Efficiency of Hydraulic Models for Flood Zoning Using GIS (Case Study: Ay-Doghmush River Basin)

Parviz Kardavani *, Mohammad Hossein Qalehe **

* Prof. in Geography, Islamic Azad University, Science and Research Branch, Tehran, Iran
** The Ph.D. Graduate in Geomorphology, Department of Geography, Science and Research Branch, Islamic Azad University, Tehran, Iran
(**Corresponding Author**: Mohammad Hossein Qalehe, The PhD Graduate in Geomorphology, Department of Geography, Science and Research Branch, Islamic Azad University, Tehran, Iran. Email: Qalehe@gmail.com)

Abstract: Zoning of flood in the rivers is one of the non-structural methods in flood management that cannot be achieved unless with hydraulic analysis. Using hydraulic models, we can determine the water surface profiles along the river. However, the most common disadvantage of these models is their disability in relating the information on the properties of the surface profile with their range on the earth. Via selecting a flood with specified return period, we can calculate the water levels in different cross sections of river and through connecting the points of corresponding levels on the topographic maps, flood zone and its spreading area can be obtained. In this study, we used HEC-RAS hydraulic model for hydraulic calculations of Ay-Doghmush River flooding, ARC GIS software to extract the cross sections using digital maps of river range toward river flood plains, and HEC-GEORAS to investigate the results of the model and flood zoning in GIS environment with of 5, 10, 20, 50 and 100 years return periods. In order to do that, we first evaluated the flood for different return periods using Log Pearson Type III Distribution as the best statistical distribution with SMADA software. Then, we used 1:1000 scale digital maps and river's hydrology data in order to simulate the geometry of river HEC-GEORAS in ARC GIS. The data was transferred to HEC-RAS software and after completion of the hydraulic flow conditions, the model was run and the output re-entered to ARC GIS via mediator files. After zoning flood for different return periods, the flood zoning map was drawn. The results indicated that, a combination of GIS and hydraulic models can be used for flood zoning of rivers and determining the levee areas.

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1. Introduction

Floods are among the most important natural hazards around the world that impose a lot of damage and loss to human societies every year. Various studies indicated that, the lack of attention to riparian areas had caused an exponential growth in frequency of floods and imposed losses. Here, urban and semi-urban areas have the highest risk potential. Given that the full protection against flood is not possible, residence along floods, regulating new policies on lands' usage management and developing of residential areas in riparian in order to reduce its harmful effects is essential. Awareness of the amount of flood and its investigating its behavior requires sufficient statistics of the hydrological conditions of river basin and river flow rate. In addition, using hydrological models in order to simulate rainfall-runoff process and using hydraulic models to analyze the runoff streams in rivers the ways of its expansion is beneficial.

Modeling rainfall runoffs has a long history and the first hydrologists tried to predict runoffs from rainfalls through hydrological processes. However, the modeling had limitations due to the lack of adequate data and available computational techniques. About 150 years ago, the first rainfall-runoff models have developed by Irish engineer Thomas James Mulvaney in 1851 (Henderson, 1966). His equation was just a simple equation, and therefore had many problems in the modeling process. The model is as follows:

$$Q_P = CA\overline{R}, \quad (1)$$

In Mulvaney' equation, only the hydrograph of peak flow rate QP has been considered for plotted hydrograph. Engineers, usually, need to estimate peak flow rate in order to design bridges and determine the capacity of rivers. Input variables in this model are area (A), Average rainfall, and experimental coefficient parameter (C). Therefore, this model will examine the methods in which flow rate values will be determined proportional increases in the area and rainfall. Parameter C indicates that, all of the rainfall will not be appeared as runoff and since, this model do not separate generated runoff and its routing, therefore, the relationship between the amount of rainfall and hydrograph of peak flow rate is not clear. In addition, the coefficient C requires calculation the nonlinear relations between antecedent conditions, rainfall profile, and the generated runoff, therefore, the parameter C is not a constant factor and differs from a shower on a basin to another shower in another basin with similar precipitation conditions. The easiest way to obtain C is calculation from the data of rainfall and observed peak flow rate. Predicting the right values for the basin without observed data is difficult. Today, even computer models are faced with similar problems. Given that runoff data are nonlinear this problem is more evident in areas with no statistics. If the observational data be available, the effective parameters can be easily obtained. According to mentioned issues, separation of the impacts of produced runoff by the model is difficult. However, the prediction of rainfall-runoff in such conditions is not impossible. Even before the invention of the computers, graphics estimation techniques have been used (Chow 1964).

Studies on simulating runoff and the use of hydrological models have often investigated the runoff flow rate in the outlet of basins.

2. Literature Review

James and colleagues (1980), while enumerating specific management needs in arid climates and zoning flood in Utah, concluded that, due to changes in dam areas from an event to another, the dangers in mapped areas should be exaggerated or understated.

Tile And colleagues (1999), have suggested a method to increase the accuracy of output of HEC-RAS at ARC View by matching the land, river geometry and controlling structures data with the available ground model in GIS.

Johnson and colleagues (1999) have used HEC-RAS model to predict and determine the wet lands along 10 kilometers of Wyoming River in North America. Using this model, they have drawn the profile of water surface and through diverting the water to a new tank and a set of boundary conditions with and without the diversion of a similar scale. They found that, with diversion, the area under the flow with 283.3 liters per second flow rate reduces from 167.2 to 149.7 hectares. They believe that this is a valid method to quantify the effect of diversion on wet lands along the rivers.

