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STUDY OF SPATIAL AND TEMPORAL VARIATIONS OF THE BUKTYRMA RIVER BANK EROSION

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Abstract

This study addressed the causes, mechanism and different forms of bank erosion of the Buktyrma River near to human settlements; their dependence on the morphology of banks, connection with river channel deformations is clearly shown. For this purpose, multi-temporal space images and cartographic materials were used. The calculation of the horizontal deformations of the riverbed was performed by GIS. When modeling channel processes, the following data was used: space images RapidEye, Landsat and Sentinel -2 for the period from 1975 to 2017, topographic maps 1960-1980, data of geodetic surveys 1965-2010, digital elevation model SRTM 2000, field observations at coastal destruction sites for 2011-2017, geological map of 1979 and geomorphological map of 2010. Based on SRTM digital elevation model drawn map showing the river systems of the structure, characteristics and hypsometric Buktyrma catchment area of the river. The article shows examples of identifying scouring river banks by space images near 5 settlements - Kaiyndy, Shyngystai, Bykovo, Parygino and Turgusun. A hydromorphological analysis of the channel and erosion processes in selected sections of the river was carried out, and the causes of the channel changes were identified. The article also provides examples of creating schemes for eroded parts of the Buktyrma river, highlighting spatial changes of erosion near the villages of Parygino and Turgusun. Recommendations have been elaborated for the improvement of the existing system through which erosion processes are monitored.

Key words: *bank erosion, river channel deformations, types of river channel processes.*

1. INTRODUCTION

Breakages in riverbanks resulting from water flows are among many destructive processes on Earth. They negatively affect human settlements, engineering sites, communications; water intakes, electric pylons, bridge crossings are destroyed; agricultural land and forests are lost.

In order to combat and prevent this phenomenon, banks are reinforced (which is costly), dams are built, various regular activities are carried out on rivers, including the creation of an artificial channel, which redirects the flow from the facility being affected; sometimes human settlements, engineering facilities and communications are relocated (Chalov, 2000). Numerous bridges cross the Buktyrma River, homes, household buildings are located on the bank of the river. Roads and railways, communication and transmission lines are laid over long distances, the Buktyrma hydropower station and hydro-melioration structures were constructed in the river valley (Yapiyev et al. 2017).

Erosion processes in the Buktyrma river valley are particularly evident near human settlements where washouts caused by permanent and temporary watercourses within the territories of Arshaty, Berel, Kaiyndy, Yenbek, Shyngystai, Parygino, Bykovo, Turgusun villages, as well as roads between Lesnaya Pristan village – Zyryanovsk town, Zyryanovsk town – Parygino village, Kutikha village - Parygino village, Stepnoye village – Novaya Buktyrma village, Katon-Karagay village – Uryl village, Zhazaba village – Uryl village. The rates of washouts reach an average of 3-5 meters per year.

Bank erosion in the Buktyrma river valley results in the fall of loose rocks, more rarely half-rocks. This is due to high cliffs of the Buktyrma river, eroded by water. The amount of falling mass is often significant and constitutes 100 m^3, however often ranges between 5-10 m^3 and 20-25 m^3. The process, as a rule, is gradual, first, the lower part of the cliff is washed out and cracking is formed along the shoreline, and then in cases of complete loss of balance block-caving of rock mass occurs. Rockfalls resulting from erosive layers in small streams during high floods lead to channels blocked with debris, followed by the occurrence of local mudflows. Scientific studies of erosion processes of the Buktyrma river basin began in the 1950s. Kazakh scientists, including A.N. Mitrofanova, R.Sh.Kalita (Mitrofanova et al. 2012), G.I. Shamov (Shamov, 1959), L.S. Nurmagambetova, I.S. Sosedov (Nurmagambetova et al. 1965), G.N. Skladchikova (Skladchikova, 1969), L.Y. Chigrinets, M.M. Aznabakiyev (Chigrinets et al. 2010) investigated the problem in different years. Their works contain information on the formation of river flows, mineralogical and granulometric composition of sediments. Regular static observations of erosion processes near human settlements and engineering structures in the Buktyrma river basin area have been performed by the State Service for Monitoring Geological Hazards from 1982 to the present, with a pause taken in 1993-2001 (The official website of the East Kazakhstan Interregional Department of Geology and Subsoil Use). However, by now, the existing monitoring system does not cover all areas of the river where erosion processes occur and develop, as well as is not based on the use of aerospace survey data due to their high cost and absence of methodological frameworks for their using. Despite the significant spatial coverage of studies performed, the scientific literature contains very scarce information on the causes, mechanisms, forms, as well as spatial and temporal variability of the bank erosion of the Buktyrma river. Without scientifically sound designs, bank protection structures and dams can be easily eroded and banks become exposed much earlier than the lifecycle of the project starts. Therefore, study of erosion processes in the Buktyrma river valley, analysis of their dynamics and assessment of the current state of erosion are important tasks in both scientific and practical terms. The objective of the work is to study the causes, mechanisms, forms, as well as spatial and temporal variability of the bank erosion of the Buktyrma river.

