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DETECTING THE IMPACT OF LAND USE CHANGES ON FLOW HYDRAULICS IN KASHAFROOD AND PRESENTING AN IMPROVEMENT PLAN

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ABSTRACT

In recent years, the effects of land use change are considered as one of the most important concerns in water management of basins. Kashafrood basin in Mashhad, for various reasons, has been affected by land use change, urban development and agricultural water resources development. Thus, doing a research using a model with a physical and distributive basis is needed to evaluate the effect of land use changes on hydrological components. The area under study is located in Razavi Khorasan province, Mashhad, and includes part of Kashafrood path between Parkand Abad refinery and Olang refinery located at a longitude of 59° 33' to 59° 50' E and a latitude of 36° 15' to 36° 24' N. GIS technology and digital software have been used to increase the accuracy of data in conducting the studies so that physiographic parameters were analyzed and estimated using digital layers with 1:250000 precision in ArcGIS and ArcView software. Between Parkand Abad refinery and the end of the studied area, the lands around the river are of particular value due to favorable conditions for agriculture and harvesting of patch products and for this reason, clear transgressions to the riverbed and river bound are evident. The results revealed that the average depth of the terraces formed on the left and right banks of the river is between 2 and 5 meters and erosion effects are visible at more than 50% of the path length. The maximum erosion length is related to the class with a wall depth of 2 to 5 meters on both right and left banks. Further, on the severity of the erosion, the class related to a length of more than 50% of the path on both banks has the highest amount of erosion. Based on the hydraulic results obtained in most cross sections, a 25-year

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discharge crosses the riverbed and enters the river bound. Hence, with regard to the changing of uses in the area around the river to agricultural and residential uses in the river bound, the necessary measures should be taken into account in this field. Accordingly, one of the practical cases is the dredging and improvement of the path and another solution is the construction of a rock, mortar or gabion wall on the left and right banks. The results of calculating the river dimensions in the final equilibrium state and movement threshold conditions at all stable sections of the studied river showed that in 71% of cross sections, the situation is unstable and in the remaining 29%, the situation is stable. The highest values of shear stress and shear velocity in unstable sections are 815.41 N/m^2 and 6.21 m/s, respectively. On the contrary, the highest values of shear stress and shear velocity parameters in stable sections are 516.7 N/m^2 and 4.92 m/s, respectively. The sensitivity analysis results demonstrated that the greatest sensitivity to the roughness coefficient changes is related to the parameters of flow area and upper surface width.

Keywords: Kashafrood; use changes; hydraulics; improvement.

INTRODUCTION

In recent years, the impacts of land use change are considered as one of the most important concerns in water management of basins. Kashafrood basin in Mashhad has been affected, for various reasons, by land use change, urban development and agricultural water resources development. Thus, it is required to do a research using a model with a physical and distributive basis to evaluate the effect of land use changes on hydraulic components. Land use and its fluctuations are among the factors that influence the natural cycle in the ecosystem. The main purpose of land management is to investigate the impacts of land use change and its hydraulic effects on the basin. Rainfall-runoff process of the basin is the result of the interaction between many factors such as climate, land use and so on. Land use changes cause changes in the basin hydrologic cycle, resulting in changed water balance between precipitation, evaporation, permeability and thus runoff. These cases will affect the hydraulic conditions of the flow in the river.

Satellite images can provide analysts with accurate and up-to-date information on land cover. The status of land use changes can be specified using data such as maps, aerial photos, satellite imagery, and so on (Shari’at Panah et al., 2010). One of the best ways to evaluate land use changes and river bed and riverside use in the past was to use aerial photos and satellite imagery. But due to the smallness of the studied units in the area, it is not possible to view and examine them on large scales with aerial photos. To this end, high-ground resolution spot or Quickbird satellite images are suitable (Ebrahimi & Yazdani, 2013).

In the city of Tirana, Albania, Valmir et al. (2019) conducted a study and showed that the highest volume of runoff in bare lands is 38829.91 liters on 74% slopes and the lowest volume is in forest lands amounting to 12840.6 liters on 64% slopes. Additionally, the highest amount of sediment in bare lands is 515.15 tons per hectare on 62% slopes and the lowest amount is in forest lands amounting to 18.18 tons per hectare on 64% slopes (Valmir et al., 2019).

Understanding the process of change and evolution of ecosystems can be helpful in predicting the future status of land use and vegetation cover (whether continuing the current trend or taking protective and managerial measures) (Ozesmi et al., 2002).

In Northwest China, in the headwater region of Heihe River, the combined impact of climate variability and land use change has been examined and the near future has been predicted while studying a decade ago or the near past. According to the results, the role of land use change should not be overlooked, especially if the climate becomes drier in the future because it increases the hydrological parameters (Zhang ling et al., 2016.(

The environmental impacts of land cover changes, whether in the short term or in the long term, appear to be very serious (Briassoulis, 2006). The potential effects of climate change on agricultural use and its damages were investigated. The researchers' studied area was a region in Western Australia whose main land use is agricultural. After studying the region's climate and how it changed, they examined the amount of crop yields. The findings indicated that as a result of climate change, the yield of crop production in the agricultural areas will increase by 10% (Vangool & Vernon, 2006). In a study, Madi et al. (2013) investigated the impact of a rainfall at the intensity of 73 mm/hr on the soil surface (soil tray) with a fixed gradient of 3 degrees with different shoot densities and concluded that shoot density affects the flow hydraulics and increases Darcy-Weisbach friction factor and Manning's roughness coefficient while decreasing flow velocity and amount of sediment (Madi et al., 2013). Nearing et al. (1997) conducted a study using several experimental methods and a wide range of hydraulic conditions including flow velocity, Froude numbers, Reynolds numbers and bed roughness on steep hills and came to the conclusion that transport rate and sediment load depend on flow velocity and power (Nearing et al., 1997).

