	China (Yangtze, Songhua)	31	3
2	1996	China (Yangtze)	24	2
3	1993	USA (Mississippi)	21	6
4	1995	North Korea	15	0
5	1993	China (Yangtze, Huai)	11	0
6	1994	Italy (North)	9.3	<1
7	1993	Bangladesh, India, Nepal	8.5	0
8	2000	Italy (North), Switzerland (South)	8.5	6
9	1999	China (Yangtze)	8	0
10	1994	China (Southeast)	7.8	0
11	1995	China (Yangtze)	6.7	1
12	2001	USA (Texas)	6.0	58
13	1997	Czech Rep., Poland, Germany (Odra)	5.9	13

The insured share of flood losses from these major events has usually been relatively small. For the insurance industry windstorms are clearly the most critical loss events, simply because the insurance density is highest for this type of peril. However, a tendency towards higher insurance densities for flood may be observed worldwide and, in particular, a tendency towards extreme single insurance losses due to water. A good example of this is Tropical Storm Allison, which drenched the Houston/Texas area with over 750 mm of rain in just five days in June 2001 and caused insured losses of US$ 3.5bn. With economic losses of US$ 6bn this event ranks 12 in Table 1, having by far the highest share of insured losses of the 13 events listed. Table 1 does not reveal any trend. However, a distinct change in flood losses over time becomes apparent in Fig. 1. Here the losses from great flood disasters for each year since 1950 are plotted vs. time. The average annual losses from such catastrophes in the period since 1990 have become a multiple of the values in the previous decades. Natural catastrophes are classed as being *great* if they cannot be handled by the affected country/region alone, but require interregional and international assistance. This is usually the case when thousands of people are killed, hundreds of thousands are made homeless, or when a country suffers substantial economic losses, depending on the economic circumstances generally prevailing in that country. Great catastrophes can be analyzed very well in retrospect because even records that go back several decades can still be investigated today. If the statistics were based on all the loss information collected (including small and medium events), the influence of advanced communication technology over the past decades would introduce an unacceptable bias. Losses that have been experienced describe the past. What we expect in the future must be based, on the one hand, on these experiences, but, on the other hand, on the analysis of each loss event too in order to determine the respective factors that exerted their influence on it. From this analysis we can derive an expected value for a (future) loss, which we call *risk.*

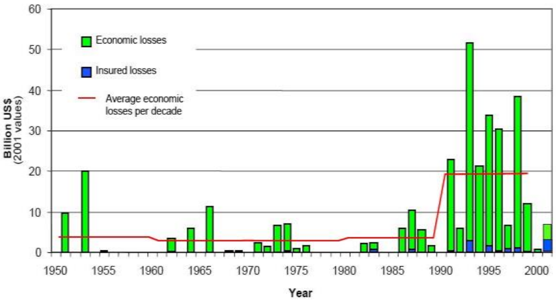

Figure 1: Great Flood Disasters 1950 - 2001

RESEARCH MODELS

In this study, the flood routing of corresponding part, was don, using the models of Muskingum - Kanzh, Canucks, At - Keen and HEC-RAS and HEC-HMS software.

3.1. Muskingum-Cunge Method

Muskingum – Cunge method is in fact the generalized of Muskingum method.
Cunge derived a relation for K and X coefficient from a finite difference approximation of the kinematic wave equation. This method can route the flood unsteady flow, based on hydraulic characteristics of the river. In Muskingum – Cunge method, routing parameters are defined, only, based on physical and hydraulic characteristics which are measurable in the channel and there is no need to calibrate the model based on past floods. Among other features of this method, there is minimum need for section removing and consequently lower cost and time, compared with hydrodynamic methods. Cunge indicate that Muskingum equation is similar to the equation of transferring diffusion and its results are the same as the results of the linear kinematic wave method. He modified the Muskingum equation by disconnecting Kinematic wave equation and matching numerical diffusion with physical diffusion, in a way that routing parameters are calculated in regard to physical characteristics of river. Differences between this method and Muskingum's include changing the base of Muskingum method by specific way of Cunge and his colleagues based on diffusion and also the possibility of considering lateral flow. On the other hand, according to determining the parameters by hydraulic and measurable data, in the River, this method can be easily used for those rivers whose discharge has not been calculated (Yu, 2001).

3.2. Muskingum Flood Routing Method

Muskingum methods, is among hydrological methods, which is extensively used in river routing. This method was introduced by McCarthy in 1935 to perform some study on Muskingum River in Ohio to control flooding.

