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[Research]

Flood hazard zoning using geographic information system (GIS) and HEC-RAS model (Case study: Rasht City)

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ABSTRACT

Rivers are important water resources for human life, but sometimes cause irreparable damages. The flood plains are fertile terrains which are endangered by flood. Flood hazard mapping is one of the basic methods in flood fighting. In order to decline flood damages, the simulation of the hydraulic behavior of the rivers during flood occurrence is very important. In this study, areas that are flooded were zoned along Siahrood and Goharrood rivers (Rasht City, northern Iran). The rivers bed and banks terrains of Goharrood and Siahrood were simulated using HEC-GeoRAS extension and digital map (scale: 1000). Pick discharges with different return periods were estimated using stochastic analysis. HEC-RAS software and geographical information system were applied for simulating the hydraulic behavior of the rivers and providing flood zoning map. The GIS was an efficient tool for data-processing and mapping stages. Finally, the flood zones associated with 2, 10, 25, 50, 100 and 200 years return periods were mapped and necessary analysis were conducted during the present research. The results showed that some parts of Rasht City (river bank terrains) are endangered flood hazard.

Key words: Flood hazard, GIS, HEC-RAS, Rasht City.

INTRODUCTION

Hydraulic models and geographic information system (GIS) can be effectively applied in flood hazard zoning. For flood studies, terrain geometry is one of the most important factors. Using GIS can provide higher speed and accuracy in simulating terrain geometry. The best strategy to avoid flood damage is certainly to avoid flood prone areas (Hooijer *et al.* 2004; Roy *et al.* 2003; Kreibich *et al.* 2005). Islam and Sado (2000) used GIS to simulate hydraulic behavior of floods in several rivers of Bangladesh. Their study showed that GIS increased the accuracy of the results in simulation.

Also, in flood management, estimating the maximum flood discharge is necessary for predicting watershed hydrological behavior (Gholami *et al.* 2010). A flood is an overflow of an expanse of water that submerges the land. Flood hazards are the most common and destructive of all natural disasters and are a constant threat to life and property. Each year, flood disasters result in tremendous losses and social disruption worldwide (Uddin *et al.* 2013). Flood management in a basin will not be successful unless the watershed's hydrological behaviors are predicted (Bhadra *et al.* 2008; Esmaeeli Gholzom & Gholami 2012; Khaleghi *et al.* 2014). We can estimate the maximum flood discharge using stochastic distributions. In recent years, agencies and other groups engaged in disaster mitigation have placed much emphasis on the objective of achieving disaster-resilient communities (Kreibich *et al.* 2005). Recently, there has been an increase of interest in using the program HEC-RAS to evaluate the river hydraulic simulation (Ortega & Graz 2009). Ortega *et al.* (2009) used hydraulic model based on the SWD-PSI by employing the program HEC-RAS, which was adjusted to the model with a calibration of the rating curve of recent floods. Balasch *et al.* (2011), calculated peak flows by utilizing the HEC-RAS hydraulic modeling software on one-dimensional, gradual, varied, steady, sub-critical flow. For flood hazard zoning, supply and processing of flood zoning maps in Vadu watershed, Austin, Texas, Anagram *et al.* (1999) used the HEC-RAS hydraulic model with the aid of aerial photographs. Hill (2001) mentioned various benefits in using HEC-GeoRAS (ArcView-GIS) extension and HEC-RAS software for flood hazard zoning. Santos *et al.* (2011), used the HEC-GeoRAS to compare historical-hydro geomorphological reconstitution and hydrological-hydraulic modeling in the estimation of flood-prone areas. Hyalmarson (1988) investigated the river bed erosion and deposition while flooding. Jonson *et al.* (1999), used HEC-RAS model in predicting and determining the boundary of wetlands along 10 km of Vioming Griol in US. Carson (2006) simulated the river hydraulic behavior and investigated the flood and bank erosion hazard in Utah, US. Different studies have been done in terms of flood hazard zoning such as: Gogoi *et al.* (2010) and Carrasco *et al.* (2013). The present study was carried out to map flood hazard zones in Goharrood and Siahrood rivers in Rasht City (Northern Iran).

