Establishment of volume of channel silting and organization of treatment works in the conditions of Amudarya River

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Abstract. The article discusses methods for ensuring guaranteed water intake and the process of sedimentation in the head sedimentation tank. Based on the results of a full-scale study of the supply channel, a recommendation was developed to improve its operation. The results of surveys of the hydraulic and alluvial regimes of sediments in the channel of supply channels are analyzed and summarized as well as the organization of cleaning work and recommendations for the appropriate placement of dredgers along the channel length. The arrangement of dredgers is carried out depending on the distribution of sediment volumes along the length of the channel, taking into account the type and performance of each dredger.

1 Introduction

Predicting the influence of the operating mode of pumping stations on the dynamics and hydrodynamic characteristics of the flow is one of the most important tasks of channel hydraulics. Especially if the water intake is carried out in a damless way, one of the muddiest rivers in Central Asia, the Amudarya. To improve the efficiency of the pumping station and reduce the abrasive wear of pumping units, ensuring a guaranteed volume of water to the pumping station and clarifying the flow in the inlet section of the machine channel is of particular relevance. Carrying out a scientific study to study the dynamics of sediment inflow into the fore chambers of pumping stations, which affects the reliability and operation of the pumping station, to determine the intensity and direction of silting of the channel of the machine channel, reducing its throughput and developing measures to ensure the receipt of a guaranteed volume of water with a minimum amount of bottom and suspended sediments is considered an urgent task for the operational services of pumping stations.

A change in the schedule of the water supply to the pumping station and a change in the hydraulic and alluvial flow regimes in the channel of supply channels significantly change the natural course of the channel process, and a forecast of this change is required. Therefore, the problem of studying channel processes and calculating morphometric characteristics in the channel of the inlet channels of pumping stations, which affect their throughput, has always attracted the attention of many scientists [1-7]. However, despite the abundant work devoted to this problem, its solution is still far from practical completion. The reason for this is the complexity and multifactorial nature of the flow of channel processes occurring in the channels of the supply channels of pumping stations in space and time. In addition, water enters the object of study from the Amudarya River, the water flow of which is characterized by a high degree of sediment saturation [8-11].

2 Methods

The study of the results of field studies in the channel of the inlet sections of the pumping station of the cascade of the Karshi Main Channel and the assessment of the state of the channel's throughput is the research method of this work.

3 Results and Discussion

In the middle reaches of the Amudarya, with a damless water intake, the inlet part of the main channels is heavily covered with bottom and suspended sediments, which makes it difficult to operate water intake units and withdraw water from the river (fig. 1).

Fig. 1. The current view of the water intake facility on the Karshi Main Channel

The fight against sediments is carried out mainly using large fractions of sediments in the head part of the channels and smaller ones - in the initial sections of inter-farm channels. Settled sediments are removed mechanically using electric and diesel dredgers.

The main difficulty that one has to face in organizing the production of treatment works is the determination of the volume of silting of the head and inter-farm settling tanks. The total volume of sediment entering the channel at its inlet is the sum of the volumes of suspended (W_s) and traction ($W_{t.s.}$) sediments, i.e.

$$W_n = W_s + W_{t.s.} \quad (1)$$

The volume of suspended sediments coming from the river into the irrigation system is determined based on the volume of water intake, water turbidity in the river, and the degree of water clarification in the sections of main and inter-farm channels:

$$W_s = \frac{\Sigma Q \rho_0}{\gamma_d} \quad (2)$$

where: ΣQ is the total volume (runoff) of water supply, m^3 per decade or month; ρ_0 is the average ten-day or average monthly water turbidity in the inlet section of the channel, kg/m3; γ_d is the density of bottom sediments (for settling tanks, on average, it is 1250 kg/m3).

The volume of entrained sediments entering the channel, due to the difficulty of measurements, can be taken as a percentage of the volume of suspended sediments. According to our measurements, the flow of traction sediments in the section of the Amudarya River in the head part of the Karshi Main Channel was 10...28%, in the area of the head part the Amu-Bukhara Main Channel 5...37%. In the calculations, approximate values of the water consumptions of traction sediments in the intra-annual context can be taken: during the flood period - 15 ... 20 and during the low water period - 20 ... 27% of the flow of suspended sediments [12-20].

