Erosion and accumulative processes in river valleys of the Upper Angara region (as exemplified by the catastrophic floods in 2019 on the rivers of Irkutsk Oblast)

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Abstract. The article considers development features of erosion-accumulative processes during catastrophic floods in 2019 on the rivers of Irkutsk oblast, in the Angara river basin (as exemplified by the Bol’shaya Belaya river). Considering the combination of morphodynamic channel types we preliminary determined main types, interaction degree of flood waters and floodplain-channel complexes in different areas. We revealed that the most intensive transformations of the floodplain-channel relief are associated with engineering and construction structures that hinder the natural exchange of floodplain and channel flows. The rates of coastal recession during the flood period were revealed; on average, they amounted to 2 m. The processes of coastal erosion - tearing away of bank are typical of sandy loam deposits composing the upper part of floodplain surfaces. The most dynamic areas of bank destruction correspond to the concave parts of the channel bends. Note is taken that the presence of linear infrastructure objects (roads) within the floodplain massifs often caused the flow rates increase and an increase in the volume of transported material, as well as formation of accumulative landforms, which can hinder water exchange between channel and floodplain streams in the future, and also serve as an additional development factor of processes that are negative for a person and can lead to total destruction of infrastructures, or cause significant damage to them.

1. Introduction
Investigation into the development of river valleys, including the geomorphological processes in the valley itself, constitutes an element of the evolutionary analysis of the environmental component, i.e. topography. Such an analysis involves an assessment of plane channel deformations in different morphodynamical river reaches, enabling the determination of the relationship of erosion and accumulation processes in the bottoms of river valleys.

Identification of patterns of channel processes manifestation and the dynamic development of floodplain-channel complexes of the rivers in the Upper Angara region under the influence of natural and anthropogenic factors is an important field both for solving applied problems of rational nature management and for theoretical issues of fluvial relief formation.
One of the factors that enhance the manifestation degree of fluvial relief formation in Irkutsk oblast, including the periods before the extreme events, was the change in synoptic conditions and catastrophic summer floods.

Nowadays, floods are recognized as one of the leading factors of emergency situations for the southern regions of Irkutsk oblast [1], and the most dangerous among them are rain floods [2, 3]. For the first time, within the framework of the project for monitoring erosion-accumulative processes in the river valleys in the foothills of the Upper Angara region, we obtained data on the spectra of processes and the rate of coastal scarp formation, features of relief formation of floodplain-channel complexes, as well as the volume of transported material during catastrophic floods.

In June-July 2019 on the rivers of Irkutsk oblast, floods resulted in loss of lives and material damage. The territory of the Belaya river basin was slightly affected by the floods, but several settlements were cut off from the world due to damage to roads by flood waters for some time. In the Bol. Belaya river basin the rise of water ranged from 1.5 (Inga gauging station) to 3.5 m (Bolshebelsk gauging station) [4].

2. Models and methods

Theoretical and methodological basis of this research was the research of representatives of national school of geographical channel study [5-8] and channel hydrodynamics [9-10].

In the preparatory phase of monitoring we analyzed geo-images of different times, literary sources, our own materials, which enabled identification of the most mobile areas for monitoring coastal deformations and dynamics of floodplain-channel complexes. Field studies included geomorphological research of river channel reformation.

Mapping of floodplain-channel complexes of the basins of the Angara tributaries were carried out on the basis of field observation data using UAV survey data and Earth remote sensing data.

The area under consideration is located in the middle reaches of the Bol. Belaya river and it covers the foothills of the Eastern Sayan and the inner zone of the Pre-Sayan depression with various relief types: from low-mountain to plateau and flat topography (figure 1).

The Bolshaya Belaya River basin lies in the field of Cambrian dolomites, limestones and Jurassic sandstones [11].

The main factor for the channel development is represented by the hydrological regime of the river, and by the runoff of channel-forming tractional load and suspended sediments. The river length is 280 km,
the catchment area is 18 thou km², the average long-term water discharge within the areas is 41.1 m³/s (vil. Novostroika) to 41.2 m³/s (vil. Inga) [12].

The heights of the watersheds reach 800 m (at the Novostroika section), decreasing downstream to 600 m (at the Bolsheviksk section). The territory belongs to the Irkutsk-Cheremkhovo hydro-morphological region, which is characterized by a pronounced summer flood [11].

The floodplain-terrace complex is represented by a low (up to 1m) and high (up to 2 m) floodplain, and by fragments of the first, second and third terraces (up to 6 m), 8-10 and 16-18 m, respectively. The age of the low terraces is estimated as the Neopleistocene.

3. Results and discussion
Wide-floodplain divided-sinuous bends with adapted and free channels with a combination of running-insular, hollow-insular and segmental floodplains are characteristic of the river valleys of the foothill territories.

Within the same massifs we can note significant rates of bank recession and areas of extreme manifestations of fluvial relief formation, which are largely correlated with the damage of the natural surface by engineering facilities. According to field observations, which were carried out during the final stage of the first flood wave in 2019, the recession due to river bank failure in the foothill part of the Belaya basin reached 2 m. Such processes were mostly developed in benches of high and low floodplains, composed of sandy loamy-sandy deposits on pebble base.