Qoddusi et al. (2012), in part of their research, used the years 1976, 1989, 2002 and 2008 as the SWAT model input in order to examine the effects of land use changes on runoff in Urmia Lake basin and calibrated the model in four states based on the closest statistics to each of these years. The results suggested a 51% decrease in the volume of outflow water from the basin with uses after 1989 and a 13% increase in actual evapotranspiration over these years. Further, they maintained that the operation of the dam under construction in that basin has also added to the above problems, followed by a 21% decrease in Lake Urmia inputs. Newbert et al. (2012) evaluated hydrological response of Wami Basin to land use changes. In order to overcome the problem of lack of observational information of the basin, they used satellite information for the use layer as input for the SWAT semi-distributed rainfall-runoff model, according to which use images related to the years 1987-2000 were prepared. The results showed a 1.4% decrease in forest lands, a 3.2% increase in agricultural lands and a 2.2% increase in urban areas. The rainfall-runoff simulation results also indicated a decrease in annual average river flow. Thus, the produced changes have led to an increase in surface flow and a decrease in river base flow. Haji Hoseini et al. (2015) investigated the effect of land use changes on runoff in Helmand transboundary basin during 1990-2012 using SWAT software. Land use change results displayed that total cultivation of aquatic products in the region has reached about 62%. SWAT model simulation results disclosed that development of the agricultural sector in Hirmand plain has resulted in an average decrease of 800 million cubic meters per year. Borzou et al. (2014) evaluated the effect of land use on runoff rate and sediment yield in Gilard basin in Tehran Province using the SWAT model. After running the model, the simulated results were compared with the measured values. Comparison of runoff and sedimentation rates with three different types of land uses indicated that due to land use change from rangelands and forests to agricultural lands and residential areas, the rate had a 30% increase and sediment yield also increased by 4 times.

Aldeen (2013) applied the ArcSWAT model to estimate sediment load in the lands on the left bank of the Mosul Dam in northeast Iraq and finally stated that the factor of runoff coefficient has a significant influence on runoff and sediment rates. This factor is variable at the basin level and its value can vary depending on the type of the soil of the land use area. Moreover, the amount of runoff coefficient, in addition to the vegetation cover of the area, depends on the soil texture characteristics of that area.

Zuo et al. (2016) examined the impact of land use change on runoff and sediment rates of Huangfuchan basin in China. The results of their study suggested that land use changes over the years 1980 to 2005 have had a significant impact on reduced basin sediment compared to runoff. On the other hand, they estimated the amount of sediment and runoff in the upstream part of the basin to be more than the downstream. Farrokhzadeh et al. (2015) evaluated the impact of land use change on the suspended load rate in Yelfan basin using the SWAT model in years 1988-2012. Results of the model output with two different land uses indicate the significant impacts of land use change on the basin suspended load and thus river hydraulics. The results revealed that land use changes from 1988 to 2012 have resulted in an increase in the amount of suspended load by approximately 30.62%. Based on the findings, the SWAT model enjoys good capability to simulate the sediment in the mentioned basin.

The passage of Kashafrood from the vicinity of the residential areas in the region under study raises concerns about the dangers and damages caused by land use change and its impact on flood hydraulics. The present study partly clarifies the ambiguities arising from this concern and identifies the vulnerable and risky points. Besides, flood catchment area has been specified as a result of the use change and based on hydraulic studies and by determining the bed of floodwaters with a higher return period in order to clarify the intensity and extent of applying protective measures. In this respect, by performing sensitivity analysis of the input parameters to the HEC-RAS model, the effectiveness of use change in the flow hydraulics will be determined.

MATERIALS AND METHODS

Geographical location of the project site

The studied area is located in Razavi Khorasan province, Mashhad, and includes part of Kashafrood path between Parkand Abad refinery and Olang refinery located at a longitude of 59° 33' to 59° 50' E and a latitude of 36° 15' to 36° 24' N (Figure 1).

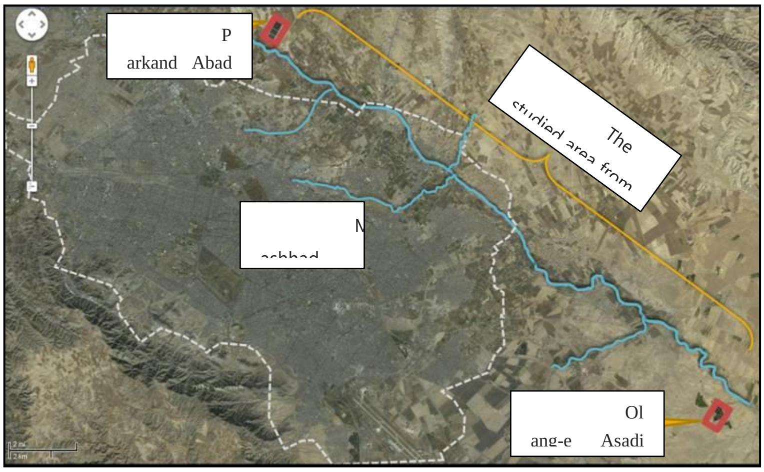

Figure 1**. Studied area of Kashafrood.**

PHYSIOGRAPHIC STUDIES

Physical properties of basins are among the important parameters in hydrological studies and flow hydraulics, whose values indicate the appearance and morphological status of the area; factors such as area and circumference, average height, river slope, etc., whose measurement plays an important and decisive role in the discharge regime, sediment regime, erosion and so on. It should be noted that the studied area was divided into 5 sub-basins with regard to the rivers joining Kashafrood. According to the physiographic conditions of the basin, the results of Bransby Williams' method were selected as final values of the concentration time of the studied basins. The physiographic characteristics of each basin are shown in Table (1).

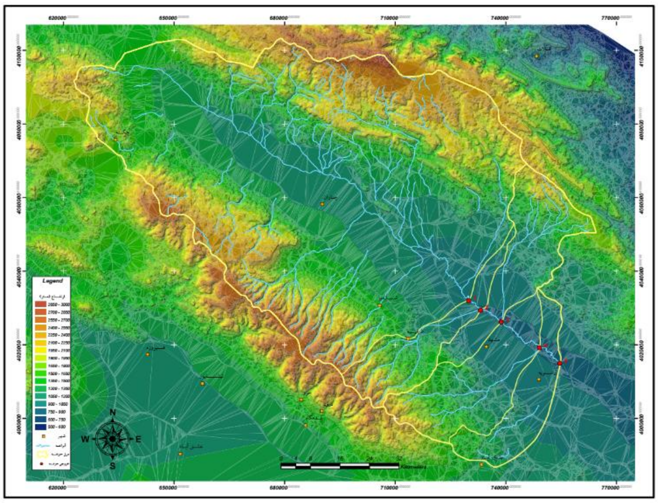

Figure 2**. Kashafrood basin (points 1 to 5 are the outlets of the studied basins).**

Table 1.
Physiographic characteristics of the studied basins (sub-basins).

