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Hydraulic modes of damless water intake

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Abstract. The article is devoted to the study of the influence of the damless water intake on the hydraulic and alluvial regime of the river, the channel of which passes through easily washed out soils. The analysis of the dynamics of the river bed morphometry and hydraulic elements of the flow in the area of the damless water intake is carried out. As a result of the analysis of the data of long-term field studies and hydrometric measurements at the closest section to the damless water intake and in the area of the damless water intake of the Amudarya River, functional relationships were established between the morphometric parameters of the channel and the hydraulic parameters of the flow. The dynamics of the Shezi coefficient, hydraulic resistance, and the channel roughness coefficient in connection with the hydrodynamic characteristic of the flow are established.

1. Introduction

Land reclamation, the development of irrigation in a hot region and global warming on the planet lead to an increase in water intake from natural drains. Especially if the region is characterized by a hot climate, then against the background of global warming, an increase in temperature is observed, which leads to a sharp increase in water consumption in the country's agriculture. Usually, of two methods: dam and damless water intake from the river, very often due to relatively lower construction costs, the second method is used. It should be noted that non-dam water intakes are quite simple in a constructive sense, require less construction costs, and have a lesser effect on the reformation of the river channel in the zone of influence of the head water intake as compared to the dam water intakes. The foregoing contributed to the introduction of efficient schemes of damless water intakes into the practice of hydraulic engineering in Uzbekistan [1, 2]. As a result of an increase in water intake from the river, intensive channel processes with an irreversible character occur throughout its flat part [3 – 7]. Channel processes, in turn, complicate the guaranteed volume of water withdrawal from the river and very often contribute to the ingress of more than the permissible amount of bottom and suspended sediments into the head structure and the supply channel of pumping stations [4 – 12]. Due to the complexity of managing these undesirable processes, the solution to this problem remains relevant. The object of the study is the channel of the Amudarya river in the area of the damless water intake in the Kaskad-Karshi Main Canal (KKMK) transporting water to the Kashkadarya valley. The KMK, consisting of six pumping stations, is a unique hydraulic engineering complex. In this complex, for the first time in the hydraulic engineering practice of Uzbekistan, powerful hydraulic units with axial pumps were installed, each with a capacity of $Q = 40\ m^3/s$, with a head of $H = 24m$. The total

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withdrawal of water from the Amudarya with a damless water intake during the year is 5.1 km3. Together with water, bottom and suspended sediments with a volume of 12-16 million m3 enter the head structure. To reduce solid abrasive sediment particles entering with water through the pumps, a double expansion of the section of its channel for 2 km is provided in the head of the supply channel of the pumping station, where the speed of water flow decreases from I to 0.4 m / s, this provides intensive precipitation of the largest suspended particles (from 60% of the total solid runoff). Smaller ones are deposited on the rest of the 18-kilometer route of the channel of the supply channel, which is connected by a 1-kilometer-long settling tank. Cleaning of the channel of the bucket of the inlet channel is carried out depending on the water intake schedule throughout the year, as well as on the basis of the planned loading of dredgers. Maintaining the channel bed section in the design dimensions should ensure stable constancy of the nominal water horizons at the first pumping station of the KKMK, which ensures a stable operation of the pumps of the entire cascade, allows for rough adjustment of sediment, and the water taken for irrigation should adapt to the wayward nature of the Amudarya. Over the years of operation, significant changes have occurred. The current difficulties with water intake have led to a sharp drop in the water level; at the head first pumping station, they caused a violation of its operation mode (cavitation destruction of pumps, a decrease in water supply, an overconsumption of electricity, a decrease in the motor resources of pumping units, etc.). In this case, ensuring the highly efficient operation of the KMC cascade primarily depends on its channel. Due to the change in the hydrological and sediment regime of the Amudarya River, currently the amount of incoming sediment is 25 million m^3 per year [12 – 17]. They create the main obstacle to the implementation of uninterrupted damless water intake, especially during the summer growing season. The reason for this is the problem of operation that has arisen - the difficulty of the guaranteed and clarified volume of water in the pumping station KKMK [17 – 23].