Kresch et al (2002), after the 1998 flood disaster in Honduras, decided to plot a Fifty years flood inundation map for Olanchiner River in Honduras. Using GIS and HEC-RAS mathematical models for 243 cubic meters per second flow rate corresponding to the 50-year flood, they performed hazard zonation of the flood.

Whiteaker et al (2004), using Map-to-Map modeling, ARC GIS 9, and HEC-RAS have created flood inundation zoning map from rainfall data on Rosillon Greek basin, Texas. It is worth mentioning that, Map-to-Map model is a method which calculates a polygon layer of flood zone from rainfall data. This method allows the user to crate flood zone maps and the possibility of predicting the real time of flood.

Papen Berger et al (2005), investigated uncertainty in unstable flows with combination of one-dimensional HEC-RAS model and GLUE. The model was run with different Manning's Roughness Coefficients (from 0.001 to 0.09) and the results were compared with flood inundation and output hydrograph. They also investigated the effect of variations of Manning's coefficient on weighted coefficients of numerical method and concluded that, using values less than 1 is not useful and suggested the use of implicit scheme with a weighted value of 1.

Domestic studies have more focused on determining the flood-proneness of different basins using hydrological modeling and flood zoning using hydraulic models.

Sadeghi and colleagues (1382) combined HEC-RAS model and GIS in order to zoning of flood in Dar Abad River concluding the efficiency of mentioned approach for flood zoning. Haji Gholizadeh (1383) investigated the role of human intervention, including bridges, gullies, water breaker, slope breakers in Kan River, Tehran using HEC-RAS. The results indicated on different effects of each structural flood control measures on the depth and level of floods with different return periods in the study site.

Bambai Chi et al (1386) analyzed unstable flows of dams' failures using HEC-RAS model. Abdollahi et al (1385) investigated water surface profile using HEC-RAS model. Mohammad Azari et al (1385) combined HEC-HMS and HEC-RAS models in GIS in order to simulate the flood. Zand Niya (1383) compared characteristics of flows in fixed-bed conditions using both HEC-RAS and BRI-STARS models and evaluated the substrate variations of coarse grained rivers with BRI-STARS.

Samii et al (1385) in a paper modified the Karun River from Molla Sany to Ahvaz using HEC-RAS.

Jalali Rad (1381) performed partial flood zoning of urban basins of Tehran. He used GIS, ARC View, and HEC-RAS and concluded that, GIS has good capability for flood zoning.

Heydari (1383), with emphasis on Qaranqo River's basin management investigated geological, climatological, geometrical, soil science, hydrological and sediment data and concluded that, an artificial imposition on the river underwent changes and shows turbulence and anomalous and complex behavior. He has concluded that, through accurate and scientific recognition of performance and behavior of basin, we can control and moderate the risks, confusions and changes.

Nik Fal and colleagues (1385), using HEC-GEORAS software performed flood zoning of Karun River. In this project, satellite images of flooded are provided and had compared with areas which have been flooded in the model. The results were used in economic analysis of flood damages and calculations of expected losses in flood-prone areas of Khuzestan plain.

Bilandi et al (1385) investigated the efficiency of HEC-RAS and HEC-GEORAS software in determining flood zone according to the available geographical and hydrometrical data along Karun River between Molla Sani and Ahvaz.

Mesbahi (1386), aiming to integrate ARC View software and HEC-RAS hydraulic models via HEC-GEORAS annex, estimated flood zones with different return periods and compared results of the model with river flood. He found 13% error in estimating flood zone.

In this study, using HEC-RAS hydraulic model and ARC GIS software, we want to simulate rainfall-runoff process and analyze flood inundation Ay-Doghmush River, South West of Miyaneh City (Char Oymaq city).

The basin of Ay-Doghmush River is located at southwest of Miyaneh city (Char Oymaq city) in the median of 46 degrees and 52 minutes and 34 seconds to 47 degrees and 44 minutes and 4 seconds of longitude and 36 degrees and 43 minutes and 24 seconds to 37 degrees 23 minutes and 14 seconds of latitude with 1828 square kilometers area as one of the sub-basins of Qizil Uzan River. It then joins with Qaranqu and Shahar Chay Rivers in west side of Miyaneh city where the resulted joins Qizil Uzan River. Ay-Doghmush River comes from foothills of Qusha Dag mountain with 2941 meters elevation and its surrounding elevation s situated at 40 km of north of Tekab city and flows to northeast. In Babouneh Olia village, other branches join it redirecting it to the north. It then, meets Qizil Qala River and redirects to northeast from Makhouleh Bala village. At the village of Takht Olia, a branch called Zolm Abad joins it from right hand. The Ay-Doghmush River, along its path to Ay-Doghmush dam, flows in a wide valley and passes along the villages such as Molla Hamza, Peyk, Takht Olia, Hossein Abad Castle, Touq and so on.in the downstream of the dam to Amirabad village, it experiences a narrow pathway in the very mountainous areas and then, until the confluence with the Qaranqu River, the river's width increases again and after crossing Amirabad and Golbus villages as well as Miyaneh city, joins Qaranqu River.