BASIN	1	2	3	4	5
Area (Km^2)	6846.3	7337.7	8022.2	8785.6	9253
Circumference (Km)	367.4	385.9	412	436.4	450.8
Average height (m)	1599	1583.8	1557.4	1531.7	1508.6
Minimum height (m)	930	898	892	883	876
Maximum height (m)	3000	3000	3000	3000	3000
Medium slope (%)	5.12	5.17	5.04	4.89	4.74
Main waterway length (Km)	139.3	141.03	147	162.71	172
Net waterway slope (%)	0.31	0.32	0.32	0.31	0.31
Equivalent rectangle length (Km)	51.96	52.11	52.15	53.27	53.98
Equivalent rectangle width (Km)	131.75	140.82	153.84	164.91	171.41
Packing factor	1.24	1.26	1.29	1.3	1.31
Shape coefficient	0.35	0.37	0.37	0.33	0.31
Maximum relief (m)	2070	2102	2108	2117	2124
Concentration time (hr)	25.15	25.23	26.2	28.91	30.59

FLOOD

Since hydraulic studies of the river require the estimation of flood discharge and its entry into the hydraulic model, flood calculation was done by experimental methods (Dicken, Fuller, Krieger) which are more applicable and with regard to the climatic conditions of the region, physiographic characteristics and the location of Olang-e Asadi hydrometric station relative to the studied basins, the calculated values of flood by Dicken method have been selected as final values of flood with different return periods for the basins under investigation (Table 4).

Dicken method:

$$\varphi_1 = \varphi_2 \left(\frac{A_1}{A_2} \right)^{0.75}$$

A_1: Basin area (Km^2), A_2: Station area (Km^2), Q_2: Station flood (m^3/s) with different return periods, Q_1: Basin flood (m^3/s) with different return periods.

The peak flood discharge in the Dicken method is obtained using the basin area and the regional coefficient (9). The regional coefficient was determined according to the statistics of hydrometric stations in the area. In this project, Olang-e Asadi station which has a proper statistical period length and is located on Kashkafrood was used. For this purpose, the recorded statistics of peak flood discharge in Olang-e Asadi hydrometric station over a 32-year period were analyzed statistically using HyFA software and the station flood values with different return periods were selected based on the best fit (3-parameter log normal).

Table 4.
Flood values of Olang-e Asadi station with different return periods (m^3/s).

Area (Km^2)	Return period (year)								
	2	5	10	20	25	50	100	200	500
9074	60.3	138.4	219.4	323.8	363.1	504.8	680.2	894.7	1248.7

Table 5.
Flood values calculated with different return periods by Dicken method (m^3/s).

Basin outlet	Area (Km^2)	Return period (year)								
		2	5	10	20	25	50	100	200	500
1	6846.3	48.9	112	177.7	262.2	293.9	408.6	550.6	724.3	1010.9
2	7337.7	51.5	118	187.1	276.1	309.6	430.4	580	762.9	1064.8
3	8022.2	55	126.2	200.1	295.3	331	460.2	620.1	815.7	1138.5
4	8785.6	58.9	135.1	214.2	316.1	354.4	492.7	663.9	873.3	1218.8
5	9253	61.2	140.4	222.7	328.6	368.4	512.2	690.2	907.9	1267.1

LAND USE DETERMINATION

Study of aerial photos and satellite images

One of the best ways to evaluate land use changes and river bed and riverside use in the past has been the use of aerial photos and satellite imagery. Comparison of aerial photos, as they are taken at different time periods, is useful in tracking and investigating changes. But due to the smallness of the studied units in the area, it is not possible to view and examine them on large scales with aerial photos. To this end, high-ground resolution spot or Quickbird satellite images are suitable. Given that the images of the desired area in Google Earth have high resolution, the mentioned images were used in this research and the border of the parts was scrutinized (Figure 3). Then, descriptive information of layers such as parts code, the name of owners of riverside lands, land use type and customary unit of the area was added to the database and area of each land unit was extracted. In the next step, by superposing a 25-year flood layer (publication No. 276 of Plan and Budget Organization) and its bound on land use layer, the profile of river bed and river bound occupants and the area of the lands located in flood zone and its bound were calculated and extracted.

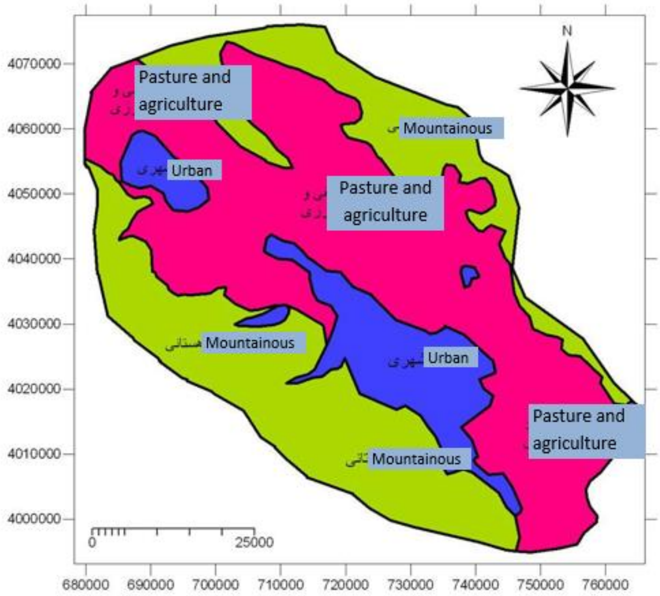

Figure 3. **Land use in 2016.**

Topography, grid plan and river geometry

The topographic map was entered into the GIS environment and cross sections along the river were extracted using the capabilities of this environment and the HEC-GEO-RAS extension for the ArcView software environment. Thus, the use of this program, in addition to reducing the volume of mapping operations, also has the advantage of more accurate computations (Yang & Tsai, 2000).

Flow simulation in the river

After entering the collected information on river topography and morphology in the GIS environment, the required information of the model was prepared in HEC-RAS software in the GIS (geographic information system) environment and was then entered into the HEC-RAS model. Afterwards, the river was simulated in different hydraulic regimes and ultimately, based on the obtained hydraulic results, the most suitable bed was selected for the river path. Then, by entering the results of HEC-RAS model into GIS with respect to river topography and water surface profile, flood zoning map within the floodplain area was prepared for different return periods of the river. It should be noted that the river's roughness coefficient was calculated by Cowan method (4).

Study of river erosion status

To determine the severity and extent of lateral erosion, the following classes were separated and the river was evaluated by measuring two factors of terrace height (H) and erosion activity (T). To this end, the height of terraces was calculated using Hec Ras software and was zoned in Arc view software into three classes (H_1 to H_3) and T classes with field surveys were also assigned to four classes (T_1 to T_4).

