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Results of a Study of Severe Deformation Below the Damless Water Intake Section

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Abstract. The paper presents the results of a full-scale study of the destruction of the banks of the lower section of the damless water intake of the KMCh. The article presents the main factors of coastal destruction during floods and low water periods. As a result of comparing field and experimental data on the intensive process of coastal collapse, a scale factor was obtained for recalculating lateral erosion. As well as studies of the process of intensive local reformation of an easily washed-out channel in the plan, hydraulic schemes for the occurrence of local erosion of the coast have been developed both with a steady and unsteady movement in an open stream. Based on the study results of intense deformation below the section of the damless water intake, recommendations were developed for protecting the banks from erosion.

INTRODUCTION

Natural deformations of river beds mainly occur due to an imbalance in the balance of sediments, both along the length and in the transverse profile of the river bed. The instability of river channels is due to the significant saturation of the river flow with channel-forming sediments, which cause an intensive development of the channel process. Such development is often carried out in directions that inconvenience human economic activity. In some situations, channel deformations cause great damage to the national economy. As an example, the following can be cited: as a result of sediment accumulation at the bottom, the water horizon can rise above the floodplain, which creates a threat of flooding of the cultural lands and settlements located on them. Intensive erosion of the banks, typical of the rivers of Central Asia, also leads to undesirable consequences, such as the erosion of nearby cultivated lands and settlements, the emergence of a threat to ensure normal water intake of irrigation canals at damless water intakes [1-9]. The channel process on the Amu Darya rivers is characterized by special cases of intensive erosion of the banks, caused by short-term dumping of the flow to the coast. In Russian, this phenomenon is called deigish, which means "bad water". Later, this term was extended to all cases of coastal erosion.

RESEARCH METHOD

The study of the results of field and experimental studies in the middle section of the Amu Darya river, assessment of the state of the Amu Darya river bed, the occurrence of local erosion of the bank both during steady and unsteady movement in an open flow is the method of the research of this work.

RESULTS AND DISCUSSION

This study found that the average flow velocity was several times greater than the wash rate determined for the soils crossing the Amu Darya River. The abrupt variability of the flow rate and level, the high velocity, the saturation of the streams with sediment moving along the bottom of the stream and their abrupt change in the nature of migration are constantly changing the stream, increasing the intensity of deformation processes in the plan. As a result of the removal of sediments from the cleaning of sediment entering the Karshi Main Canal, a narrowing of the riverbed in the lower basin is observed, and the left bank is being washed away. Due to the sharp fluctuations of the level, deigish also occurs in this area on the left bank. In this hydraulic process, the wash length was up to 1.5 km [10-17]. The Amudarya has a complex hydrograph in this area, so there may be several types of macro and meso

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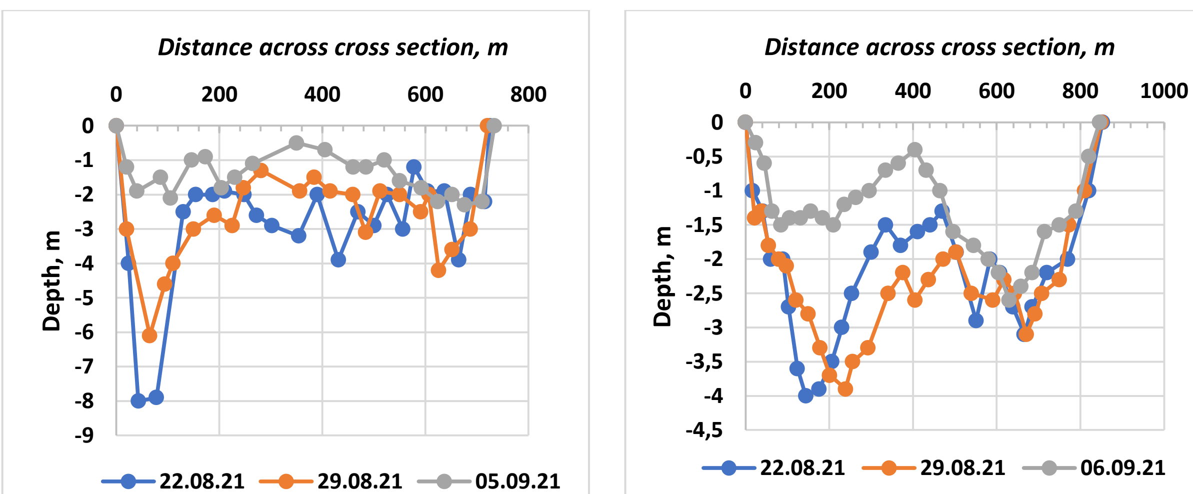
forms in a single section of the river. In particular, changes in the water regime of the river have little effect on the shape of the river, and these cases can be observed when the river regime of the previous regime is preserved.

