# The influence of disastrous floods on riverbeds processes in the Far East of Russia

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**Abstract.** The article is focused on great influence of disastrous floods on riverbeds processes and repartition of water flow between distributaries in the Amur basin rivers. In the result of morphological analysis of the Far eastern riverbeds and their dynamics the places with the most intensive riverbed reformations were revealed. The intensiveness of erosive-accumulative processes caused by the Amur flood in 2013 was estimated. Some upper reaches of secondary branches and estuaries of large tributaries were recognized as zones of increased accumulative alluviums in the Amur riverbed.

## Introduction

In recent decades, in the Far Eastern region of Russia there is an intensification of dangerous hydrological phenomena and erosion-accumulative processes in rivers. This is the consequence of climate change and impact of economic activity. High summer and autumn floods with rain genesis are particularly dangerous [1]. During this period within a short time in many rivers there are noticeable changes of bed. These processes exacerbate the problems related to safety of navigation, stability of hydraulic structures and various riverside facilities. The high rise of flood waters in the rivers and the considerable duration of floods complicate the living conditions and activities of the population in river valleys and lead to great economic damage.

In order to identify the negative effects of floods on riverbeds the observations in the middle and lower reaches of the Amur river and its large tributaries were made after the catastrophic flood in 2013.

The results of the research can be required for the development of measures to prevent possible negative consequences of floods, manifested by banks erosion, depths changes, formation of accumulative forms of relief in the riverbed, repartition of water flow along the distributaries.

## 1 Subjects and methods

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The Amur and other major rivers of the region covering a considerable extent are composed of many distributaries of various sizes, which form an extremely complex hydrographic network. In many areas there is a floodplain-riverbed furcation which form the most complex and unstable parts of the river. The main riverbed and large distributaries have specific water and bed regimes and particular morphometric characteristics, such as a significant width at a relatively small depth. That is the reason for active reformations.

The observations were made in rivers with different morphological characteristics. In the satellite images, the areas with the heavily modified by the flood river sections were selected. In these sections the dynamics of the channel before and after the flood was analyzed fully. The Amur riverbed within the Sredneamurskaya lowland, which is the most populated territory of the Lower Amur region, was studied in more detail. In some areas location observations were carried out.

Directly in the field the features of the riverbed structure and the conditions of riverbed alluvium flow were revealed. Numerous observations on the formation and position of intensively eroded banks, the size of newly formed accumulative bodies in the river bed were made. On the basis of the obtained data the current dynamics of accumulative formations in riverbeds under the influence of floods was evaluated.

Estimates of the bank erosion rate were carried out reasoning from the morphological features of the riverside ledges, as well as with a help of comparison of free access space images, made before and after the flood. Comparison of the data obtained with the materials of space survey also made it possible to assess the dynamics of the largest forms of riverbed relief. During the research it was found out that activity of erosion processes was a significant factor affecting the structure of riverbeds and their dynamics.

## 2 Results and analysis

### 2.1 Characteristic of channel processes on the rivers of the region

The Far eastern rivers as a whole are characterized by high dynamics of riverbed transformations. This is manifested in intensive erosion of banks, expansion of existing distributaries and formation of new ones, displacement of reaches and rifts, formation of extensive forelands and isles. The available few data about the rates of these processes [2], as well as comparisons of planned mapping of the riverbeds in some part over several years indicate a significant irregularity of these processes intensity in morphologically different parts of rivers.

The most dynamic transformations of the riverbed occur in the middle reaches of the Amur river, as well as in its low reaches within the bounds of Sredneamurskaya and Udil-Kizinskaya lowlands. Particularly active erosion-accumulative processes occur in areas of multifactor economic impact on the river bed e.g. near Sergeevka, Konstantinovka, Poyarkovo villages in Amurskaya territory and near the cities of Khabarovsk, Amursk, Komsomolsk-on-Amur. Similar phenomena are also observed in areas of inflowing of large tributaries (the Bureya, the Songhua rivers, etc.). The speed of banks erosion is often about 20 m / year, causing the active formation of extensive moving forelands. Their development leads to further furcation of tributaries, reducing their transporting capacity and accumulation of a significant alluvium in the beds. In some parts of the river, when the flow is redistributed to the tributaries, banks erosion is observed even in winter period, which is typically for canals straightening the bend [3].

