Research Journal of Recent Sciences ISSN 2277-2502
Vol. **4(8),** 122-127, August **(2015)** *Res.J.Recent Sci.*

Combination of HEC-HMS and HEC-RAS models in GIS in order to Simulate Flood (Case study: Khoshke Rudan river in Fars province, Iran)

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Available online at: www.isca.in, www.isca.me
Received 7th January 2014, revised 22nd April 2015, accepted 27th September 2015

Abstract

Residential and urban development in flood plains beds and riverbanks, regardless of hydrological and hydraulic conditions governing watershed and river, on the one hand, increase the risk of flooding and on the other hand, loss of investment in this area. In the present study to investigate the behavior of the rivers flood and how to expand its range in a reach of khoshke Rudan river, located in the Chaharmahal and Bakhtiari province, it was used from the integration of HEC-HMS hydrological and HEC-RAS hydraulic model. HEC-HMS model was calibrated for the study area by surveying of the cross sections of the rive using the rain gauge and rainfall gauging stations of the neighboring basins. Flood zones associated precipitations with periods of 10, 20, 50 and 100 years was determined by using HEC-GeoRAS extension in GIS environment. The results obtained from the study confirmed the high efficiency of the combination of GIS and HEC-RAS model and while provening the performance the model, recommend its application in program planning and management of residential and agricultural areas.

Keywords: Combination, HEC-HMS, GIS, simulate flood.

Introduction

Flood plains are association of agricultural and entertainment activities and hence must be protected against risks. Flood is a natural disaster that its damages to human are higher than other natural disasters such as drought and famine and is a major concern in many regions of the world[1-8]. Therefore, we must to select appropriate and effective methods for management and flood control by understanding the hydraulic flow in floodplains. Land use change can result in change of hydrological conditions[9] such as flood frequency[10], base flow[11], and annual mean discharge[12]. Various studies show that lack of attention to rivers and oueds make an exponential growth in flood frequency and the amount of damages and in the meantime urban and semi-urban areas have highest potential risk to flooding. Since complete protection from flood risk is not possible, living in the flood and implementation of new policies about land use management and residential development in riverbank to reduce the impact of its destruction is necessary. Awareness of flood and the study of its behavior require sufficient data about the basin hydrologic condition and river discharge and since achieving this goal is not possible in seasonal rivers and regions where no steady flow, hence implementation of hydrologic models is useful to simulation of rainfall-runoff process and hydraulic models for analysis of the runoff flow in the river and its distribution. Traditional rain gages provide a fine enough resolution for accurate runoff calculations and flood warnings[1,13]. Hence flood modeling requires distributed model predictions relating to planning and insurance[14]. Recently, there has been an increase of interest in flood simulation using Geographic information systems (GIS) a powerful tool for managing spatially distributed data and also the distributed catchment model[15-21]. Using GIS and hydrological watershed parameters, one can to create a hydrological information development system[22]. The rapid distribution of GIS techniques to a wider population has the potential to make various hydrological models more transparent and to enable the communication of GIS operations and results to a large group of users[23]. It is possible to facilitate Hydraulic modeling of river systems using GIS. While Data preparation and model interpretation are time-consuming operations, hence using GIS can simplify this process. Also, differences in data models have a significant impact on the computational manipulation of data in the above coupling process[23]. For predicting effects of bed forms on flow depth with known discharge and slope, a method was derived through dimensional analysis, statistical analysis of an extensive laboratory and field database, and fundamental hydraulic principles[24]. However, little research has been undertaken to study the problem of flood zoning. The present study aims at highlighting some meteorological and hydrological factors which could enhance the hydro-meteorological modeling of such hazardous events. At this purpose, two different hydrological models have been used over the upper Khoshk Rud river basin: HEC-HMS model – run in a semi-distributed and event-based configuration) and HEC-RAS (the distributed and physically-based). These models differ in their physical parameterizations and structure. HEC-HMS utilizes a graphical interface to build the semi-distributed watershed model and to set up precipitation and control variables for the simulations. The two-way nesting allows a feedback upscale of the small-scale features from the fine to the coarse domain, and therefore, it influences the features in the large-scale[25]. Therefore, both nesting techniques could lead to rather different results on the simulated precipitation fields. It would be thus of interest to investigate the behavior of the rivers flood.