The problems of protecting the head structures of damless water intakes, water intake waterworks from entrainment of channel sediments (suspended and bottom) are especially acute when water is taken from rivers, the channel of which passes through easily washed out soils, transporting a large amount of alluvial material of large fractions [9, 10, 6]. Providing high-quality water intake, with the least possible entrainment of river bed sediments to the head structure of the damless water intake for the purpose of uninterrupted supply of clarified water to the first pumping station of the KMK and other irrigation canals, can be attributed to the number of complex problems of channel hydraulics. The reason is the complexity and multifactorial nature of channel processes in time and space [6]. At present, on the basis of well-known theoretical developments, carried out extensive scientific studies of the processes occurring in the river bed in the area of the damless water intake, begun in the last century [11-16] by domestic and foreign scientists, a large number of layout schemes for water intake have been proposed and introduced into the practice of hydraulic engineering hydrosystem with different operational characteristics [15]. Despite the extensive scientific basis of the issue under study, it has not yet been possible to completely solve the problem of sediment control in the head structures of pumping stations with damless water intake. This circumstance allows the authors of this work to conclude that there are no unambiguous recommendations in the scientific literature on the design and operation of various types of anti-load structural elements in the head structures of damless water intakes. To make the most correct solution to this problem of channel hydraulics, it is necessary to have an idea of the dynamics of the hydraulic and alluvial regime of the research object. Based on the foregoing, the main goal of this work is determined - to establish a regularity between the main parameters of the flow and the river bed.

2. Methods

Analysis of the data of field studies carried out in the area of the damless water intake and the establishment of a pattern between the main parameters of the flow and the river bed by methods of mathematical statistics is the main method of research in this work.

3. Results and Discussion

As a result of water withdrawal in the area of the damless water intake, an intensive channel process and irreversible channel deformations take place, which increasingly complicate the guaranteed water withdrawal to the first pumping station of the KPS KMK.

In the area of the damless water intake, intensive planned channel processes take place; above the water intake, the channel gradually moves towards the left bank, trying to move away from the water intake point into the KMC cascade. Below the water intake point, the channel intensively erodes the left bank, gradually approaching the village of Kyzylayak.

In this channel setting, the chronology of water discharge in the area of the damless water intake is as follows:

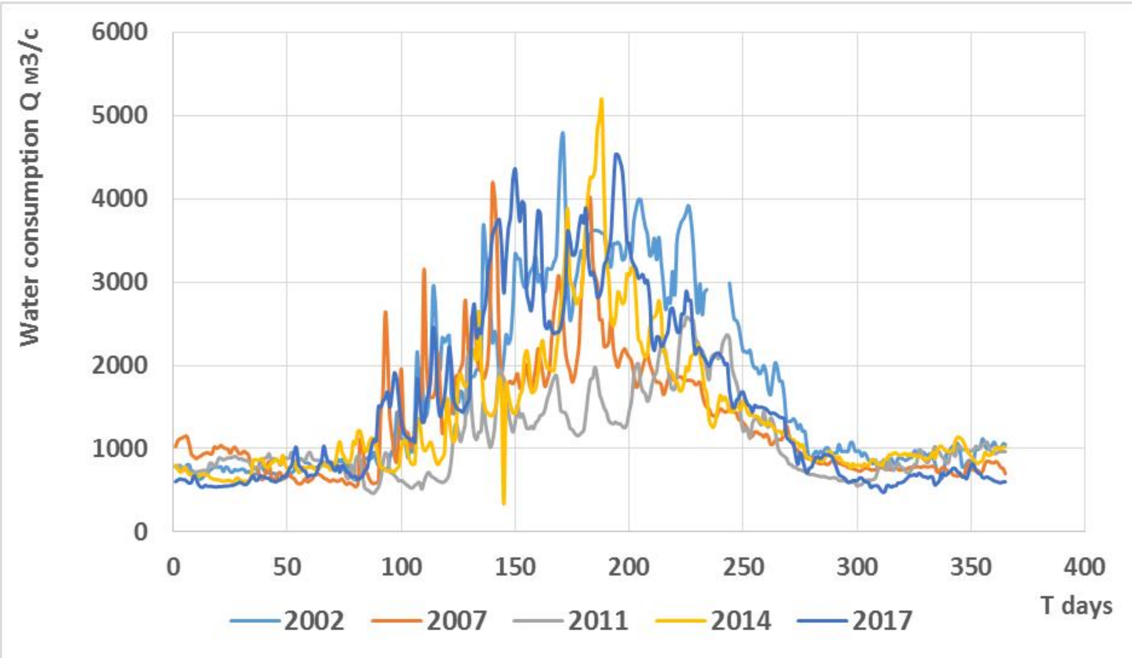

Figure 1. Chronology of water discharge in the area of the damless water intake at the KMK

Judging by the chronology of the water discharge in the area of the damless water intake at the KKMK, one can observe its sharp change.