To achieve the goal of the research, space-time images, cartographic and statistical materials, data on the hydrological regime of the Buktyrma river were collected and analyzed. The materials of previous scientific studies of scientists on the channel and erosion processes of the Buktyrma river have been studied. Geodetic measurements and observations were carried out at coastline destruction sites. The values of erosion of the banks of the river in areas near settlements are determined. The maps of the eroded sections of the river with the selection of the dynamics and zones of erosion were compiled. The causes, mechanism and forms of erosion manifestations of the banks of the river Buktyrma are revealed.

2. METHODOLOGY AND DATA

In order to obtain the most complete information on the subject of study – the river with its valley, floodplain, the data of aerial and space surveys, ground-based geodesic studies, hydrological stations, scientific literature is used in in integrated way (Khmeleva et al. 2000). The information carrier in the case of aerospace surveys is multispectral reflected radiation, which characterizes the optical properties of natural objects. The state and the composition of the latter can be measured by these properties. The optical properties of the objects in the images change during the year, the season and a day. The informative nature of aerospace surveys is influenced by a range of natural factors and phenomena (Knizhnikov et al. 2014).

Data on changes in horizontal properties of valleys, floodplains, channels and riverbed forms in terms of the length of the river are extracted from the space images of different time through image interpretation. The results are shown on maps. For interpretation, the data on the hydrological regime of the river, hydromorphological descriptions of river sections, details of the floodplain, various maps are used. The reason for these changes become apparent after the analysis of all existing materials (Chalov, 2008).

In order to measure horizontal deformations (the rate of erosion and alluvion) multi-temporal aerospace and geodetic surveys data are chosen. It might be preferable to involve survey data fulfilled during low water periods and periods with the highest level of contrast between the channel, floodplain and slopes of the valley (Savinykh et al. 2001). The images and maps of different time obtained using geoinfomation systems are corrected to one scale and combined; displacements of contours are become visible on combined schemes (Sujit, 2017). This makes it possible to figure out horizontal deformations – the value of displacements in meters per year. If records of early aerospace and geodetic surveys are unavailable to obtain approximate data on changes in the channel and floodplains, aerospace survey data are combined with old topographic and pilot maps.

Very little special images have been taken in necessary spatial and temporal resolutions for study plots of the Buktyrma river. In that respect, the available space images, geodetic survey data on erosion processes, topographic maps and the data on the hydrological regime of the Buktyrma river have been used for this study. In addition, during the study, field observations have been conducted along river lines, where sites of the destroyed bank were identified; the geodetic measurements of most affected sites were taken; main morphometric properties of the sites were defined.

Characteristics of data used for study are shown in Table 1. Materials collected (of different time) have allowed to assess the state of the channel, floodplain, valley consistently across all years, and to identify linkages between the rate of displacement (erosion and alluvion) and changes in the water content (changes in the levels and consumption). Using the selected materials a detailed hydromorphological analysis of channel and erosion processes of the selected river sections was conducted, the results of ground-based surveys were shown schematically, changes in the width of the valley, floodplain were analysed on the spatial and temporal scale.

Table 1. Data used in the study

No.	Data	Dates of Surveys	Scale/Resolution	Source
1	Geodetic surveys of erosion processes	1965-1970, 1973, 1980, 1981-1986, 2003-2010.	1: 2 000	East Kazakhstan Interregional Department of Geology and Subsoil Use
2	Topographic maps	1960, 1970, 1978, 1980	1: 100 000	Cartographic Web Service http://loadmap.net/