Hydrometric measurements were carried out in the lower reaches of the Karshi Main Canal to determine the intensity of the flood. At the same time, the displacement rate was 1 m / day when the water level was low and 10-15 m / day when the water level was high. In winter, when the level was high, this magnitude was 4 m per day, ranging from 0.5-1.5 km to 10 km along the coast. In the direction of the stream, the left bank shifted 110 meters to the right during the period from July 7 to September 10, 2021. In 2019-2021, 15-30 meters of the Amudarya riverbank was washed away for 30-40 minutes [1].

FIGURE 1. Observations in the lower reaches of the KMCh dam-free water intake zone to determine the intensity of the riverbed processes

Especially great difficulties arise in the design of head structures with a damless water intake from the Amu Darya, the channel of which, due to the large slopes of the bottom, high flow rates and easy erosion of bottom sediments (represented by fine sandy weak soils), is subject to extremely complex intense planned and deep deformations. To analyze the deformation processes in the depths of the Amudarya River, field observations were carried out in the field of research. Based on this, the dynamics of flow hydraulic parameters were analyzed. The slope of the water level curve in the study area was 0.0002: 0.00025 [18-26].



At the lower of 200 m of the water intake facility | At the lower of 400 m of the water intake facility

FIGURE 2. Dynamics of changes in the cross-section of the bottom of the Amudarya River in the lower part of the catchment area of the KMCh dam

As can be seen from figure 2, the flow is redistributed under the influence of the dam-free water intake main structure, the river bed elevation mark rises on the right and middle banks, and the shores are in the process of reshaping. The graphs of the correlation between water level and flow in this area have a different variable character (Figure 3).

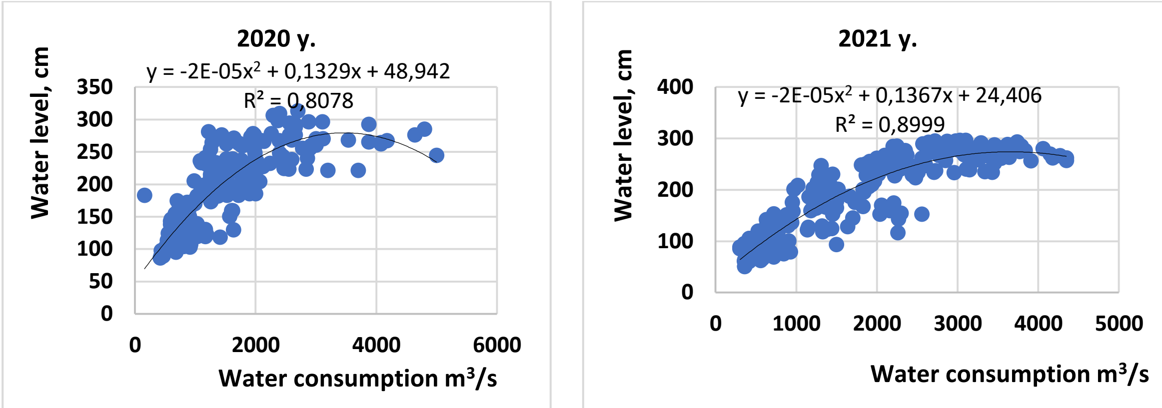


FIGURE 3. Dynamics of the dependence of the water level of the Amudarya on the flow rate in the area of the Karshi Main Canal without dams