MATERIALS AND METHODS

Rasht City is located in northern Iran which is the capital of Guilan Province (Fig. 1). Goharrood and Siahrood rivers after passing from the Alborz Mountains and then Rasht City fall into the Caspian Sea. The rivers flow from Sefidrood River watershed. Sefidrood River is the biggest river in Guilan Province. Urban flood is one of the main problems in the Rasht City management (Fig. 2). This study has been done in the urban part of the rivers in Rasht City. Rasht is one of the most vulnerable cities of Iran in terms of crisis management planning and dealing with disasters such as earthquakes, floods, and snow. Rasht City has an area of about 10, 2 hectares and 104 urban districts. Regarding the items mentioned above and considering Rasht as one of the large cities in the north of Iran, with high population density and old texture, and one of Iran most vulnerable cities in Iran, comprehensive planning in crisis management is necessary in this city and the preparedness of governmental organizations as supportive and protective forces for citizens is more important (Hosseini *et al.* 2013). Past floods caused damages to the trains of rivers banks. Urban flood is one of the main problems in the Rasht City, especially for traffic.

To simulate the hydraulic behavior of the river, geographic information system (HEC-GeoRAS extension and ArcView software) and HEC-RAS software were used, due to their very high ability of mentioned software (Kang 2010). At first, the annual statistical data of maximum instantaneous discharges were analyzed in terms of homogeneity, relevancy and adequacy then verified with 95% of confident limit via Run test method. Then, the best statistical distribution was selected using Smada software (Log Pearson III) and the maximum discharges were estimated by applying suitable statistical distribution. In this method, statistical distribution which can cover most of the calculated and observed data was selected as the best distribution. With the aid of the HEC-GeoRAS extension in ArcView software, the data of hydrometric stations in Lakan and Siahrood were used according to the river plan maps with the scale of 1:1000. The bed conditions such as the center stream line, banks, flow paths, cutlines and river floodplain in the objective section, were also simulated. A view of urban map with a scale of 1:1000 is presented in Fig. 3. Cross-sections 134 for Goharrood and cross-sections 63 for Siahrood were introduced as the general conditions of the rivers based on their bed situation. In next step, then, Manning coefficient of these cross-sections were separately determined for bed, right and left banks by field studies, and river path monitoring. Cawen method and GPS set were also employed. According to Cawen method, to estimate the Manning roughness coefficient, $n = (n_0 + n_1 + n_2 + n_3 + n_4)\ m_5$ in which n is Manning roughness coefficient, n_0 is bed roughness coefficient that depends on channel materials, which is selected for homogeny, smooth and direct channels and other roughness coefficients which include n_1 , n_2 , n_3 , n_4 and m_5. They are coefficients of the effects of cross section irregularity, variation of cross section, existence of barriers in channel path, vegetation and meandering degree in the path (Kang 2010). The simulated bed conditions were imported from GIS to HEC-RAS medium to present a model and simulation of the hydraulic behavior of Goharrood and Siahrood rivers. Flow regime was considered mixed and normal depth was used. Finally, hydraulic behavior (water level and depth, water velocity and so on) of these rivers in different return periods were simulated and flood hazard zones were identified in Rasht City.

Fig. 1. Location of Rasht City in the north of Iran**.**

Fig. 2. Urban flood due to rainfall in Rasht. Flood results from river overflowing and the inefficiency of drainage channels in the City.

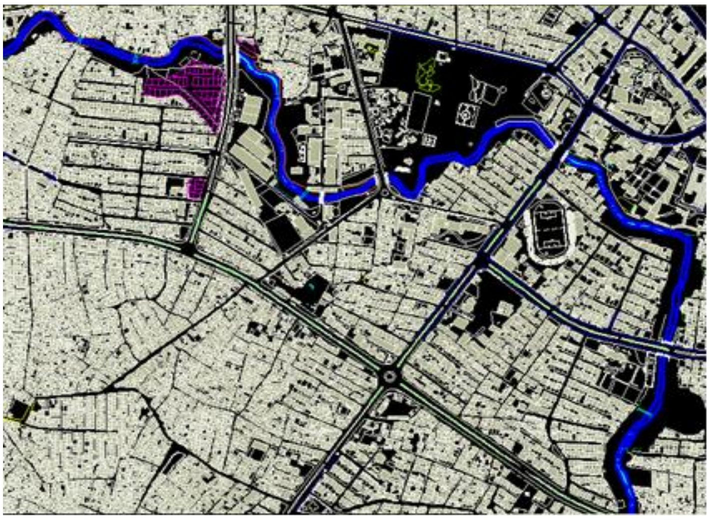

Fig. 3. The map of Rasht City, scale 1:1000.