3. Methodology and Data

In this paper, we first introduce the concepts and terminology of HEC-RAS model and then we will zone Ay-Doghmush River flood using this model. The process is as follows:

3.1. Using GIS in Hydraulic Modeling

GIS is a computer-based system capable of analyzing and illustrating geographical information. Although this tool was initially being used for cartography activities, but it then have been, extensively, used in engineering design and analysis, particularly in the field of water resources, hydrology and hydraulics. GIS, through putting the layers on each other and creating an environment for data analysis, produces new location data. As a result, we can produce and tabulate digital maps as well as data analysis and quick decision making. Structurally, GIS is a content of computer environment that according to the data, displays geographic elements as polygons, lines and points. The advantages of GIS are different from other computer software. For example, in GIS, graphical elements not only exhibit the position and shape of the river but also describe its name, length and flow rate. The possible relationships between forms and elements of the environment GIS Makes it unique.

The access to position data, grants ARC GIS software the ability of managing location data, fast processing and the ability to connect to other models in order to perform simulation. It is why we use GIS in modeling basins. HEC - GEORAS tool, attaching GIS, simulates HEC – RAS model. The HEC – GEORAS tool enables engineers to focus on hydraulic models and analyze them in GIS. Furthermore, this system provides a real understanding of phenomena, correcting errors and quick decision making. In this approach, the basin is divided into units with similar physical and rainfall-runoff properties. This method reduces the complexity and the need for spatial data of distribution. In GIS system, the ARC Hydro tool is used the processing of spatial data.

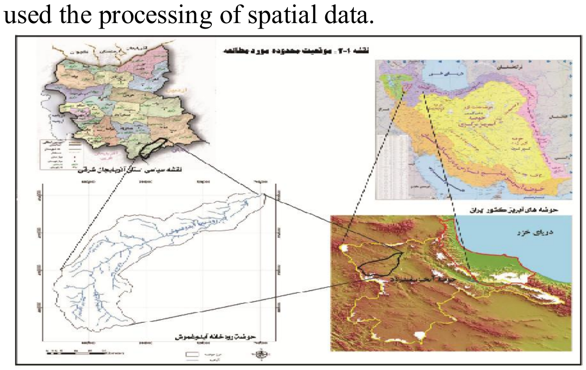

Figure 1 - Study area of Ay-Doghmush river basin

In order to show the surfaces, both digital formats of Digital Elevation Model (DEM) and Triangular Irregular Network (TIN) is used. The DEM model is a network that stores the data in the cells. The resolution of DEM depends on cells' size; each cell shows a elevation data. The TIN format shows surfaces as triangles formed by connection of the dots and broken lines. These dots are used to exhibit valleys, upland points and abrupt changes at high altitude locations. Broken lines may represent shapes such as beaches, roads and division lines of basins. Generally, TIN is more accurate than DEM, however, data processing is faster in DEM. TIN is used in the analysis of aerial photographs. Due to limitations of TIN format in producing sub-marine information, it is less used in hydrological issues. This can cause major problems in the study of large rivers

3.2. ARC-Hydro Tool

ARC-Hydro processes spatial and time data of water resources. This tool alone is cannot perform simulation, but it makes the data ready for use in hydrologic simulation models. In this tool, the phenomena are showed as Triangular Irregular Network (TIN) and Digital Elevation Models.

3.3. HEC-GEORAS System

HEC-GEORAS system is a set of tools designed to use in GIS. This system is an interface between HEC-RAS software and ARC GIS. This tool provides the data set to be used in RAS model and processes the obtained results in GIS Process. Information processing in ARCGIS and HEC-GEORAS makes it possible to create required geometrical files for RAS analysis. The produced geometry files include information on stations, river, branches, cross-sectional cuts, position of the coasts, beaches lengths in the left and right coasts, roughness coefficient, positions of barriers in the path, data of ports and bridges, and the surfaces influenced from river and reservoir areas. The results of the RAS model simulation will be entered to GIS environment and further analyses will be performed using HEC - GEORAS tool. The GIS data exchanged between RAS and ARC GIS are in sdf file format. For proper implementation of GEORAS tool, the additional expansion tools of 3D Analyst and spatial Analyst are required.

3.4. HEC-RAS Model

HEC-RAS model is a hydraulic model designed by Hydraulic Engineering Center of US military. In 1964, the HEC-2 computer model was introduced in order to help Hydraulic engineers to in the field of river channels and floodplains. The model has been rapidly developed as hydraulic analysis program and was used in the analysis of bridges and ports. Although the HEC-2 model is designed to use in central processor of large computers, but it can also be used in personal computers. In 1990, due to increased use of the Windows operating system, HEC-2 software was upgraded to be used in this operating system and was named as River Analysis System (RAS). This graphical software was developed in Visual Basic and benefits computational algorithms of FORTRAN. HEC-RAS software, in addition to calculating one-dimensional profile of water surface in stable rivers, it also is used for simulating unstable flows in rivers and calculating delivered sediment load. Moreover, the system is also capable of modeling flows below and above critical conditions as well as a combination of them for rivers composed from complete network of drainage channels, dendritic branches, or single branches of the river. Model results are used to evaluate the impact of flood and management of floodplains.