A) Erosion activity rate

T_1: The river flows on a calm bed and erosion is evident at the site of arches; T_2: The effects of erosion are seen in 10 to 30 percent of the river path; T_3: The effects of erosion are seen in 30 to 50 percent of the river path; T_4: The effects of erosion are visible in over 50 percent of the river path.

B) Terrace height

H_1: Depth of wall caused by lateral erosion between 0 and 2 meters; H_2: Depth of wall caused by lateral erosion between 2 and 5 meters; H_3: Depth of wall caused by lateral erosion between 5 and 10 meters.

EFFECTS OF LAND USE CHANGE ON RIVER HYDRAULICS

The basis for calculating the drop in Ras Hec software is the Manning equation. Among the parameters used in this equation, all parameters applied in river modeling such as hydraulic radius, slope of the river floor and cross-sectional area are derived from river geometry and only Manning's roughness coefficient value is estimated based on expert opinion and vegetation characteristics (land use). Accordingly, this parameter is the only parameter that can be sensitized. In addition, this parameter plays an important role in simulating the flow and determining the flow characteristics. Hence, in order to reveal the impact of land use change on river hydraulics, the effect of land use change was investigated by applying changes in the amount of Manning's roughness coefficient as ±10, ±20 and ±30 percent relative to actual conditions.

RESULTS AND DISCUSSION

Study of river erosion status

The lengths of erosion classes along the riverbanks are shown in Table (5). As displayed in the following table, the greatest erosion length belongs to H_2 class on both right and left banks. Moreover, regarding erosion severity, class T_4 has the highest amount of erosion on both banks. Accordingly, the sections that fall into the H_4T_4-H_3T_3-H_3T_4 erosion class have high erosion potential. These sections are mostly seen in population centers that threaten riverside resources. So, they need protection programs along the path.

Table 6.
The length of erosion classes on the banks of the studied river.

Bank	Depth and severity of erosion	Signs	Length (km)
Left	Depth of terrace	H1	11/51
		H2	19/83
		H3	1/73
		H4	-
	Severity of erosion	T1	6/31
		T2	0/139
		T3	3/57
		T4	23/06
Average erosion class on the left bank		H2T4	
Right	Depth of terrace	H1	11/54
		H2	19/97
		H3	1/19
		H4	-
	Severity of erosion	T1	-
		T2	0/615
		T3	5/77
		T4	26/33
Average erosion class on the right bank		H2T4	

Cross sections of the river

The cross sections of the HEC-RAS model are shown below. They provide the water surface profile of critical flow line for a 25-year return period. Given that in most of the cross sections, the 25-year flood crosses the riverbed and enters the river bound, it is concluded that the paths are dangerous during floods. According to the hydraulic results obtained, the flow conditions are appropriate within the first 2 km of the path and the flow is controlled in the riverbed. But further down the path, because of the addition of the floods of other branches and muddy water, more destruction and erosion have occurred so that the flood goes out of the main bed. These conditions can be associated with the maze of river path such that if the turn is to the right, the left bank is destroyed or vice versa and it has evolved into the current form over time. There were numerous arches along the path, where hydraulic conditions are very specific and sensitive. The results related to the characteristics of arches are shown in Table (6) (Figure 11). Field surveys of Kashafrood indicate that small and large floods occur every year in the studied river and cause damages to agricultural lands, communication roads, residential areas and buildings along the path. But what is inferred from the river basin hydrological studies suggests that a basin with an area of 9253 km^2 and average rainfall of 287.1 mm per year with physiographic characteristics of the basin must have significant floods so that the 25-year flood peak discharge of this river to the main basin outlet is 368.4 m^3/s. Currently, in all the path of Kashafrood and its banks, agricultural lands, residential areas, communication roads, sand harvesting and soil accumulation can be seen, which makes it very difficult to conduct river simulations in conditions devoid of such facilities because in the studies on riverbed and river bound, the bed is the part of the river that can cause a 25-year flood to pass the river regardless of the structures built in it and the river bound is a band from the edge of the riverbed that varies between one and 20 meters on either side of the river depending on the importance, hydrological status, price of land adjacent to it and so on and thus, the simulation results may be affected, which is uncontrollable. Based on the surveys and calculations, the technical bound of the river was 20 meters and the qualitative bound of the river was 150 meters.