This method is based on the relation between discharge and storage. When the input and output values are equal, Storage volume establish a simple linear relationship with output flow. Storage volume shall not be determined solely by the discharge, but if the input and output discharge within a certain scope are the function of the upstream and downstream depth, total storage is depend on both input and output discharge and is divided to two part, Prism Storage which is only the function of output discharge and Wedge Storage which is depend on the difference of input and output discharge. In this method, the routing parameters are determined in regard to input and output hydrograph. In Muskingum method the storage equation can be expressed as follows:

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

3.3. Hec-Hms Software Model

HEC-HMS model is an advanced version of the HEC-1 model, which is introduced by hydrologic engineering center of U.S. army in. each of the routing methods in this software, is performed by solving the energy and continuity equations problems. But in these methods, some simplifying assumptions are intended for solving equations. Thus, according to intended hypothesis A Convenient method should be selected. In this study, the Muskingum – Cunge method is used.

3.4. Hydrodynamic Model With Hec-Ras Software

HEC-RAS Model is widely used in the various fields of hydraulic problems, where routing process is performed according to Sant Vnant Equation. In this model the upstream boundary conditions are defined by input hydrograph and downstream boundary condition are defined by the normal depth. The base discharge of the river is considered as the initial condition.

3.5. Golestan Dam Characteristics

Golestan Dam is located 12 km north east of Gonbad Kavus in Iran. It is constructed on Gorgan Rood River to develop the agricultural farms and products. The dam is made of clay with concrete membrane over it. The main characteristics are listed in the below table:

Table 2: Golestan Dam Characteristics

Crest Length	1350 m
Foundation width	200 m
Crest Elevation	66 m
Reservoir volume (N.W)	56 million m^3

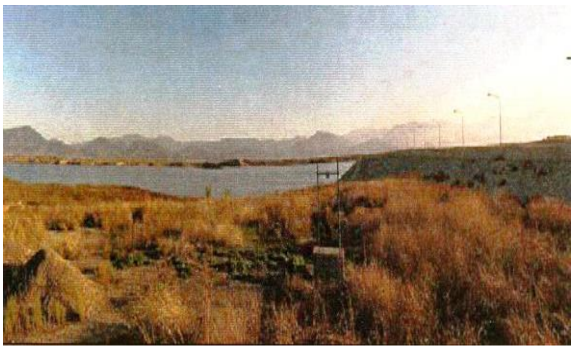

Figure 2: View from the river and the basin

3.6. Flood Routing And Boundary Conditions

The Muskingun_Cunge method was used for flood routing (Kron and Willems, 2002). A discharge-stage was used as upstream boundary conditions and normal depth as downstream conditions in the HEC-RAS model. After introducing the required data to HEC-RAS and executing the model, the output files and flow characteristics extracted. Then, the HEC-RAS data was imported into ArcView.

3.7. Digitizing Topography Map and Digital Evaluation Model (Dem)

First, the topography map (1:50,000) was digitized and it was georeferenced using some control points. The required DEM was extracted. For hydraulic modeling of river channels, a TIN model was preferred. By combining the vector and raster data to form a TIN, the intended result is a continuous three-dimensional landscape surface that contains additional details in stream channels (Kron, 1999). This approach was employed to form the TIN terrain model.

3.8. Floodplain Mapping

Areas inundated by flooding occur wherever the elevation of the floodwater exceeds that of the land. After importing water surface elevation with distance from the stream centerline to the left and right floodplain boundaries into ArcView and subtracting land elevations from floodwater elevations, flooded areas were delineated.

RESULTS AND DISCUSSION

By field measuring, some cross sections with different distance (regard to river morphology) and floodplain characteristics around river were surveyed. The resulted tables and figures are shown as below:

4.1. First Scenario: Maximum Occurred Flood

In this situation the maximum flood velocity is no more than 1.5 m/s. moreover, the flood depth is illustrated in Figures 3 and 4.

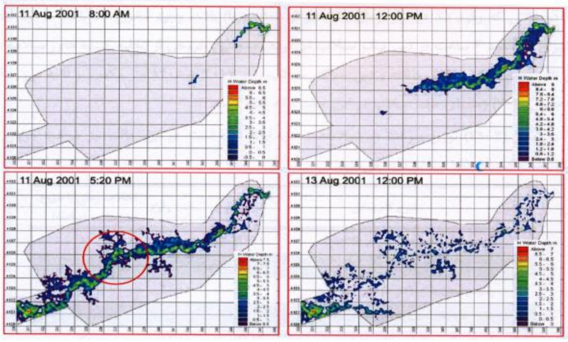

Figure 3: Flood zoning for the maximum occurred flood.