The highest average annual water discharge was observed in the following years: in 1983 - 1905 m^3/s; in 1984 - 2210 m^3/s; in 1985 - 2052 m^3/s; in 1992 - 1995 m^3/s; in 1998 2035 m^3/s; 2002 1658 m^3/s; 2005 1936 m^3/s; 2010 1993 m3/s; 2015 1719 m^3/s;

Accordingly, low water discharges fell on: 1986 985 m3 / s; 1989 885 m^3/s; 1994 955 m^3/s; 2001 1064 m^3/s; 2008 850 m^3/s; 2011 1107 m^3/s;

Change in the daily water level of the river. The Amudarya shows that it is characterized by sharp ups and downs. During a rise in the water level, the water intake at the KMK is favorable, and during the decline, the water intake conditions deteriorate, associated with the departure of the flow from the water intake point... The nature of the change in the level of the river in the KMK area on a daily basis for 2018. As follows from this figure, up to 16 large and small peaks of the rise and fall of the water level were observed on the river in the KMK area during the year of observation. The rise in water level with some declines continued until August, and starting from mid-August, general decreases in water level and discharge were observed and continued until October.

Subsequently, there was a certain low-water rise associated with the descent from the Nurek reservoir of water flows associated with the generation of electricity for the needs of the national economy.

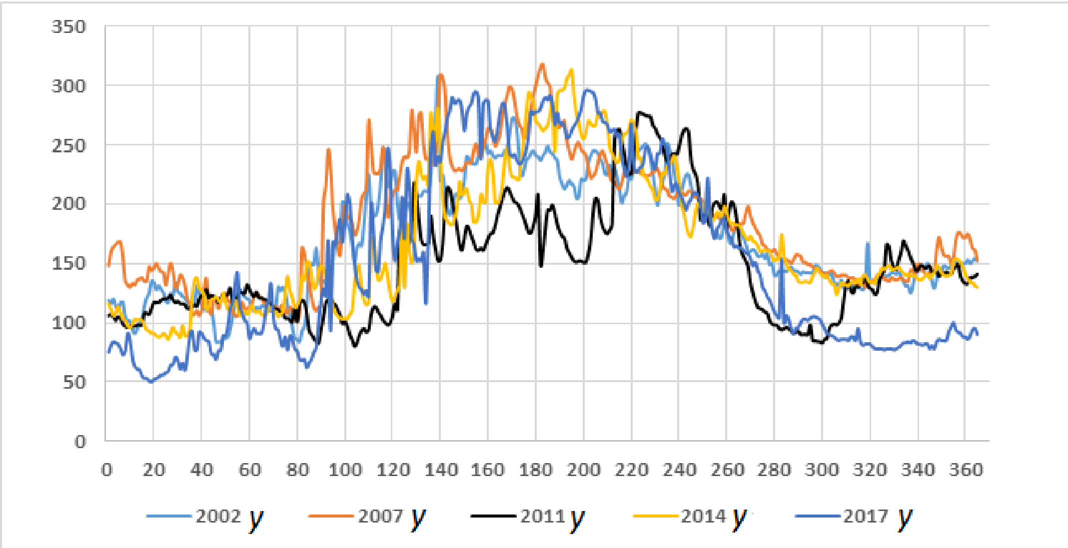

Figure 2. Chronology of the water level of the Amudarya river in the area of the damless water intake at the KMK