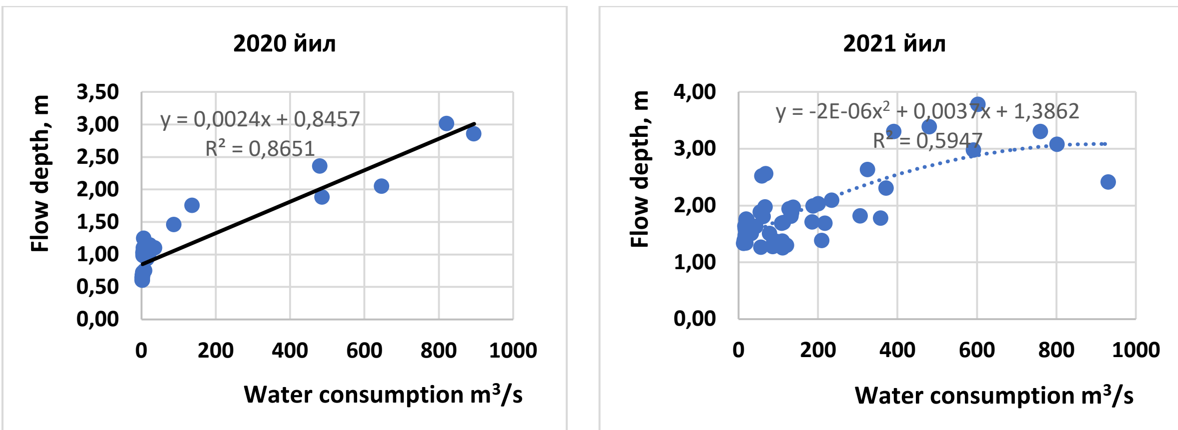


FIGURE 4. Dynamics of depth dependence of KMCh dam intake water flow rate

The situation analysis in Figure 4 shows that the depth at one value of the flow has different values, corresponding to a depth of 1.25 - 2.8 m for a flow of 100 m3 / sec, 400 m3 / sec for a flow of 1.80 - 3.0 m. The dynamics of the change in depth showed that when the water level rises, the height mark of the bottom of the river rises, while in low water, it decreases. Over many years, consumption and the height of the bottom of the stream have remained virtually unchanged. This continuity can be explained by the high saturation of the current with sediment, based on the result in the last graph [27-31].

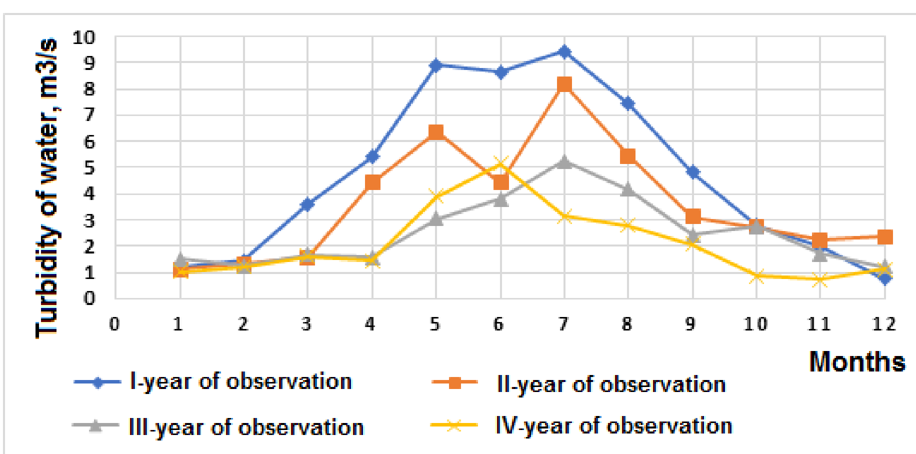


FIGURE 5. Graph of flow turbidity change

The turbidity of the flow reached its maximum values during the spring and summer periods. Maximum clarity of water flow was observed in autumn and winter (Fig. 5).

The results of a comparison of the river's course change over the years showed that the main deigish take place in the left bank area in the lower bay from the so-called water intake facility. The reversal of the flow increases the meandering of the riverbed in the study area. The washing rate has been 20-300 hectares in the last ten years at a width of 100-300 meters. The total washed area in this area is 400-450 hectares, which increases the risk of washing in settlement of Kyzylayak. It should be noted that in the field of study, although the average flow velocity is several times higher than the allowable washout rate for this subsoil through which the river flows, no significant depth deformations occur. The reason for this can be justified by the fact that the stream in the field of the research object is highly saturated with nanos. The first priority measures to prevent coastal erosion are the installation of coastal dams, spurs.