In HEC-RAS model, in order to calculate flow rates in rivers, following equations are used:

$$\frac{\partial A}{\partial t} + \frac{\partial \emptyset Q}{\partial X_C} + \frac{\partial (1-\emptyset)Q}{\partial X_f} = 0, \quad (2)$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial X_C}\left(\frac{\emptyset^2 Q^2}{A_C}\right) + \frac{\partial}{\partial X_f}\left(\frac{1-\emptyset^2 Q^2}{A_f}\right) gA_C\left(\frac{\partial Z}{\partial X_C} + S_C\right) gA_f\left(\frac{\partial Z}{\partial X_f} + S_f\right) = 0, \quad (3)$$

$$\emptyset = \frac{K_C}{K_C + K_f}, K = \frac{A^{\frac{5}{3}}}{nP^{\frac{2}{3}}}, \quad (4)$$

$$S_C = \frac{\emptyset^2 Q^2 n_C^2}{R_C^{\frac{4}{3}} A_C^2}, S_f = \frac{(1-\emptyset^2) Q^2 n_f^2}{R_f^{\frac{4}{3}} A_F^2}, \quad (5)$$

Where,
Q is total flow rate of the river,
Ac, Af is cross-sectional area of the channel and floodplain,
Xc, Xf is river length,
P is circumference of the areas affected by the river,
R is hydraulic radius,
n is Manning's roughness coefficient, and
S is slope of the river.
The values of Ø are obtained from dividing flow rate between river channels and floodplain which is a function transitional value of Kc, Kf.

3.5. Parameters Used in the HEC-RAS Model

HEC-RAS model uses several parameters for hydraulic analysis of water flow and the shape of channels. The parameters are used to determine a series of cross sections along the river. In each cross-section, shore locations are identified and divided into three sections of right bank, left bank, and main part of the river. This division is due to differences in hydraulic parameters. For example, the circumference of wet part of the banks is more than the main channel. Therefore, the friction force between the water and the bed has the greatest impact on the flow resistance and reduces the Manning's coefficient. As a result, the flow velocity and water transport in the central part of the river are more than banks. In each cross section, HEC-RAS model uses several input parameter to describe the shape, elevation and relative position of the river as follows:

- The number of cross sections of the river
- Roughness coordinates of each point of the river
- Position the left and right banks
- Branch length between the left and right sections, and adjacent intermediate cross sections (branch length may be different due to the river curvature)
- Manning's roughness coefficient
- Expansion and contraction coefficients of intake duct

In HEC-RAS model, it is thought that, the amounts of energy at cross section are constant and velocity vector is perpendicular to the cross section. After determining the channel geometry, flow data of each part of the river will be entered to system.

4. Results

4.1. Flood Zoning Using HEC-RAS Model

After the computations performed by HEC-RAS software, river flood modeling results are shown graphical and tabular formats. These results include longitudinal profile, cross sections, hydrographs, flood zoning maps, output tables in each cross-section, and so on.

4.1.1. Cross Sections

One method of flood zoning is the use of mathematical models. In this study, we have used HEC-RAS model for zoning. In order to use this model, first, the topographic maps were prepared using AutoCAD. Using elevation points around and even inside the river, selected elevation points have introduced to AutoLand software and cross sections, using Cross section menu, were marked with 100 meters of distance. In addition, longitudinal profile of the river has introduced and mapped with Profile menu of Auto Land software. In order to export the obtained data with AutoLand, produced files have converted to shp format to import in ArcGIS. Transferring elevation points to ArcGIS, the triangular irregular network of selected area was mapped. The files of left and right banks, the middle line of the bed, and cross sections have called and placed on TIN map of the region.

After this step, the Hec-GeoRAS expansion was used to prepare the data to enter HEC-RAS. Using ID and Select flow path menus, right and left banks as well as main channel have introduced to software followed by introducing stations' cross-sections using Stream centerline attribute menu. After these steps, the saved file in Hec-GeoRAS imported to HEC-RAS. Using Cross section data menu, the information about roughness coefficients, substrates' tightness and wideness data, upstream and downstream slopes of the river as well as information of return periods of maximum flow rates at five periods of 5, 10, 20, 50 and 100 years were loaded on the model. Figure 1 is an example of cross-sections for floods with return periods of 5, 10, 20, 50 and 100 years for substrates with narrow and wide width. In selected sections, number of the X and Y axes represent station numbers and their elevation s of a section, respectively.

Number of stations can be calculated manually with Auto Land software or using HEC-GeoRAS software so that, the starting station is zero and according to upward or downward direction of river bed at the selected station, their numbers will be added or subtracted, respectively.

Arrows above each graph indicate Manning's roughness coefficient of them. These values have selected from roughness coefficients according to the usage of the land. Selecting five return periods of 5, 10, 20, 50 and 100 years in map legend will show these five return periods. Water levels of each return period have been distinguished by different colors. Cross section profiles have used to show narrowness, wideness, location and information of bridges, dams, walls and other structures, and also to express the surface, distribution, and spread data of water.

4.1.2. Longitudinal Profile of the Ay-Doghmush River

Longitudinal profiles are used to specify the parameters such as natural ground level, flow level balance in different flow rates and so on. In order to show longitudinal profile of the river, the Plot profile menu in HEC-RAS is used. Axis X shows the main channel and Y axis represents the elevation . Diagram 2 shows the longitudinal profile of floods with return periods of 5, 10.20, 50 and 100 years. It is observed that, with increasing return period, water elevation in the longitudinal profile will be increased too.

