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The Causes of Morphological and Sedimentary Changes of Jajrood River Upstream of Latyan Dam

As Causas Das Alterações Morfológicas e Sedimentárias do Rio Jajrood a Montante da Barragem Latiana

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Abstract

Studying the morphology of rivers leads to a better prediction of the rivers' behavior. Two categories of natural and human factors affect the behavior of rivers. Natural factors such as floods, soil erosion, landslides and human factors such as construction and installation of facilities, change of land use along the river and sand removal from the riverbed have an impact on the intensification of river morphological changes. In this research, it has been investigated the morphological changes of Jajrood river and its causes upstream of the dam with an approximate length of 140 km. For ease of work, the river is divided into four zones: A) mountainous and high area, B) split zone under the influence of Mosha -Fasham fault, C) transition zone between the riffle and the mountain, D) the river riffle and Latyan dam. In general, Jajrood river is morphologically steep (average slope of 4%), mountainous, braided and gravel. The torsion factor of the river is 1.06. Jajrood River is a straight river upstream, and braided and gravel downstream that particle size and sorting changes from upstream to downstream does not follow a specific trend. Tectonic activity in the Mosha Fasham fault causes the large particles to enter the river environment as the debris streams. Some erosion-sensitive geological formations, such as the shale units of the Shemshak Formation and the shale parts of the Karaj Formation in the Mosha-

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Fasham fault zone, under the influence of landslide processes, introduce a large sedimentary load into the river channel during heavy rainfall. In general, common forms of river canals in the region include canal bed sediments, inter Channel Islands, foothills and old alluvial terraces in the downstream areas (Lavasan). Examination of the longitudinal profile of the main part the river from the junction of Sarbandan and Shemshak tributaries downstream to the dam site showed that the middle part of this section of the river is affected by a sudden change of slope due to the Mosha Fasham fault. The changes in the bed level and the increase of the mentioned slope in the river route are due to the function of fault displacements in the region and the entry of large volumes of gravel flows from the river valley walls into the river channel flow path. In the riffle of Jajrood River, Lavasan Municipality has implemented dams to beautify and build a park for tourism that have upset the balance of the waterway. This raises the bed level upstream. Besides, river water quality has also been affected due to time delays in water flow.

Keywords: Multi-Tributary; Mosha-Fasham Fault; Straight River; River Profile; Sinuosity.

Resumo

O estudo da morfologia dos rios permite uma melhor previsão do comportamento dos rios. Duas categorias de fatores naturais e humanos afetam o comportamento dos rios. Fatores naturais como inundações, erosão do solo, deslizamentos de terra e fatores humanos como construção e instalação de instalações, alteração do uso do solo ao longo do rio e remoção de areia do leito do rio têm impacto na intensificação das mudanças morfológicas do rio. Nesta pesquisa, foram investigadas as mudanças morfológicas do rio Jajrood e suas causas a montante da barragem com extensão aproximada de 140 km. Para facilitar o trabalho, o rio está dividido em quatro zonas: A) zona montanhosa e alta, B) zona dividida sob a influência de Mosha -Falha de Fasham, C) zona de transição entre o riffle e a montanha, D) o riffle e Barragem da Letônia. Em geral, o rio Jajrood é morfologicamente íngreme (declive médio de 4%), montanhoso, trançado e de cascalho. O fator de torção do rio é 1,06. O Rio Jajrood é um rio direto a montante, e trançado e cascalho a jusante que o tamanho das partículas e as mudanças de classificação de montante para jusante não seguem uma tendência específica. A atividade tectônica na falha de Mosha Fasham faz com que as grandes partículas entrem no ambiente do rio como o fluxo de detritos. Algumas formações geológicas sensíveis à erosão, como as unidades de xisto da Formação Shemshak e as partes de xisto da Formação Karaj na zona de falha de Mosha-Fasham, sob a influência de processos de deslizamento de terra, introduzem uma grande carga sedimentar no canal do rio durante chuva. Em geral, as formas comuns de canais de rios na região incluem sedimentos do leito do canal, ilhas do canal inter, contrafortes e antigos terraços aluviais nas áreas a jusante (Lavasan). O exame do perfil longitudinal da parte principal do rio da junção dos afluentes Sarbandan e Shemshak a jusante até o local da barragem mostrou que a parte média desta seção do rio é afetada por uma mudança repentina de declive devido à falha de Mosha Fasham. As alterações no nível do leito e o aumento da referida declividade no percurso do rio devem-se à função de deslocamentos de falhas na região e à entrada de grandes volumes de fluxos de cascalho das paredes do vale do rio para o curso de escoamento do canal do rio. No riffle do rio Jajrood, o município de Lavasan implantou represas para embelezar e construir um parque turístico que alterou o equilíbrio do curso de água. Isso aumenta o nível do leito rio acima. Além disso, a qualidade da água do rio também foi afetada devido a atrasos no fluxo de água.

