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Issues of channel processes research for the waterways maintenance at unconfined river channels in Russia

Abstract: The article uses the example of the selected reaches of the main Russian rivers to discuss river transport capacity and difficulties in the maintenance of waterways in Russia that arise from the dynamics of fluvial processes. Attention is drawn to changeable river conditions resulting from both natural factors and the presence of hydrotechnical structures. An attempt is made to indicate "natural" river reaches and the ones transformed as a result of damming, which include the accumulation and erosion zones (above and below a dam). It is emphasized that the issues related to the use of waterways are affected by changeable hydroclimatic conditions and the occurrence of ice phenomena.

Keywords: channel processes, channel morphology, sedimentation, bed-erosion, midland waterways, reservoirs

Waterways and the maintenance of the required depths are closely connected with channel processes research. This is why the origin of channel processes as a geomorphological (and hydrological) discipline was initially came from applied engineering.

In Russian scientific literature there is a great variety of terms which come from the Ancient Russian language because in the old times Russian rivers were the most important communication lines. Many terms came from barge haulers. In the Russian classic fiction there are descriptions of river channels and certain difficulties of navigation due to river shallows (for example, in the novels of P.I. Melnikov-Pecherskiy "On the mountains", D.N. Mamin-Sibiryak "The bread", P.D. Bobortkin "Vasiliy Terkin"). Also such descriptions we have in "Life on the Mississippi" of Mark Twain.

More than century old history of channel regulations for waterways maintenance have been done in the rivers until end of 1980 and still have a large impact on navigation conditions. Stream system changes can be due to flow, sediment, or many of the interrelated variables that have produced the modern channel. It has been fully confirmed by certain correlations between recognized channel types and various hydrological and geomorphologic events and variables. Bank erosion, bed shifts, avulsions and human activities cause progressive stages in channel adjustment. These adjustments occur partially as a result of change in stream-flow magnitude and/or timing, sediment supply and/or size, confinement changes, human-induced disturbance, and vegetation changes. Observed changes in channel morphology over time were successfully expressed in terms of stream type changes. Dredging operations are conducted in many Russian rivers, involving the removal of some deposits and transferring them to a peripheral section of the channel. By the end of 1980, the dredging in the country's waterways (total length up to 100 km^2) exceeded 3000 m^3 year along 1 km of the waterway. However, in most cases this has not led to noticeable changes in the morphology of the channel, but it provided for increased stability (Lena, Ob, Severnaya Dvina, Vychegda), and sometimes simplification of their morphology, especially along braided channels. River and conversion of single braided reaches to one-sided reaches due to slits on the branches along the native bank at the Vychegda River are the main examples of the phenomena. To a great extent, changes in the channels are associated with the extraction of sand and gravel from the riverbed and floodplain quarries. This has been produced since the beginning of the 1950s, reaching its highest level in the 1990s. In some rivers, the volume of extracted sand and gravel material is one to two orders of magni-

tude higher than the volume of sediment yield. In the upper 250 km of the highest reaches of the Oka River, 26 major channel quarries have been developed or are in the process of development, each with an average length of 5.5 km.. In the zone of variable backwater at the Novosibirsk Reservoir on the Ob River in northern Siberia (average yearly turbidity 0.35 kg·m-1), the sedimentation rate (1960–1970) was no less than 5 cm/year, and only at the backwater border (280–290 km from the dam) was it approximately 8 cm per year. Today the rate of accumulation here has decreased to 3 cm per year, and the front of regressive accumulation over 45 years moved 150 m. The effect of the regulations work stop for the last 25 years caused 25-30 cm decrease of water level at upper Severnaya Dvina, upper Ob (below confluence with the Charysh river). This also caused significant impact on ice jams formation (Chalov Eds., 2012) – the example again confirmed during the spring flood of 2016 at the Sukhano river and the Veliky Ustug city.

