Geographic information system technologies in the study of deformation in rivers

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Abstract. The article examines the possibilities of assessing the changes and condition of the riverbed using remote sensing (RS) and geoinformation systems (GIS) technologies. Deformation processes observed in the last 25 years in the Sox stream bed selected as a research object were evaluated on the basis of modern geoinformation systems. The processes taking place in River were studied on the basis of satellite data. Landsat satellite generations were selected for analysis. To download the data, the official site of GloVis, which is widely used today, was used. The data was analyzed using the ArcMap software. The results of GIS analysis were compared with field experiments. In the last 20 years, the direction of the flow along the right bank has changed, the left bank sections are covered with silt particles, grass growth and washing processes are observed on the left bank. Over the past 5 years, 30 m of cultivated land has been washed away along the right bank between PK 3 and PK 4. These changes average 4-5 m per year. The deformation processes observed in the river are analyzed and conclusions are drawn.

1 Introduction

Channel processes reflect a number of processes associated with the interaction of a stream and a river between them. They are associated with the formation of channels and banks, the removal of soil particles by the current, washing, and the accumulation of silt particles, i.e., the pressure of silt. It is a product of seasonal, long-term and centuries-old impact of river runoff. Processes in the riverbed lead to the formation of the riverbed and topography of the river, its morphological parameters. [1-2].

The processes occurring between the stream and the soil forming the channel reflect the hydromechanical properties of the processes in the channel. The hydrodynamic characteristics of the flow interact with the channel, influence the morphology of the channel, create bends, branches and various changes in the channel and banks. The channel formed by the flow affects the flow under its own power, and various hydraulic changes occur in the flow. Processes in the river basin are associated with the interaction of runoff and river soil. These processes include seasonal, multi-year and multi-century erosion, accumulation,

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washing of the river bank and bottom, phenomena related to the topography of the river bottom [3-4].

Natural river flows are determined by the water regime depending on the climatic characteristics and different water consumptions. The flow of turbidity into the river depends on its geological structure, topography and soil type[5]. Flow rates and water levels are also affected to some extent by runoff, riparian and riverine vegetation, and wind. These phenomena show that the flow process is a hydromechanical phenomenon that obeys the laws of nature. In the river, the flow and movement of the cross-sectional surface is associated with increased erosion. This causes a lot of discharge to the river bed. As a result, the activity of the river section decreases [6,7].

The law of stream control is reflected in the flow's carrying capacity [8]. If the transport volume of the stream is greater than the actual solid waste consumption (S_0>S), the flow of waste in the rivers increases, this condition is visible from the balance of waste in the riverbed [9]:

$$S_{i+1} = S_i + \nabla S \tag{1}$$

where: S_{i+1}, S_i. – volume of blurs in i and (i+1) frames;

ΔS - the difference of turbidity amounts;

\+ - flow of material between beams.

\- is a decrease in the amount of material transported due to sedimentation at the bottom of the stream.

The channel's topology changes as a result of siltation, channel development, or bank washing activity when the flow of runoff between the stream and the channel rises [10]. In terms of meters per year, the rates of bends and washing of banks in the horizontal bed are many times higher than those in the vertical bed. The river bed is permanently altered by river bed deformations, and the valley floor is widened as a result. A hefty washing product is brought to me in this instance [11].

As mentioned above, the formation of the riverbed is influenced by many factors. Taking these factors into account, theoretical correlations alone are not sufficient to calculate bone morphometric parameters. Therefore, the morphometric ratios proposed by various scientists are based on data and observations collected over many years in natural field and laboratory conditions. The essence of this lies in the fact that the riverbed is formed as a result of long-term interaction between the flow and the channel, and the morphometric parameters of the formed channel are expressed by certain ratios [12,13].

In the course of the interaction between the stream and the riverbed, certain relationships are established between the morphometric and hydraulic properties between them, which are called hydromorphometric connections. Certain forms of the body are formed by the passage of these factors of the body processes, body-forming fluids, body-forming expenses. Hydromorphometric correlations are sometimes used as indicators of strength [14,15].