Palavras-chave: Multitributário; Falha Mosha-Fasham; Rio Retilíneo; Perfil de Drenagem; Sinuosidade.

Introduction

As Worcester (1984) put it, geomorphology is the science of the earth shapes and the interpretive definition of the low and high characteristics of the earth. The surface currents that are formed due to precipitation according to the amount of water and the duration of their activity are called rivers. Rivers communicate between sediment production areas in catchments and its sedimentary basins. To the geologists and geomorphologists, the structure and shape of rivers and adjacent areas are constantly changing due to erosion and sedimentation. This causes many problems in the rivers, and must be solved in a planned way.

The river canal may be straight, braided, anastomosed, and meandering. All channels carry small to large particles due to the difference in their shape.

According to McCain (1948), a balanced canal is a canal whose dimensions and slope are adjusted over a period of time to carry the incoming sediment load and water flow without significant erosion or sedimentation.

The natural tendency of land and river masses is to gradually erode to sea level, and because the flow rate is constantly changing, the river cannot reach its true equilibrium. In the meantime, natural or human interventions in some condition upset this balance.

When a large dam is constructed on a river, the sediment transport capacity upstream of the dam decreases and therefore raises the level in the main reservoir as well as in the upstream tributaries. This has many adverse effects including reduced reservoir capacity and overflow in upstream areas. In some cases, such as the Imperial Dam on the Colorado River and the Bhakra Dam on the Sutlej River in India, sediment deposition has been observed 70 to 80 km upstream.

The water released from the reservoir is also without sediment and therefore removes sediment from the bed and shore of the canal, and causes hydrodynamic scour along the canal route. Roheh (1971) describes a case in which the straightening of a canal has had the consequences for the entire watershed area. The straightening of the Willow River (Iowa, Crawford County) deepened and widened the canal. When urbanization is done, large-scale changes take place in the watershed.

The runoff and cloudburst flow increase due to the rupture of new lands, the loss of plants and the use of construction equipment. As a result, it accelerates erosion, and the sediment load of the canal often increases dramatically. Wellman and Schick (1967) recorded a sediment load up to 50,000 tons per square kilometer per year in one place, compared to 80 to 200 tons per square kilometer per year under normal conditions. developing the urban areas, the infiltration of water into the ground decreases and the groundwater level decreases.

Untreated waste, including sewage, can also enter canals and cause pollution; This in turn is deadly to aquatic life and detrimental to the use of water downstream for drinking and tourism. Urban planning causes the damage to the floodplain and narrowing of canals and as a result, the rise of floods level. Earthquakes and movements of the earth's crust, such as subsidence or uplift, also affect the river stability. Earthquakes with a magnitude greater than eight Richter can cause tens of thousands of landslides throughout the region. Rainfall after landslides can bring huge amounts of sediment into the canal and change its regime.

Gay (1951) has reported the damage from the August 15, 1950 earthquake in the Brahmaputra Valley, which was measured 8.6 on the Richter scale. He concluded that 75% of the hills in an area of 43,000 square kilometers were destroyed by landslides. The flood destroyed the dams in the area after the earthquake, a large amount of sediment and rock material was transported downstream, the bed rose a few meters, and it took several years for the excess sediment to be transported downstream. In the available sources, attention has been paid to the role of tectonics as an influential factor on river morphology. In the field of sedimentology, watershed management and landslides in the study basin, the study by Fattahi Ardakani (2000), National Geosciences Database, sedimentology studies of Latyan Dam Lake (Ministry of Energy, 1974-1982) and the comprehensive watershed management plan of Latyan Dam by the Office of Soil Protection and Watershed Management of the Forests and Rangelands Organization (1972).

Peyrovan et al. (2017) conducted a study in the watershed of Latyan Dam to determine the relationship between landslides and increase the sediment load of Jajrood River. In this study, it was investigated the observational statistics of water and sediment debris in Najjar kola, Rudak, Mosha, Tang-e Bagh, Kond Sofla, Kamar Khani-Kalugan, Narun, Aliabad-Lavarak and Fasham hydrometric stations since 1968. Sedimentation rate of six watershedsub-basins was calculated by two estimation and observation methods. Using the ETM + satellite imagery and Google Earth, the location of 146 landslides were identified and mapped. According to the data analysis of Rudak hydrometric station at the outlet of Jajrood basin, the average monthly sediment of Jajrood river in five months before the landslide from March 2003 to July 2004 was 630 tons; In the corresponding five months from March 2004 to July 2005 in the range time landslide and after that, the average monthly sediment of the river increased to 3066.8 tons.