4.1.3. Output Tables of HEC-RAS

Output tables HEC-RAS are the summary of detailed calculations of water profiles and display a large amount of computational results of HEC-RAS. The first column is river name and due to the lack of secondary sub-branches, the word, main, is selected. The second column is river stations. Profile column represents return periods of the flood, Q total is total flow rate in terms of cubic meters per second, and main channel elevation is the height of each station in terms of meter. Moreover, w.s Elev is water level's height in meters, Crit w.s is critical height of water in meter, Flow Area is flood spread area in square meters, Top Width is the highest width of flooding spread in meters, and Froude Chl Froude is Froude number. Froude number can be under critical, critical, or supercritical.

Diagram 1: Cross sections of Ay-Doghmush River at upstream sections

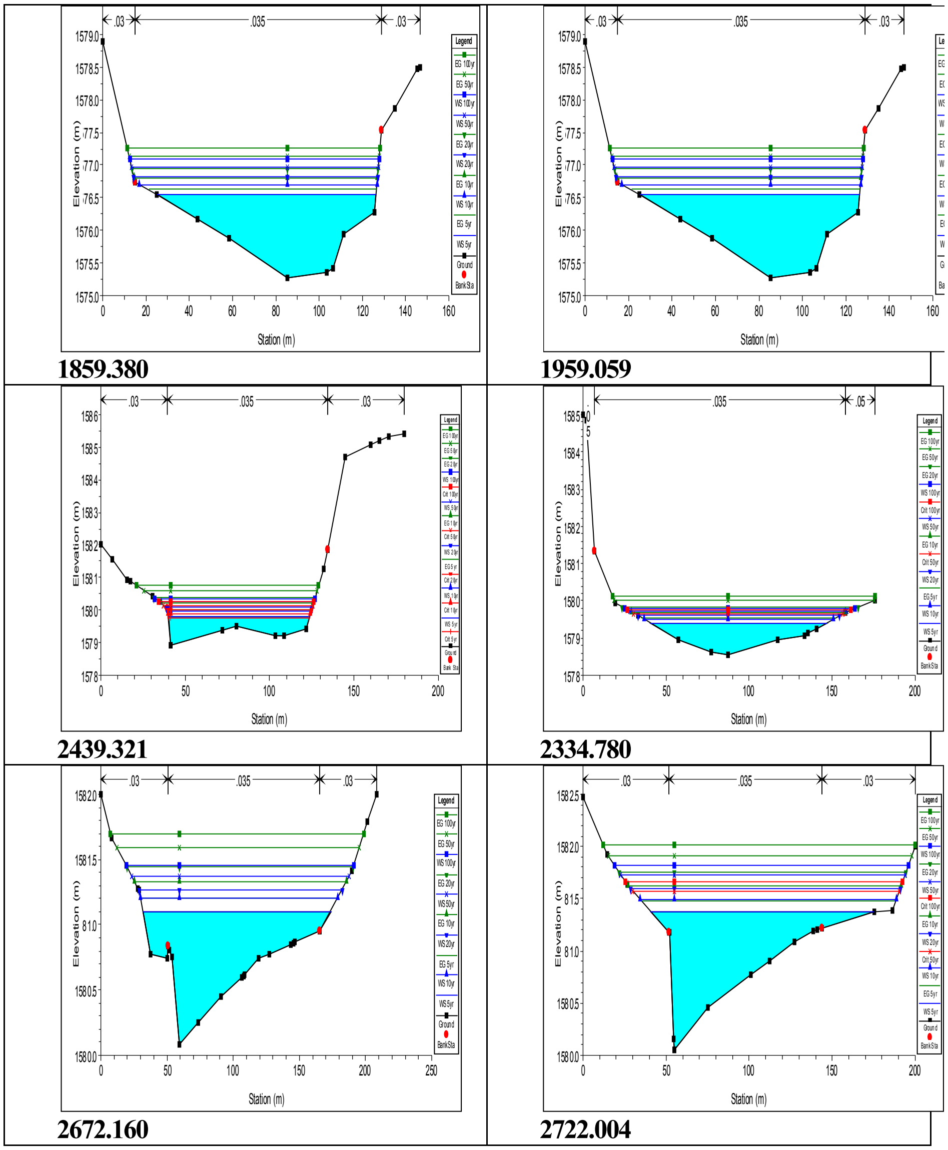

Figure 1. Cross sections of Ay-Doghmush River at upstream sections

Cross sections of this river are shown in the following figure.