River shapes the flow and in turn has a constant effect on its velocity field. In this case, the turbulent flow cannot maintain a rectangular cross-section, if it is artificially given, it will change as a result of the exchange of liquid and water mass. The wetted perimeter takes the form of a smooth curve. Compared to the coastal area, the riverbed area has a greater depth. It is hydraulically convenient to have a semicircular view of the wetted perimeter in the form of a cross-section. Due to channel bends and other causes of transverse circulation in the current, the area of greatest depth tends to move from one bank to the other. Cross section of trunk is determined by the conditions of the trunk formation [16,17].

Work on determining morphometric connections in the riverbed is based on the following expression proposed by M.V.Velikanov on the theory of units of measurement:

$$\frac{\mathrm{B}}{\mathrm{H}} = f\left(\frac{Q}{d^2\sqrt{gdI}}\right) \tag{2}$$

Later, developments based on this connection were developed by a number of scientists. In particular V.S. Altunin recommends expressing morphometric connections for sandy beds (0.15-0.25 mm) as follows:

$$\frac{\mathrm{B}}{\mathrm{H}} = \left(\frac{Q}{d^2\sqrt{gd}}\right)^{1/8} \tag{3}$$

However, the given expression does not take into account the influence of currents and their movement on morphometric parameters [18].

Today, siltation and leaching are observed at the bottom of rivers, irrigation canals, hydrotechnical structures, and these processes have a sharp impact on the effective use of water resources. Continuous monitoring of these changes, prediction of the future based on data collected over several years, identification and prevention of areas with a risk of flooding or flooding, improvement of water transfer methods, determination of new measures remains an urgent problem [19-22]. In this regard, special focus is placed on scientific study aiming to enhance quick, precise, and trustworthy techniques of hydraulic computations, taking into consideration the variables seen at the river's bottom. There are currently several challenges with hydraulic and hydrological studies used to evaluate river bottom dynamics. These demand a significant investment of time, money, and labor. In the study of these issues, the demand for analyzing the conditions observed in the riverbed and ensuring their reliable operation with the help of geoinformation technologies is growing. At the time of rapid development of innovative technologies, rapid assessment of morphometric changes in the river bed, continuous monitoring, prevention of washing and silting processes, and forecasting for the future are the main issues. As a solution to the problem of quick and accurate assessment of river morphometric connections, it is possible to show the geographical information system (GIS), widely used in the field of application [23-28].

The geographic information system allows you to get information and learn about any object. With the help of GIS, it is now possible to determine and analyze many other parameters related to the Earth's features, climate, boundaries, population, resources and places of human interest. In the past, people had to use paper maps, globes, and various paper data sources to perform these analyses. GIS now includes computerized maps, globes, data, and analysis tools that allow us to perform complex analyses, transfer map results, and digitally store and share data.

2 Materials and methods

Among the sub-mountain rivers in Central Asia, the Sokh stream, located in the Syrdarya water basin, was accepted as a research object. In natural field studies, 9 species of trees were selected along the Sox stream bed. Taking into account the change in water consumption, quantity of suspended and bottom water in the stream was measured from each reservoir selected every 10 days. In the geodetic measurement works, the cross-sectional surfaces of the shafts were measured using the N3 brand level and Garmin GPS devices. In order to study the movement of river-forming discharges, their quantity and fractional composition were measured separately during low water and during high water using a bar bathometer and Shamov bathometer devices. Measurement works were carried out in parallel on the hydraulic elements and morphometric parameters of the flow. A hydropost was specially equipped to determine water consumption and take measurements in the Sox stream.

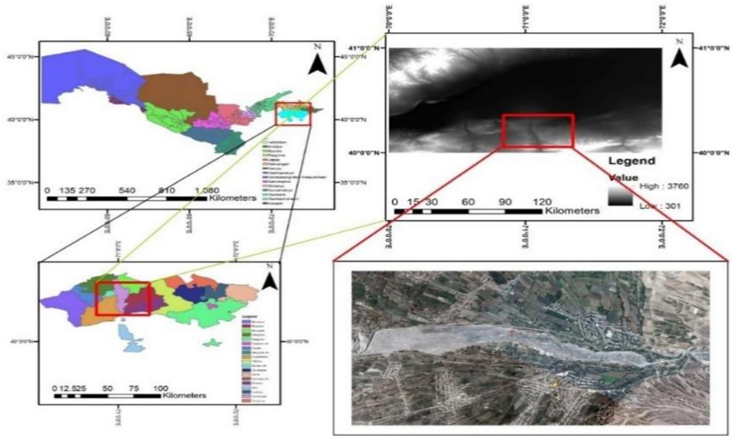

Fig. 1. Sox stream bed

In natural field studies in the river bed of the Sox river, flow hydraulic elements and dynamics of changes, accumulation and erosion processes in the river bed were analyzed. In the results of geodetic measurements, cross-sectional surfaces of flow movement in characteristic walls were determined.