To solve this problem, an experimental study is recommended that can give a specific forecast of channel deformations below the damless water intake of the KMCh. Therefore, we made an experimental study of the structures and the adjacent section of the river channel where the damless water intake is carried out at the KMCh.

A scale of 1:60 was adopted to study unstable and steady motion of the flow. It has been recognized that a 1:60 scale acceptance using the proposed formula is effective in modeling aquifers.

Experimental studies were conducted in 2 series. Initially, the hydraulic parameters of the flow were determined in 5 wells set on a smooth surface, followed by experimental studies on shoreline washing and riverbed adjustment (Figure 6).

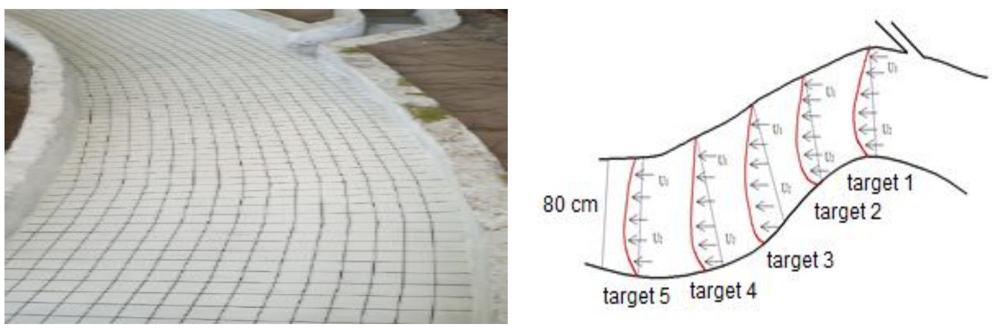


FIGURE 6. View of the flow direction on the smooth surface of the bottom of the stream

In Series 1, the initial state of the flow was determined by the hydraulic parameters without considering the hydraulic resistances in the basin, which initially had a smooth bottom. In the initial case, the GMTsM-1 microverter was used to measure the flow rate in the 1st target and was performed at the 0.6h observation point. Graphs of flow velocity variation were plotted. At the 1st target, the average velocity of the flow was 0.43 m / s, the depth was 3.42 cm, and the cross-sectional area of the stream was 280 cm^2.

Experiments were carried out in a mixed state of turbid sediments: liquid 5.0 cm, flow rate 0.76 m / s, the lower part of which is covered with a mixture of sand, gravel, fine-grained and 3.0-5.0 mm gravel of different fractions. Measurements were made in three verticals of time movement. The maximum flow rate is 17.8 l / s, the maximum liquid flow is 5 cm, and the maximum flow rate is 0.79 m / s. A mixture of sand and gravel was carried out at the height of 1.2 cm and a length of 2.6 m. It was observed that the flow shifted its update to 3 sts and pushed towards the print edge.

Our research work was continued in series 2 by mixing turbid sediments with a model's dispenser.

TABLE 1. Fractional composition of turbid sediments used in experimental studies

Fraction size, mm	1.0	1.0-0.5	0.5-0.25	0.25-0.10	0.10-0.05	0.05
Fractional composition, %	1.5	1.5	12.0	14.0	39.5	31.5