3	Satellite images with a high spatial resolution	03.05.2002 06.2003 21.07.2007 07.04.2007 10.05.2011 08.2011 15.07.2012 17.10.2013 05.05.2016 07.2017	1 m	Geoinformation systems Google Earth Pro, SasPlanet.
4	Satellite images with a medium spatial resolution: RapidEye	15.08.2017 04.07.17	5 m	Geoinformation system Planet Explorer https://www.planet.com Trial access.
5	Satellite images with a low spatial resolution: 1) Landsat Landsat 5 MSS, 4 TM, 5 TM, 7 ETM+, 8	11.05.1975 25.07.1978 30.07.1979 14.08.2009	30 – 90 m	The website of the US Geological Survey http://earthexplorer.usgs.gov/
	2) Sentinel -2	04-08.2016- 04-08.2017	10-60 m	Geoinformation system Sentinel Hub https://apps.sentinel-hub.com
6	Digital terrain model SRTM (Shuttle Radar Topography Mission)	11.02.2000	30 m	The website of the US Geological Survey http://earthexplorer.usgs.gov/
7	Field observations along river lines, on sites of the destroyed bank: maps of changes in bank status at a scale of 1: 2000; geological and geomorphological descriptions.	2011–2017.	1: 1 000	Field data obtained by the authors of the article
8	The hydrological regime of the Buktyrma river near Berel, Pechi, Lesnaya Pristan, Uryl, Chernovoye, Beloye, Turgusun: monthly/yearly average water levels.	2010–2017.	Hydrological stations	East Kazakhstan Center for Hydrometeorology
9	Geological map of the Kazakh Soviet Socialist Republic: M-45-B	1979	1:500 000	Geological library GeoKniga www.geokniga.org
10	National Atlas of the Republic of Kazakhstan. Volume 1: Geomorphology.	2010	1:5 00 000	National Library of the Republic of Kazakhstan https://nlrk.kz/
11	Atlas of natural and technogenic hazards and risks of emergency situations in the Republic of Kazakhstan. The danger of the erosion and soil blowing.	2010	1:5 000 000	
12	Atlas of natural and technogenic hazards and risks of emergency situations in the Republic of Kazakhstan. The risk of bank erosion: Lake Zhaisan and Buktyrma reservoir.		1:5 00 000	

3. STUDY AREA

The Bukhtyrma river belongs to the Arctic basin and is the largest of the Altai tributaries of the Irtysh river. The basin lies within the South-Western Altai, in the southern half of the temperate zone. The river flows into the Buktyrma reservoir on the right (Janaleeva, 2010). The river's total length is 336 km, the basin area is 12 660 km^2. The structure of river systems, the hypsometric characteristics and the catchment area of Buktyrma are shown on the map of the river basin (Figure 1).

The article summarizes the results of the study of the bank erosion of the Buktyrma river, using the areas in the vicinity of Kaindy, Shyngystai, Bykovo, Parygino and Turgusun villages as an example. Examples of plotting sites created by the authors of Parygino and Turgusun are given.

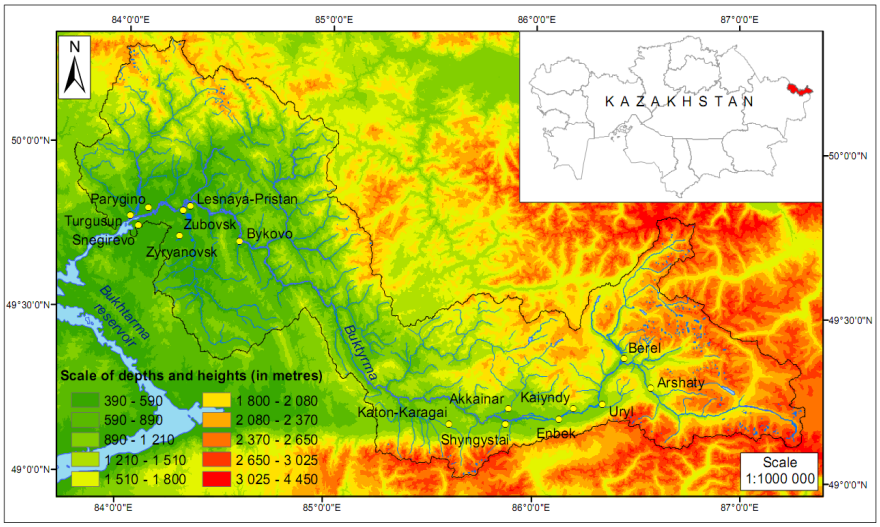

Figure 1. Map of the Buktyrma river basin

The map is based on the SRTM digital elevation model using the Spatial Analyst tools of the ArcGIS 10.3 geographic information system (Djokic et al. 2011). *Bank erosion area in the vicinity of village Kaiyndy.* Village Kaiyndy is situated in the Katon-Karagai district of the East-Kazakhstan Oblast. About 300 people live in the village. In a geomorphological sense the district is situated on the first inundated terrace of the Buktyrma river, complicated by small discharge depressions and Berezovka river channel. In the north and northwest, the terrace abruptly tips into the piedmont slope with nullae and ravines. In the east and northeast, there is an alluvial-proluvial cone (talus) of the Buktyrma river drift. The geological structure of the study area includes predominantly unconsolidated quaternary deposits.