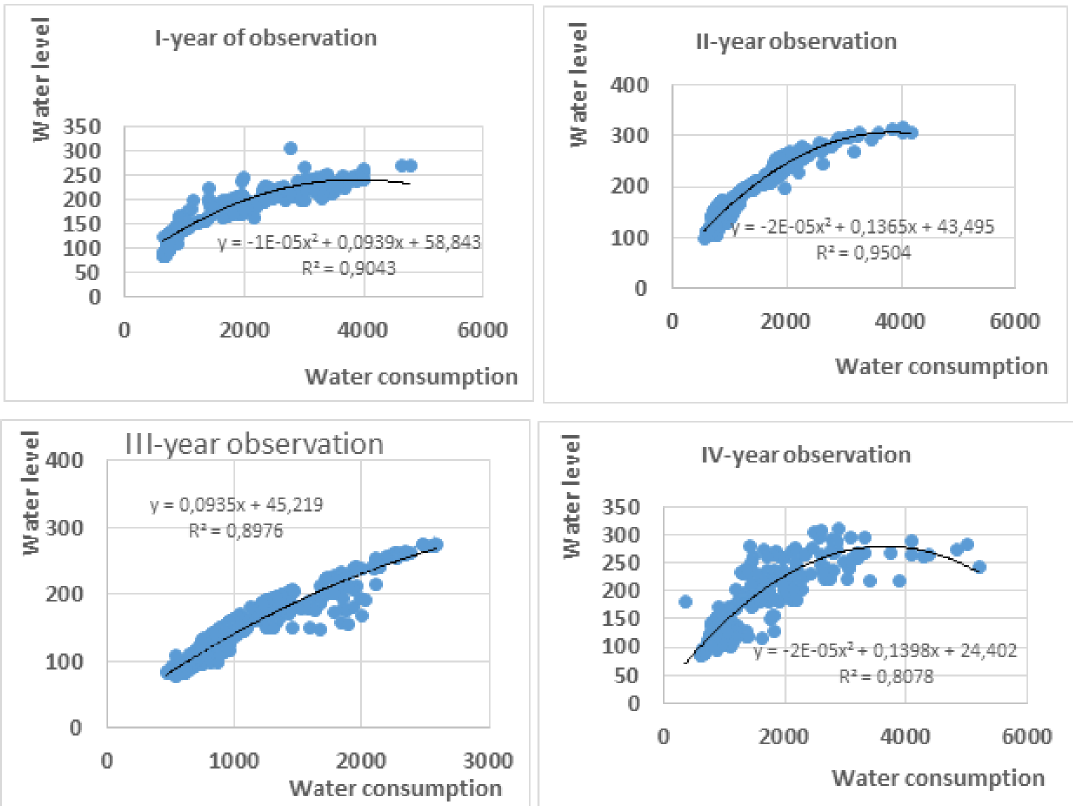

Figure 3. Flow rate versus level graph

An increase in the water level leads to an increase in the average flow rate, which contributes to the beginning of the erosion of the right bank of the river above the water intake point. The washed-out product from the left bank is carried by the water flow towards the right bank and it is deposited at the points of the channel where the water velocity is less than the average or less than the transporting capacity of the flow.

At different verticals, the flow depths have a wide range of variation. The depth of the stream will vary from about 4m to 6 meters. Closer to the right bank, which is not washed out, the depth is of great importance.

As a result of channel deformations and the movement of products of the left bank, after the passage of the flood period, in the low-water period above the water intake point in the river bed, interstices with different sizes are formed. The average depth and width of the river flow in the water intake area is also non-stationary.