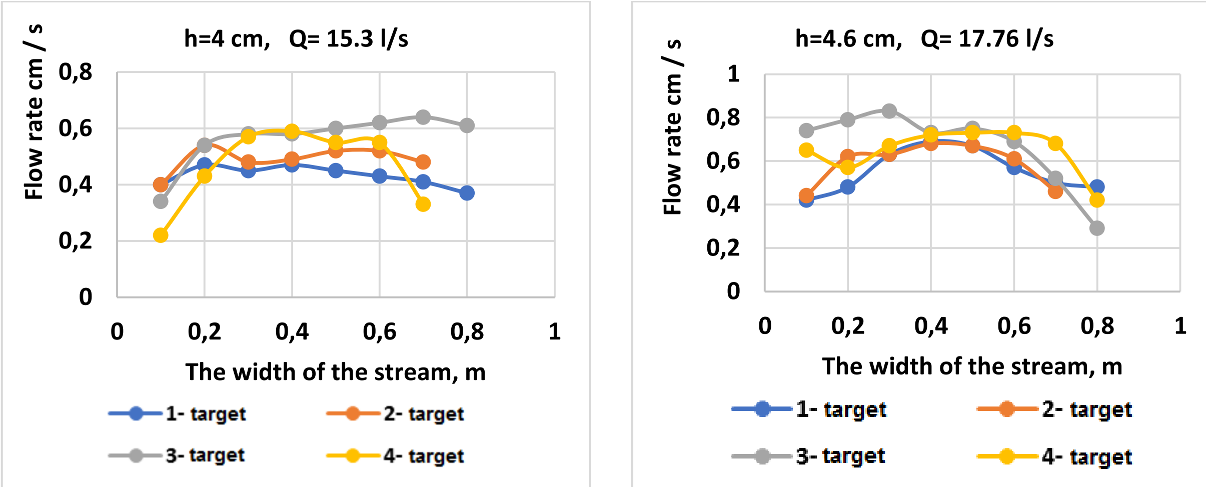
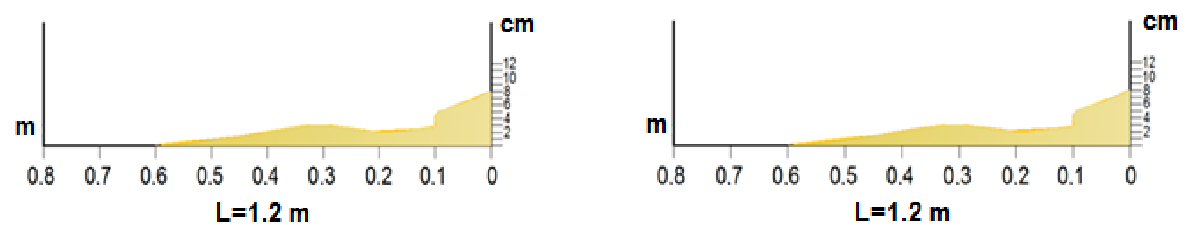
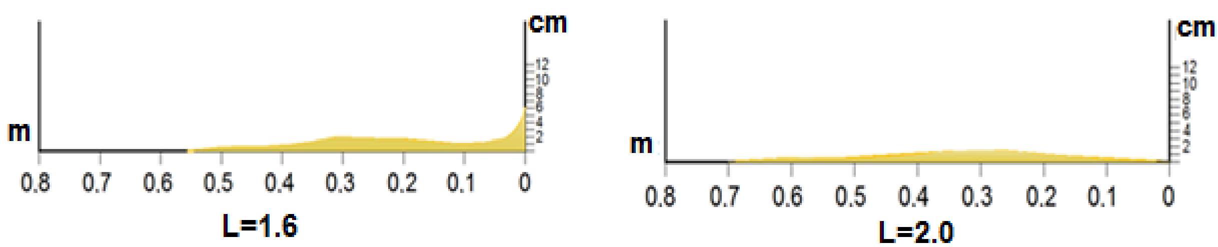


FIGURE 7. Preliminary studies have shown the velocity distribution along the channel width in the presence of turbid sediments

In the 2nd series of experimental studies, our initial observations were made at water consumption of 1.2 l / s. From the 7th minute of our observations, the process of washing the bottom of the river was observed.



$Q = 12\ l/s$, **the first 7 minutes** $Q = 13.5\ l/s$, **time 25 minutes;**



$Q = 15.2\ l/s$, **time 48 minutes;** $Q = 14\ l/s$, **time 68 minutes;**

FIGURE 8. Experimental studies to determine the latitudinal variation of the river bed at different water flows

During the experiment, along with the increase in the volume of water intake, the volume of turbidity entering the water was also increased. This is because many suspended and inlet streams naturally enter from the river sink in the canal bed, leading to a decrease in the moving cross-section of the canal and water permeability (Figure 7-8). When we compare the experimental and field research work, we can see that the condition of the riverbed at the head of the Amudarya KMCh, i.e. the lower part of the dam without water, has changed significantly due to deep and new river processes in the region. In this area, the main riverbed forms a wide meandering stream.

