Shoreline deformation of the Konda river: trends and threats

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Abstract. The study of the hydrological hazards in the north of Western Siberia is important because settlements in this territory are generally located on the banks of rivers and are therefore subject to the negative effects of water. The purpose of this study is to identify the dynamics of hydrological hazards in the settlements of the Konda river basin. The objectives of the study are aimed at identifying hazardous areas, which is necessary to make informed decisions related to rational bank reinforcement. The research object was the settlements of the Khanty-Mansi Autonomous district–Yugra (Kama village, Altay village, Vykatnoy settlement) within the latitudinal flow of the Konda river between 59 and 61 N and between 66 and 70 E, where the manifestation of hydrological hazards is active in nature. Research methods are based on field surveys using satellite geodetic surveying, remote probing, and bed mapping analysis. The data obtained during the study show that the most significant bank line deformations occur within the Vykatnoy, Kama, and Altay areas. The results showed the need for engineering solutions to bank reinforcement and protection of these settlements from the negative impact of river.

1 Introduction

In the current concepts of the riverbed process as a form of stream and bed interaction, significant emphasis is made on planned riverbed deformation, which allows identifying trends and direction of riverbed deformation, predict bank line erosion rates, which, in turn, enables decisions on location of various facilities near rivers and protection of settlements from negative water impacts.

Analysis of spatio-temporal structure of hydrological hazards is based on a dynamic representation of the riverbed as a geographic system and visualized in a geographic information system, which provides qualitative and quantitative values. Hydrological hazard mapping is a necessary step in basic scientific research on terrain formation processes and an effective tool for finding solutions to natural resources problems. Digital cartographic model of hydrological hazards with developed attributive block, stipulates the possibility of using territory for various household purposes and includes the characteristics of possible flooding zones, riverbed and erosion processes. Theoretical and methodological basis of this study is papers of authors such as R. S. Chalov, A. S. Zavadsky, and A. V. Panin [1-3], and at the regional level – S. E. Korkin, V. A. Isypov and V. A. Zemtsov [4-6].

Konda River flows through West Siberian Plain, belongs to Ob-Irtysh basin and is one of the main rivers of the Khanty-Mansi autonomous district–Yugra. Because the river basin area is located within the Konda lowlands with low hypsometric elevations, it is characterized by frequent high levels of spring floods, leading to flooding of floodplain. Furthermore, hydrological hazards for this area includes location of main settlements in bank line zones. Thus, the territories of settlements are affected by erosion activity of the river, which leads to periodic flooding of inhabited areas, reducing their area, destruction of residential structures, flooding of infrastructure and industrial facilities. Despite its importance as the main waterway in the southwestern part of KMAO–Yugra, Konda basin has not been practically studied before in terms of riverbed processes, thus allowing to determine goals and objectives of this study.

Study area.

The object of the study were settlements within the lower and middle reaches of the Konda River between 59 and 61 ° N and between 66 and 70 ° E, where the manifestation of hydrological hazards is active. The terrain of this territory is flat with prevailing heights from 40 to 60 m.

In order to analyze the scale, peculiarities of the manifestation and intensity of the development of hydrological hazards and to assess hydrological risks, the settlements with flood zones caused by various hydrological and hydrodynamic phenomena and processes were selected. The key areas along the bank line of the settlements were selected: Kama village, Altay village, Vykatnoy settlement, Bolchary settlement, Kondinskoye settlement, Yumas village, Yamki village (figure 1).

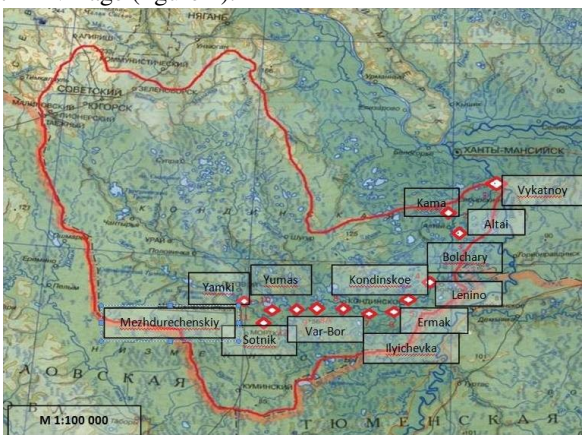

Figure 1. Map of the Konda River basin with survey points.

2 Materials and methods

The basis for identifying hydrological hazards within the lower and middle reaches of the Konda River was the materials of our own expedition research, in the course of which during the summer seasons of 2018-2019 field studies were conducted to study the deformation of the Konda River bank line. A field survey of the settlements was performed in order to identify and photo-fixate the changes in the bank line at the monitoring areas.