The present study was aimed to investigate the behavior of the rivers flood and how to expand its range in a reach of the Khoshke Rudan River using the integration of hydrological model HEC-HMS and hydraulic model HEC-RAS.

Material and Methods

Case Study: The study area with 2.9 km long of khoshke Rudan river is located in the in Chaharmahal and Bakhtiari Province. Using only published data sources and used to simulate a large flood event that occurred in January 2012. According to UTM system, the coordinates of the study area is as flow;

X_{Min}=455031/91, X_{Max} = 456981/2 Y_{Min} = 351947/39, Y_{Max}=3569757

The mean annual rainfall of the region is estimated to 500 mm by Isohyets method and 516.2 mm by Theissen method. The main part of the basin has semi arid climate by De-marten method. The concentration time of the watershed is about 3.2 hour. In practice, a flood event at such a river section is defined when the water level, recorded by the gauge station, reaches or exceeds the value of 0.8m (in terms of discharge, a value of about 80 m3s−1), corresponding to the warning threshold. The pre-alarm level is set to 1.6m (corresponding to a discharge value of about 630 (m3s−1)[25]. To recognize the khoshke Rudan river watershed, some of information such as the vegetation, geology, soil and other information were prepared in the form of maps. Also the evaluation of the correctness has been performed to compare the results of hydrological model HEC-HMS and hydraulic model HEC-RAS with observed flow data for calibration of the model. Some of GIG techniques such as; HEC-GeoRAS extension v.3.1, ArcView software, 3D Analysis and Spatial Analysis has used in order to the regional modeling, simulation and flooding. To determine the water velocity in the selected reaches, a cross section was surveyed between the highest and lowest main channels in each hydrological unit[26]. Also, these sections should be regular and constant in shape. After estimation of roughness coefficient by Chow method[27], Manning equation was used to calculation of the water velocity for the main river and each tributary. Finally, 7 return periods of 2, 5, 10, 25, 50, 100 and 200 years has selected in order to the flood zonation of the 2.9 km section of the khoshke Rudan river watershed[28].

The hydrological models: The hydro-meteorological model inter-comparison study proposed in the present work is carried out by using two different physically-based rainfall-runoff models to generate simulated discharges. These are: (i) HEC-HMS and; (ii) HEC-RAS[25]. The modeling features in a hydrologic or hydraulic simulation model must be uniquely identified so that input and output time series associated with them can be labeled appropriately.

HEC-HMS model: HEC-HMS model for flood simulation utilizes a graphical interface to build the semi-distributed watershed model. For each sub-basin in the mentioned watershed, the hydrological model is forced by using a single hyetograph.. Firstly, using kriging method, rainfall spatial distributions were generated from hourly values recorded at the automatic rain-gauge station located in the upper section of the khoshke Rudan river. Then, for each sub-basin the hourly rainfall series were calculated. The Soil Conservation Service Curve Number method (SCS-CN) was used to calculation of runoff volumes in the rainfall-runoff model.

Development of HEC-RAS flood simulation Model (Geometric simulation of river): The HEC-RAS model when presented with the appropriate hydraulic and geometric data, calculates water-surface profiles. The original reference for the method to determining the roughness coefficient[27] in reaches is Cowan method because it includes several factors control the roughness coefficient[29-32]. Then HEC-Geo RAS extension was used to preparing and inputting geometric information about the reach that these data are include flow path, left and right bank and cross sections that in the form of new data layers was entered into HEC-RAS model. Then while importing of the output hydrographs resulted from HEC-HMS and introducing the roughness, channel convergence and divergence coefficients, HEC-RAS model was run and the results of the hydraulic analysis and extracting of flood zones and flood depth was done in ARCVIEW software and the flood plains was determined for return periods of 10, 20 and 50 years. Figure-1 presents the floodplain zone map with different return periods.