As a result of practical studies of the process of rapid local regeneration of the light-washed basin in the plan, hydraulic schemes have been developed in the stable and unstable movements of the open river in the occurrence of local washing of the coast.

In the area, the most intense local erosion of the banks was observed during the period of the appearance of a characteristic drift loop on the $H = f(Q)$ graph (Fig. 9.). The most intense erosion occurs during the flood recession, when the slopes of the water surface from the rift to the reach, i.e., towards the concave coast, increase 2 - 3 times, and in some cases up to 10 times, and the local speed of the current running on the coast, increase sharply.

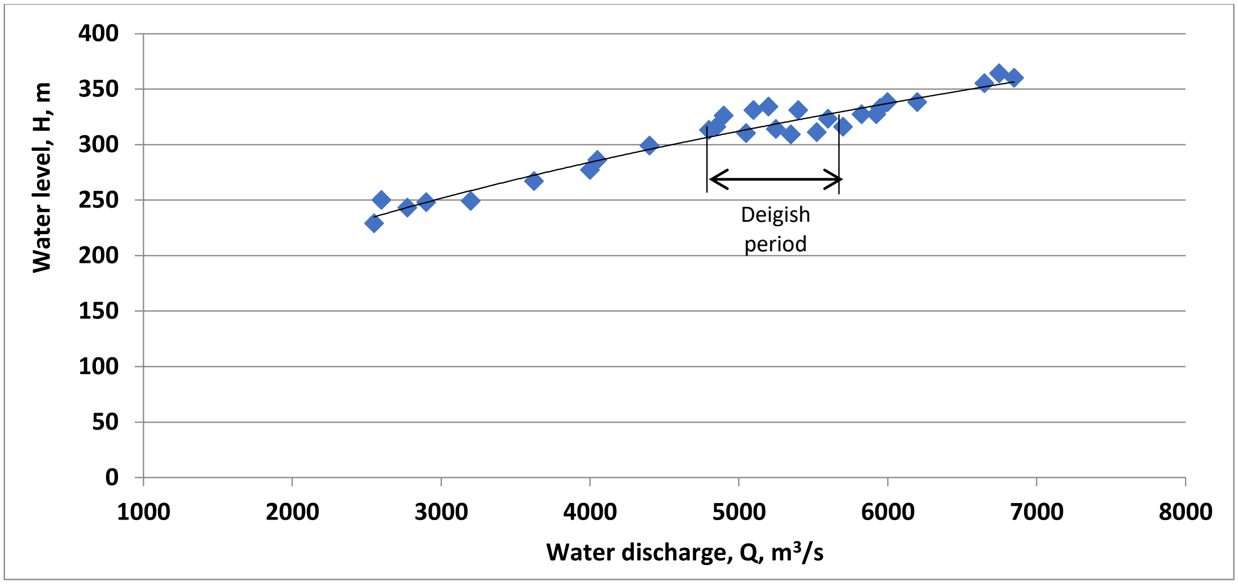


FIGURE 9. Graph of the dependence of the H level on the water discharge Q during the flood period in the deigish zone in the middle section of the Amu Darya river

It should be noted that the wandering of the main channel of the Amu Darya river occurs due to an increase in water intake; river overload is difficult below the water intake section due to frequent discharge of sediments during cleaning into the river floodplain. This led to the deposition and uplift of the channel bottom and intense wandering of the stream and, thus, partially affects the displacement of the main stream to the left bank. As a result of a change in the channel profile, the formation of a dumping doctrine, the main channel wanders along a wide floodplain [12]. A meandering channel is formed in the water intake area and in the coastal zones of intense erosion, especially on the left bank of the river below the water intake section at the KMCh head structure; a deigish is observed. The erosion area for the period 2010-2017 of the left bank of the river below the head water intake of the KMCh is 200-250 hectares with a strip width of 100-300 m. The Amu Darya in this area in the zone of the dumping current of the coastal territory amounted to 170-200 hectares. The total erosion area is 300-450 hectares. Based on the current channel situation in the area of the village Kyzylayak on the rise and fall of the flood due to the intensive change in the planned position and deformation of the main channel, an emergency situation may occur, the destruction of the Kyzylayak settlement [9, 14].

