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Sub-basin participation in flood producing of Basin

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ABSTRACT

Flood is often called a phenomenon that leaves harmful effects by submerging lands and coastal areas. Flood control is in fact said to all preparations and methods that lead to reduction of the harmful effects of a flood. Since Gorgan River basin is prone to flooding, identifying areas prone to flooding is essential. The present study is a way of using hydrology model and flood risk prone areas within watershed and determining these verities of floods, i.e. to prioritize the rise in each sub-basin or hydrologic units. First, the watershed in GIS environment (GIS) software using Arc- Hydro basin was divided into nine areas, then the physical properties of basins and sub-basins was determined. With data required for flood hydrographs design for each sub-basin and watershed through the implementation of the entire HEC-HMS model was obtained. With peak discharge under consideration based on watershed and flood index definition for the rise in this research, it is proposed in each model run the efficacy of each sub-basin is removed from the flood routing of basin process and the amount of basin output discharge without participation of the corresponding sub-basin was calculated. In this respect among sub-basins in terms of impact on the flood basin outflow, sub-basin No.W 150 is more critical.

***Key words** : Flood rise, Return period, HEC-HMS, Arc Hydro, Peak discharge*

Introduction

To deal with the phenomenon of destructive floods and protection of human life and property and farms and facilities, a variety of ways, including construction of dams and structures and engineering operations for the rivers and beaches and watersheds are resorted. That it is essential to recognize critical areas. And because science and technology now is not reached that level of evolution to prevent these harmful phenomena can change the elements to create the atmosphere. So, any solution and remedial principles should be investigated on the earth especially in watershed areas. In this connection, the first step to reduce the flood risk posed is to stop floods in the watershed, *i.e.* sub-basin. In this context, identifying areas prone to flooding within the basin is very important, because due to the large watershed areas and enforcement operations throughout the basin and flood control is not possible even if not inspected carefully could allow intensifying the discharge of peak by changing the coincided discharges of peak in sub-basins. So areas that are potential to produce flooding should be identified to have the possibility to optimize the enforcement operation in smaller and risky levels and the cost of providing additional flood control projects be prevented.

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Generally two categories of climatic and basin factors are involved in creating floods. Source of many floods, especially in arid and semi-arid regions is rainstorms with high intensity and relatively short persistence of events. Thus in storms review, continuation, intensity and their spatial and temporal distribution in flood formation should be considered. One of the most important basin factors, land use, geological situation, vegetation, area, and slope and drainage network could be noted. The level of participation of each of these factors in flood formation is called flood formation potential (Slobodan, 2009). Khakbaz *et al.* (2009) calculated Clark instantaneous unit hydrograph and its Geomorphology instantaneous unit hydrograph GIUH parameters using GIS. They studied the basin located in northern Khorasan called Kardeh. He used GIS software to gain basin Hydrographic specification and then proceeded to calculate Clark instantaneous unit hydrograph. In Ankara University Department of Engineering Science, a study carried out on Yvachyk basin located in southeastern Turkey. Basin simulation using software HEC-HMS and HEC-GeoHMS took place. Using GIS information and maps of the area and after modeling, flood hydrographs were obtained (Yener and ªorman, 2008). A joint investigation was conducted by the Department of Civil Engineering, Environmental Engineering, and Center for Remote sensing and hydrometeorology of American University of California on Illinois River basin of Arkansas State. In this study, rainfall - runoff system of basin was stimulated by semi-distributed and lumped models. Then using the recorded output hydrograph of the basin, calibration was done and outflow discharges of the models were calculated (Khakbaz, 2009). Sunwan werakamtorm (1994) using HMS and Geographic Information System (GIS) studied effects of user changes in upstream lands of watershed on the pattern of flooding in downstream areas of basin assessed that in this study, five variables as inputs to the system used. The five variables include rainfall, infiltration rate, surface runoff, watershed area and the flood routing factors. He has used ArcGIS software to determine and integrate maps. Simulation of flood hydrographs in the past and future with loss scenarios and increasing basin forests showed that decreasing forest area, main and sub-basin runoff basins will be more. Saghafian and Khosrowshahi (2005) using satellite imagery GIS prepared Damavand basin vegetation map and then in the GIS environment using ArcView software combined user map of farms and soil hydrologic groups and calculated the curve number CN for the entire basin and sub-basins. Then using HMS hydrologic model and SCS method design got the hydrograph design caused by rainfalls (12-hour rainfall with are turn period of 50 years). They combined HMS model with three rainfall runoff observed events, and were calibrated to determine the flood-producing rainfall, average rainfall of each sub-basin at the time of flood in Arc View environment and was introduced to the model. In this study for the flood routing Muskingum method was used and finally, the intensity of sub-basins flood rise prioritized with regard to their participation in the total output discharge of the basin.