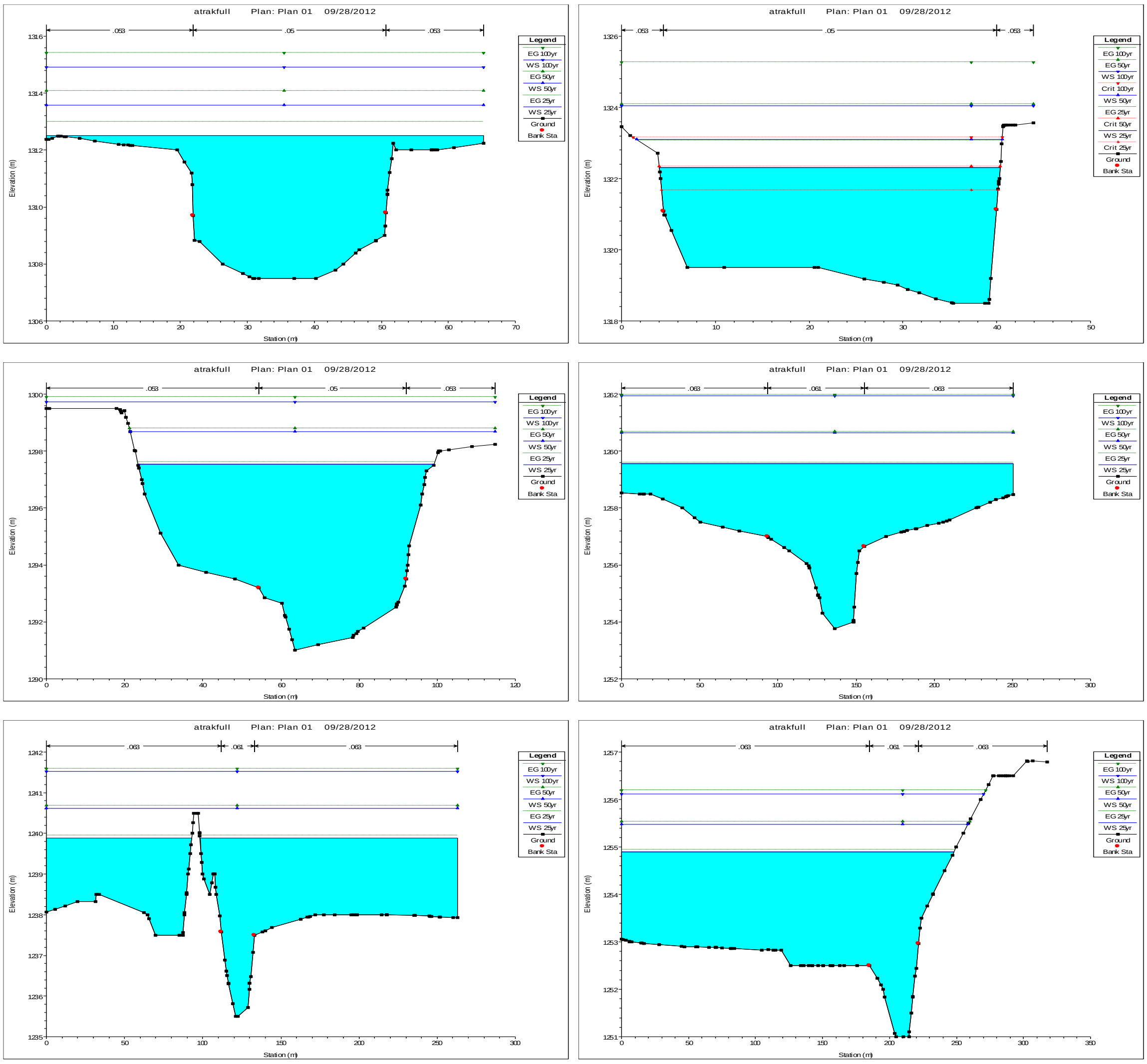

Figure 5. **Water level alignment in the cross-section.**

Table 7.
River arch profile.

code	ANG	R	T	L	B	XPC	YPC	XPI	YPI	XPT	YPT
1	122d41'22.0"	16.99	31.09	36.38	18.44	621487	4113478.54	621471.8	4113453	621455.92	4113480
2	59d44'16.9"	52.92	30.39	55.18	8.11	621551.5	4113460.02	621503	4113481	621533.18	4113484
3	173d25'6.4"	30.04	522.39	90.91	493.21	624592.3	4111940.52	624648.26	4111919	624433.21	4111443
4	191d49'11.4"	23.31	-225.15	78.03	-249.66	624710.4	4111939.74	624664.85	4111948	624645.86	4111719
5	130d13'21.2"	35.06	75.57	79.69	48.25	624740.6	4111868.54	624804.03	4111864	624766.94	4111798
6	204d18'42.2"	10.08	-46.81	35.96	-57.97	625010.1	4111655.65	625027.34	4111646	624994.62	4111607
7	174d8'25.2"	34.06	665.51	103.52	632.32	625548.6	4111114.84	625532.93	4111181	624893.94	4110995
8	165d0'35.9"	10.32	78.42	29.71	68.77	625533.8	4111110.96	625531.15	4111091	625455.39	4111111
9	152d23'29.4"	27.06	110.14	71.98	86.36	628939.6	4109957.97	628968.9	4109914	628865.47	4109876
10	136d59'31.4"	19.79	50.23	47.32	34.2	630608.6	4109277.25	630644.06	4109287	630638.85	4109237
11	238d46'6.2"	12.7	-22.55	52.92	-38.58	630736.6	4109321.04	630723.6	4109339	630704.1	4109311
12	159d1'53.6"	27.94	150.99	77.55	125.61	630729.3	4109231.22	630783.19	4109220	630726.89	4109080

ANG: Arch angle; B: The distance between confluence of chords and the location of the arch; R: Arc radius; L: Arc length; T: Chord length

Based on the results obtained above, two options of dredging and the creation of a coastal wall were investigated to eliminate the effects of land use change. For this purpose, in Hec-Ras software, the wall cross sections were placed on the bank (coast). Additionally, the options of dredging and improvement were applied in some cross sections and the results were entered into the software. As can be seen in the following figure, flood can be controlled by creating a coastal wall. Also, by dredging the path, the flow will be less in width. Accordingly, in the sections where there are residential areas at a short distance from the river, the design and construction of a flood wall and dredging of the path are essential.