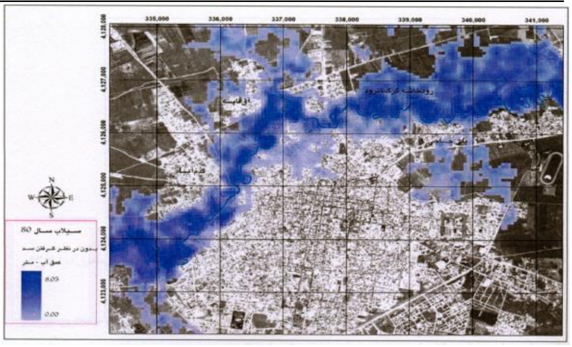

Figure 4: Maximum flood depth in the plain

4.2. Second Scenarios: Floods Of Various Return Periods

Floods with return periods of 100 year, 1000 year and 10000 year are simulated at first. In this part the effects of the presence of the Golestan dam is also demonstrated. As results the flood zoning is illustrated for both conditionds: 1- presence of dam 2-if there was no dam there. For the first situation it is also assumed that the normal water level is 62 m above sea mean level.

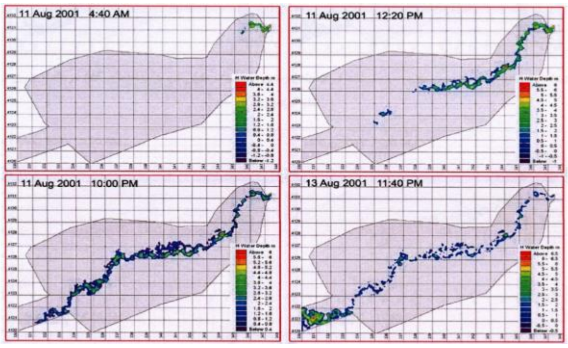

Figure 5: 100 year flood zoning (No Dam)

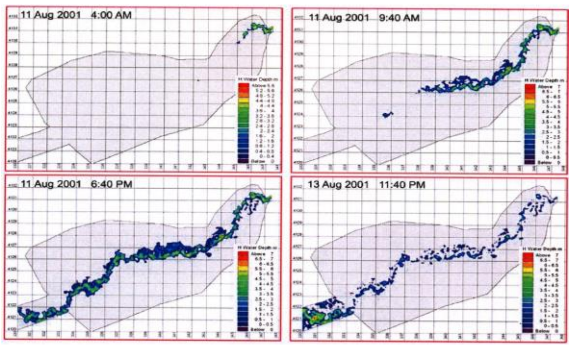

Figure 6: 1000 year flood zoning (No Dam)

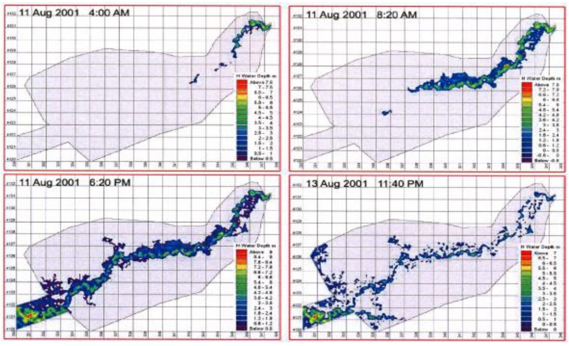

Figure 7: 10000 year flood zoning (No Dam)

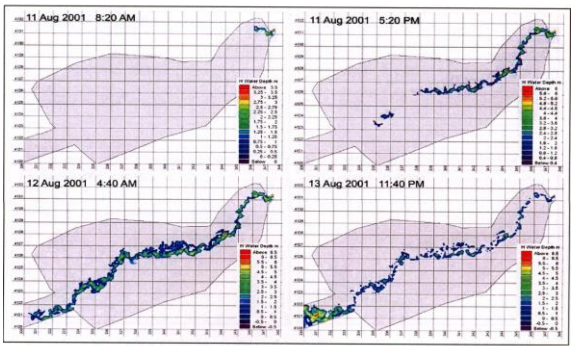

Figure 8: 1000 year flood zoning (N.W.L)

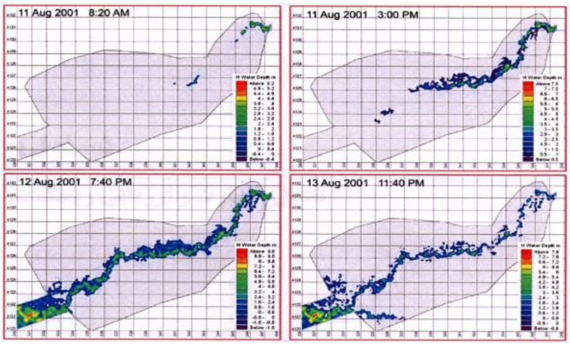

Figure 9: 10000 year flood zoning (N.W.L)

CONCLUSION

Flood zoning maps, could be a suitable and lawful tool for determination of development strategies. In this research, flooding area and flow depth in different return periods using HEC-RAS model and ArcView were determined. The accuracy and precision of flooding maps were evaluated by comparison with information and local investigations. Regard to these comparisons, the precision of resulted maps is reliable.

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