The right-bank escarpment of the Buktyrma river branch that extends approximately 1.5 km is exposed to erosion. The height of the escarpment is 0,9-5,7 m, represented by loamy and sandy clays and gravel. The intensification of the erosion process stems from the instability to the slaking of rocks, forming the escarpment. Water washing away river sediments, carries the fine sand away, touches the foot of the loam clay escarpment, moistening it, producing a crash of soil blocks followed by the erosion. *Bank erosion area in the vicinity of village Shyngystai.* Village Shyngystai is situated in the Katon-Karagai district of the East-Kazakhstan Oblast. About 800 people live in the village. In a geomorphological sense, the site is situated in the Bukhtyrma river valley at the outlet of the river where upper quaternary fan of the Kokterek river enters. The surface of the alluvial fan is located at the absolute maximum of 920-950 m, slightly transformed by water flows. An inundated terrace is developed within the study plot in the Buktyrma river valley, which forms a scarp above water level, 5,5-10,4 m height, and a scarp above the floodplain, 3-3,5 m height. The surface of the terrace with the elevation of

875-880 m, flat-undulated, carved to discharge depressions of watercourses, slightly inclined to the river. The total length of the eroded bank is 1,5 km.

The geological structure of the study area includes predominantly unconsolidated quaternary deposits. Loams, sand clays admixed with gravel, screes underlain by gravel/shingle with small sandy boulders. *Bank erosion area in the vicinity of village Bykovo.* Village Bykovo is situated in the Zyryanovskiy district of the East-Kazakhstan Oblast, 21 km east of the district center, Zyryanovsk town. About 600 people live in the village. In a geomorphological sense the district is situated on the first left bank inundated terrace. The surface of the terrace is flat, carved to watercourses, slightly inclined to the river, overgrown by the forest.

The plot consists of quaternary alluvial deposits. A scarp of approximately 500 m length, 1,5-3,5 m height, formed by loams with frequent gravel layers is prone to erosion. Erosion of river cliffs is noted on the bend of the Buktyrma river. The most intensive erosion process occurs in northeastern and southeastern parts of the village where there are residencies and farm structures. *Bank erosion area in the vicinity of village Parygino.* Village Parygino is situated in the Zyryanovskiy district of the East-Kazakhstan Oblast. About 2000 people live in the village. In a geomorphological sense the study plot is situated on the right bank of the valley on the surface of the mean-upper quaternary plume, framing the ridge of low bald peaks with the elevation of 560-580 m and on the second inundated terrace of the Buktyrma river. The alluvial piedmont plain and the second inundated terrace form a scarp above the water level, 10-12 and 7-9 m height accordingly. The channel sharply meanders, overwashing and redepositing its sediments with the formation of numerous spits and shallow waters.

The geological structure of the study plot of the river includes predominantly unconsolidated quaternary deposits. Sediments of the second inundated terrace of the Buktyrma river and loess-like deposits of the alluvial piedmont plain are prone to erosion. These are loess-like loams, clays, which are almost instantly or very rapidly get soaked, exacerbated by relatively high content of water-soluble salts of rocks. Numerous separation cracks are forming with mud sedimentation and block-caving in loess-like rocks near the bench crest as a result of soaking and drying, as well as repeated destabilization of the section of the scarp as its lower part is washed out.

Bank erosion area in the vicinity of village Turgusun. Village Turgusun is situated in the Zyryanovskiy district of the East-Kazakhstan Oblast. About 1500 people live in the village. In a geomorphological sense, the study plot is situated on the right bank of the valley composed of upper quaternary sediments, with the elevation of 395-398 m and on the first inundated terrace of the Buktyrma river. Alluvial-proluvial cone of the Topnushka river drift protracts in the west. The surface of the inundated terrace forms a cliff of 3-5 m height above the shoreline. The river channel has many branches, divided by floodplain islands. The floodplain is wide, low, extensively swamped with drastically different in terms of size channel margin sand and channel sand, with different vegetation in the floodplain islands and channel islands. The geological structure of the study plot includes predominantly unconsolidated quaternary deposits. Deposits of the first inundated terrace of the Buktyrma river are prone to erosion. These are gravel and sandy deposits admixed with crushed stone and silt, with pocket clay and loam layers.

4. RESULTS

As a result of the study, the magnitude of horizontal deformations of the river channel was identified within the selected plots. At the same time, it should be mentioned that while using the materials obtained in different years and seasons, not just a single sector of the channel was considered but a river sector of considerable length with its floodplain and valley. *Bank erosion area in the vicinity of village Kaiyndy.* According to the materials of previous studies, the erosion process either decreased in terms of time (1981-1986) or intensified (2003-2010), which is

driven by the redistribution of the water flow of the Buktyrma river through streams with increased volumes of water going towards either the right or the left sides of the valley. Such a situation can be observed on other sites of the Buktyrma river as well.