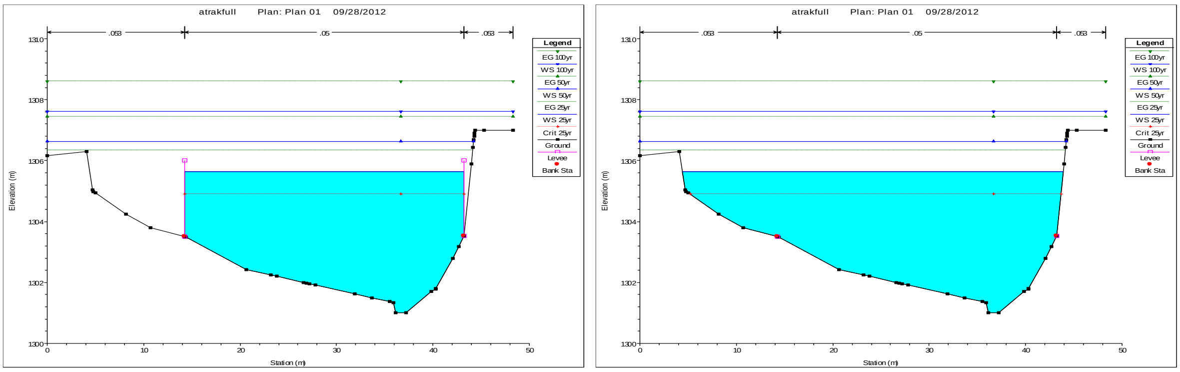

Figure 6. **The impact of the creation of walls on the river bank.**

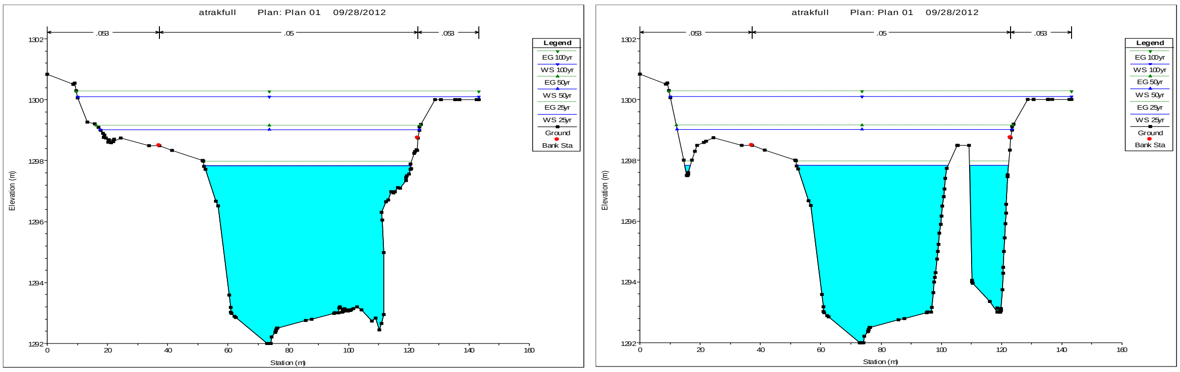

Figure 7. **The impact of dredging and improvement of the flow on the river.**

Velocity profile and Froude number variations

Longitudinal velocity profile and Froude number have been depicted in the studied section of Kashafrood with respect to the distance from the most downstream section of the flow, in which the general trend of velocity changes is quite clear. As shown in Figure (8), Froude number is less than one in all sections. In other words, in the entire path, the flow status in the river with a 25-year discharge is sub-critical. But it should be noted that with increasing flood discharge (50-year floods), the flow is in critical and supercritical conditions in most sections. In these conditions, the river situation will be critical in terms of erosion and sedimentation. Therefore, it is of great importance to carry out improvement operations of Kashafrood section. According to the obtained hydraulic results, the flow velocity in the middle of the river is higher than the left and right sides of the river. The reason can be attributed to the high roughness along the riverbank. It should be noted that the maximum flow velocity in the 25-year discharge in Kashafrood is equal to 2.6 m/s.

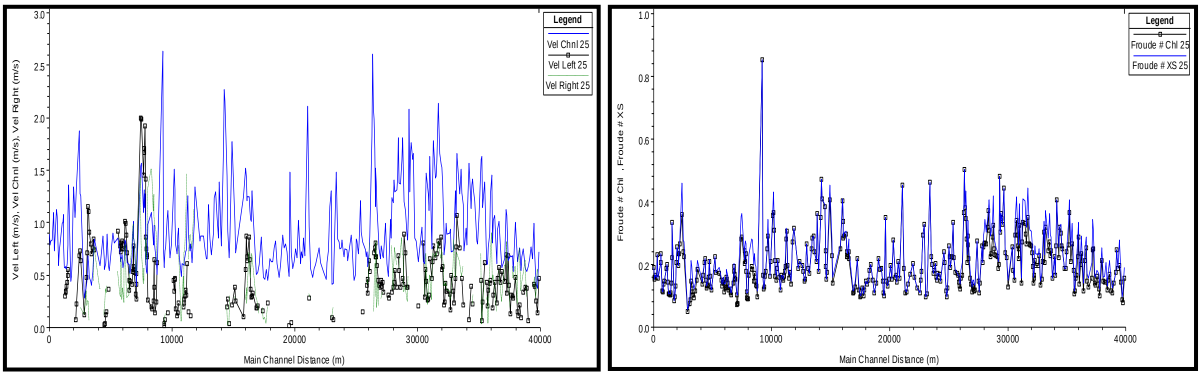

Figure 8. **Flow velocity and Froude number variations in Kashafrood in the studied section.**

The final river equilibrium

The results of calculations of river dimensions at the final equilibrium state and movement threshold conditions at all stable river sections showed that in 71% of the cross sections, the situation is unstable and in the remaining 29%, the situation is stable. The values of shear stress, shear velocity and Shields parameter for stable and unstable sections are displayed in Figures (8) and (9). As is evident in the following figures, most sections have an unstable situation. The highest values of shear stress and shear velocity in unstable sections are 815.41 N/m^2 and 6.21 m/s, respectively. In contrast, the highest values of shear stress and shear velocity parameters in stable sections are equal to 516.7 N/m^2 and 4.92 m/s, respectively. Moreover, the minimum value of Shields parameter is 0.42 in unstable sections and 1.1 in stable sections. The minimum, maximum, mean and standard deviation of the parameters of shear velocity, shear stress, Froude number, slope, hydraulic radius, flow depth, wetted perimeter and Shields parameter are given in Table (9) (unstable sections) and Table (10) (stable sections). As shown in Tables (9) and (10), the average value of the parameters presented in the stable sections is higher than the unstable sections. Such a result applies to the minimum and standard deviation of the presented parameters. On the contrary, the maximum value of parameters and also Shields parameter in the unstable sections is higher than the stable ones.

Detection of the effect of land use changes on the flow hydraulics

The sensitivity of the HEC-RAS model to Manning's roughness coefficient changes was evaluated by applying 10%, 20% and 30% changes in Manning's roughness coefficient, indicating land use changes in a 40-year interval in Kashafrood. Due to the high number of results, all of them have not been provided here and the results of the RMSE and AME parameters are shown in the following table. As provided in Table (9), with increasing the roughness coefficient value changes, the model outputs show more errors. It should be noted that the highest sensitivity to roughness coefficient changes is related to the parameters of flow area and upper surface width. It is worth noting that an increase or decrease in the value of roughness coefficient has an effect on the output results and the corresponding parameter value is not the same. But overall, the error parameters of RMSE and AME are equal (Table 9). What is clear from the following results is that by precisely estimating the roughness coefficient value, one can expect the acquisition of good accuracy. In this regard, Stevenson (2009) conducted a study on the Claire River and made a sensitivity analysis for the one-dimensional HEC-RAS model and referred to the high impact of roughness coefficient due to land use changes on results.