The aim of this study is a way of using hydrology model and flood risk prone areas within watershed and determining these verities of floods, i.e. to prioritize the rise in each sub-basin or hydrologic units.

Materials and Methods

The studied area, the main basin is the Gorganrood River that its major part is located in Golestan province and a small part in the province of Semnan and Khorasan. The geographical coordinate of this area is 36° 44' to 37° 49' north latitude and 54° 42' to 56° 28' east longitude and its area is about 532 square km. the Gorganrood River is formed by joining of Zav and Gharnave rivers in the northern city Kalaleh. The Haji Qushan River before the Golestan dam and the Dough and Oghan rivers join the Gorganrood River at the Golestan dam. Finally, this river flows into the Caspian Sea. Among the studied basins, the Dough River has the longest path.

HMS Model

HMS model is the Windows version of HEC-1 model. HMS model was presented by the hydrologic center of US Corp of Engineers to supply the flood's hydrograph in 1981 and after that, so many changes were made on that and finally in 1998 presented as HMS and under the license of a Windows. HMS is one of the computer mathematical models which itself consists of some subcategories as runoff sections, the surface flow, the base flow and the total flow and they are used to simulate the hydrologic behavior of the basins. His model includes three main sections by the names of Basin Model, Meteorological Model and Control Specification. In addition, this model is able to optimize and calibrate the parameters. This model can be used for simulation and predicting the effects of the parameters' variation after validation. The basin simulator is responsible to clarify the whole structure of the basin and simulation will be possible by clarifying the overall structure of the basin.

Model Calibration

Every model which exists in HEC-HMS has some parameters. The amount for every parameter must be determined to estimate the runoff and the flood hydrograph. How can suitable adjustable values be chosen for every parameter? In case of having observable rainfall and runoff, calibration will be the answer of this question. Calibration makes use of the observable hydro climate data parameters to be determined to make the best fit between the observable and simulated results in a systematic study. This study is often called optimization. Calibration starts with the collection of the data. The time periods of rainfall-runoff are the required data for the rainfall-runoff models. The model by the primary amounts can measure the considered output (the runoff hydrograph). In this research, the data of 15 floods, which had more complete hydrographs compared to the other floods happened, were chosen from 2000 to 2007. 10 floods among the 15 floods were chosen for calibration and the other 5 floods were used for validation assessment (Fig. 1).

HEC-GeoHMS Extension

HEC-GeoHMS is a software in GIS field presented by the Environmental Systems Research Institute (ESRI) to analyze spatial data used in HEC-HMS software. The application generates a geographical data file to use in HEC-HMS. The output HEC-HMS in graphical mode can also be observed by this software. Other features include the annex to create field maps, basin model files, meteorological model files that can be used for hydrology modeling by the HEC-HMS.

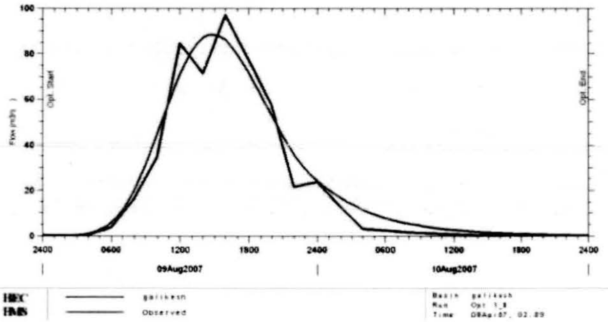

Fig. 1. Comparison of measured and simulated hydrographs

The hydrology model has been produced by the corp. of engineer's center of the U.S. Army. This software provides the ability to stimulate the rainfall-runoff at the basin. The HEC-HMS software can be used to solve a wide range of geographical levels by different topographies. Catchment Simulation in HEC-HMS is done by three major factors called basin model, meteorological model and control specification.