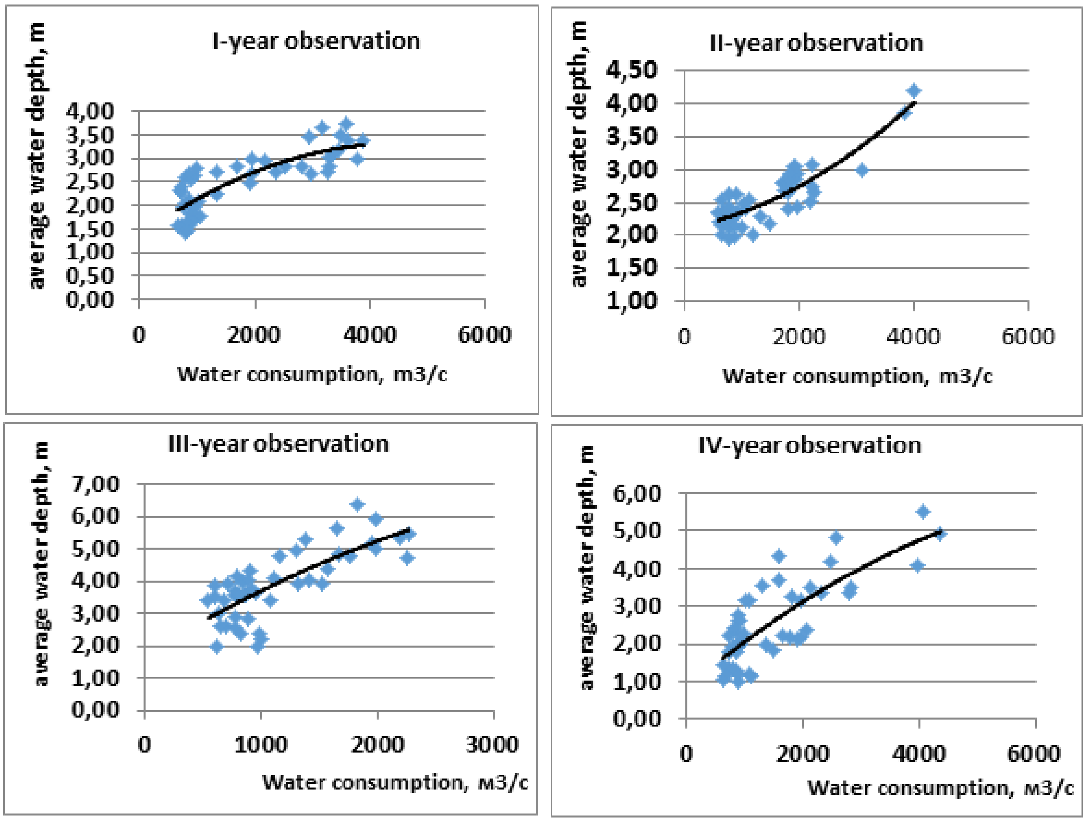

Figure 4. Graph of the relationship between water flow and flow depth

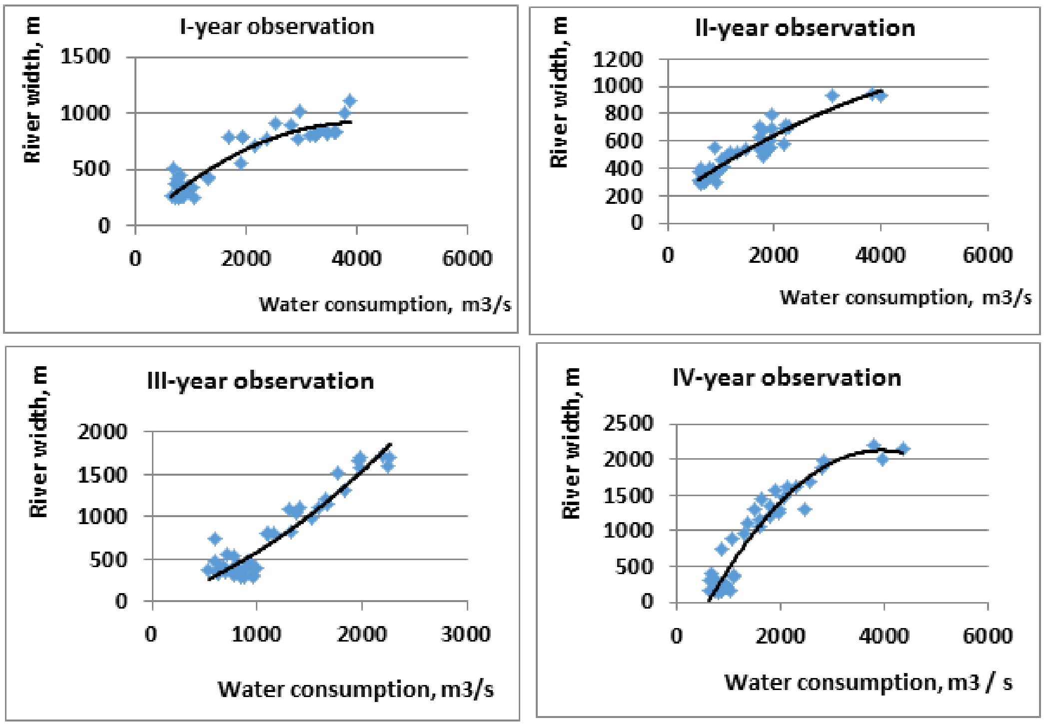

Figure 5. The graph of the relationship between water discharge and the width of the Amudarya river bed in the area of the damless water intake of the KMK

The turbidity of water or the content of solids in one cubic meter of water is an indicator of the transport capacity of a stream. In accordance with changes in the conditions for the formation of liquid runoff and the water content of the river, the turbidity of the water in the river Kerki section is 3.3 kg / m3, varying within 1.7 – 5.1 kg/m^3.

The maximum observed turbidity was noted on May 13, 1969 and was 22 kg/m^3. The number of days with turbidity exceeding 1.0 kg/m^3 can be up to 330 days.

The increase in turbidity begins in March, the maximum values are observed in May-June. The decrease in turbidity continues until the end of September.

To determine the coverage area of the resulting curve, the upper and lower envelopes are built. To reconstruct the turbidity values in the KMC head depending on the turbidity in the Pulizindan section, the middle curve is used for low turbidity values, and the upper envelope for large values.

The monthly average turbidity values for the average maximum and minimum distribution are given in Table 1 and Table 2.