RESULTS

Physical model of beds and adjacent areas of the rivers (geometry) were simulated using GIS (HEC-GeoRAS extension) and digital maps are given in Fig. 4. The hydrometric stations data of Lakan (Goharrood River) and Siahrood were applied in estimating the maximum instantaneous discharges and were analyzed by means of Smada software. According to Figs. 5 and 6, the Log Pearson Type III distribution is the best for estimating the maximum instantaneous discharges in different return periods, the results are demonstrated in Table 1.

In order to study the rivers, a comparison between observed and estimated discharge values have been exhibited in Figs. 5 and 6 using the Log Pearson type III distribution. After presenting the hydraulic model of Siahrood and Goharrood rivers and simulating hydraulic behavior in discharges with different return periods, length-section of the rivers and water level in different return periods are given in Figs. 7 and 8. A cross-section in Goharrood River and water level in different return periods are demonstrated in Fig. 9. The results revealed that the Goharrood and Siahrood rivers have not been flooded in most of their sections in time return (Tr) 2 to 50 years. In the current geometric conditions of the rivers, we observed the river floods in T_r 200 year. So, considering floods with time return of 200 years is essential for management against disaster and planning the flood control projects. After modeling the hydraulic behavior of the river in HEC-RAS model, we imported the hydraulic model results in GIS medium. We evaluated the zoning of flood in 200 years because the other times flood hazards were not notable. In fact, A 200-year flood zoning was investigated because other flood time return zones were not extensive. Some examples of a 200-year flood hazard zoning map for the rivers in Rasht City are shown in Figs. 9 - 11.

Table 1. Maximum instantaneous discharges in Siahrood and Goharrood rivers.

Return Period	Siahrood River ($m^3.s^{-1}$)	Goharrood River ($m^3.s^{-1}$)
2	54.4	35.4
5	72.8	56.7
10	85.3	79.1
25	101.5	121.8
50	113.9	168.4
100	126.5	232.6
200	139.5	321.5

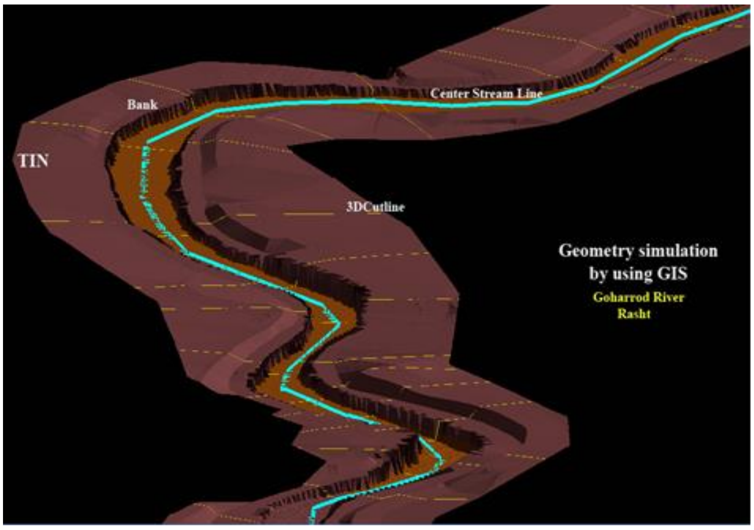

Fig. 4. 3D model (TIN), center stream line, banks and 3D cutlines in a part of study path, Goharrood River.

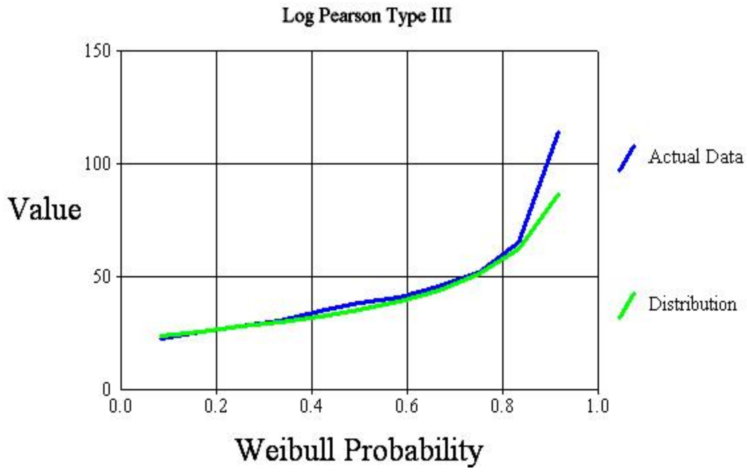

Fig. 5. Comparison between observed and estimated values using Log Pearson type III distribution (Lakan, Goharrood station).