The annual average erosion during intensification of the erosion process in high-water years of 1966, 1969, 1973, 1980 achieved 6 m a year. In the period of 2005-2007 the annual average erosion constituted 1,91-2,15 m a year, which is below that of the previous period, whereas in the period of 2011-2017 overall erosion in the western outskirts of the village constituted 0,38-0,39 m a year, which means that another period of the erosion process decrease is likely to start. However, the situation in the western outskirts of the village reached a critical level by May 2010.

There was a 9 m distance between the nearest house and the bench crest, part of the road was destroyed. In spring 2010 measures were taken by state bodies before floods to reinforce the cliff. An earth embankment was erected in the western outskirts of the village, made of coarse-grained material of rocks with the ledge up to 6 m height, up to 4 m width and 1 km length.

The shoreline in the eastern outskirts of the village remained unchanged, where maximum erosion level in 2011-2017 constituted 0,65 m. The erosion process in this part is inactive, there is no direct threat to residential dwellings, road, which are 25-30 m from the cliff. The branch of the Buktyrma river is almost dry owing to the construction of another facility – a protective dam, blocking the water flow and directing main volumes of water to the own channel of the Buktyrma river (Figure 2).

Figure 2. Bank erosion within village Kaiyndy

Bank erosion area in the vicinity of village Shyngystai. The erosion process is weaker in the village of Shyngystai than in Bykovo and Parygino sites, which is probably due to the remoteness of this river sector from the mouth of the river Buktyrma and water flowing closer to the right bank of the current valley. However, there is widespread development of the erosion process along the shore. The cliff extends to about 1,5 km. The northwestern part of the village is destroyed intensively most of all. The maximum erosion rate of the site constituted 12,3 m in 2011-2017.

The intensification of the erosion process, when greatest erosion can be observed, occurs during flood periods, when it is time of flood flows of the Buktyrma river, therefore, highest river levels, which is explained by the year rainfall of the cold season. According to previous studies (1983-1984) in the eastern part of the post the creek moved closer to the

right bank of the current valley and the erosion of the cliff is eased a bit, however the energy of the water flow within the site is so high that the erosion process does not stop even in low-water seasons, it just decreases. The erosion of the cliff poses a threat to residences and farm structures, lands of the village (Figure 3).

Figure 3. Bank erosion within village Shyngystai

Bank erosion area in the vicinity of village Bykovo. There is erosion of the cliff in the study area, threatening to facilities that ensure the day-to-day existence of the population. The actively eroded bank is most clearly seen during flood periods.

The erosion of the left bank of the Buktyrma river in the north-eastern and south-eastern parts of the village annually until 2010 constituted from 1,5 to 2,5 m with the overall length of the eroded bank 2,0 km. In spring 2010 in the north-eastern part of the village was small erosion (0,5 and 0,8 m) since protective measures were implemented before the start of the flood period. An embankment was erected, made of coarse-grained material of rocks, with the ledge up to about 500 m length, up to 4,5 m width and with erosion-preventive embankments deep into the river to reduce the speed of the current so that the destructive impact of the great water flow could be minimized.

Therefore, the threat to residencies and farm structures passed for some time, however the erosion process can be intensified above the protective embankment due to the redistribution of the water flow from the principal channel to left bank streams, especially during flood periods. The maximum erosion rate of the site in the south-eastern part of the village 9 m in 2011-2017. Residencies and farm structures are still under the threat of collapse (Figure 4).

Bank erosion area in the vicinity of village Parygino. The study suggests that the erosion process had developed intensively. This evidenced by fresh deformations of the channel throughout the study area, growing ravine tributaries, abandoned, uncultivated vegetable gardens as people move to more safe places.

In the study plot the main volume of water of the Buktyrma river redistributed in 1970-1980 to the right bank stream, which at a right angle heading to the cliff of high plain, thus causing its intensive erosion. Such a situation with the main water flow prevails until now.

Intensive development of the erosion process is noted throughout the shoreline being studied. Erosion of the right bank of the Buktyrma river in the north-east part of Parygino village is from 1,5 to 3 meters width annually. During 2011-2017, the shoreline has receded 17,7 m.

Figure 4. Bank erosion within village Bykovo

The length of the eroded bank is 0,9 km, every year there is a risk of collapse of a road Zyryanovsk town – Parygino village – Kutikha village, as well as destruction of houses in Parygino village (Figure 5). Protective measures were not implemented in the human settlements destroyed. According to local residents, authorities are seeking funds for the extension of another branch of the river in order to redirect the main water flow away from the stream, where the cliff is currently being transformed.

Bank reinforcement was done on both the right and left banks of the river above the road bridge. The bridge connects the road between Paygino and Zubovsk villages. The banks filled with large stones, concrete slabs were refined (Figure 6).