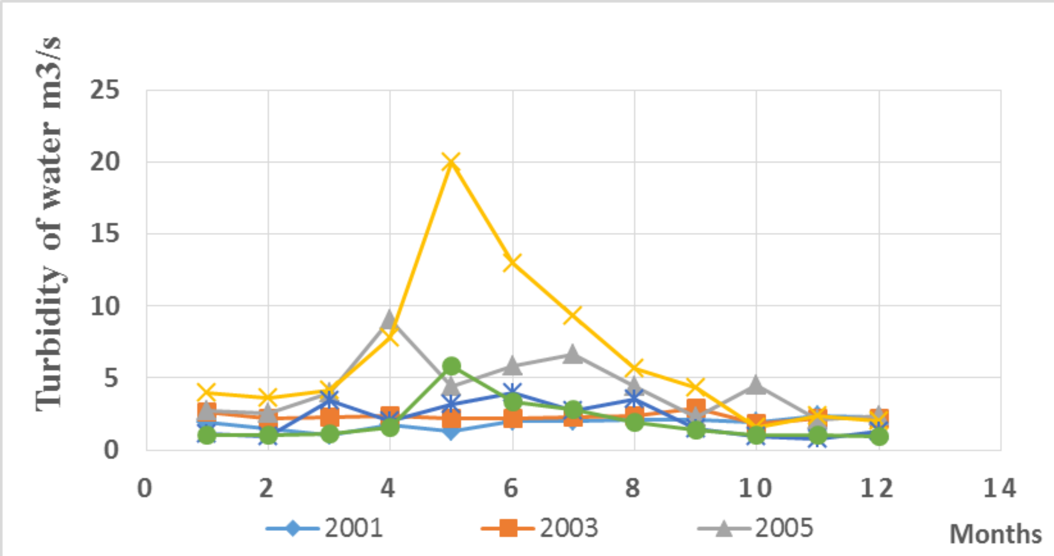

Figure 6. Average monthly water turbidity of the Amudarya river st. Kerki

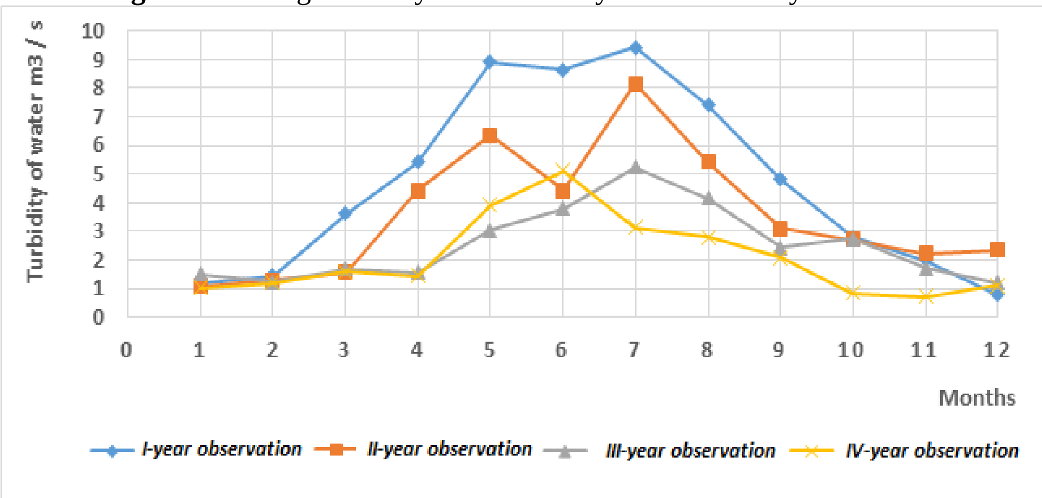

Figure 7. Average monthly water turbidity of the Amudarya river – gauging station Pulizindan located 18 km above the gauging station Kerki

The results of the study made it possible to determine the quantitative ratio of bottom sediments to suspended sediments. It ranges from 18 to 35%. In the section of Cape Pulizindan, where the main water intake at the KMK is located, the average long-term water turbidity, according to field measurements, is 3.58 kg / m^3. The measured average daily turbidity of water in the river for 2002-2017 years of observations was 5.12 kg / m^3. At the same time, the average long-term annual flow of suspended sediments of the Amudarya near Cape Pulizindan amounted to 23 million tons. This is 6 million tons more than the design. A distinctive feature of the regime of the Amudarya River is the significant content of solid material in the flow. This is due to the intense flat washout in the river basin and also an active channel process in the channel itself. The variability of the morphometric and hydraulic characteristics of the flow, associated with changes in the water content, determines the large transport capacity of the river.

The highest value of sediment discharge can reach up to 95000 kg / sec. The average annual value of suspended sediment discharge for a long-term period is 6500 kg/s.

The annual sediment runoff over a long-term period is 210,000 thousand tons or 168 million m^3, which gives an average washout from the basin area of 650 t/km^2 or 520 m^3/km^2.

The fractional composition of sediments is formed both in the river basin and in the channel. Both the total turbidity and the fractional composition of sediments in the river are continuously changing (Table 1, 2). Therefore, for the most correct characterization of them, it is required to have data from a larger number of observations.

The mechanical composition of suspended sediments undergoes significant changes along the length of the river, this is due to the hydraulic characteristics of the flow and the transporting capacity of the river. Usually, along the length of the river, the fractional composition decreases. This is especially true for fractions less than 0.01 mm.

There is also a change in the fractional composition depending on the change in water content, i.e. from the season. Due to the fact that turbidity during the low-water period is mainly formed due to channel re-sedimentation, an increase in large fractions is noted during this period. Therefore, a special grouping of the mechanical composition according to the size for long-term periods (large, medium and small) has been made. The data are taken from the Kerki gauging station and are given below.