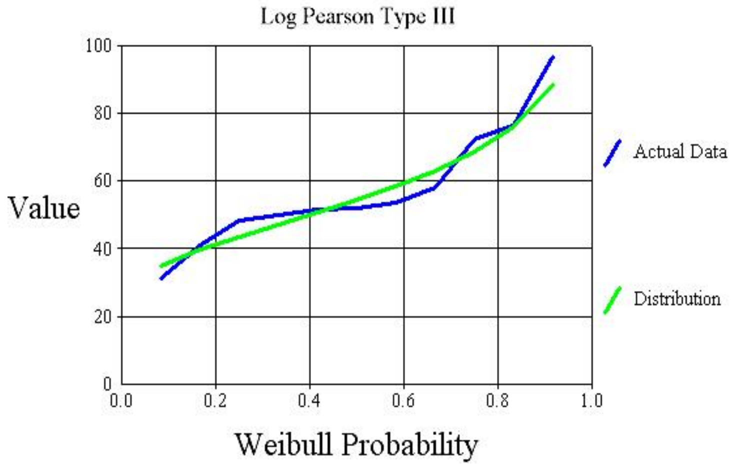

Fig. 6. A comparison between observed and estimated values using Log Pearson type III distribution (Siahrood Station).

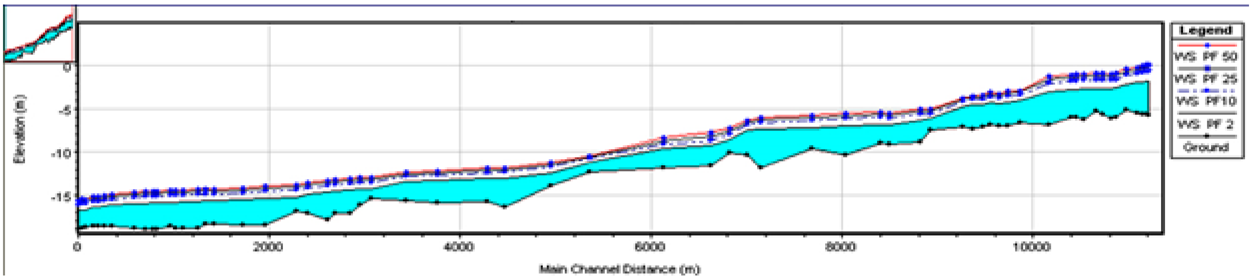

Fig. 7. Length-section of Siahrood and water level in different return periods.

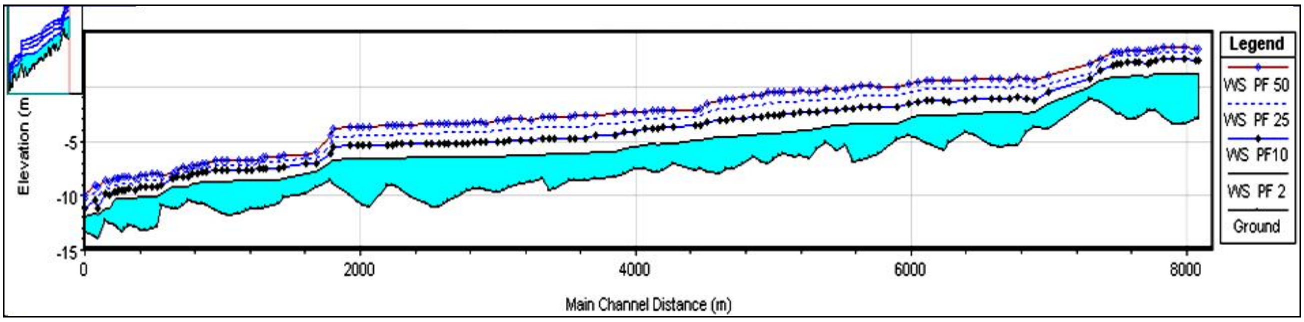

Fig. 8. Length-section of Goharrood and water level in the different return periods.