In order to monitor the bank line deformation the reference points on the site have been established, on which the reference points were fixed with precise coordinate referencing using remote research methods with the GPS navigator GARMIN. Bank deformations were measured and bank line changes at the monitoring locations were photo-fixated. The coordinates and height of characteristic points of the bank line in the area of erosion activity

were determined during the study. Horizontal bed deformations were monitored through annual measurements of bank line retreat rates at locations anchored on the site using satellite positioning systems [7].

During the camera period, a generalized bed analysis was performed, which allowed us to characterize general bed deformations and bank line deformations. Cartometric method was used for retrospective analysis of the Konda river bed location changes, which consisted in determining the location and area of water bodies using 1:50000-1:25000 scale cartographic material. For this purpose, the multi-temporal maps were superimposed on the up-to-date satellite images in Google Earth or SAS.Planet.Release.160606 [8-9].
To estimate the rates of multi-year average annual values of bed displacements, the traditional method of combining the positions of bank berms for different years was applied. BING and Kosmosnimki.ru satellite images were used to measure the length of the bank erosion front and the average erosion rate, and pilot maps from 1927, 1988, and topographic maps from 2000-2001 were compared with space images from 2018-2021. The navigational (pilot) map of the Konda River (from 760 km to the mouth) issued in 1988 was used as source cartographic material [10]. As a result, the bank erosion fronts for the selected key sites were established, for each of them, the average annual coastal displacement rates were calculated as the quotient of the bank line retreat divided by the time interval.

3 Results

The Kama village is located within the lower reach of the river Konda at a distance of 35 km from the mouth (80 km from Khanty-Mansiysk on river). It is located on the right root bank of the Konda. The bank is flat, its height varies from 1 to 2.5 m, the length of the eroded shoreline is 1000 m. In order to monitor the bank line deformation a reference point was fixed on the site with coordinates: latitude - 60 20' 00.9" N, longitude - 68 57' 52.7" E. Absolute mark - 29 m (BS). According to the results of field studies, there is a tendency of destruction of the native bank line - the negative impact is manifested in the erosion of the bank line and flooding of the territory of the settlement. The area of the flooding site of the settlement's territory is 0,29 km^2. The length of the bank line erosion section is 1596 m. (2000), 2455 m. (2011).

The data obtained during the study show that the Kamsky section (60-65 km from the mouth) consists of 3 bends, the degree of development l/L which has changed from the late 1980s to the present as follows: 1.82 → 2.07, 1.48 → 1.72, 1.56→1.78. For the first bend during this period there was a transition from the segmental steep stage to the loop stage due to essential (1,82-2,07) increase in the degree of bend development, increase in the deflection arm and radius of curvature. For the second and third bends, the trend of progressive changes in the deflection and radius of curvature was also identified. The development of the bends is due to the erosion of the Kamsky, First and Second Upper Kamsky pits, which results in the retreat of the eroded bank.

Progressive destruction of the bank line is also confirmed by the results of cartographic studies when different-age maps of the key site were overlaid - topographic map of 2000 (used for interpretation, the source Topomap (marshruty.ru) and 'Bing Satellite' satellite images. The size of the bedrock bank retreat over 20 years was 45-48 meters, the rate of erosion was 2.25-2.40 m/year.

Based on the trend and rate of destruction of the bank line, we can predict the danger of destruction of the nearest household structures within 15-20 years (figure 2).

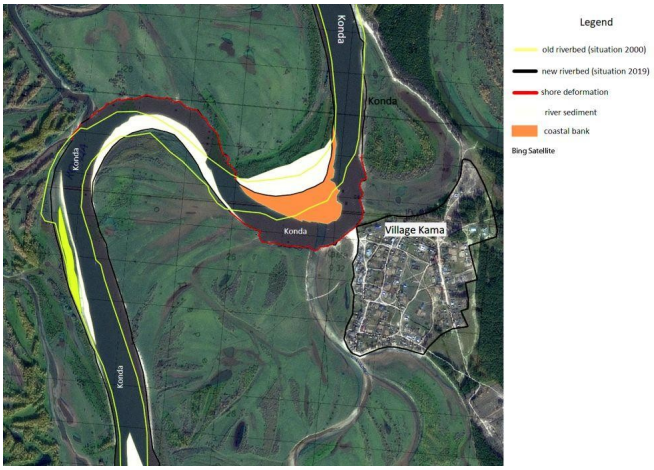

Figure 2. Bank line change map (Kama village) for the 2000-2020 period.

The Altai village of Kondinsky district, is located on the right bank of the Konda river, 50 km from the mouth of the Konda river. The bank height varies from 1 to 2,5 m. The area of the flooded site of the settlement: 0.343 km^2. Length of the bank line erosion area: 2,115 m. (2000), 3,959 m. (2011 r.).