Table 1. Distribution of water turbidity per year (kg/m^3)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Wed.	2.3	2.0	3.19	4.60	4.85	4.55	4.25	3.44	2.35	2.0	1.90	2.20
Max.	2.3	2.2	4.0	5.70	4.20	4.70	4.90	4.20	2.80	4.30	1.90	2.20
Min.	1.10	1.00	2.70	2.00	3.00	4.00	2.70	3.54	1.50	1.00	1.00	1.30

Table 2. Fractional composition of suspended sediments of the Amudarya river – Kerki section

Composition	Distribution	Fractional composition (mm) and content by weight					
		1.0-0.25	0.25-0.10	0.10-0.05	0.05-0.01	0.01-0.005	<0.005
Large	1	1.0	13.7	31.0	32.1	15.0	7.2
	2	1.3	13.8	31.5	31.0	10.0	13.4
	3	1.2	13.5	30.1	31.0	11.0	14.2
	4	3.0	14.2	29.4	28.7	14.0	10.7
	Average	1.5	13.8	30.5	30.7	12.5	11.0
Middle	1	0.8	3.5	19.4	24.8	35.8	10.7
	2	1.3	3.6	18.9	30.1	28.0	19.1
	3	1.2	2.8	20.1	27.6	29.8	18.5
	4	1.8	0.9	8.1	20.2	42.1	26.5
	Average	1.3	2.7	16.6	26.7	33.9	18.8
Small	1	0.5	1.6	12.0	7.2	40.3	38.4
	2	0.5	0.6	3.5	13.0	45.8	37.6
	3	0.5	1.0	5.9	12.1	45.6	35.9
	4	0.3	1.8	4.5	7.8	41.8	43.8
	Average	0.5	1.1	6.5	10.0	43.0	38.9

4. Conclusions

Based on the discussion of the results of monitoring the dynamics of the river bed morphometry and the hydraulic parameters of the water flow of the damless water intake into the Cascade-Karshi Main Canal, the following conclusion can be drawn:

The water discharge in the area of the damless water intake during the year varies in a wide range and has a sharply variable character;

1. The relationship between the morphometric parameters of the channel and the hydraulic parameters of the flow in the area of the damless water intake at the KMK is unstable;
2. The depth of the flow varies rapidly over a wide range;
3. Above the water intake points on the right bank of the river, intense deformations occur, as a result of the washed-off product in the water intake area, midges of various sizes are formed. This circumstance complicates guaranteed water withdrawal for the head structure;

4. On the left bank, below the water intake point, erosion occurs, contributing to the diversion of the river bed to the left side of the water intake point and erosion of cultural areas and settlements of the neighboring state;
5. To prevent these negative phenomena, it is necessary to conduct experimental and numerical studies aimed at regulating the direction of the flow and the nature of planned deformations in the area of the damless water intake.