In other words, the occurrence of landslides has increased the sediment load of the river by more than five times, while the average monthly volume of flow was 15 and 19 m^3/s, in this period. This means that the increase in sediment load was not due to the increase in flow rate and was affected by landslides. Taheri (2009) studied the sedimentology and morphology of a part of the Atrak River in the northeast of Bojnourd. Sedimentological analysis and the trend of changes in textural parameters in a section of the river with a length of 63.18 km showed that the river bed material in this period was mostly made of sand and the river had a fine-grained bed in this area (Kheiri Namin et al. 2015).

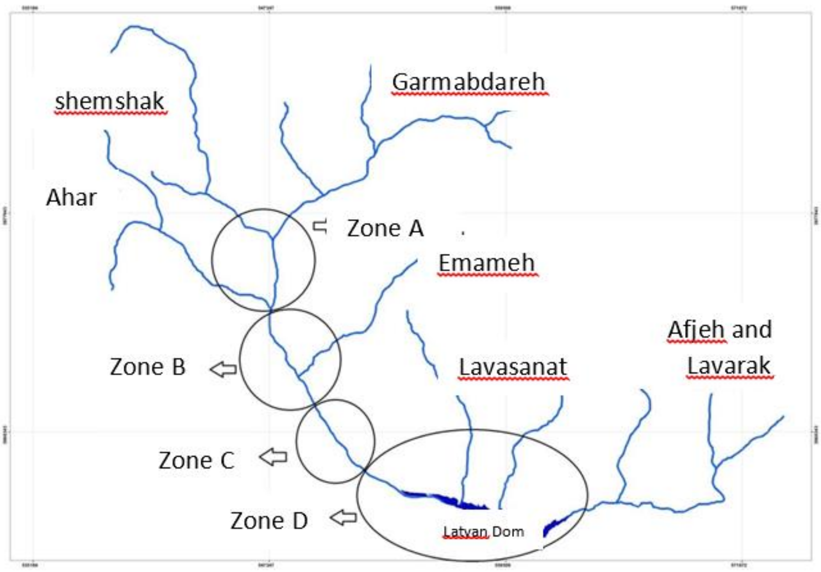
Another point is that the texture changes along this river was complex and did not show a specific trend; Different natural and abnormal factors could be effective in this phenomenon. The entry of sub-tributaryes and the change of the slope of the riverbed were realized as the most important factors. Quantifying the qualitative geomorphological method for estimating water erosion in the watershed of Latyan Dam has been performed by Ahmadi et al. (2007). In this study, 81 indices in the form of nine effective criteria in soil erosion and sediment production, including geomorphological facies, soil, land use, and vegetation were examined. From upstream to downstream, the changes of the physical and morphological conditions of the river are well observed, and these changes affect the sedimentary and erosive regime, because the watershed of Latyan Dam and Jajrood River are located in the Alborz fault zone, especially the Mosha -Fasham fault zone, and it has been subjected to severe changes in various uses and villas due to the favorable weather conditions. In this research, it has been investigated the causes of changes in sedimentary and morphological regime of the river.

Materials and Methods

In this research, Google Earth images and field visits have been used to collect the river information. According to Figure 1, Jajrood river is divided into four zones based on the network map of canals and field navigation and for ease of interpretation of laboratory results; A) the mountainous and highlands, B) the fragmented area affected by Masha-Fasham fault, C) the transition zone between the riffle and the mountains, D) and the end part of the river riffle and Latyan dam.

The canal network map was prepared digitally, the longitudinal profile of the river was drawn in GIS environment and the torsion or sinuosity coefficient of the river was also calculated.

Figure 1 - Zoning map of Jajrood river.