Hydraulic engineering construction on the Amur riverside, including installation of the river flood control dams and bank protection fortifications (their total length in the middle Amur river is about 300 km) leads to the instability of the bed and its intense deformation

in other areas, followed by destruction of valuable floodplain soil and its replacement with less productive islands ranges. As a result of active redistribution of water flow between the tributaries, the natural structure of the riverbed is simplified along with the activation of erosion and accumulative processes, complicating the working conditions of water transport and urban water intakes, in particular, in the cities of Khabarovsk and Amursk [4]. The increase of alluvium load in rivers following the ploughing of land, deforestation and fires heighten instability of the channel, leads to the formation of extensive sandbanks and shoals, the destruction of secondary river distributaries.

### 2.2 Particular features of the flood in 2013

Extreme flooding in the middle and lower reaches of the Amur river and its large tributaries in the summer-autumn period of 2013 was the largest for the entire period of observations (Fig. 1).

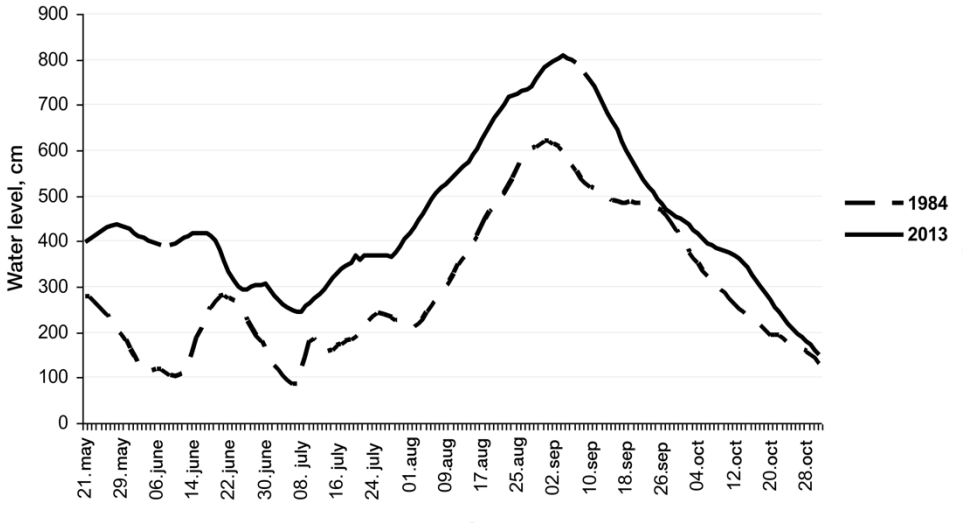


**Fig. 1.** Hydrography of the last two largest floods in the Amur river near Khabarovsk city

The scale of this flood is classified as disastrous. It covered vast territories within the two countries Russia and China. In some regions, economic and industrial activity was paralysed, there was a need for the evacuation of the population.

Analysis of space images and location research allowed to estimate the scale of the riverbed reformation, to identify the areas of the most intensive activation of erosion-accumulative processes and mechanism of water flow redistribution in furcated sections of the river bed following the flooding.

In 2013 in formation of a combination of natural and anthropogenic factors was manifested [5]. The main reason for the formation of catastrophic floods was abnormally high amount of precipitation during the two summer months – July and August. During this period there were particularly heavy and prolonged rains over the large area of the Amur basin. For example, the level of precipitation was: on July 7-8 in Shimanovsk 62.3 mm; on July 22 in Blagoveshchensk 101.3 mm, on August 8-9 in Ekaterinoslavka 139.8 mm, on August 13 in Ivanovka 78.8 mm. During two months in some parts of Priamurskiy region precipitation level exceeded the annual, and sometimes one and a half year norm. With high previous soil moisture, the flow coefficient in some river basins was close to very high values – 0.7-0.8.

One of the reasons of high-water levels was the sequential coincidence of the flood peak in the Amur as it moved down the river with the peaks of floods in the main tributaries. A certain role in high rise of water in the local areas of the Amur river was played by economic activities e.g. the construction of riverside dams, polders, bridges, as well as forest exploitation and fires in river basins. In the area of Khabarovsk, the high rise in water level was undoubtedly influenced by the railway embankment of the TRANS-Siberian railway passing through the Amur floodplain. The railroad embankment has no water drains. Blocking the entire floodplain, it had created backwaters, which lead to the additional rise of water in the city area by about 50-70 cm.

### 2.3 The influence of floods on riverbeds

Major floods are making significant changes in the riverbed, which must be taken into account in various economic activities. As a result of high floods, the morphological characteristics of rivers and the direction of riverbed processes transform significantly. Floods further to redistribution of water flow between distributaries, change the dynamics of their development, increase the speed of banks erosion and lead to the formation of large accumulative relief forms in the riverbed and extensive sand plumes in the floodplain.