The speed of the bank cliff erosion is first due to hydrological regimes of the Buktyrma river (high flood discharges, high water level owing to the year rainfall of the cold season and therefore an increase in the flow speed). In addition, it directly depends on the overall humidity of the area. The intensification of the erosion process is exacerbated by constant contact of the cliff with water with rapidly swelling grounds of the cliff's foot. The erosion process intensifies either with some delay or in most cases affected by the factors that influence this intensification.

Bank erosion area in the vicinity of village Turgusun. The Turgusun area is not included in the static observations of the intensification of erosion processes. The comparative analysis of topographic maps of different time, space images and field survey data shows that the Buktyrma river in the Turgusun area had the channel closer to Snegirevo and Krestovka villages in 1960s. In 1965–1970, after flooding of the part of the valley by waters of the Buktyrma reservoir, the main channel of the river eventually moved to the right bank of the valley, closer to village Turgusun. The mouth of the river Turgusun, as the Buktyrma river approached, went up towards its current and therefore was 4 km higher (Figure 7).

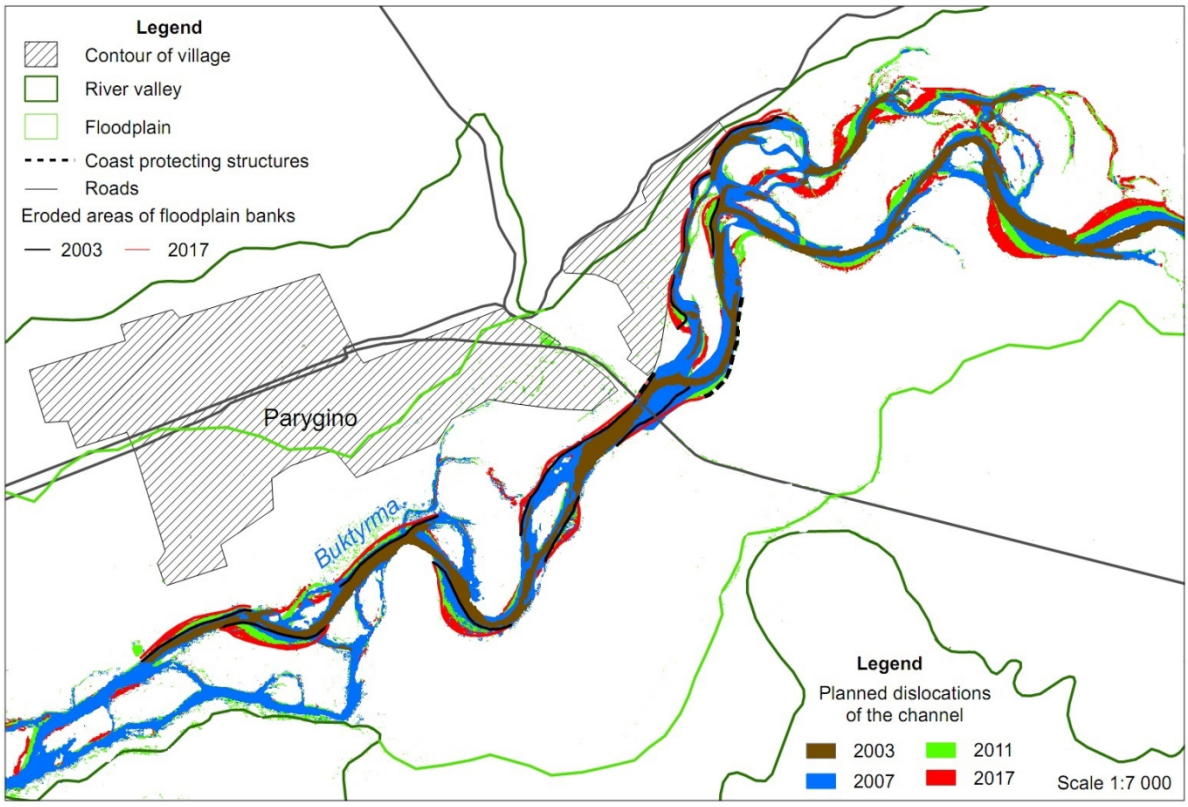

Figure 5. The scheme of the bank erosion area in the vicinity of village Parygino