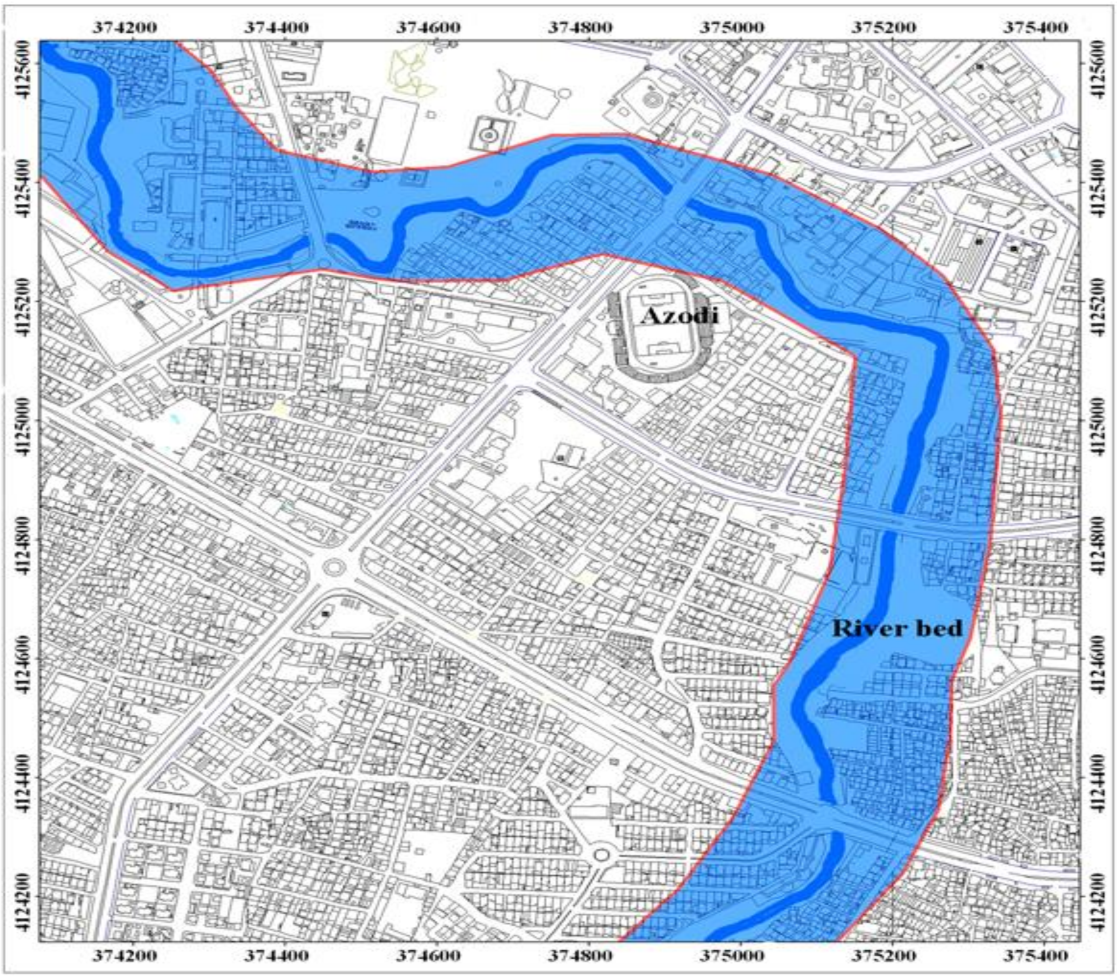

Fig. 9. Flood zone with Tr200 of Goharrood River on the surface of Rasht City.