The most problematic areas of rivers are large floodplain and bed furcation, where the current distribution of water flow between distributaries in relative terms indicates a clear direction in their development. At the same time, the development trend of distributary can be judged by the change in its relative water content in different phases of hydrological regime. Developing distributaries, as a rule, increase the share of water flow in them as water levels decrease; dying or shallow ones increase their relative water content in the high-water phase of the water regime [6]. Such areas of the rivers are indicated in the middle reaches of the Amur river and in the lower reaches of the Ussuri river.

The disastrous flood of 2013 in the Amur river made a significant erosion-accumulative activity in the river bed. Especially intensive banks erosion occurred in the Amur distributaries which had increased their water content resulting the redistribution of flow. Steep erosion ledges, formed as a result of erosion, stretched in the head of flat bends of the main riverbed for several kilometers (Fig. 2).

**Fig. 2.** Intensive erosion of the Amur bank following the flood of 2013.

The observations, conducted in 2014 after the flood, revealed the accelerated bank erosion in the areas where it had occurred before. The activation of erosion is often caused by displacement of the rifts in the Amur or formation of accumulative forms in the main and secondary distributaries of the river.

The most significant changes in the bottom relief of the river bed occurred in areas near the sources and estuaries of secondary distributaries, as well as near the large settlements. Here accumulative processes intensified, following the increase in size and rapid displacement of existing and newly formed forelands [7]. There was an increase in water flow and deepening of the river bed in the largest tributaries. In the river bed, numerous new shelfs and forelands were formed. These typical for the Amur processes intensified after the flood of 2013, aggravating the problems of navigation safety, water supply, resistance of coastal protection constructions and other economic facilities in the vicinity of the cities of Khabarovsk and Komsomolsk-on-Amur.

### 2.3 Anthropogenic factors and problems of protection of river banks from erosion made by floods

Large-scale economic activity in the Amur basin (including regulation of flow by hydroelectric dams, expansion of agricultural areas, logging, fires, etc.) are also the cause of increased activity of riverbed processes. In the lower reaches of the Amur river, the main problem areas are mainly connected with economic effect on the riverbed. Various coastal and riverbed hydraulic structures as well as extraction of sand and gravel mixture contributed to the artificial redistribution of water flow along the branches in the areas of floodplain-bed and riverbed branching. They resulted in more intensive manifestation of erosion-accumulative processes, destruction of banks, passing some secondary branches away. This leads to intensification of undesirable trends in the development of the riverbed.

At present time, there are not enough data for assessing the extent and predicting the reformation of the riverbed to justify the most effective ways and amounts of work for bank and riverbed protection. It is necessary to monitor the riverbed processes on the basis of serious observations for dynamics of distributaries and riverbed banks of the Amur, Ussuri and other rivers for obtaining reliable quantitative data to assess the trend in the development of bed transformations. These observations should also cover the most dynamic parts of the banks of the bordering rivers, where the beds are transforming rapidly.

In connection with the activation of dangerous hydrological processes in the Far Eastern region, the problem of water and economic systems management in extreme conditions is of particular relevance now. In the Amur basin, it is possible to manage water resources quickly in order to mitigate the adverse effects of emergencies. One of the most important method is water release, if necessary, from reservoirs located at different distances from the main bed of the Amur river, as well as the possibility of flow redistribution between the river tributaries. These methods showed high efficiency when they were used during the threat of environmental pollution of the Amur river after the accident in the Songhua river in November 2005. On the territory of the Russian Federation, the example of effective solution to problems of undesirable water flow redistribution between tributaries and protection from banks erosion is the creation of overflow dams in Pemzenskaya and Beshenaya canals in the vicinity of Khabarovsk.

## Conclusions

Thus during the flooding, in the Amur riverbed there indicated high activity of erosion-accumulation processes caused by the transition of considerable water flow. The analysis of space materials and the data of expedition work indicate significant morphological

transformation of riverbeds characteristics. In many parts of the rivers branch erosion intensively developed. The length of the banks with steep erosion ledges sometimes reaches several kilometers, and the amount of erosion runs up to 20 m.

The most significant changes occurred in the Amur river in the section of the branched riverbed. Near the reaches and estuaries of the secondary tributaries accumulative processes intensified. That caused an increase in size and rapid displacement of existing and newly formed forelands. These processes, which are typical for the Amur as a whole, intensified after the flood of 2013, exacerbating the problems of navigation safety, water supply, fixedness of riverside protection structures and other economic facilities.

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