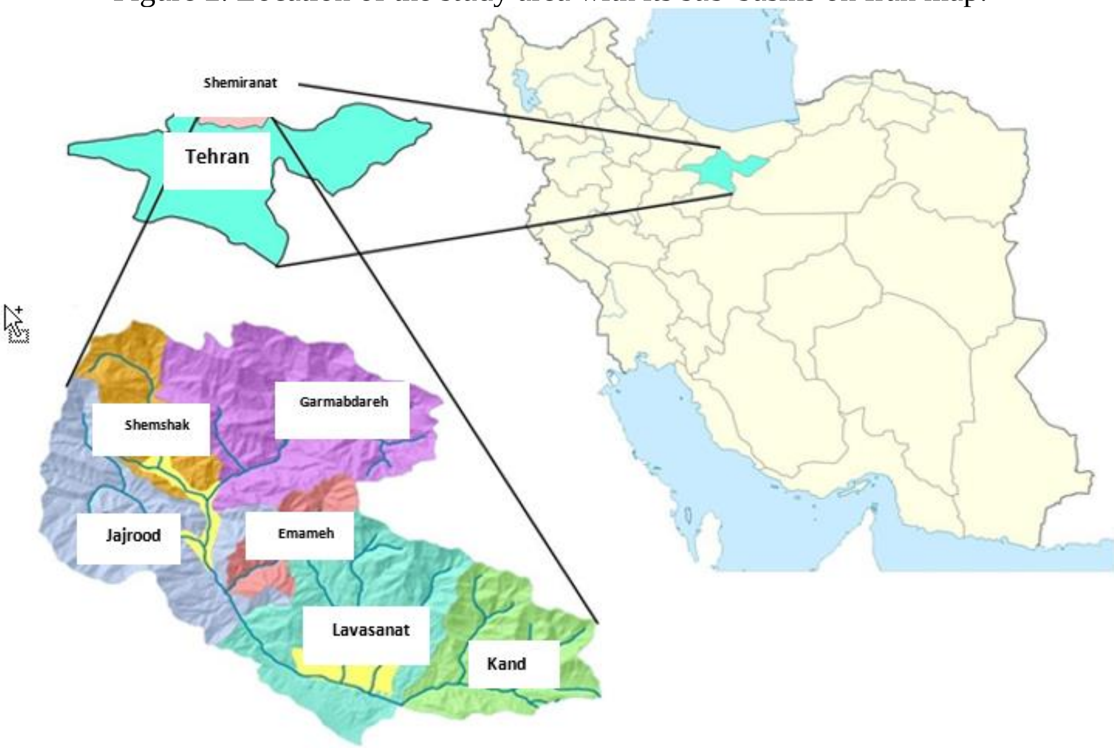


Source: Authors (2022).

Introduction to the Region and Climate

Latyan Dam basin with an area of 710 square kilometers in terms of national divisions is under the jurisdiction of Tehran province and is completely within the governorate of Shemiranat county, which shares borders with five cities of Noor, Amol, Damavand, Karaj and Tehran. It is located between longitudes 51 degrees and 25 minutes to 55 degrees and 51 minutes and latitudes of 35 degrees and 45 minutes to 36 degrees between the tropic of Cancer and the North Pole. This county has two parts of Rudbar-e Qasran and Lavasan. Figure 2 shows the location of the study area on Iran map with its sub-basins. The average altitude of this area from Latyan Basin is between 1500 to 3720 meters and has a wide range of mountainous roughness, which is formed according to tectonic and climatic conditions and abnormal encroachments.

Figure 2. Location of the study area with its sub-basins on Iran map.



Source: Authors (2022).

This basin collects the rivers that make up the Jajrood River and finally enters the Varamin Plain. To the north of the river, there are three main tributaries of Garmābdar, Shemshak and Ahar, which join in Fasham and Mosha. In the middle part of basin, the Ammameh River and small tributaries join it and then flow into the Latyan Dam Lake. In the eastern part of the basin, the Kand, Afjeh and Lavark rivers, with a number of small tributaries, enter directly into the dam lake.

In general, 80% of the lands are more than 2500 meters high and the average slope of the basin is 43%. Regarding the mountainous nature of the region and low spread along latitude, its climate is more affected by altitude factor and two important elements of rainfall and temperature. The average temperature of 25 years in Shemiranat County is 12.7° C (the average temperature of the earth is 22° C). The average annual rainfall during the last 25 years is 813 mm from Rahatabad station, the maximum rainfall per day during 1971-1991 in Rudbar-e Qasran is 89 mm, and the average number of icy days during the last 25 years is 155 days in Garmābdar.

Geology of the Basin

The study area located in Central Alborz has a mountainous and steep appearance under the influence of tectonic phases of Central Alborz. The height difference in Quchak Pass in a distance of three km from the top to the bottom of the valley is more than 100 meters and this difference in height is due to the thrust fault in the north of Tehran.