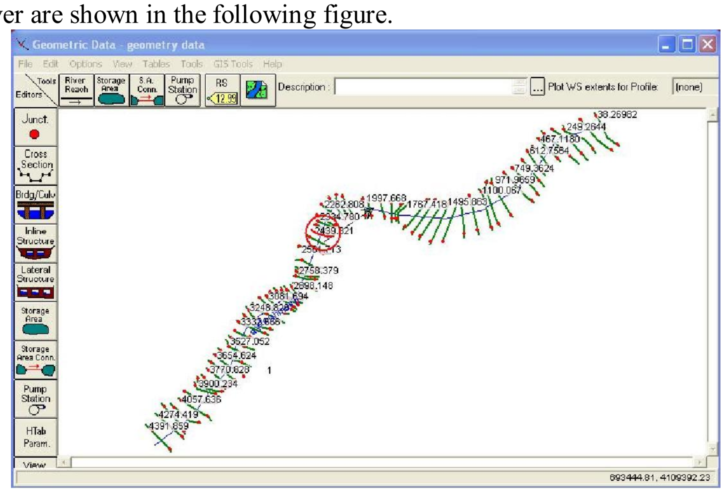

Figure 2: Mapped cross-section of Ay-Doghmush River with their numbers

Diagram 2: A part of longitudinal profiles of the Ay-Doghmush River concerning 5, 10, 20, 50 and 100 years old floods

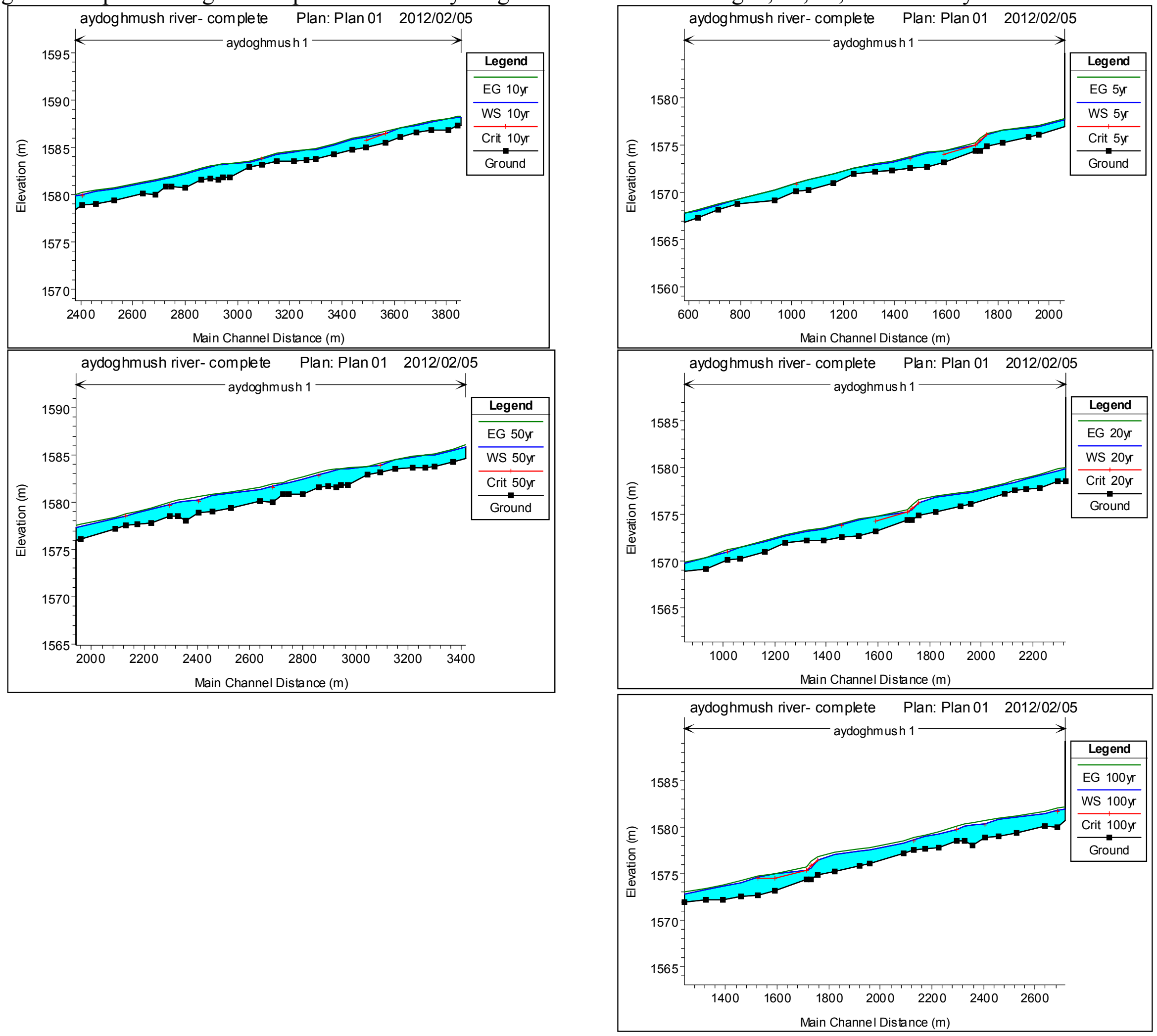

Figure 3. A part of longitudinal profiles of the Ay-Doghmush River concerning 5, 10, 20, 50 and 100 years old floods