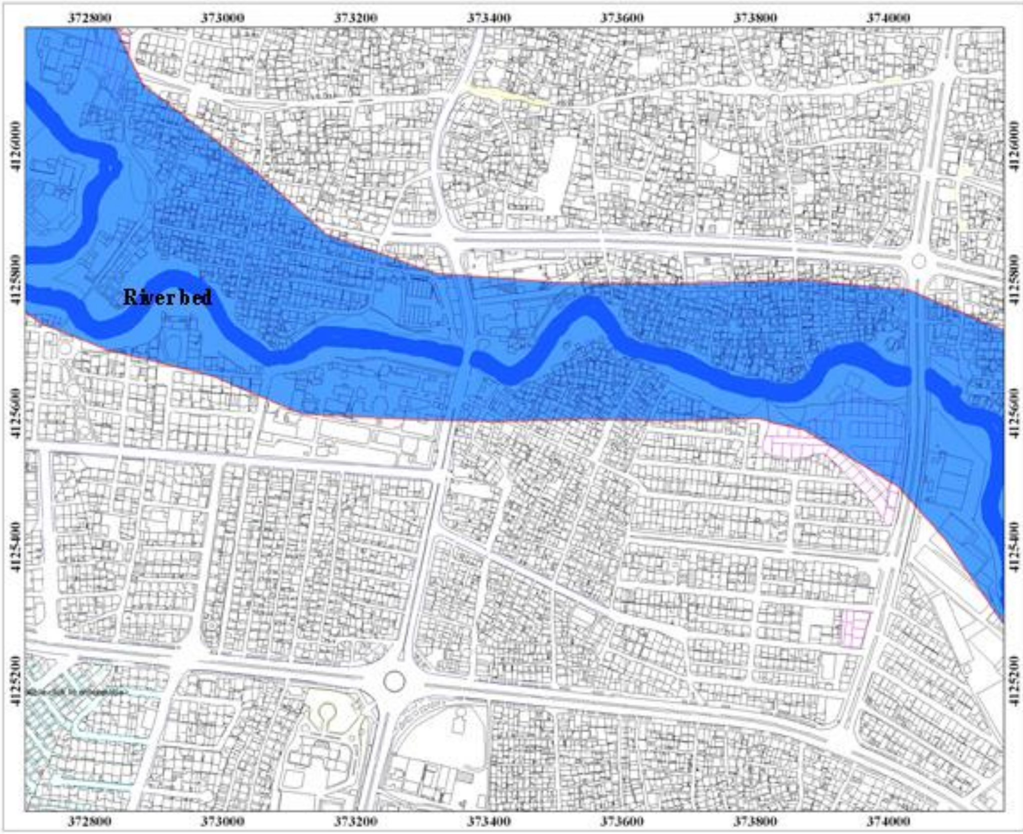

Fig. 10. Flood zone with Tr200 of Goharrood River on the surface of Rasht City.

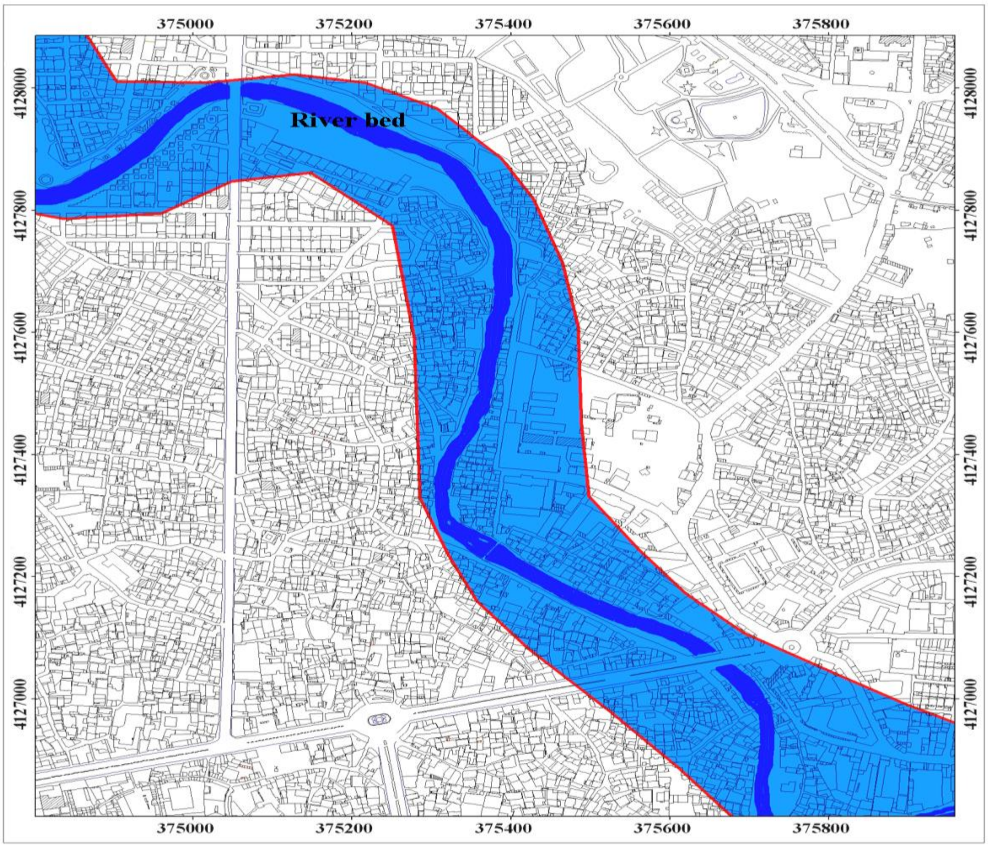

Fig. 11. Flood zone with Tr200 of Siahrood River on the surface of Rasht City.