The Altai section (72-81 km from the mouth) consists of 3 bends, the degree of l/L development of which has changed from the late 1980s to the present time as follows: the first bend during this period had changes in the degree of bend development (1.56–1.59), increase in the deflection boom (1160-1213 m) and decrease in the radius of curvature (1360-1127 m). For the second (1.51→1.56) and third bends (1.41→1.59) a similar trend was also identified. The development of the bends is due to erosion of the Nizhny and Upper Altai pits.

The progressive destruction of the bank line is confirmed by the results of cartographic studies by overlaying the different-age maps of the key area - the pilot map of 1988 (used for interpretation) and space images in the Yandex Satellite program (figure 3).

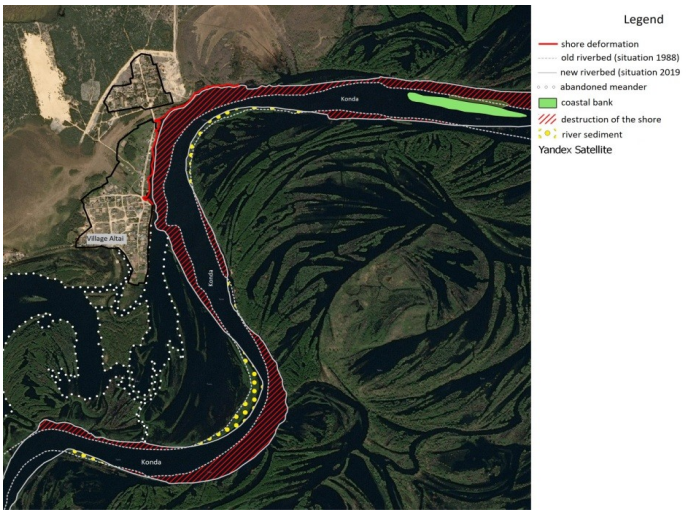

Figure 3. Shoreline change map of the Altai village (1988-2020).

The size of the retreat of the native bank for 30 years was 10-12 meters, the rate of erosion is 0,33-0,40 m / year. There are 21 residential buildings in the flood zone, the number of population in the flood zone is 61 people. The embankment dam with the length of 1000 m was built by economic method, and is in emergency condition and does not perform protective functions. It is necessary to replace the dam with capital bank protection structures with the length of 1547.00 linear meters.

The bank line deformation is particularly intense in the lower reaches of the Konda River near the Vykatnoy settlement. The bank height is from 2 to 4 m, the length of the collapse section is 800 m. According to the results of field surveys in 2018-2019, the trend of bedrock bank collapse continues. Repeated observations recorded that the distance from the rafter to the bedrock bank edge decreased - 8.00 m (02.08.2018), 7.48 m (27.07.2019).

The progressive destruction of the bank line is also confirmed by the results of cartographic studies by overlaying different-age maps of the key area - the topographic map of 2000 (Topomap marshruty.ru) and the Yandex Satellite satellite image (figure 4).

There are 15 residential buildings in the bank collapse zone. The number of people living in the collapse zone is 32 people. At present, there is a threat of residential houses collapsing. The existing bank protection dam was built by economic method, it is necessary to replace it with capital bank protection structures with a length of 800 linear meters.

Figure 4. Bank line Change Map, Vykatnoy settlement (2000-2020).

4 Discussion

Within the key area in the Kama village, the value of bedrock bank retreat over 20 years was 45-48 meters, the rate of erosion was 2.25-2.40 m/year. For the area of the Altay village, the value of bedrock bank retreat over 30 years was 10-12 meters, the rate of erosion was 0.33-0.40 m/year. In Vykatnoy settlement, the value of bedrock bank retreat over 20 years was 14-16 meters, the rate of erosion was 1.25-1.40 m/year.

5 Conclusion

Within the investigated section of the lower and middle reaches of the Konda River the most significant deformations of the bank line occur within the Vykatny, Kama, and Altay sections, which requires engineering solutions for bank protection and protection of the settlements from the negative impact of water.

The data show that erosion activity is spotted at the considered key sites: for the village of Kama, the value of the retreat of the native bank over 20 years was 45-48 meters, the rate of erosion is 2.25-2.40 m / year. The settlement of Vykatnoy is also experiencing bank line erosion, and from 2000 to 2019, under the influence of erosion activity, the value of bank line retreat was 14-16 meters, erosion rate 1.25-1.40 m / year. In the village of Altay, the average annual erosion rate of the bank line was 0.35 m/year and for 30 years, the value of bedrock bank retreat was 10-12 meters.

In order to prevent the danger of erosion processes in the settlements of the Konda river basin it is necessary to create capital bank protection structures, since the existing bank protection dams, as a rule, are built by economic methods, are significantly destroyed and do not fulfill their function.

The use of the cartographic method of overlaying maps of different ages gives us an opportunity to see the trend and direction of bed deformations, and natural instrumental measurements allow us to record these changes and calculate the rates of bank line erosion, which is important for forecasting and taking measures to protect settlements from hydrological hazards.

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