The total volume of sediments entering the irrigation system for a decade or a month, taking into account the suspended and traction sediments, can be determined by the formula

$$W_n = \frac{\Sigma Q \, \rho_0 (1 + K_g)}{\gamma_d}, \quad (3)$$

where: $K_g = (0.15 \ldots 0.2)$ during the flood period; $K_g = (0.2 \ldots 0.27)$ during low water period.

The volume of siltation of the head sedimentation tank is set taking into account the retention in it of the full flow of tractable and part of suspended sediments:

$$W_з = \frac{\Sigma Q \, \rho_0 (\eta_b + K_g)}{\gamma_d}, \quad (4)$$

where: η_b is the degree of water clarification in the outlet section.

The value of the water clarification coefficient is determined according to the data of calculations or special field observations of the silting regime of the head sedimentation tank according to the dependence:

$$\eta_b = \frac{\rho_0 - \rho_{out}}{\rho}$$

where: ρ_{out} is the turbidity of water in the outlet of the sump.

When calculating the volume of silting of the head settling tank, the turbidity at the inlet section of the channel (ρ_0) is assumed to be equal to the turbidity of the river in the section of the water intake, established according to the data of the nearest gauging stations of the Hydraulic System Control (HSC), and the calculated turbidity at the outlet of the settling tank (ρ_{out}) is equal to the critical turbidity (corresponding to the transporting capacity (ρ_t) of the flow in the protected from channel silting) multiplied by the channel efficiency (K_c), i.e.

$$\rho_{out} = \rho_t \cdot \mathrm{K_c}$$

In the absence of data to establish ρ_{out} and $\mathrm{K_c}$ the coefficients η_b and Kg can be taken according to the data obtained by us on the example of Karshi Main Channel and Amu-Bukhara Main Channel. The volume of suspended sediments transiting the downstream sump (W_T), is the difference between the volume of sediments that passed through the inlet (3) and deposited in the sump (4):

$$W_T = W_n - W_{sil} = \frac{\sum Q\ \rho_0(1+\eta_b)}{\gamma_d} \quad (5)$$

The volume of the finest fractions of sediments passing through all channels of the irrigation network (including on-farm channels) and carried to irrigated lands can be determined from the dependence

$$W_0 = \frac{K_c K_n \sum Q \rho_0 (1-\eta)}{\gamma_d}, \quad (6)$$

where: K_c is the efficiency of the irrigation system (from the head sedimentation tank to household sprinklers); K_n is a coefficient that considers the settling of part of the sediment under the influence of the backwater of hydraulic structures.

The total volume of silting of inter-farm and on-farm channels, representing the difference between the volume of sediments passing through the head sedimentation tank and sediments carried to irrigated lands, can be determined by the expression

$$W_M = W_T - W_0 = (1 - K_c K_n) \frac{\sum Q \rho_0 (1-\eta_b)}{\gamma_d}, \quad (7)$$

In preliminary calculations, concerning the conditions of the Amudarya River in its middle course and clay and silt particles prevailing in the fractional composition of sediments (more than 80%), one can take

$$K_c \cdot K_n \approx \eta \cdot \rho\ \% \approx \frac{0.4 * 83}{100} \approx 0.33$$

For the timely removal of sediments, it is recommended to clean the head section of the inlet part of the channel with high-performance dredgers united in a group developing a single macro bottom, and downstream, where the volume of siltation is less, proceed to clean with micro bottoms evenly distributed along the length of the channel.