Results

Using digital elevation map of the desired basin and considering the main rivers in the Arc GIS environment, the studied basin was divided into nine Sub-basins (Fig. 2). All drainages were identified. The physical properties of the basin and Sub-basin (Table 1) were determined using HEC-GeoHMS accessions. Also by spatial Analyst accession and by combining user raster maps of land use and soil permeability compared with standard CN tables, CN

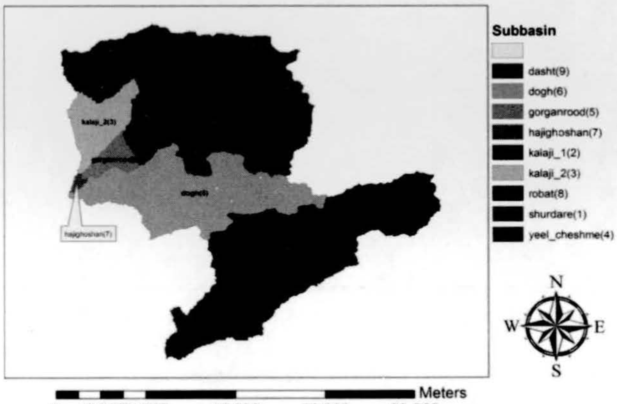

Fig. 2. Division of Golestan province to nine major Sub-basins

values were calculated for each cell and CN map of the whole basin was obtained. By determining the needed data, the flood hydrograph for each Sub-basin and the entire Basin was done by running the HEC-HMS model (Fig. 4).

To complete and rebuilding the data of the stations that their statistics are incomplete were used in the SPSS and SMADA software's. In this study, an-

Table 1. Physical properties of the basin and Sub-basins that have been obtained using HEC-GeoHMS accessions

Sub-Basin	Area (Km^2)	Perimeter (m)	River slope (%)	CN	River length (km)	Lag time (hr)	Time of concentration (hr)
Shurdareh	814.5	199817	7.7	84	68.49	5.56	8.68
Kalaji 1	306	105874	6.7	58	29.73	3.27	5.8
Kalaji 2	240.7	113268	3.9	76	37.8	5.48	8.55
Yel cheshmeh	707.2	212421	12.5	70	97.24	8.44	13.2
Gorganrood	89.4	68398	2	82	25.8	6.37	9.94
Doogh	856.4	265190	10.8	78	89.5	6.75	10.5
Haji ghoshan	13.3	26384	4.69	84	8.92	3.04	4.74
Robat	446.7	147384	9.2	50	51.48	6.32	9.85
Dasht	1033.1	242503	6.9	60	86.81	9.2	14.4
Total basin	4507.3	1381239					

nual, monthly and daily discharge of the rivers at hydrometric stations has been studied. According to the statistical period of the hydrometric stations and to have the same statistical indicators in the discharge and rainfall part of this research and also existing relatively the same wet and dry periods in the 44-year statistical period 1964 to 2008, this course has been considered as the statistical indicator period.