Hydrological model and choose of suitable software: In this study to simulation of rainfall and runoff and to determining the output flood hydrograph, the HEC-HMS model version 3.5 was used. Model inputs were identified according to selective methods in this model. To convert the rainfall data to the runoff data, curve number method or CN was used. CN map was prepared by integrating the maps of vegetation, hydrologic soil groups and land use in GIS and Arc View 3.3 software. Figure-2 shows CN map in Cheharmehal-o-bakhteyari province. Model calibration and validation was done using rainfall-runoff events in the region stations that to investigation of spatial distribution of rainfall, IDW method in GIS was used and to determining of the temporal pattern of precipitation for each sub-basin, precipitation pattern belong to the nearest register station was used. After calibration and validation of model extraction of optimal parameters, precipitation of return periods 10, 20, 50 and 100 years was extracted from intensity, duration; frequency curves (IDF) of synoptic station in the basin and was entered into the model. Then flood hydrograph was computed for various return periods using HEC-RAS software for Jonghan sub-basin and was presented in figure 2. To calculation of average reach velocity, a spatial harmonic mean travel time was computed[33].

Results and Discussion

Discharge Estimation for Different Return Period: The probability maximum discharges between different statistical distributions of discharges, using Hyfa software was prepared and then the best one with different return period for each station was determined. The result shows that in this study, Pearson type III has the best statistical distribution. The flow rates used in simulation of flood discharge in the khoshke Rudan river watershed are shown in table-1.

Determination of Manning roughness coefficient: In order to determination of manning`s coefficient, all measurable characteristics in right, left and the main bed of the river channel of the selected sections, separately have measured in the field (table-2).

The results of this study indicate the ability of HEC-RAS model to simulate the hydraulic behavior of a catchment and determination of spatial parameters are easy by hydrological model systems and the results can be generalized. Also, the ability of GIS to accurately preparation of the input and output of model data shows their combining performance. Also detailed surveying of the river bed and flood plain residential areas can increase the efficiency and accuracy of the output map. Hence we can to recommend the application of this method in flood plain management and flood insurance and also planning for residential development for similar areas and especially for urban areas. If the present study be accompanied with hydrometric data, it is capable of simulating flood. This is consistent with some researchers[1,34,35]. The application HEC-GeoRAS extension is reach TIN1 that is considered as the base of extraction of geometric properties of the reach that has shown in figure-2.

Table-1
The best statistical distribution data used for simulation of flood discharge in khoshke Rudan river watershed

Analysis method	Discharges with different return periods (m3/s)							
Distr./Ret.(yr)	2	5	10	20	25	50	100	200
Log. Normal (2 parameter)	17.2	52.3	72.5	97.88	124.35	157.28	195	223
Log. Normal (3 parameter)	20.15	63.5	74.3	99.36	118.51	162.3	191	212
Pearson III	12.56	46.5	69.7	94.32	114.88	168.32	184	197
Log. Pearson III	25.63	52.6	65.96	75.26	129.65	181.12	172	183
Gamble	18.6	67.2	89.21	88.94	134	155	169.22	177
Selected Pearson III	15.243	41.898	60.898	83.95	113.25	137.32	150.243	182.898

Table-2
Determination of coefficient for each section

No. Section	Right Bank	Left Bank	Main Channel	Number for each section
1	0.050	0.050	0.040	1 to 46
2	0.035	0.035	0.030	46 to 93