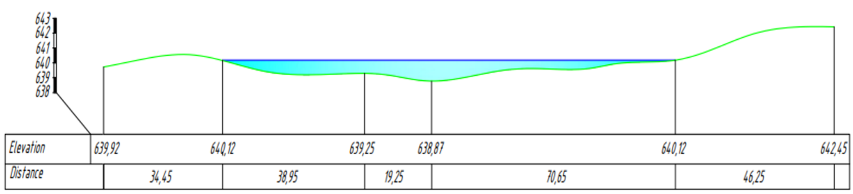

Fig. 2. Cross-section of the Sox stream bed, 2018

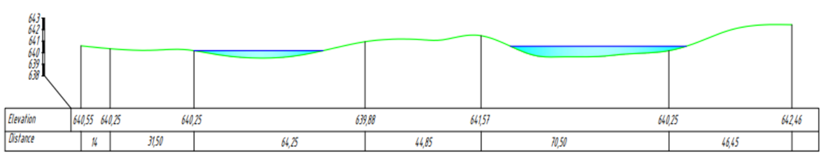

Fig. 3. Cross-section of the Sox stream bed 2019

From the analysis of the research carried out can be seen in natural field conditions that washing and silting processes occur in the considered part of the riverbed. A characteristic feature of the bottom of the mountain river is that erosion and accumulation occur abruptly. The current load becomes saturated with turbidity during the washing process, the movement of the current with such a load slows down in the next stream, and the current expands and forms a new core. This process can be repeated continuously throughout the year. The effluents in the stream did not significantly differ from the carrying capacity of the stream (10.09.2018). It is observed that the process of washing occurs in the bed at a certain current consumption and depending on the initial turbidity.

Table 1. Hydraulic elements of flow through walls

Wall number	**Q, m^3/s**	**B, m**	**ϑ, m/s**	**h_{mid}, m**	**i**	**d, m**

12	110	72	1,74	0,9	0,01	0,0055
32	108	90	1,54	0,68	0,011	0,0055
42	110	100	1,24	0,58	0,01	0,0055

A conclusion can be drawn from the analysis of the data obtained from the wells determined in the natural field studies in the Sokh river bed that there are different hydraulic parameters at the same flow in the river bed. These conditions indicate that active erosion and accumulation processes have been taking place in the Sox stream bed for years.

Development of the database of the research object carried out on the basis of the majority years of data analysis. During the last 25 years, the dynamics of changes in the Sox river bed were studied. To do this, satellite data for the years 1995-2020 were downloaded from the GloVis official site. It used Landsat 5 for the period 1995-2000, Landsat 7 for the period 2000-2013, and Sentinel 2 for the period 2013-2020. The uploaded data has been entered into the ArcGIS software. To study the processes underlying the Sox flow, 9 unchanging sites along the length of the stream were selected. Changes in width and surface area of each tree were observed over the years. In Sox river, the last 25 years of data have shown that the river has changed its shape on a per-storage basis.

3 Results

Based on the chart above, it can be seen that the change in the area of the water surface depends on the flow of water. It can be observed that the water consumption is in the range of 0-52 m^3/s, and the water surface area increases in a straight line with the increase of water consumption. But after the average water consumption exceeds 60 m^3/s, it can be seen that the straight line changes to a curved line and the above law is violated. This shows that when the average water consumption of the Sox stream exceeds 60 m^3/s, washing, i.e., deformation of the riverbed, is taking place at the bottom of the riverbed.

A graph of measured daily average water consumption and water surface area data determined in ArcGIS software was developed (Figure 4).