CONCLUSION

In the present study, river beds and adjacent areas were geometrically simulated using GIS and hydraulic behavior via HEC-RAS due to its accuracy and speed. The previous studies confirmed that urban expansion has more influence in runoff generation of surface unit (Riley 1998). The simulation of the hydraulic behavior of Siahrood and Goharrood rivers was carried out by utilizing GIS and HEC-RAS hydraulic model. The previous investigations indicated that the capabilities of GIS provide acceptable results in the simulating river conditions and adjacent areas (Hirsch *et al.* 1990; Hill 2001; Burns *et al.* 2005). It also leads to higher efficiency and lower expenses (Pistocchi & Mazzoli 2002; Pappas *et al.* 2008). During the flood occurrence in a 50-year return period in Siahrood River, it was found that there was no danger on river banks adjacent areas but in some locations, water flow can reach to the banks or overflow. It is essential to manage the location which has limited discharge capacity such as under bridges. Thus, by organizing rivers, preventing sedimentation, and crossing trunk of trees, overflowing rivers can be prevented. According to obtained results, the probability of river flood in the Goharrood River path is higher than in Siahrood path. Generally, the 100 and 200 years floods can damage Rasht City. Sedimentation and point bars in the river beds have a significant influence on the reduction of river flood hazard. River improvements (point bars, large stones and existing vegetation in riverbed) will reduce the roughness coefficient. An increase in water depth will increase water velocity which in turn will considerably reduce the water height and area during the flood. Finally, it is suggested to investigate the effects of urban development in the runoff generation and the flash floods occurrence in North Iran. This study presented an effective method for simulating the rivers hydraulic behavior during flood occurrence. The lack of flood data is a serious problem for hydrological studies and hydrologic modeling in Iran. In fact, many past floods have not been recorded by hydrometric stations, and many basin areas lack stations. Thus, the present models could be applied to simulate flood hydrographs and flood zones for the basins which have not been studied yet.

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REFERENCES

Azarga, E 1999, *Flood plain visualization using Tins.* MSc Thesis, University of Texas at Austin, 136p.

Balasch, JC, Ruiz-Bellet, JL & Tuset, J 2011, Historical flash floods retromodeling in the Ondara River in T` arrega (NE Iberian Peninsula), *Natural Hazards and Earth System Sciences*, 11: 3359–3371.

Bhadra, A, Panigrahy, N, Singh, R, Raghuwanshi, NS, Mal, BC & Tripathi, MP 2008, Development of a geomorphological instantaneous unit hydrograph model for scantily gauged watersheds. *Journal of Environmental Modeling & Software,* 23: 1013-1025.

Burns, D, Vitvarb, T, McDonnellc, J, Hassettb, J, Duncanb, j & Kendalld, C 2005, Effects of suburban development on runoff generation in the Croton River basin, New York, USA. *Journal of Hydrology*, 311: 266-281.

Carson, E 2006, Hydrologic modeling of flood conveyance and impacts of historic overbank sedimentation on West Fork Black s Fork. Vinta Mountains, northeastern Utah, USA. *Geomorphology*, 75: 368-383.

Esmaeeli Gholzom, H & Gholami, V 2012, A comparison between natural forests and reforested lands in terms of runoff generation potential and hydrologic response (Case study: Kasilian

Watershed). *Soil & Water Research,* 7: 166–173.

Gholami, V, Mohseni Saravi, M & Ahmadi, H 2010, Effects of impervious surfaces and urban development on runoff generation and flood hazard in the Hajighoshan watershed. *Caspian Journal of Environmental Sciences*, 8: 1-12.

Gholami, V & Khaleigh, MR 2013, The impact of vegetation on the bank erosion (Case study: Haraz River). *Soil & Water Research,* 8: 158–164.

Hill, M 2001, Flood plain delineation using the HEC-GeoRAS extention for ArcView. Brigham Young University, 514p.

Hirsch, RM, Walker, JF, Day, JC & Kallio, R 1990, The influence of man on hydrologic systems. In MG Wolman & HC Riggs (eds), Surface Water Hydrology. *Geological Society of America*, 1: 329-359.

Hooijer, A, Klijn, F, Pedroli, GBM & Van Os, AG 2004, Towards sustainable flood risk management in the Rhine and Meuse river basins: Synopsis of the findings of IRMA-SPONGE. *River Research Application*, 20: 343–357.