To ensure sufficient uniform loading of dredgers and maintain the required throughput of the channel during the active growing season, it is necessary to periodically change the organization of cleaning as follows. During intensive sediment inflow (May-August), the head sedimentation tank should be cleaned using a trench method to an incomplete width and during the low water period (September-April) - to the full extent. At the same time, the optimal number of dredgers, and the place and size of the bottoms along the length of the channel are determined from the condition of balancing the volumes of silting and cleaning:

$$\Sigma W_{sil} = \Sigma W_{cl}$$

where: W_{sil} is the total volume of siltation, m^3/year; $W_{оч}$ is the total volume of treatment, m3/year;

In the intra-annual context, it is practically impossible to maintain a balance in the volumes of silting and cleaning due to the uneven flow of sediments over time and the limited number of dredgers.

The settling tank's length, width, and depth (dredging faces) are assigned depending on the modes of sediment inflow and settling and the technical parameters of the dredgers and are set for each stage in the following sequence.

1. The average monthly volumes of silting and cleaning are determined

$$W_M = \frac{\Sigma W_{sil}}{12}$$

2. Required number of dredgers per channel section per month

$$PK_n W_{\mathrm{M}} = P_1 N_1 + P_2 N_2 + P_i N_i.$$

where: P is the proportion of sediments deposited along the channel sections, % (for Karshi Main Channel it is determined according to the data in table 1); K_n is the coefficient taking into account the unevenness of cleaning: for the period April-August $K_n = 1.2$, for other months $K_n = 0.8$; $P_1, P_2 \dots . P_i$ is the average actual productivity of dredgers; $N_1, N_2 \dots . N_i$ is the number of dredgers.

Table 1. Change in the average values of the volumes of silting and cleaning along the length of the inlet part of the Karshi Main Channel

Channel section	Inlet - 0	0-20	20-40	40-65	65-103	103-PS-1	Total, %
Cleaning	22.3	51.7	3.4	8.6	8	6	100
Silting	12	46	27	6	3	6	100

3. Optimal length of the cleaning section in the sump, providing high productivity of dredgers and throughput of the channel

$$L_1 = \frac{P \cdot W_M}{\Delta B \cdot \Delta H}$$

where: W_M is the average monthly volume of silting or cleaning; ΔB *and* ΔH is the width and depth of suction faces.

4. Optimal bottom hole sizes ΔB and ΔH from the technical parameters of the dredger and channel, according to the conditions

$$B_{min} \leq \Delta B \leq B_g$$
$$H_{min} \leq \Delta H \leq H_{max}.$$

where: B_g is the width of the sump along the bottom; $B_g = B_n - 2mH$ (B_n is the width of the sump channel along the water line; m is the laying the slope; H is the greatest depth of water in the channel sump); $H_{max}, H_{min}, B_{min}$ - the maximum and minimum depth and width of the dredgers of the faces, which are equal to:

$$H_{max} = 10 \dots 12\ m, H_{min} = 2 \dots 3\ m \text{ and } B_{min} = 20 \dots 45\ m.$$

Thus, the dependence makes it possible to establish the volumes of silting of the brain of the sump and inter-farm absorptions in the case of incorporeal water intake and to determine the number of dredgers and the size of the faces for organizing cleaning work according to the channel structure.

4 Conclusions

Based on the results of field studies conducted in the Karshi Main Channel, based on an assessment of its passability, the following conclusions can be drawn:

1. The maximum water consumption of Karshi Main Channel for 3 years was 195 m^3/s; the average annual water consumption is 120 m^3/s: 150 m^3/s; that is, the minimum water consumption is 45 m^3/s.
2. Considering the mode of operation of pumping stations, a method has been developed for determining the dynamics of sedimentation of turbid liquids along the length of the water supply channel. As a result, it was possible to increase the efficiency of the use of submersible apparatus and units of pumping stations.
3. To reduce the sediment inflow into the Karshi Main Channel inlet channel, it is necessary to reconstruct the channel structure of the inlet section in such a way that, by improving the circulation of runoff in the river, the runoff with the main part of the turbid runoff is directed down from the water intake structure of the river, and part of its runoff with less turbid runoff enters into the channel. Also, important tasks are developing hydraulic schemes for the placement of dredgers to improve the working conditions of the sump, and increase the channel's culvert capacity.

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