Table 1: output of HEC-RAS calculations

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	G. ev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	249.3	5yr	89	1564	1565		1565	0.008	1.31	71.17	178.9	0.68
1	249.3	10yr	124	1564	1565		1565	0.007	1.44	90.47	186.9	0.67
1	249.3	20yr	160	1564	1565		1565	0.007	1.49	110.5	215.3	0.69
1	249.3	50yr	212	1564	1565		1566	0.008	1.51	140.9	285	0.71
1	249.3	100yr	254	1564	1566		1566	0.008	1.62	158.3	285.1	0.72
1	134.7	5yr	89	1564	1565		1565	0.002	0.79	114.1	268.9	0.39
1	134.7	10yr	124	1564	1565		1565	0.003	0.88	143	307.6	0.42
1	134.7	20yr	160	1564	1565		1565	0.003	0.96	168.8	330.2	0.43
1	134.7	50yr	212	1564	1565		1565	0.003	1.08	197.8	330.8	0.45
1	134.7	100yr	254	1564	1565		1565	0.003	1.17	220	331.2	0.46
1	38.27	5yr	89	1564	1564	1564	1564	0.022	1.51	59.56	275.2	1.05
1	38.27	10yr	124	1564	1564	1564	1564	0.021	1.69	74.34	275.3	1.05
1	38.27	20yr	160	1564	1564	1564	1564	0.019	1.83	88.48	275.3	1.04
1	38.27	50yr	212	1564	1564	1564	1564	0.017	2	107.7	275.4	1.03
1	38.27	100yr	254	1564	1564	1564	1565	0.017	2.13	121.1	275.5	1.03

4.2. Showing Flood zoning in the Form of ArcGIS Software and HEC- GeoRAS tools

Because of the growing population and the rapid development of urban and rural life in the riparian lands and natural increase in demand for building and construction in these areas, unfortunately, the invasion to rivers' frontage and illegal possession of such lands and their manipulation have been increased. Therefore, in order to prevent and reduce the associated damages, concrete measures should be considered. The most important step before any action in the issue of flood management is climatological analyses and the determination of water flood level in time of inundation i.e. determining flood zone. Flood zoning is one of the nonstructural methods to cope with the floods. Although, using structural methods, we can estimate flood intensity and water level before flood inundation and reduces potential damages through diverting, but these methods were unsatisfactory in the past decades. Experts believe that, combining structural and nonstructural methods is an optimal solution for minimizing flood damages. After conducting meteorological and hydrological investigations and determining flood flow rate in different intervals using hydrological procedures, hydraulic calculations of water level were performed using mathematical models at different cross sections of the river. In order to determine that, after having a rainfall and given intensity and duration in a basin, what amounts of water levels i.e. waterlogging is to be expected at different downstream cross sections, the flood zoning was necessary. Thanks to GIS Tool menu in HEC-RAS 4.1 software, flood zoning is possible within this software. The required information for flood zoning in HEC-RAS software are TIN file which previously converted to FLOAT in GIS, the corresponding layers of the left and right banks, main channel, and the cross sections. In addition, 3-D view of the river bed and flood spreading area is possible in HEC-RAS at different intervals with the help of XYZ Perspective plot menu. Figure 3, shows the 3D view of Ay-Doghmush River with return period of 100 years.

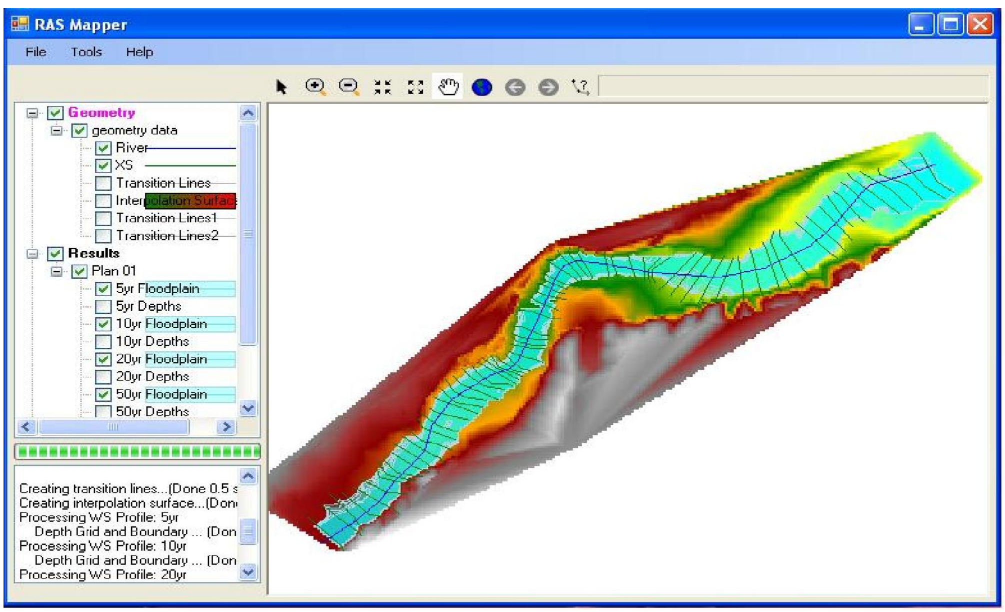

Figure 4: View of a part of Ay-Doghmush River flood zoning in HEC-RAS

4.3. Displaying Floods Returns in Different Time Periods

After performing all steps in HEC-RAS, the data were entered to ArcGIS and flood zone data were called by Inundation mapping menu; the remaining steps were performed by Assign Unique ID menu. Finally, flood zones were entered ARC GIS software in the graphical forms. In order to remove sharp and angular lines, the zones were smoothed. The zoning was performed for an upstream section of Ay-Doghmush River which can be seen in Figure 5. As can be seen in the map, the selected return periods in this study were 5, 10.20, 50 and 100 years and flood zone in selected period is depicted with different colors. In addition, the usage maps of land were used in order to investigate the impact of inundation in these areas.