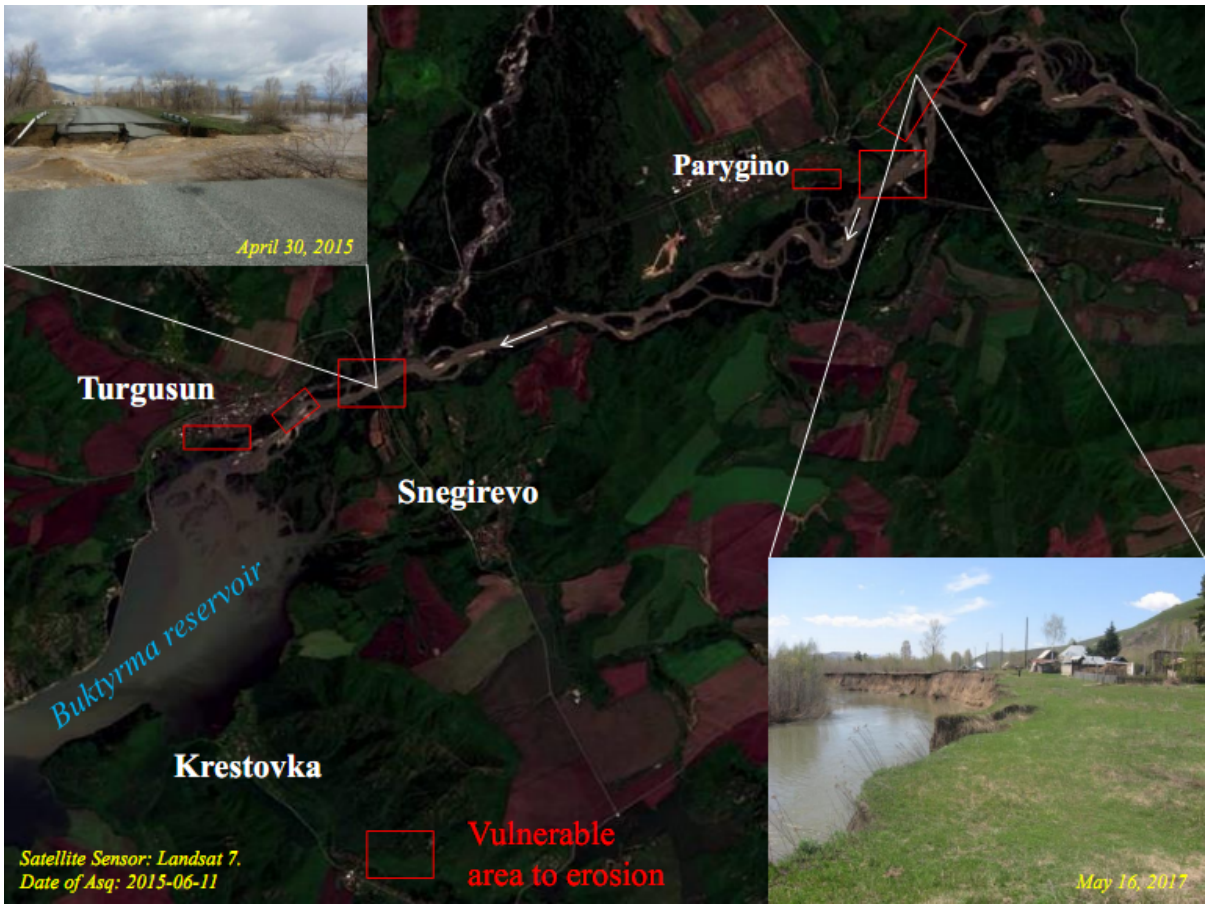

Figure 6. Bank erosion within villages Parygino and Turgusun

To date, there are threats of destruction to residential houses and roads of the village of Turgusun, which is 20-50 m away from the channel and road bridge, connecting Turgusun and Snegirevo villages.