Barnt, Zagon, Lalon, Mila, Jiroud, Mubarak, Doroud, Ruteh and Nesen formations related to the Paleozoic period, Elika, Shemshak, Delichai, Lar and Tizkooh formations from the Mesozoic period, Fajn, Ziarat and Karaj formations from the Cenozoic are exposed at the basin level. Quaternary deposits and sediments include old and new alluvial terraces that protrude along the rivers and most of them are gardens and agricultural lands. In these sediments, all kinds of falls and landslides are observed, especially in the margins of canals. In terms of material, various sedimentary rocks of limestone, sandstone, marl, shale and igneous rocks are spread in the basin.

Findings

The morphology and geometric characteristics of the river were studied in four zones; The results of are as follows:

Zone A

In this part, the river is located in a high and mountainous area. The river is mountainous and carries large amounts of coarse-grained sediments from the highlands of its source (Figure 3). In the upstream areas and early parts of the watershed tributaries in the Kharsang area and in a very limited area, a straight river can be identified, which is very rare in nature. It should be noted that this classification is based on the classification of river channels (Rast, 1978; GhasemShirazi et al. 2014; Bazoobandi et al. 2016; Yazdi et al. 2019; Baratian et al. 2018), because their torsion is less than 1.5 and their parameters are less than one. After a short distance, the river has a torsion of more than 1.5 and a dam parameter of more than one (Table 1). Based on two parameters of dam and torsion, this river is of the braided type that is found in abundance in nature (Figure 4).

On both sides of the river, villas and landscaping have been done in this period and therefore the river has been artificially channeled.

Figure 6 shows the river channel at the site of Ashkarchal (near Fasham Square). Coarse-grained sediments have caused water to flow turbulently in this part of the river. Approximate estimates of the river debris in the summer of 2018 indicated a water velocity of 1.38 m/s and a water debris of 3.03 m3/s at the Ashkarchal site (Figures 5 and 6). This range continues from the river to the junction of the Ahar tributary. Coarse-grained sedimentary islands have been formed at the confluence of the Garmābdar-Fasham tributary with the Ahar tributary, and the predominant feature of the river is multi-tributary (Figure 7). Erosion along the river has also occurred due to the increase in river debris at the riffle of this range of the river (Figure 8).

Table 1 - Segmentation of river canals (adapted from right, 1978)

Torsion	**Single channel (Dam parameters less than one)**	**Composite channel (Dam parameters less than one)**
Low (less than 1.5)	straight	braided
High (more than 1.5)	meandering	Anastomosis

Figure 3 - Upstream of Jajrood river tributary in Garmābdar region.

Source: Authors (2022).

Figure 4 - Shemshak tributary (an example of a longitudinal dam)

Source: Authors (2022).

Figure 5 - Hydrometer scale in Bakhbagh (Fasham) área.

(The river is directly visible in a limited area)

(Water velocity was estimated 0.9 m/s and flow rate was 3.82 m^3/s in summer 2018)

Source: Authors (2022).

Figure 6 - The river at Ashkarchal site (near Fasham Square).

(Water velocity was estimated 1.38 m/s and flow rate was 3.03 m^3/s in the summer of 2018)
Source: Authors (2022).

Figure 7 - The junction of Ahar river which originates from Tochal mountains and Fasham tributary (Erosion is seen along a river).

Source: Authors (2022).

Figure 8. Erosion along the river at the site of Fasham refinery.

Source: Authors (2022).

Zone B

In section B, the river passes through the fragmented zone of the Mosha -Fasham fault. The morphology of the river in this part is influenced by tectonic movements. As a result, in the course of the river, many small and large stone blocks caused by landslides can be seen from the sides of the river valley. Apart from lateral landslides, slopes with abundant gravel flows can also be seen in this section, which during the heavy rains and even sudden melting of snow, the occurrence of gravel flows is very likely, and suddenly, a large volume of mountain debris enters the main course of the river and has an increasing effect on the criticality of the area by blocking the water flow during floods (Figures 9 and 10).

Figure 9 - Shredded area of Mosha Fasham fault in Hajjiabad.

(In this place, large rock falls are observed from the sides into the river channel).
Source: Authors (2022).

Figure 10. Hajjiabad shredded zone.

Source: Authors (2022).