Hyalmarson, HW 1988, *Flood hazard zonation in Arid land.* Wesley Publishers, 114p.

Jahnson, G, Strickland, M & Byyok, D 1999, Quantifying impacts to riparian wetlands associated with reduced flows along the Greybull River, Wyoming. *Wetlands,* 19: 71-77.

Islam, MD & Sado, K 2000, Development of flood hazard maps of Bangladesh using NOAA-AVHRR images with GIS. *Hydrological Sciences Journal,* 45: 337-355.

Kang, SH 2010, Tight coupling UFM ArcGIS for simulating inundation depth in densely area. *Natural Hazards and Earth System Sciences*, 10: 1523–1530.

Khaleghi, MR, Ghodusi, J & Ahmad, H 2014, Regional analysis using the geomorphologic instantaneous unit hydrograph (GIUH) method. *Soil & Water Research,* 9: 25–30.

Kreibich, H, Thieken, AH, Petrow, T, Muller, M & Merz, B 2005, Flood loss reduction of private households due to building precautionary measures – lessons learned from the Elbe flood in August 2002. *Natural Hazards and Earth System Sciences*, 5: 117–126.

Ortega, JA & Garzon, G 2009, A contribution to improved flood magnitude estimation in base of palaeoflood record and climatic implications–Guadiana River (Iberian Peninsula). *Natural Hazards and Earth System Sciences*, 9: 229–239.

Pappas, EA, Smith, DR, Huang, C, Shuster, WC & Bonta, JV 2008, impervious surface impacts to runoff and sediment discharge under laboratory rainfall simulation. *CATENA*, 72: 146-152.

Pistocchi, A & Mazzoli, P 2002, Use of HEC-RAS and HEC-HMS models with ArcView for hydrologic risk management, Autorità dei Bacini Regionali Romagnoli. *P, Zza GB Morgagni,* 2 – 47100 Forl, Italy, 7P.

Roy, E, Rousselle, J & Lacroix, J 2003, Flood damage reduction Program (FDRP) in Quebec: Case study of the Chaudiere River. *Natural Hazards,* 28: 387–405.

پهنه بندی خطر سیلاب با به کارگیری سیستم اطلاعات جغرافیایی (GIS) و مدل HEC-RAS (مطاله موردی شهر رشت)

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چکیده

رودخانه‌ها، مهم‌ترین منابع آبی برای زندگی بشر به حساب می‌آیند، اما گاهی موجب خسارات جبران‌ناپذیری می‌شوند. از طرفی، دشت‌های سیلابی اراضی حاصلخیزی می‌باشند که در معرض خطر وقوع سیلاب قرار دارند. پهنه‌بندی سیلاب یکی از روش‌های مبارزه با خطر سیلاب است. هم‌چنین، شبیه‌سازی رفتار هیدرولیکی رودخانه در حین وقوع سیلاب برای برنامه‌ریزی کاهش خطر آن، امری ضروری و مهم است. در تحقیق حاضر، پهنه‌های سیلاب در طول بازه‌هایی از رودخانه‌های سیاهرود و گوهررود در شمال ایران، در سطح شهر رشت مطالعه شد. بستر رودخانه‌های مذکور و اراضی حاشیه آن‌ها با به کارگیری الحاقیه HEC-GeoRAS (GIS) و نقشه‌های رقومی با مقیاس ۱:۱۰۰۰ شبیه‌سازی شد. دبی‌های بیشینه لحظه‌ای با به کارگیری تجزیه و تحلیل‌های آماری با دوره بازگشت‌های مختلف برآورد گشتند. مدل هیدرولیکی HEC-RAS و سیستم اطلاعات جغرافیایی برای شبیه‌سازی رفتار هیدرولیکی رودخانه و پهنه‌بندی خطر سیلاب به کار گرفته شدند. سیستم اطلاعات جغرافیایی ابزاری کارآمد در مراحل پیش‌پردازش و پس‌پردازش داده‌ها و تهیه نقشه‌های پهنه‌بندی بوده است. سرانجام، نقشه پهنه‌های سیلاب با دوره های بازگشت ۲، ۱۰، ۲۵، ۵۰، ۱۰۰ و ۲۰۰ ساله تهیه و تحلیل‌های لازمه بر روی نقشه‌های شهری از طریق آنالیز همپوشانی انجام پذیرفت. نتایج تحقیق نشان داد که بخشی از سطح شهر رشت (اراضی حاشیه رودخانه) در معرض خطر وقوع سیلاب می‌باشند.

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