River bank failure due to slope processes like the sliding of the sod horizon along the pebble base was also often observed. Stability parameters of the pebble strata are reduced due to the water saturation of the aggregate, which activates the erosion processes. The thickness of sandy deposits on the surface of the floodplain reached 0.6-0.8 m and the depth of erosion was 0.5 m. Roads within this territory often run along the riverbed, crossing numerous channels. During low-water level these ducts, as a rule, are drained, therefore, there are no bridge crossings are constructed, only heaping of concave forms.

We observed the processes of relief formation of running-island floodplains and the reformation of the channel relief in the mouth parts of the channels in the lower reaches of the Bol’shaya Belaya river (Novostroika and Bolsheviksk sections).

Two areas with the formation of estuarine pebble banks were observed. In both cases, highways were the trigger for the formation of the accumulative forms in the mouths of canals, which played the role of dams when the territory was flooded.

“Novostroika” section is located four kilometers upstream from the mouth of the Urik river. The height of the floodplain here is 2-2.5 m above the water level. The floodplain is composed of a pebble pack 1.3-1.5 m thick, with a sandy loam deposits up to 0.7 m thick lying on it.

At the “Novostroika” section, as a result of backwater flow in the channel, with further breakthrough and destruction of the automobile bridge, the flow was saturated with coarse material and there was further redeposition in the mouth of the channel. The length of the channel below the destroyed bridge was 40 m, with a width of 4-5 m. In the channel, there are water niches up to 1 m in depth and up to 10-11 m long, and along its periphery there are ridges formed by pebble material up to 1.2 m high and up to 13 m long. The thickness of the sand deposits formed during the spreading of the flow below the destroyed bridge is 20 cm.

The channel pebbles in the area below the collapse of dike-bridge are stacked vertically (oriented with their long axis perpendicular to the surface), which is typical for mountain rivers with high flow turbulence, downstream there is the texture of usual tiled stacking (the long axis of the debris coincides with the flow direction). The pebble material is quite homogeneous for the two samples taken in the channel part and in the riverine part of the alluvial cone, the median pebble diameter (Me) is 6 cm, the
modal value (Mod) is 5 cm, the sorting coefficient is 1.1 (good sorting). The aggregate is mixed-grained sand.

An accumulative pebble body was formed in the mouth of the channel. The accumulative form has a swell-like shape with a longer slope towards the river (steepness from 15° to 24°) and a steep bank scarp (30° to 31°). The estuary swell is a fragment of the alluvial cone, which extends into the channel from 2 to 4 m with an area of 27 m². Dimensions of its surface are 13×5×1.5 m, that is, the volume of the accumulative body is approximately 130 m³.

According to the analysis of the orthophotograph, the area of its underwater part is about 162 m², the initial volume of the carried material is difficult to estimate. In the near-mouth part the swell body is cut by small ducts up to 35-40 cm deep and 1.5 m wide.

The Bolshebel’sk section is located 53 km downstream, just as in the above-mentioned area the floodplain massif is crossed by a road. The relief structure is more complex here: the area of the relief reshaping is located in the junction zone of the main channel, active channel and secondary channel, which is partially flooded during low water (images from Google Earth, Bing, Landsat). The main channel forms here a steep segment bend with a step of 0.7 km, a radius of 0.18 km, and a deflection boom of 0.44 km.

In the place where the main stream and the channel are separated, a steep segmented bend is formed, the width of the main stream in this place is 150 m, and of the channels – 43 m. The relief of the low floodplain is represented by a combination of hollows up to 6 m wide and weakly expressed ridges. At the top of the bend, there is a mouth of a secondary channel up to 18 m wide, which is crossed by an unformed road. The formation of an estuary swell at the Bolshebel’sk section occurred according to the above-mentioned scenario. Difference concerns the number of newly formed several channels in the swell body, as well as the formation of a terrace up to 0.9 m high from the side of the main river.

It should be noted that the volume of transported material increases several times during the extreme hydrological events in anthropogenically disturbed areas.

4. Conclusion
In view of this, the accumulative forms in the mouth parts of the channels are created by interaction under the influence of anthropogenic and natural factors. It can be assumed that similar scenarios of extreme manifestation of exogenous geomorphological processes will be repeated in the future: when the roads are restored to their previous condition and the territory is sufficiently water-cut, an additional factor for spreading of the flow and deposition of material on the floodplain surface will be the estuary swell, which will block water exchange between the main river and channels, as well as the floodplain. As a result, change of the type of floodplains from flow-insular to hollow-insular is possible.

The roads crossing the channels play the role of dams during floods and inundation of the territory. The destruction of engineering structures during floods often increases the intensity of manifestation of fluvial erosion-accumulative processes, threatening humans and causing material damage.

In addition, the morphology of the underwater part of the bank in such channel mouths changes. The flattening and channel erosion base rise (due to the alluvial cone material) occurs.

As a result, it is possible to activate the accumulation processes in the duct. For further studies of the development of processes within these areas, it is planned to continue monitoring work.

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