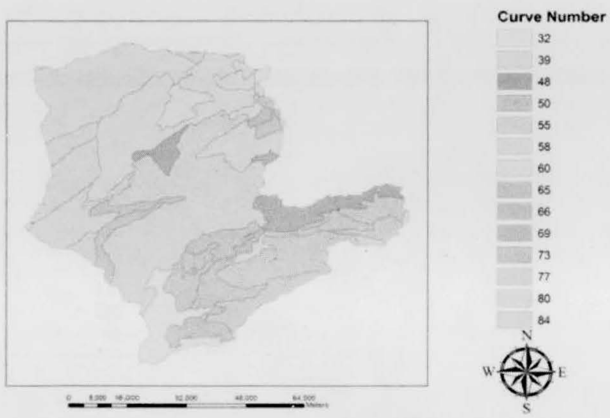

Fig. 3. Map Curve Number (CN) in Golestan Province

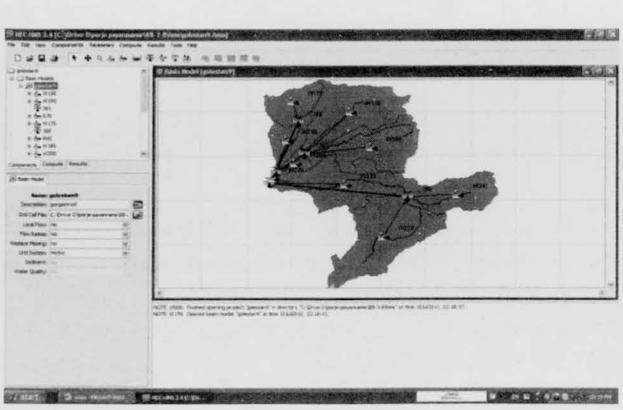

Fig. 4. Entering Sub-basins map in the in HEC-HMS environment

To run the model in addition to the physical properties of the Sub-basins determining the Storm specifications in continuous and different return periods are required. Therefore, using the existing statistical period, the amount of rainfall for different stations in 2 to 1000 years return periods were estimated. In the studied range of the Arazkouseh, Minoodasht, Golestan forest, Golestan Dam and Dasht Shaad stations were equipped by recording rain gauge and to determine the rainfall pattern, the statistics of these stations have been used and relatively recovered significant rainfalls have been extracted. Rainfalls were divided into two short term (less than 8 hours) and long (more than 8 hours) groups and to compare the temporal distribution of the rainfall stations there was an attempt to make the rainfall dimensionless distribution at each and the temporal distribution of the rainfalls were obtained.

Floods with different instantaneous discharges at the hydrometric stations of the basin have been recorded. Because the goal was to analyze the discharges that are not involved in the melting of snow in, thus a desired number of data was removed and the floods under research were limited to the days when the flood caused by rain is desired.

At the calibration level regarding in adequate level observed hydrographs on the other hand, due to the importance of peak floods in flood events, the maximum amount of Discharge as a calibration index were considered. Weighted Curve Number (CN) of basins was extracted from the CN maps. In

Table 2. Participation Priority of sub-basins in flood output

Sub-Basin	Area (km^2)	Discharge (m^3/s)	discharge without sub-basin (m^3/s)	Decrease in outlet (m^3/s)	Decrease in outlet (%)	Preference according of outlet	Specific discharge ($m^3/s/km^2$)	Preference according of Specific discharge	Decrease in unit area(%)	Preference according unit area
Shurdareh	814.5	317	618.3	298.8	32.6	1	0.39	1	0.040	1
Kalaji 1	306.0	115.5	832.3	84.8	9.2	5	0.38	2	0.030	2
Kalaji 2	240.7	78	892.8	24.3	2.6	7	0.32	4	0.011	8
Yel cheshmeh	707.2	159.5	807.9	109.2	11.9	3	0.226	8	0.017	6
Gorganrood	89.4	20.9	907	10.1	1.1	8	0.234	7	0.012	7
Doogh	856.4	230.5	858.4	58.7	6.4	6	0.27	5	0.007	9
Haji ghoshan	13.3	4.8	914	3.1	0.3	9	0.36	3	0.025	4
robat	446.7	113.1	811.9	105.2	11.5	4	0.25	6	0.026	3
Dasht	1033.1	208.8	719.6	197.5	21.5	2	0.20	9	0.021	5
Total basin	4507.3	917.1								

order to compare the basins momentary peak discharge, some observations and computations of the peak stream error percentage method has been used. The equation is as follows:

(1) $$PE = (\{Q_{ob} - Q_{si}\} / Q_{ob}) \times 100$$

Where PE =different percent

Q_{ob} = observed peak discharge hydrograph

Q_{si}= simulated peak discharge hydrograph

This point should be added that the method of determining severity of floods rise is not an urgent need of this research is to model calibration because the main goal of prioritization of Sub-basins in terms of potential to produce flooding is to compare them to one another. So Sub-basins are compared with each other in calculation conditions or parameters estimation considering physical characteristics. Nevertheless to increase the accuracy of results, much time spent under the parameters calibration of the sub-basins with available rainfall data.

For flood routing of the rivers Muskingum method was used. The two factors X and K are required for this method. K has time dimension and equals to the flood wave transmission time interval from beginning to the end of flood routing. X is a dimensionless coefficient and indicates the relative impact of Discharge in the amount of input and output storage. X amount of storage in different rivers varies from 0 to 0.5. This value for the two studied rivers was considered 0.2. K values in each interval were obtained by dividing the interval length on the speed of water into that interval. According to statistics available in Golestan Regional Water Authority and hydraulic similarity interval, the speed of water for the intervals was considered 1.3 meter per second and was then calibrated.

Determining the severity of Sub-basins flood rise of 50 years rainfall sample continuing 16 hours was as follows. Since the maximum time of concentration was calculated for about 15 hours so the rainfall design with 16 hours continuity was chosen because rainfall with more continuity has not changed the peak discharge as long as rainfall continues, flows outside the basin with the same peak discharge.