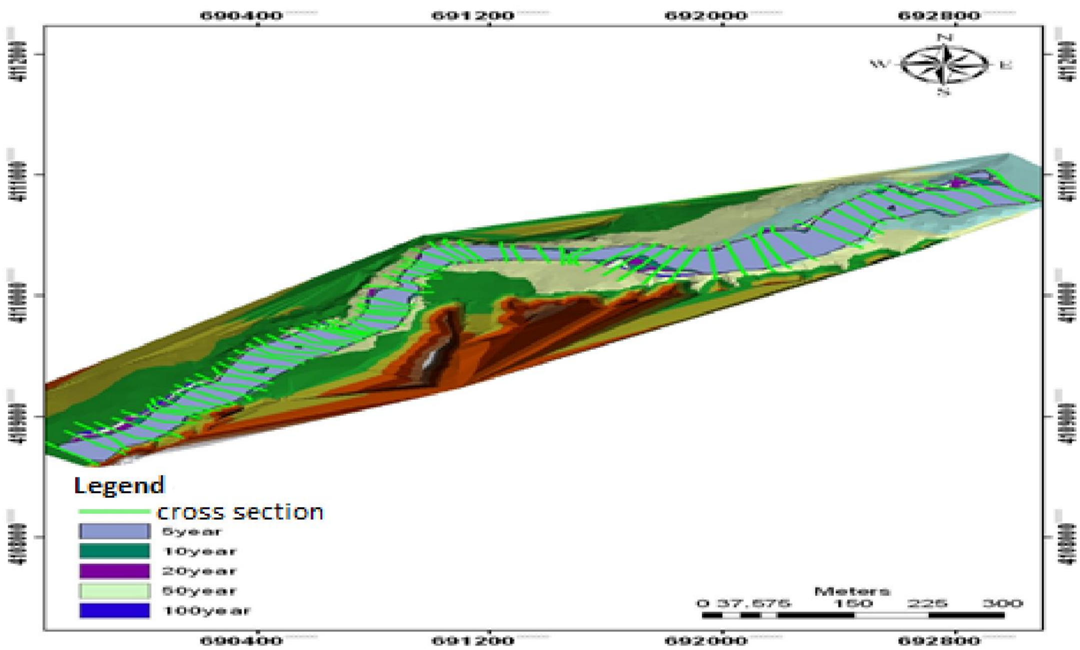

Figure 5: Flood zoning of a part of Ay-Doghmush River using HEC-RAS model and ARC GIS software

5. Conclusions

In this study, we have used HEC-RAS model for zoning. In order to use this model, first, the topographic maps were prepared using AutoCAD. Using elevation points around and even inside the river, selected elevation points have introduced to AutoLand software and cross sections, using Cross section menu, were marked with 100 meters of distance. After this step, the HEC-GEORAS expansion was used to prepare the data to import to HEC-RAS. Conducting mentioned steps, longitudinal and transverse cross sections, output tables, and flood zoning maps were designed based on the expansion, contraction values and Manning coefficient. Flood inundation map was plotted corresponding to 5, 10, 20, 50 and 100 years return periods. For drawing cross sections, thousands of sections can be extracted from software, but it is very time consuming, so only a few section were selected. In these sections, the width and elevation of each section is determined on the margins. After plotting longitudinal profile we benefitted Plot profile menu. However, regarding the return periods of 5, 10, 20, 50 and 100 years, only five longitudinal sections were plotted. The graphs indicate that, with the increase in return periods, the water level rises. After doing all of the above steps in HEC-RAS, the data were entered to ARC GIS and flood zones were mapped graphically. The zoning was drawn only for 4 km of the upstream of the river. The reason for this is the need for large volumes of data and drawing thousands of sections which are very time consuming and costly. As it can be seen in the maps, the developed flood in this research is 5, 10, 20, 50 and 100 year old and flood zone within the selected period is displayed with various colors. This map indicates that, the right hand downstream section in the map is most likely to be vulnerable to flooding.

Studying flood control methods and reducing associated losses was performed across the country in a limited and scattered fashion, indicating that, there is no a clear and reliable solution for all flood prone areas. However, it is obvious that, flood, despite of all complexity it has, can be studied in order to find reliable solutions to control and reduce its hazards and even taking advantage of its potential benefits. Therefore, emergency management to prevent and reduce flood damages in the form of guidelines and action plan is of a great importance.

However, management of flood prone areas does not mean that no structures should be constructed along the rivers, but it means that, reform and rehabilitate of river path could reduce flood damage and also contribute to proper use of water resources. Therefore, it is recommended to build the needed structures observing appropriate principles of river engineering as well as climatological, biological, topographical and hydrological conditions of basins and waterways.

Corresponding Author:
Mohammad Hossein Qalehe,
The Ph.D. Graduate in Geomorphology, Department of Geography, Science and Research Branch, Islamic Azad University, Tehran, Iran. Email: Qalehe@gmail.com .

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