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Water flow motion in the vehicle of main channels

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Abstract. The article considers a numerical study of the movement of water flow in the Amu-Bukhara Machine Channel (ABMCh-Bukhara region). Water intake to the inlet channel is carried out from one of the most muddy rivers in Central Asia in a damless manner, therefore, ensuring the flow of clarified water into the anterior chambers of pumping stations is an urgent task. A numerical study is a study of the hydrodynamic parameters of the flow and, based on the data obtained, the developed recommendation is the aim of this work. The determination of the main hydraulic parameters of the flow moving in the riverbed by numerical research is accepted as a research method. According to the developed model, consisting of hydrodynamic equations, based on the law of conservation of momentum and mass, data on the dynamics of velocities of the ABMCh supply channel are obtained and zones of uneven flow in the channel are determined. A recommendation has been developed that allows quasi-uniform movement, which helps to prevent the formation of deformation of the supply channel of the pumping station and the entry of suspended and bottom sediments into the chamber of the pumping station.

1. Introduction

Water is supplied to the main irrigated area of Uzbekistan by machine lift. When transporting water in the beds of machine channels, the problem of supplying clarified water with a guaranteed volume very often causes great difficulties. Particularly great difficulties arise during the operation of the supply channels of pumping stations, the channel of which, due to large slopes of the bottom, high flow velocities, and easy erosion of bottom sediments (represented by fine sandy soft soils), is subject to extremely complex intense planned and deep deformations. Despite the abundance of 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 channel processes in space and time in the channel of the supply channels, in conjunction with the operating mode of the pumping stations. Therefore, the solution to the above problem is an urgent task of channel hydraulics. Based on the foregoing, a large machine channel, the Abu-Bukhara Machine Channel, was chosen as the object of study. Construction of the first and second phases of one of the most complex irrigation and drainage systems in Uzbekistan of the Amu-Bukhara Machine Channel with lengths of 197 km and 233 km. Accordingly, with a capacity of 118 m³ (in the place with the Amu-Karakul channel) and 112 m³, they facilitated the transition to irrigation land from the Amudarya in the Zarafshan Valley with a significant improvement in their water availability. This irrigation network in the initial section runs along the continuous dunes of the desert, and mail the entire length of the system in the recess[1, 2, 3, 4]. Due to the long period of operation (introduced in 1965), the unsteadiness of the hydrological and hydraulic characteristics of the supplied water, and the systematic cleaning work by dredgers in the beds of this complex irrigation and drainage system, the likelihood of hydrodynamic accidents increased [5, 6, 7].

In addition, due to the uneven movement of the water flow in the channels of the supply channels of the pumping station, intensive channel processes occur that contribute to an increase in sediment



volume entering the pump chamber advance chambers. This sharply worsens the operating mode of pumping stations. The study of channel processes in the channel was carried out by many scientists and researchers [8, 9, 10, 11]. Based on the foregoing, the purpose of the study in this work is determined, which consists of obtaining predicted data for the dynamics of the hydrodynamic characteristics of the flow and the relationship with the morphometry of the channel of the supply channels of the pumping stations. Generally speaking, only numerical or physical modeling can give a concrete forecast of channel deformations in the channel of the supply channels of pumping stations. Based on the foregoing, a numerical study of the dynamics of the hydrodynamic parameters of the flow and based on the data obtained, the developed recommendation is defined as the main goal of this work. This information can be obtained by numerically studying the flow regime in the channels of the supply channels of the irrigation and drainage system – ABMCh, and it is possible to develop recommendations for ensuring the optimal flow regime in the area of the pumping station.

2. Methods

To establish the forecast in case of possible problems with taking emergency measures for the operation of the ABMCh, as well as obtaining data on the hydrodynamic characteristics of the flow in the channels of the supply channels of the pumping stations. The authors of this work used the method of numerical modeling as a method requiring much fewer material costs and allowing a series of calculations of the problems considered. The calculation technique was developed and improved taking into account the goals and features of the object of study. For many years, computer modeling of unsteady water flow in open channels has been carried out, based on the numerical solution of the one-dimensional, two-dimensional, and three-dimensional Saint-Venant equations (shallow water equations). The determination of the main hydraulic parameters of the flow moving in the riverbed by numerical research is accepted as a research method.

3. Results and Discussion

The developed model is compiled by the one-dimensional Saint-Venant equations of hydrodynamics based on the law of conservation of mass and momentum [4].