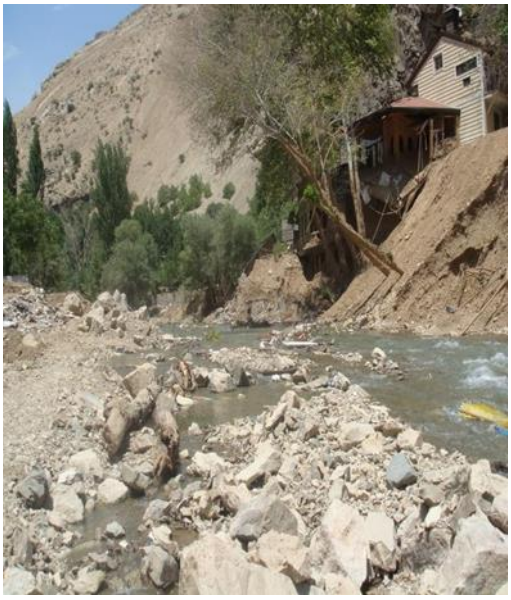
A large number of boulders can be seen along the river. In this section, a large volume of debris enters the river channel.

Zone C

This zone is the area between the riffle of the river and the mountains. In this part, the river comes out of the mountain valley and as it approaches Lavasan and Latyan dam, the width of the river increases. In this part of the river, the slopes overlooking the river are prone to slipping.

For example, during a field trip (2018) in the Rudak region on the slopes of Karaj Formation, landslides occurred after heavy rains, a large volume of solids entered the canal, and a terrible flood occurred and the river flow path deviated into the street.

Figure 11 - Effects of river bank and villa demolition and accumulation of a large volume of bed load after the flood subsided in Rudak area in June 2018.



Source: Authors (2022).

Figure 12 - Effects of tree trunks and destruction of river banks due to floods in 2018 and unfortunately dumping garbage into the river channel.

Source: Authors (2022).

Zone D

The river reaches Latyan dam lake in zone D. At the same time, the canals under Lavark and Afjeh basins enter directly into Latyan dam lake. The Kund tributary also joins the Jajrood River in this part. The river is wide in the form of a multi-tributary river upstream of the entrance to Latyan dam. Coarse-grained yields of upstream, especially in the Mosha -Fasham fault zone, and the sudden deposition of sediments due to the failure of the riverbed slope, have led to the formation of this morphological type (Figure 14).

The river continues its way to the dam through the conglomerate slopes of Hezār Darreh and at least one terrace is formed along the river (Figure 13). Lavasan Municipality has constructed dams along the river to prevent sediments from entering the dam reservoir and to create a space for tourism (Figure 15).

While affecting the hydraulic and sedimentary parameters of the river, especially upstream, it has caused the pollution by stopping the water. At the end of this part of the river, large Cebu, Kund and Lavark tributaries are attached to the river inlet water to the dam (Figures 17 and 18). All of these tributaries have the characteristic of a river with a bed load in the form of several tributaries.

Figure 13 - Alluvial terrace with characteristics of sandy gravel sediments in Lavasan.

(The upstream altitudes belong to the conglomerate formation of Hezār Darreh).
Source: Authors (2022).

Figure 14 - River at Lavasan metal bridge.

(The width of the river increases and longitudinal and transverse dams are observed).
Source: Authors (2022).

Figure 15 - Lavasan Municipality has constructed dams along the river to prevent sediments from entering the dam reservoir and has created a space for tourism.

Source: Authors (2022).

Figure 16 - Jajrood river at the entrance to Latyan dam.

Source: Authors (2022).

Figure 17 - Left, the seasonal river at the site of the Great Cebu, which had no water flow at the time of the visit.

(The figure on the right is a slow tributary entering straight into the Latyan Dam Lake).
Source: Authors (2022).

Figure 18 - Entry of Lavarak tributary from the east of the basin to Latyan dam lake.

Source: Authors (2022).

The left side of the tributary in the site of Lavark with a bed of sand gravel and boulder parts. The major sediments carried by this tributary are of the bed load type. On the left bank of the river, a sandy river terrace is observed. In the figure on the right, the entrance of the Lavark tributary to the Delta dam lake is formed.

Discussion and Conclusion

In GIS environment, the geometric parameters of Jajrood River and its tributaries were measured; the results are presented in Table 2. Regarding the river upstream of Latian dam flows mainly in the mountain range, therefore the slope of the main river and its tributaries is high and is classified as a steep river.

The erosion bed of the river follows the path provided by the lithological and tectonic structure of the river. Therefore, the main route of the river from Shemshak village to the dam site with a length of about 37 km, has a sinuosity coefficient of 1.06, which indicates that the river is of the straight type. Of course, it should be noted that the river flows on a wide bed after the Lavasan Kouchak bridge, leaving the mountain range with a sudden decrease in slope, and has loaded coarse-grained sediments and morphologically, manifests braided (Figure 20).

Table 2 - Geometric characteristics of Jajrood river and its tributaries.