Discussion

Using the above data, the HMS model for Discharge calculation with the participation of all basins was run and total amount of flood from the entire basin was calculated. Then run this model was applied again, but in each model run, one of the sub-basin and as a result its hydrograph was omitted from flood routing of the basin and the output discharge was stimulated without considering that sub-basin. Also For other Sub-basins at each model run, effectiveness of each Sub-basin was omitted from the basin flood routing and the amount of outflow discharge of basin without the participation of related Sub-basins were calculated. After finishing sub-basins flood routing the effectiveness of each sub-basin in reduction of output discharge was obtained.

At the first implementation of the model that was done with 50-years design rainfall the amounts of each Sub-basin Discharge with regard to the specified parameters was calculated (column 3 Table 2). Shourdareh Sub-basin by producing 317 cubic meters per second peak Discharge and the Haji Qushan sub-basin with 4.8 cubic meters per second relatively allocated to have the most and the lowest amount. It is noteworthy that the Shourdareh Sub-basin is second in size of area. Since the rainfall for all Sub-basins has been considered the same, so the different amounts of Discharge can not necessarily be affected only by area and other physical properties of Sub-basins are involved.

For example, outflow discharge of basin without much participation of the Shourdareh sub-basin was 618.3 cubic meters per second (column 4 Table 7).By omission of KalAji1 and replacing Shourdareh Sub-basin the amount of outflow discharge was calculated 832.3 cubic meters per second. By subtracting these values from the outflow Discharge and the entire basin, the level of participation of each sub-basin was obtained in the outflow discharge (columns 5 and 6, Table 7). When the effect of sub-basins Discharge at peak discharge of the entire basin is into consideration, their impact does not only depend on the area of sub-basin, but the interaction of effective factors (including the location of Sub-basins) can be decisive. Thus, hydrological effect of Sub-basins on the output of the entire basin will cause nonlinear behavior, so that the basin that necessarily has larger area or higher Discharge would not have more influence on the output flood of the basin. For example, the Dough Sub-basin in terms of peak discharge is ranked the second, in terms of participation in the flood basin output is placed the sixth. Although the Sub-basin seven has the lowest distance to output of basin, and due of its spatial location takes the shortest time to participate the output discharge of the entire basin, its final participation in peak discharge of the entire basin due to non-simultaneity of peak discharge with other sub-basins is not noticeable. This represents an interaction effects between factors such as spatial location, area and characteristics of Sub-basins in determining contribution in the peak discharge of the whole basin. To remove the effect of basin area in prioritizing the Sub-basins flood rise, the level of effect of each sub-basin's unit area on output floods were considered (Table 2 Column 8). Column9 in table 2 indicates the priority of Sub-basins from the specific discharge of Sub-basin (peak discharge on the unit area) and column 10 has been obtained by dividing column 6 by column 2 of the same table. Shourdareh Sub-basin had the highest participation level in the output flow of the entire basin, also will be place the first rank per each unit of area of the Sub-basin.

Conclusion

Must accept the fact that one of the basic and remedial solutions to prevent and contain flooding, is to identify areas prone to flooding risk within the watershed and primarily inhibit and prevent flooding in the head origin must be done. Thus, providing a suitable method to identify areas with higher potential for flooding in the basin is essential. Ways to check this thread have been applied so far, or the entire basin has been considered integrated (lumped) and due to the breadth and extract of the watersheds for administrative remedies have always been difficult or in rare cases in which this issue has been studied in the surface of the sub-basins, usually the hydrologic behavior of the Sub-basins is assumed linear and only Sub-basins Discharge without considering the effects of hydrograph reduction (in the rivers flood routing) and its arrival coincidence to the output of the basin has been considered, including many Renewable Natural Resources study projects by the Forests and Rangelands Organization of Iran. Even the definition of the concept of the index or a member of the floods rise of various sources has presented different viewpoints.

Model run calculations from the proposed method showed that the way Sub-basins participated in output is not proportional to the peak discharge of the sub-basins and the sub-basins that have more Discharge do not necessarily have the most impact on the output flood because the flood routing of the waterways and the location of the

Sub-basins can cause changes in how contributions are. So for any flood control operations or reduction of peak discharge in the basin output the impact of each Sub-basin must be considered according to their portion in making output flood. In cases that the area where Sub-basins influence flood rise prioritizing, we can do this prioritizing for each unit of the sub-basin. The index of flood rise severity determination per area unit of the catchment in prioritizing of the flood control operation designation per each available facility can be considered proper to a certain area. Also in executive sections that design economic matters is one of decisive factors. The level of output flood reduction per each surface unit of the sub-basins has more importance. A proposed method for each catchment and in each climate is investigated and its enforcement is advice in the control flood study form.

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