As you know, with a calm flow of the water stream ($Fr < 1$), the following boundary conditions are used to close the Saint-Venant equations [14]:

1. On a non-flowing border: on the shore, dam, spur, one boundary condition is required - the normal border that makes up the velocity vector should be 0 (thus, the normal border that makes up the specific flow rate vector will be 0);
2. At the inlet boundary, at which the flow flows into the region, two boundary conditions are required. The first of them, as a rule, is setting a normal border for the value of speed or specific consumption of water, but it is also possible to set the water level; the second is setting the value of the tangential boundary of the water velocity value. Often, this speed is set equal to 0, but we must keep in mind that this is a hypothesis, and it can lead to distortion of the results.
3. At the outlet boundary, at which the flow flows from the region, one boundary condition is required - the water level or the specific water flow rate. Note that in a calm stream, waves of small amplitude can propagate both in the direction of the flow and against it. Thus, the flow in the region of interest to the researcher depends on the entire flow region. Situations are possible when the planned distribution of depths, velocities, and specific water flows at the border are reliably known. Such boundaries are, for example, the exit from the water well (the hypothesis of the equality of the specific water flow in the direction of the flow of the culvert is plausible on it).

In addition, in the zones of influence of hydraulic structures or hydropower facilities on the flow dynamics, modeling of the entire channel is impossible, it is necessary to extract a design fragment from it and assign boundary conditions for general reasons. With an increase in the size of the calculated fragment, the planned picture is adjusted under the influence of the channel shape and

friction on the bottom, which increases the reliability of the results in the area of interest to the researcher. Of course, the same should be done with the physical modeling of hydraulic phenomena in riverbeds and channels. Based on the foregoing, the one-dimensional Saint-Venant equations of hydrodynamics based on the laws of conservation of mass and momentum have the following form:

$$\frac{\partial \omega}{\partial t} + \frac{\partial \omega V}{\partial x} = 0 \quad (1)$$

$$\frac{\partial \omega V}{\partial t} + \frac{\partial \omega V^2 + gS}{\partial x} - g \frac{\partial S}{\partial x} \Big|_{Z_{fs}=const} + \frac{\lambda}{2} V |V| \chi = 0 \quad (2)$$

here t - is time; x - spatial coordinate directed along the axis of the flow; V - average cross-section speed; ω - living cross-sectional area of the stream; Z_{fs} - the level of the free surface of the water; S - the static moment of the live section of the flow relative to its free surface; χ - wetted perimeter of the flow section; g - acceleration of gravity; λ - coefficient of hydraulic friction, adopted based on the Shezy formula:

$$\lambda = \frac{2gn^2}{R^{1/3}} \quad (3)$$

It should be noted that in the numerical simulation of hydraulic problems, the hypothesis is accepted that hydraulic friction in unsteady processes can be specified using the same formulas as in a steady flow. Generally speaking, in an unsteady flow, the actual hydraulic friction at the bottom of the flow may differ from that calculated by the standard formulas [15], but in practically important cases, in mathematical modeling of releases and flood waves, sharply changing flow motions, etc., such a difference will be small. In calculations of flows in channels, the Manning formula, which has the following form in the case of isotropic roughness, is most widely used:

$$\vec{\tau} = -\frac{\lambda}{2} \vec{V} |\vec{V}| \quad (4)$$

here: $\vec{V} = \frac{\bar{q}}{h}$ – depth-averaged water velocity; λ – hydraulic friction coefficient, which can be calculated using the Manning formula:

$$\lambda = \frac{2g}{C^2} = \frac{2gn^2}{h^{1/3}} \quad (5)$$

here: C – Shezy coefficient, n – roughness coefficient. Formula (4) reflects the fact that the hydraulic resistance is collinear to the speed and is directed in the opposite direction to it.

In systems (1), (2), friction between the jets in plan (turbulent viscosity of Saint-Venant fluid) is not taken into account. A number of papers used the Saint-Venant equations with the introduction of the corresponding terms. To account for this phenomenon, in the columns we add additional terms X_1 and X_2 of the system of equations (1), (2):

$$X_1 = \begin{pmatrix} q_1 \\ \alpha_{11}q_1^2/h + gh^2/2 - N_{11} \\ \alpha_{21}q_1q_2 - N_{12} \end{pmatrix}; \quad X_2 = \begin{pmatrix} q_2 \\ \alpha_{12}q_1q_2 - N_{21} \\ \alpha_{22}q_2^2/h + gh^2/2 - N_{22} \end{pmatrix}, \quad (6)$$

$$N_{ij} = D_{ij} \left(\frac{\partial q_i}{\partial x_j} + \frac{\partial q_j}{\partial x_i} \right), \quad D_{ij} = D_{ji} \quad (7)$$

here: $\{D_{ij}\}$ is turbulent viscosity tensor; i, j take values 1 and 2. In anisotropic flow $D_{11} = D_{12} = D_{22} = D$, D called the coefficient of turbulent viscosity. In real calculations, the appointment of a tensor or coefficient of turbulent viscosity is accompanied by great difficulties. These values strongly depend on the nature of the current, and when studying currents in large water areas, reservoirs and lakes, they also depend on wind and waves. In engineering practice, to set the coefficient of turbulent viscosity, the formula A.V. Karaushev:

$$D = \frac{gq}{MC} \quad (8)$$

here: C – Shezi coefficient,

$$M = \begin{cases} 0.7C + 8 & \text{at } 10 \leq C \leq 60 \quad \sqrt{m}/s \\ 48 & \text{at } C > 60 \quad \sqrt{m}/s. \end{cases} \quad (9)$$

Note that this formula includes dimensional empirical quantities that create a limitation to use.