References

[1] Averkiyev, A.G. Besplotinnyye vodozabornyye sooruzheniya //I.V.Averkiyev, I.I.Makarov, V.I.Sinotin. – L.: Energiya, 1969. – 164 s.
[2] Rumyantsev, I.S. Nauchnyy obzor izuchennosti voprosov proyektirovaniya i beznanosnoy ekspluatatsii besplotinnykh vodozabornykh gidrouzlov / I.S. Rumyantsev, A.V.Klovskiy // Mezhdunarodnyy tekhniko-ekonomicheskiy zhurnal. – 2014. – N 2. – S.101-106.
[3] Bondarenko, V.S. Razrabotka i issledovaniya besplotinnogo vodozabora dlya rek s tyazhelymi gidrologicheskim i nanosnym rezhimami: dis. ... kand. tekhn. nauk: 05.23.07 / Bondarenko Vladimir Stepanovich. – Novocherkassk, 1975. – 212 s.
[4] Daneliya, N.F. Vodozabornyye sooruzheniya na rekakh s obil'nymi nanosami / N.F.Daneliya. – M.: Kolos, 1964. – 336 s.
[5] Klovskiy, A.V. Nekotoryye puti sovershenstvovaniya gidravlicheskikh usloviy raboty besplotinnykh vodozabornykh gidrouzlov s donnymi tsirkulyatsionnymi porogami / A.V.Klovskiy, I.S.Rumyantsev, D.V.Kozlov // Prirodoobustroystvo. – 2015. – N 3. – S.45-52.
[6] Bazarov, D.R., Vokhidov, O.F., Lutsenko, L.A., Sultanov, S. Restrictions Applied When Solving One-Dimensional Hydrodynamic Equations. Proceedings of EECE 2019, Lecture Notes in Civil Engineering 70. 2019. Pp. 299–305. DOI:10.1007/978-3-030-42351-3_26.
[7] Bazarov, D., Norkulov, B., Vokhidov, O., Uljaev, F., Ishankulov, Z. Two-dimensional flow movement in the area of protective regulatory structures. IOP Conference Series: Materials Science and Engineering. 2020. 890(1). DOI:10.1088/1757-899X/890/1/012162.
[8] Mamajonov, M., Bazarov, D.R., Uralov, B.R., Djumabaeva, G.U., Rahmatov, N. The impact of hydro-wear parts of pumps for operational efficiency of the pumping station. Journal of Physics: Conference Series. 2020. 1425(1). DOI:10.1088/1742-6596/1425/1
[9] Bazarov, D., Uralov, B., Matyakubov, B., Vokhidov, O., Uljaev, F., Akhmadi, M. The effects of morphometric elements of the channel on hydraulic resistance of machine channels of pumping stations. IOP Conference Series: Materials Science and Engineering. 2020. 869(7). DOI:10.1088/1757-899X/869/7/072015.
[10] Obidov, B., Vokhidov, O., Shodiev, B., Ashirov, B., Sapaeva, M. Hydrodynamic loads on a water drain with cavitation quenchers. IOP Conference Series: Materials Science and Engineering. 2020. 883. Pp. 012011. DOI:10.1088/1757-899x/883/1/012011.
[11] Obidov, B., Choriev, R., Vokhidov, O., Rajabov, M. Experimental studies of horizontal flow effects in the presence of cavitation on erosion – free dampers. IOP Conference Series: Materials Science and Engineering. 2020. 883. Pp. 012051. DOI:10.1088/1757-899x/883/1/012051.
[12] Bazarov, D.R., Mavlyanova, D.A. Numerical studies of long-wave processes in the reaches of hydrosystems and reservoirs. Magazine of Civil Engineering. 2019. 87(3). Pp. 123–135. DOI:10.18720/MCE.87.10.
[13] Kattakulov, F., Muslimov, T., Khusainov, A., Sharopov, S., Vokhidov, O., Sultanov, S. Water resource saving in irrigation networks through improving the efficiency of reinforced concrete coatings. IOP Conference Series: Materials Science and Engineering. 2020. 883. Pp. 012053. DOI:10.1088/1757-899x/883/1/012053.
[14] Bazarov, D., Shaazizov, F., Erjigitov, S.: Transfer of Amudarya flowing part to increase the supportability of the Uzbekistan southern regions. IOP Conf. Ser. Mater. Sci. Eng. 883, 012068 (2020). https://doi.org/10.1088/1757-899x/883/1/012068.

[15] Bazarov, D., Markova, I., Norkulov, B., Isabaev, K., Sapaeva, M. Operational efficiency of water damless intake. IOP Conference Series: Materials Science and Engineering. 2020. 869(7). DOI:10.1088/1757-899X/869/7/072051.
[16] Bazarov, D., Markova, I., Raimova, I., Sultanov, S.: Water flow motion in the vehicle of main channels. IOP Conf. Ser. Mater. Sci. Eng. 883, 012001 (2020). https://doi.org/10.1088/1757-899x/883/1/012001.
[17] Krutov, A., Bazarov, D., Norkulov, B., Obidov, B., Nazarov, B. Experience of employment of computational models for water quality modelling. E3S Web of Conferences. 2019. 97. DOI:10.1051/e3sconf/20199705030.
[18] Militeev, A.N., Bazarov, D.R. A two-dimensional mathematical model of the horizontal deformations of river channels. Water Resources. 1999. 26(1). Pp. 17–21.
[19] Eshev, S.S., Khazratov, A.N., O'Gli Rahimov, A.R., O`Gli Latipov, S.A.: Influence of wind waves on the flow in flowing reservoirs. IIUM Eng. J. 21, 125–132 (2020). https://doi.org/10.31436/iiumej.v21i2.1329.
[20] Krutov, A., Norkulov, B., Artikbekova, F., Nurmatov, P. Optimal location of an intake at a reservoir prone to salt diffusion. IOP Conference Series: Materials Science and Engineering. 2020. 869. Pp. 072020. DOI:10.1088/1757-899x/869/7/072020.
[21] Krutov, A., Norkulov, B., Nurmatov, P., Mirzaev, M. Applicability of zero-dimensional equations to forecast nonconservative components concentration in water bodies. IOP Conference Series: Materials Science and Engineering. 2020. 883. Pp. 012064. DOI:10.1088/1757-899x/883/1/012064.
[22] Khidirov, S., Norkulov, B., Ishankulov, Z., Nurmatov, P., Gayur, A. Linked pools culverts facilities. IOP Conference Series: Materials Science and Engineering. 2020. 883. Pp. 012004. DOI:10.1088/1757-899x/883/1/012004.
[23] Yangiev, A., Eshev, S., Panjiev, S., Rakhimov, A.: Calculation of sediment flow in channels taking into account passing and counter wind waves. In: IOP Conference Series: Materials Science and Engineering (2020). https://doi.org/10.1088/1757-899X/883/1/012036.