The main river	Tributary name	Length (kilometer)	The highest height (meters)	Minimum height (meters)	Height difference at the beginning and end of the river (meters)	River slope (percentage)	River torsion factor
-	Shemshak	17.58	3314	1948	1366	7.77	-
-	Āhar	14.97	2646	1585	1061	7.09	-
-	Garmābdar	19.84	2838	1948	890	4.49	-
Shemshak-Jajrood	-	36.66	3314	1605	1709	4.66	1.06

Changes in particle size and sorting of river sediments from upstream to downstream do not show a particular trend. Tectonic activity in the area of Mosha Fasham fault causes large particles to enter the river in the form of debris streams. The results of geomorphological indices indicate that the study basin is structurally active, but the activity of new tectonic movements is not the same everywhere and the upstream areas of the basin are more active in this regard (Sadeghipour et al. 2015; Yazdi et al. 2017; Yazdi and sharifi teshnizi 2021). The presence of long alluvial terraces in the area of the Felezi Bridge (Figure 19) and at the edge of the main river channel indicates the tectonic uplift of the riverbed and intensification of canal bed excavation.

Some erosion-sensitive geological formations, such as the shale units of Shemshak formation and the shale parts of the Karaj formation, introduce a large sedimentary load into the river channel during heavy rainfall due to the special geology of the region affected by the landslide processes. Hezar Dareh formation has water erosion effects in the region. Meanwhile, many landslides have occurred in this formation due to drift in the north of Tehran. In general, common forms of river canals in the region include channel bed sediments, inter-Channel Islands, foothills debris and old alluvial terraces in the downstream areas (Lavasan).

Figure 19. Old alluvial terraces in Lavasan area (Felezi Bridge).

Source: Authors (2022).

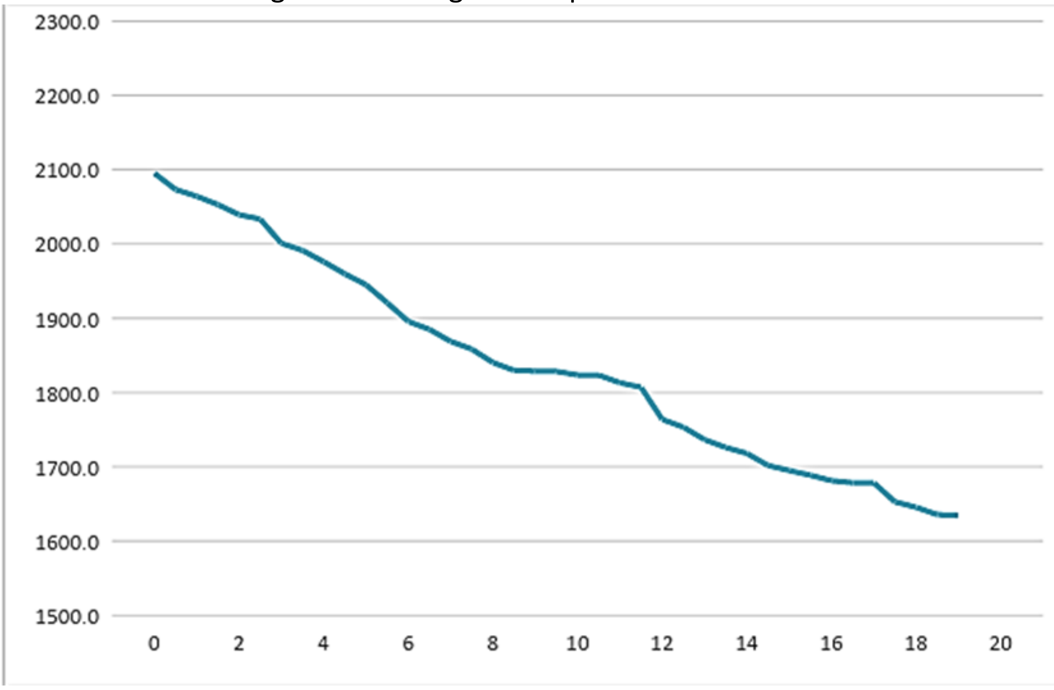
The river terrace is the rest of the old bed bottom that remains on both sides of the river after the river dug a newer bed. The rest of the alluvial terrace is the result of uplift of the region due to the north fault of Tehran. The height of the terrace is about 20 meters.

Figure 20 - Jajrood river at the exit of the mountain and entering Sardasht plain.

Source: Authors (2022).

After leaving the mountain, the river flows on a wide bed with a sedimentary load on the floor and takes on a multi-torsional state. Lavasan county and successive dams along the river can be observed in the picture.