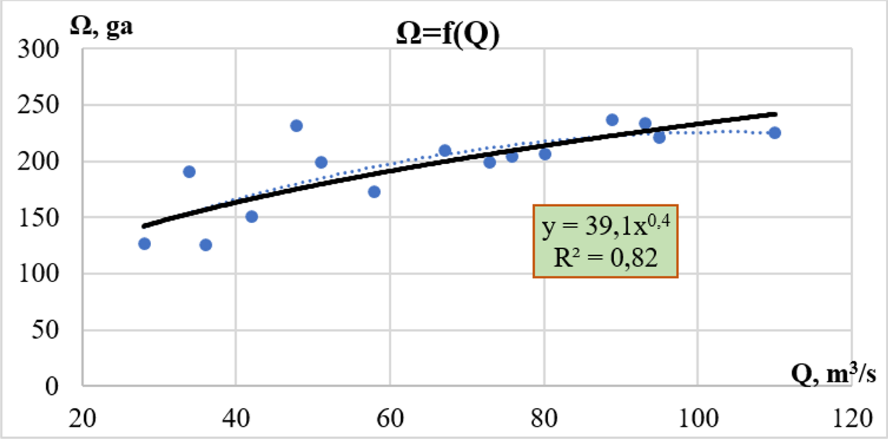

Fig. 4. Graph of dependence of water surface area Ω=f(Q) on water consumption

The graph of the water level breadth for each picket, Q=f(B), is dependent on the water discharge. This demonstrates how the water level rises in direct proportion to the amount of water used up to a certain point. On the other side, we can see the process of the groundwater

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level being lowered as water use rises. By examining the correlation between water use and water level width, it will be possible to assess the processes of erosion and accumulation in the valleys.

It can be seen from the graph that the dependence of the width of the water mirror on the water flow is non-linear. According to the connection developed above, it will be possible to determine the process of erosion and accumulation in river beds. To calculate this situation, we need to find the water level using GIS technology. After that, we will be able to determine the direct process of deformation depending on the flow of water.

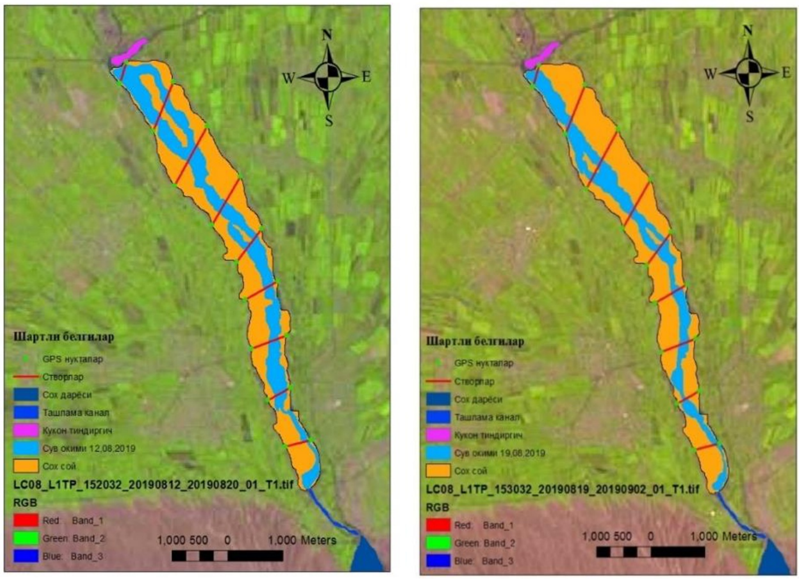

Fig. 5. View of the Formation

The evolution of the core's properties over time is one of the key determinants for assessing the processes in the core. In early July, the main current moved from the right bank of the stream, and after a while the current changed its movement towards the left bank. Due to this, the suspended and bottom sediments in the stream are accumulating in the stream over time. These discharges are changing the morphometry of the stream. These changes can be observed along the length of the stream. During the last 5 years, it was observed that 35 m was washed to the right bank in the interval of 3-4 meters. These changes are on average 5-6 meters per year. This leads to the destruction of gardens and plantations located on the right bank.

4 Conclusions

Using GIS technologies, a map of the research subject was produced in the studies. A graph showing the relationship between the width of the water level and the water flow for each picket was built using the map as a foundation. Depending on the shift in river level, it was feasible to calculate the morphometric characteristics of the riverbed. It is advised to use a novel method to evaluate the erosion-accumulation processes that occur in river channels as a result of water level rise brought on by an increase in open channel water consumption up to a particular point. New constant coefficients for the morphometric connections of the river bed in the study were proposed based on the examination of the results.

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