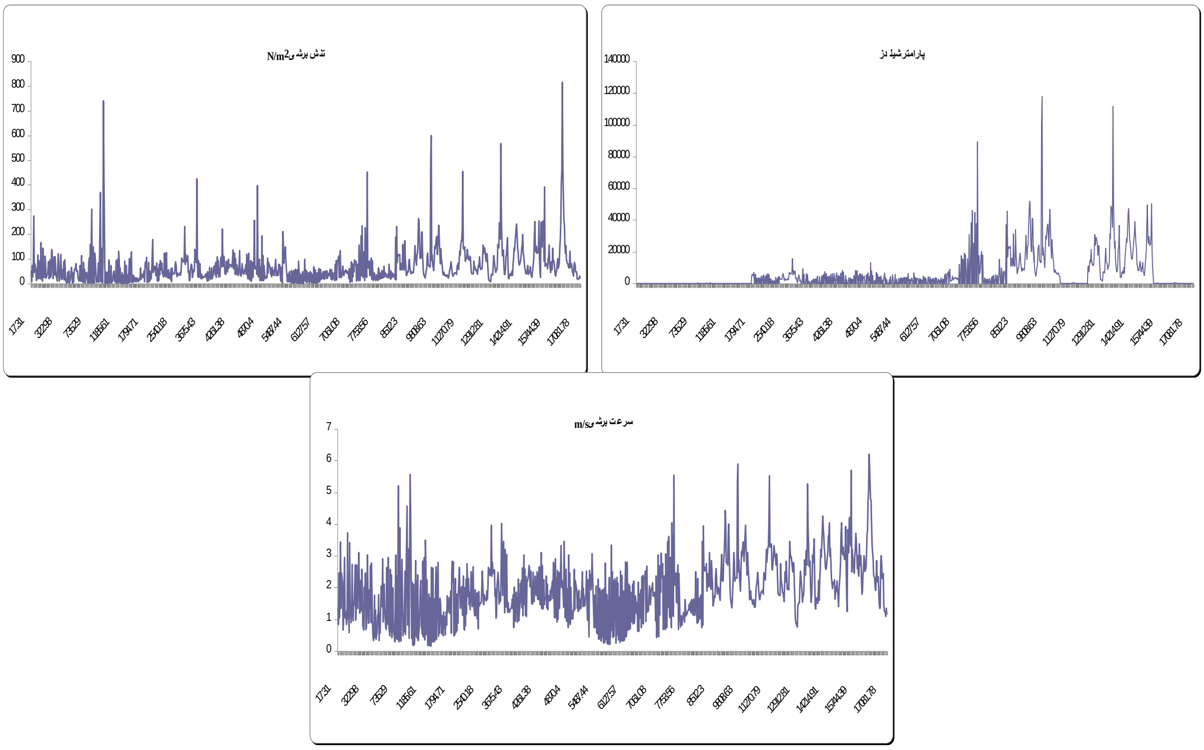

Figure 9. **Shear velocity, shear stress and Shields parameter values in unstable sections.**

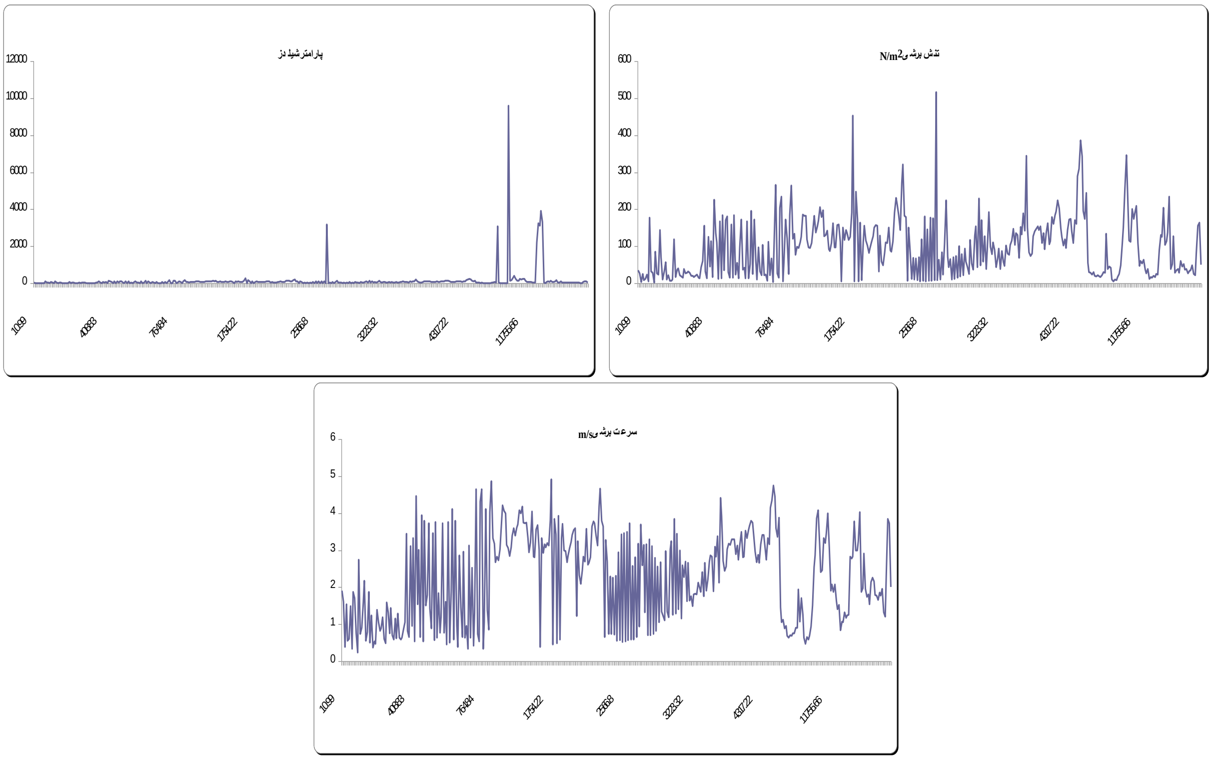

Figure 10. **Shear velocity, shear stress and Shields parameter values in stable sections.**

Table 9.
Flow properties in unstable sections.

No.	Shear velocity (m/s)	Shear stress (N/m²)	Froude number	Features of the sections in the final equilibrium state				Shields parameter
				Slope	Hydraulic radius	Depth of flow	Wetted perimeter	
Mean	1.95	71.31	0.34	0.00	2.12	4.53	17.12	5878.65
Minimum	0.16	0.68	0.04	-0.02	0.11	0.12	6.55	0.42
Maximum	6.21	815.41	1.68	0.19	4.90	8.91	29.55	117947.00
SD	0.98	76.90	0.16	0.01	1.07	2.21	8.88	11602.01

Table 10.
Features of flow in stable sections.

No.	Shear velocity (m/s)	Shear stress (N/m²)	Froude number	Features of the sections in the final equilibrium state				Shields parameter
				Slope	Hydraulic radius	Depth of flow	Wetted perimeter	
Mean	2.27	108.08	0.43	0.01	2.39	3.84	13.52	142.18
Minimum	0.24	1.81	0.10	-0.01	0.12	0.16	6.55	1.11
Maximum	4.92	5163.76	1.02	0.09	5.16	8.51	29.55	9595.66
SD	1.22	367.07	0.19	0.01	1.33	2.16	8.00	789.48

Table 11.
Error parameter values for changes in the roughness coefficient value.