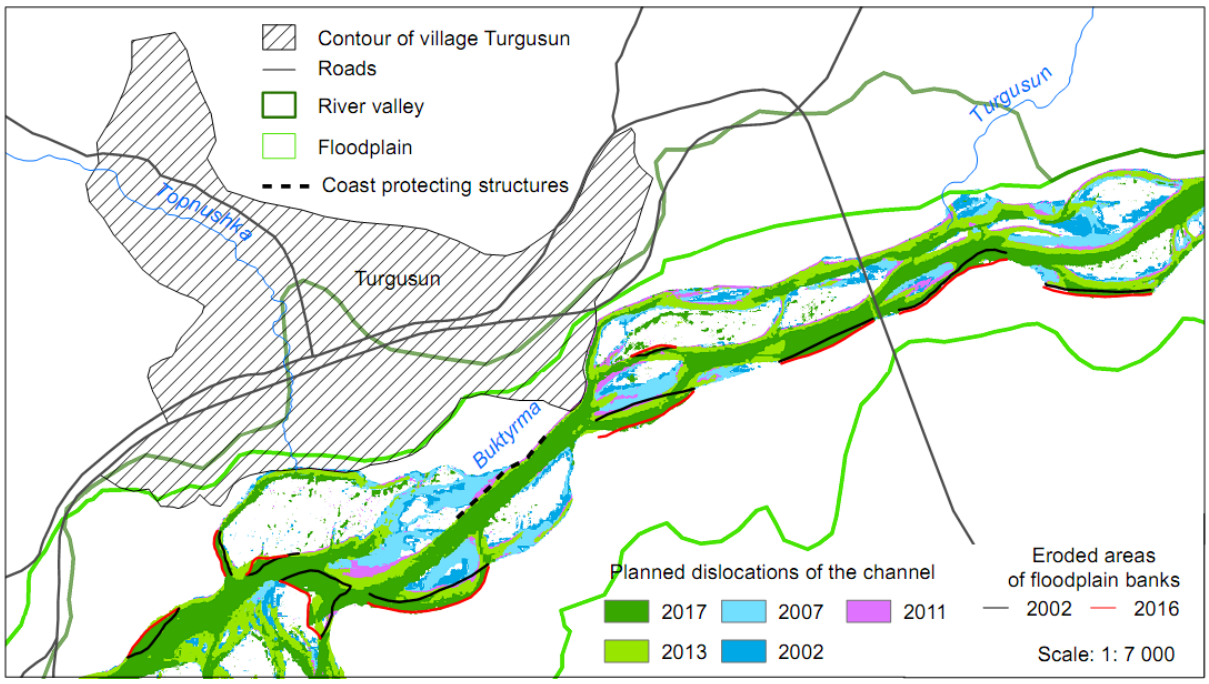

Figure 7. The scheme of the bank erosion area in the vicinity of village Turgusun

In the Turgusun village area the erosion process develops in the right bank branches of the Buktyrma river. The intensification of the erosion process is similar to other water courses, occurs during flood periods, the process decreases at other times. Bank erosion 0,5-1,0 m a year is noted in south-eastern and south-western outskirts of the village, as well as above and below the road bridge. Overall length of the bank eroded by streams in the outskirts of the village is 1,1 km. In spring 2015, with abnormal high waters, the bridge turned to mud because of flood waters. According to the data of the hydrological station, located in the village of Turgusun, in the spring of that year the water level in the Buktyrma river reached 7 m with the critical indicator of 5,3 m.

The bank of the principal channel in the central part of village Turgusun of about 1,5-2 m height, was erected using stony gravel with sandy loam filler as part of erosion-preventive activities. The crest of the cliff is covered with turf and forest. There are no active threats to residential houses and roads, which are 450-500 m away from the main channel.

CONCLUSIONS

In the Buktyrma river valley the intensification of erosion processes along the shoreline is connected with the hydrological regime of the river, geological and geomorphological conditions of its valley and channel processes. In the delta part, this phenomenon is also associated with the rise of the base level of erosion, due to the creation of the Buktyrma reservoir in 1960-1965 and storage of sedimentation in the estuarine part of the river, which is continuing at present.

Bank erosion processes near human settlements occur both in right and left bank areas from the head of the river to its mouth. Their speeds range 0,5-5,0 meters a year, vary from

floods to low-water seasons, from year to year, depending on a stage of development, which may occur, intensify, decrease, stop and resume.

The bank erosion areas in the study plots of the river are connected with the form of the channel, i.e. its morphodynamic type. The Buktyrma river near human settlements is divided into numerous branches. Both islands and river banks are prone to erosion. Areas prone to erosion and alluviation (storage of sediments) occur at branching points of the river. Islands are eroding from the upper part, facing directly into the direction of the flow of the river and other sides of the bank in the lower part of the node. In case of large sediment yields in sites with shingle alluvium in the upper parts of the islands, shallow waters form, whereas islands have a spindle shape. Areas prone to erosion are localized by riverbanks opposite to their lower part. In case of long varieties of shape, hooks or smaller islands emerge in each of the branches, which form additional branches. Periodic development of branches usually happens in both cases. In a suppressed branch the accumulation processes prevail, erosions are localized over short distances; channel scour prevails in developing branches, the length of eroded banks increases. As a result, a peculiar kind of ring of braches emerges, which are at different stages of development and intensification, as well as varied by the length of areas prone to erosion.

This study has demonstrated the obtainment of information on the causes of the Buktyrma river bank erosion using materials with inadequate cartographic high spatial and temporal resolution data. The findings can be used as a scientific substantiation for the design and the implementation of bank protection activities and the projection of the intensificationof dangerous forms of erosion processes. Based on the results of the study, the authors of the article propose to maintain permanent space and ground observations of the dynamics of the development of erosion processes in the valley of the Buktyrma river to improve the existing monitoring system for the channel and erosion processes. The monitoring results are very important for forecasting and timely notifying emergency services and other government agencies about the threat of erosion processes to the public. The methodological basis for monitoring channel and erosion processes should be based on the use of aerospace images with different spatial and temporal resolutions, as well as the capabilities of modern geographic information systems. In the course of conducting monitoring, the identification of all eroded sections of the river basin of the Buktyrma River should be systematically carried out.

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