As a result of comparing field and experimental data on the intensive process of coastal collapse, a scale factor was obtained for recalculating lateral erosion in this form [8].

$$M_{\Delta B} = \frac{\Delta B_n}{\Delta B_m} = \frac{M_h^m}{(M_l M_d)^{0.5m-0.5}} \tag{1}$$

where ΔB is channel broadening; M_h is vertical scale of the model; M_l is the planned scale of the model; M_d is the scale of the diameter of soil particles composing the river bed (when modeling fine sandy soils of the Amu Darya river, $M_d = 1$ can be taken); t is a variable indicator that depends on the phase of sediment movement and varies within 1.1 <m <2.

In the zone of intense planned channel deformations when the flow dips to the coast, $m = 2$ and, since in hydraulic modeling of bank erosion $M_l = M_h$, then when using fine sandy soils on the model.

$$M_{\Delta B} = M_h^{1.5} \tag{2}$$

To regulate the river channel with regulatory structures (straightening, etc.), it is necessary to determine the width B and the average depth h_{av} of a stable channel.

As a result of studying the kinematics-morphological regularities of the river flow, formulas were obtained to determine

$$B = A_1 \frac{Q^{\frac{1+2x}{2.5+3x}}}{(gI)^{\frac{0.5+x}{2.5+3x}} * d^{\frac{2x}{2.5+3x}}} \tag{3}$$

$$h_{\mathrm{cp}} = A_2 \frac{Q^{\frac{1}{2.5+3x}} * d^{\frac{3x}{2.5+3x}}}{(gI)^{\frac{0.5}{2.5+3x}}} \quad (4)$$

where A_1 is the kinematic-morphological parameter of the flow width; A_2 is the kinematics-morphological parameter of the flow depth; Q is the estimated flow rate during the deigish period; I is the longitudinal slope of the free surface of the water; g is the acceleration of gravity; d is the average soil diameter; $x = \frac{v_{f.r.} - v}{v}$; $v_{f.r.}$ is the average surface flow rate; v is average speed of the whole stream. The conducted studies of the deigish should allow the development of rational schemes for protecting the banks from erosion.

CONCLUSIONS

Based on the results of the study of the deigish and the observation of the dynamics of the morphometry of the river bed of the water flow in the middle course of the Amu Darya river, the following conclusions can be drawn:

1. Damless water intake structure Under the influence of the main water intake structure without the dam, the flow is redistributed, the height mark of the bottom of the river rises on the right and middle banks, and the process of shoreline reconstruction is underway.
2. It was found that the average flow rate in the area of the main water intake facility without dams of MMC is several times higher than the wash rate determined for the soils crossing the Amudarya river. The abrupt variability of the flow rate and level, the high velocity, the saturation of the stream with nanos moving and suspended along the bottom of the stream, and their abrupt change in the nature of migration are constantly changing the channel, increasing the intensity of deformation processes in the plan. As a result of the removal of sediments from the cleaning of nanos entering the Karshi Main Channel, a narrowing of the riverbed in the lower basin is observed, and the left bank is being washed away. Based on this result, it was recognized that there is a need for more accurate research in the future.
3. According to the results of hydrometric measurements carried out in the lower reaches of the KMCh damless catchment area, the rate of displacement was 1 m / day when the water level was low and 10-15 m / day when the water level was high. When the level was high in winter, this magnitude was 4 m / day. The length of the coast was 0.5-1.5 km to 10 km. In the direction of the stream, the left bank shifted 110 meters to the right during the period from July 7 to September 10, 2021. In 2019-2021, 15-30 meters of the Amudarya riverbank was washed away for 30-40 minutes. Given the value of concrete and steel structures in constructing protective adjustment structures, it is advisable to use local materials.
4. When water is scarce, the main stream flows along the left bank or the water flow on the left and right banks is almost the same. The main stream flows into the coastal zone to the left of the completely dam-free catchment area, forming turbid sediments. This showed the intensity of the processes in the river.

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