All navigable rivers in free conditions of channel deformations development could be divided into several categories (Chalov, 2004). Each category is corresponded to special plan of channel processes management, abilities of forecast and account of river riffles development:

1. Rivers with natural hydrological regime and regime of channel processes development, which include:

a) Rivers where human impact on the channel processes regime was minimal and consisted only of operational excavation on the reaches of river rifts (among Russian rivers there are Pechora, Mezen', Lena in the middle and lower reaches, Ob' in the middle and lower reaches);
b) Rivers where widespread activities concerning the enhancement of navigation conditions were done (Severnaya Dvina, Vichegda, the Ob' from the confluence of Biya and Katun' rivers up to the Novosibirskoe water reservoir);
c) Rivers under the wide-scale development of channel careers of building materials (Oka, Vyatka, Belaya, Tom');
d) Rivers with canalization sections for the raising of water levels during low-water period (Oka, Moskva).

2. River reaches in the downstream of hydroelectric complexes which include:

a) River reaches with the single or the last in the cascade hydroelectric system (Ob' from the Novosibirskaya hydro power station to the Tom' river mouth, Volga from the Volgogradskaya hydro power station to the mouth, Enisey downstream the Krasnoyarsk city), where there were also organized large-scale works concerning the enhancement of navigation conditions (Chalov *et al.*, 2001);
b) River reaches in the middle of water reservoirs cascades which are situated in the downstream of hydroelectric system and are under the influence of backwater of the system below (Volga between the Nijegorodskiy hydroelectric complex and Cheboksarskoe water reservoir, Kama between the Votkinskiy hydroelectric complex and Nijnekamskoe water reservoir, Enisey between Mainskiy hydroelectric complex and Krasnoyarskoe water reservoir);
c) River reaches in the downstream of single hydroelectric system , but under the influence of the low-head water power system (Don in the downstream of Tsimlyanskoe water reservoir).

3. River reaches upstream the single or the first in the cascade water reservoirs which are under regressive accumulation of sediment (Don upstream the Tsimlyanskoe water reservoir, Ob' upstream the Novosibirskoe water reservoir).

There are few questions arise regarding channel processes monitoring. The systematic surveys are still exist in the Lena, Ob and Severnaya Dvina rivers using contemporary measurement techniques. Both with numerical modeling techniques these data contribute to the feasibility studies of water management in the unconfined rivers. Channel flow partitioning in the braided channels is important parameters which should be adopted into the system of channel processes surveys.

The classification of the channel according the susceptibility to waterways maintenance is the prerequisite for monitoring system. The whole variety of hazardous processes is provoked by one of the certain causes which could be classified either by spatial scale (regional or local) or origin (natural or human-induced).

Thus natural regional (water and sediment flow fluctuations), natural local (log jam formation), human-induced regional (mining, water transfers, dams and hydropower stations) and human-induced local (bridges, pipeline channel crossings) could be recognized as the main effects on fluvial system. Meanwhile they influence on different elements of economical activity, situated in different parts of the river valley: in-channel objects (underwater crossings, etc.), near channel objects (dams, bank levees, wharfs) and flood-plain objects (cities and settlements, etc.). River bank and bottom erosion, flooding of riverine areas, drying and silting of river channels – are recognized to be the main forms of dangerous occurrences of channel processes (Chalov *et al.*, 2015).

Hydroclimatic fluctuations of water flow and sediment causes special impact on gravel bed channels. They are responsible for the corresponding temporal variability of the features and waterways maintenance. For the majority of Russian rivers, long-term low-water period accounts for the transport capacity and induced new limits of navigation along the rock riffles of lower katun, Amur and Enisey rivers (Zaytsev, 1989).

The most drastic problems occur in the downstream reaches below dams. Deposition of most suspended and bed particles leads to a sharp deficit of transported material and intensification of channel erosion. In actual conditions, intensity of channel erosion varies depending on alluvial retention capacity, type of channel sediment (silt, dust, sand, pebbles, boulders, rocks) and distance from a dam. Based on these factors, the average maximum depth of erosion of the channel sediments ranged from 0.3 to 2.0 m per year. The extended reservoir construction is probably the most extended influence on morphodynamic of the largest rivers of Russia (Frolov, 2000).

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