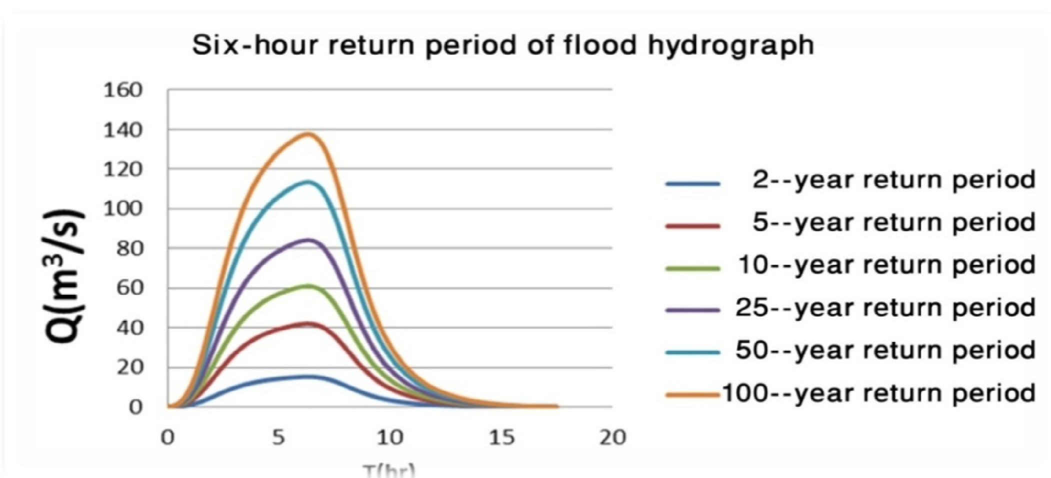

Figure-1
Flood hydrograph for various return periods

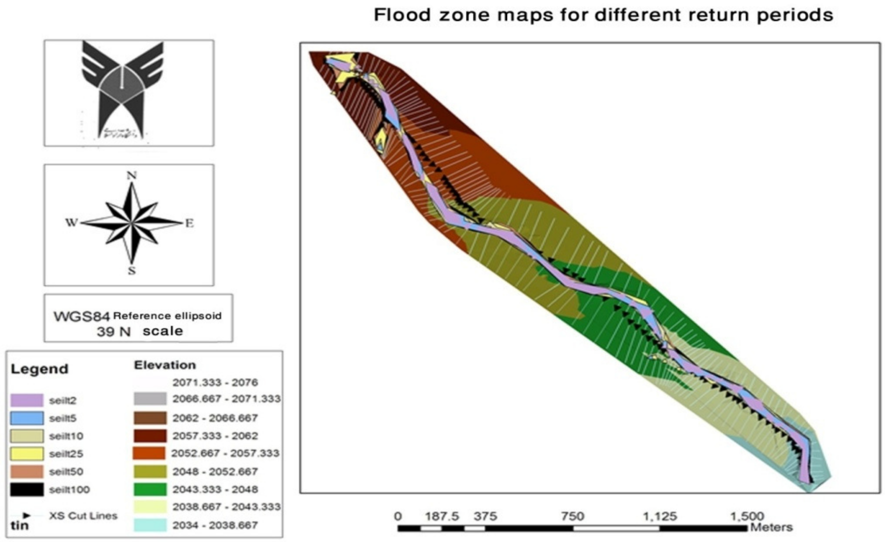

Figure-2
Floodplain zone map with different return periods

Conclusion

The results show that model performs satisfactorily for both test watersheds and performance is much better with HEC-RAS model option of flood calculation as compared to HEC-HMS model. Thus, HEC-RAS model can be adopted as a standard tool for modeling rainfall runoff transformation process in scantily gauged watersheds. The surface flood dominates any flood event[36]. The different model responses to friction parameterizations cause the differences in predictive performance[37]. Hence, the results of the experiment question/undermine the previous research. The results presented here indicate that the HEC-RAS model is an efficient model for this reach. Hence, the mentioned model will have the capability to perform hydrological studies on a regional scale. Also, the successful incorporation of the HEC-RAS and HEC-HMS models at a regional scale demonstrates the versatility of this technique for flood inundation studies at the city, county, and regional levels. This is consistent with some researchers[38]. The catastrophic effects of flooding disaster can be mitigated by integrating scientifically reliable information obtained from a risk assessment studies developed using this hybrid approach. Flood risk assessed by simulating higher magnitude flood events magnifies the vulnerability of the region and reinforces the fact that any land use planning decisions in floodplains should make informed choices and the corresponding developmental activities should be carried out in a sensible and careful manner[38]. Equipping the watershed to the register rain gauge stations to analysis the time pattern of rainfall in the case study and increasing the accuracy of the studies there. Due to the high economic value of the land area, it is recommended for flood control to use structures that occupy a smaller width. Use of Gabion check dams' structures for controlling river erosion in sensitive areas and the combination of structural and non-structural methods based on various results is the best way to flood control and management.

Acknowledgment

The authors thank Chaharmahal and Bakhtiari Regional Water Company and TAMAB (Researches Organization of Water Resources) for providing the data of discharge, maps and for helping us with data preprocessing.

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