Percentage of changes	+10		-10		+20		-20		+30		-30	
Parameter	RMSE	AME	RMSE	AME	RMSE	AME	RMSE	AME	RMSE	AME	RMSE	AME
W.S. Elev	0.44	0.48	0.44	0.48	0.59	0.64	0.59	0.64	0.79	0.88	0.79	0.88
E.G. Elev	0.43	0.47	0.43	0.47	0.57	0.63	0.57	0.63	0.67	0.82	0.67	0.82
E.G. Slope	0.01	0.06	0.01	0.06	0.01	0.06	0.01	0.06	0.07	0.1	0.07	0.1
Vel Chnl	0.56	0.57	0.56	0.57	0.66	0.63	0.66	0.63	0.87	0.84	0.87	0.84
Flow Area	40.7	4.98	40.7	4.98	53.6	5.7	53.6	5.7	57	7.8	57	7.8
Top Width	34.17	4.53	34.17	4.53	35.8	4.7	35.8	4.7	37.2	6.5	37.2	6.5
Froude	0.21	0.34	0.21	0.34	0.21	0.35	0.21	0.35	0.4	0.45	0.4	0.45

Suggested areas for geotextile application in Kashafrood

Along Kashafrood, based on the height of the terraces formed along the riverbank and studies of the erosion in the river, four erosion classes were identified. Areas of the river where the effects of lateral erosion of the river are more than 50% are recommended as suitable areas for geotextile application. The surveys of the lateral erosion status of the river under study demonstrate that river walls are unstable in many places and often have high potential for erosion so that some of the trenches in the riverside are being destroyed and advancing to agricultural lands or buildings.

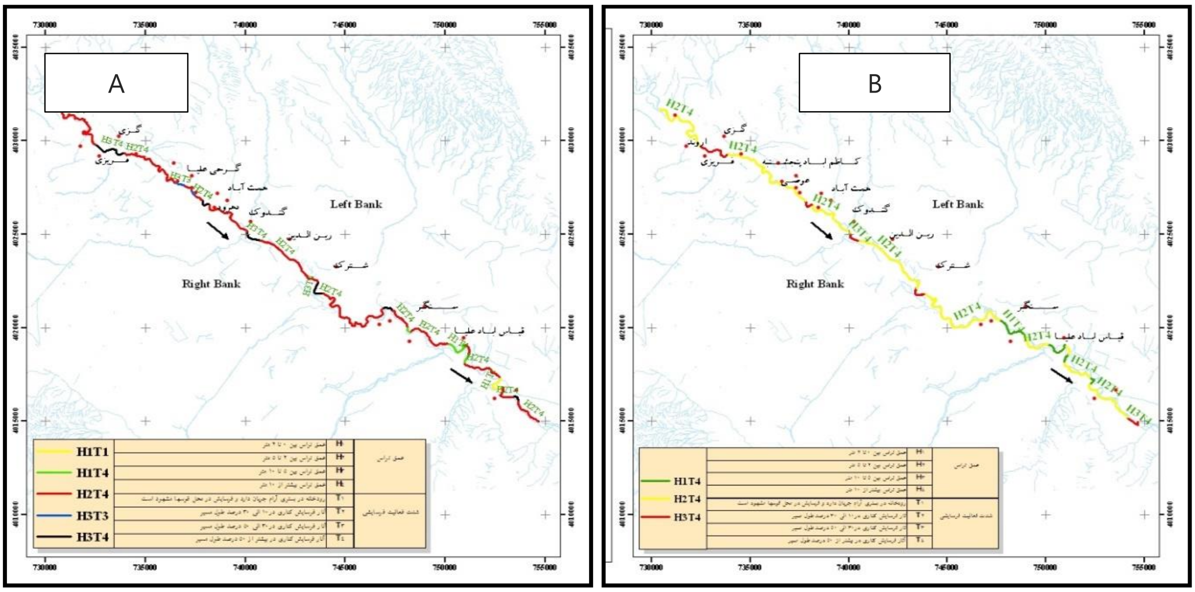

Figure 11. **Erosion status; A) left bank and B) right bank of Kashafrood.**

CONCLUSION

The results of calculations of river dimensions at the final equilibrium state and movement threshold conditions at all stable river sections revealed that in 71% of the cross sections, the situation is unstable and in the remaining 29%, the situation is stable. Also, due to land use changes that have taken place, most sections have an unstable situation. The highest values of shear stress and shear velocity in unstable sections are 815.41 N/m^2 and 6.21 m/s, respectively. On the contrary, the highest values of shear stress and shear velocity parameters in stable sections are 516.7 N/m^2 and 4.92 m/s, respectively. The minimum value of Shields parameter is 0.42 in unstable sections and 1.1 in stable sections. As shown in the results, the average value of the parameters presented in the stable sections is higher than the unstable sections. Such a result also applies to the minimum and standard deviation of the presented parameters. On the contrary, the maximum value of parameters and also Shields parameter in the unstable sections is higher than the stable ones. Results of sensitivity analysis and determination of the impact of land use change on river hydraulics indicated that as the roughness coefficient changes increase, the model outputs show more error than the initial conditions. It should be noted that the highest sensitivity to roughness coefficient changes is related to the parameters of flow area and upper surface width. It is worth noting that an increase or decrease in the value of roughness coefficient is effective in the output results and the related parameter value is not the same. But overall, the error parameters of RMSE and AME are equal.

As previously mentioned, human encroachments in Kashafrood bed and bound have occurred in various ways and their severity and weakness vary from place to place. Along Kashafrood, based on the height of the terraces formed along the riverbank and studies of the erosion in the river, four erosion classes were identified. Surveys of the lateral erosion status of the river under study suggest that river walls are unstable in many places and often have high potential for erosion so that some of the trenches along the river are being demolished and advancing to agricultural lands or buildings.

According to the results, the following are suggested for the organization of Kashafrood:

1- Modification of land use changes, including dredging and reopening of the river path, prohibition of agricultural and horticultural activities done or being done in the riverbed and doing such activities in the river bound in accordance with specific regulations.
2- Construction of several cross structures of staircase apron for aeration to unwanted fluids in the river.
3- Prevention of further land use changes, including the construction of coastal walls in areas where the villages' advance to the river is great and the risk of flood threatens these areas (such as Cement Road Bridge) and the use of geotextile to stabilize river walls and residential areas of the studied region and the sections adjacent to the river within a reasonable distance from the river while respecting the river bound.

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