Figure - 21. Longitudinal profile of the river.



Horizontal axis: river length (kilometers); Vertical axis: height (meters)
Source: Authors (2022).

The longitudinal profile of the river is illustrated in Figure 21. This profile is related to the main part of the river from the junction of Sarbandan and Shemshak tributaries downstream to the dam site. Since the middle part of this range of the river is affected by the Mosha Fasham fault zone, thus the bed level changes along with increasing slope in the river is due to the fault displacement of the region and the entry of large volumes of debris flow from the valley walls of river flows into the channel. The changes in the bed surface are also caused by land use change, destructive floods and tectonic activity.

The general view of Jajrood River from the connection point of Latyan dam to the main tributary of the river is illustrated in Figure 22.

The morphological and sedimentary characteristics of the river can be summarized as follows:

1- Lavark tributary at the Latyan dam has a sand gravel bed with boulder fragments.

2- Jajrood river at the dam site is multi-tributary due to the reduction of slope and has a torsional feature. At the entrance to the Latyan dam lake, the whole area of the flood plain goes under water during the flooding of the river. The mud sediments deposited on the banks of the river are evidence of this.

3- At least one river terrace with the characteristics of sandy gravel sediments is observed at the connection of the river to the dam.

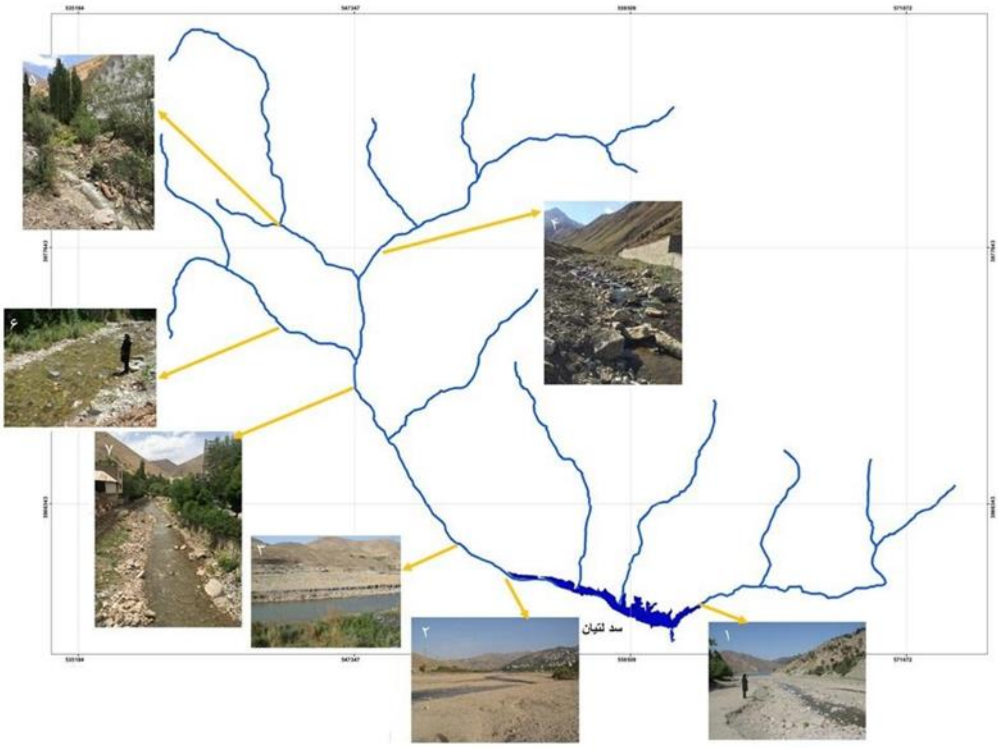
4- In Garmabdar tributary, sand gravel bed with many boulder fragments is the dominant feature of the river. The high slope of the river and coarse-grained fragments in the riverbed during floods cause the transfer of large volumes of coarse-grained sediments.

5- In Shemshak tributary, sandy gravel bed with many boulder fragments can be observed along the canal.

6- The bed load is the predominant feature of river in Ahar tributary.

7- The longitudinal dam in the river path in the middle of the river is well formed.

Figure 22 - General view of Jajrood river from the connection point of Latyan dam to the main tributary of the river.



Source: Authors (2022).

It is concluded that the total geological and structural geology factors and anthropogenic factors have affected the morphological and sedimentary characteristics of the river. Land use changes, the occurrence of annual landslides and fine-grained flows have a significant role in changing the morphology of the river, especially during floods.

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