The Saint-Venant equation can be stated for general physical reasons, by compiling the laws of conservation of mass and momentum (that is, Newton's second law) for a column of liquid separated in the open stream water stream (in approximately the same way the planning equations of Saint-Venant were constructed in [14, 15]. Another way to derive the system of equations (1) is to derive them from the three-dimensional equations of fluid flow by averaging over the depth of the stream.

An important fact should be noted, namely, that the system of equations (1), (2) does not allow the existence of stationary, time-independent, separated flows and whirlpool regions of the flow, due to energy dissipation in the whirlpool region and the lack of a mechanism for its recharge from the transit stream.

The proposed model has been successfully verified and tested with the test problems of flow hydraulics [16, 17, 18, 19, 20, 24].

the first stage of the calculated water management facility consists of a gateway for the passage of dredgers, Dengizkul waste dump channel (length 6.5 km), 11 hydraulic structures, 5 structures at intersections with gas pipelines and collectors, the 1st Pump Station with a geometric height of 45 m and capacity of 66.4 m³/s, Kuyumazar reservoir and pumping station and flows into the channels Shokhrud and Vobkent river.

the second stage of the calculated water management facility on the site of the Karakul water separator is combined with the first stage of the ABMCh by broadening it. Next, the II pump station was built, which has a geometric height of 47 m and a capacity of 150 m³/s. Behind the pumping station the channel is again connected to the first stage expanded to the design dimensions of the second stage ABMCh. At 191 km, the second phase of the ABMCh ends with the Kyzyltinsk pumping station with two stages with geometric heights of 48 and 57 m and with capacities of 40 m³/s and 60 m³/s supplying water to the Kharkhur and Shafrikan hydropower plants, respectively. The water level

in the upper pool of the pumping station is supported by a waste facility in the Tudakul depression [23].

The linear diagram and other hydraulic elements of the ABMCh used in the numerical study are shown in the following Figure 1.

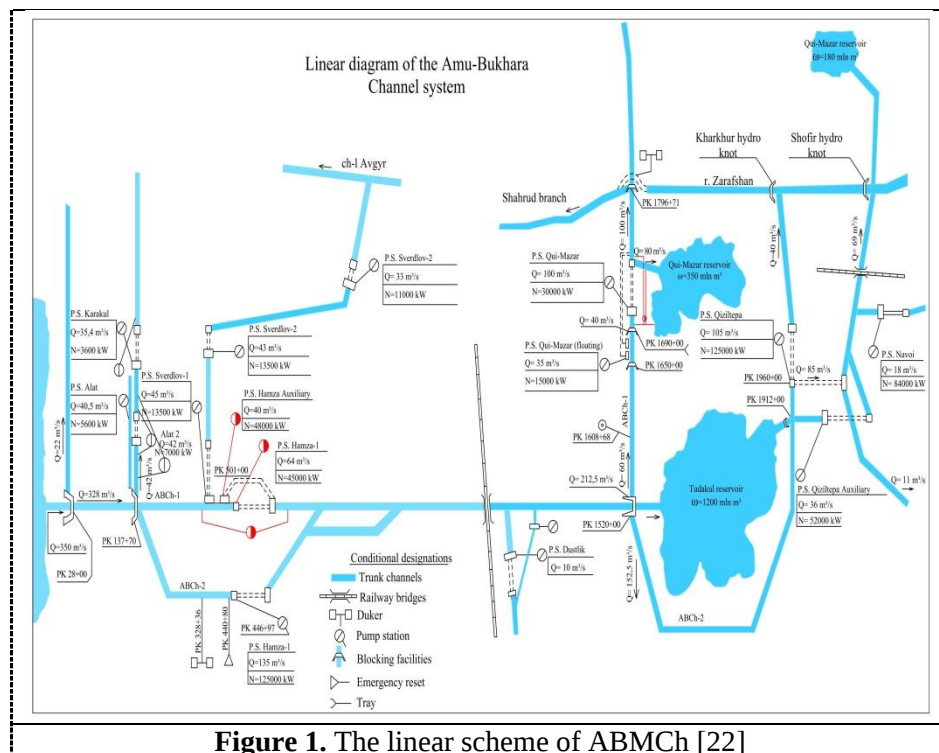


Figure 1. The linear scheme of ABMCh [22]

According to the above scheme, a calculation scheme for numerical calculation has been compiled. Based on the available hydrological and topographic materials, the soil of the channel part, the water level, the dynamics of the water flow in the channel, the hydraulic resistance of the channel, the mark of the channel bottom and the water flow in the initial section of the channel and the data of the pumping station related to the operating mode of the ABMCh are taken according to the results of field studies (Figures 2, 3).

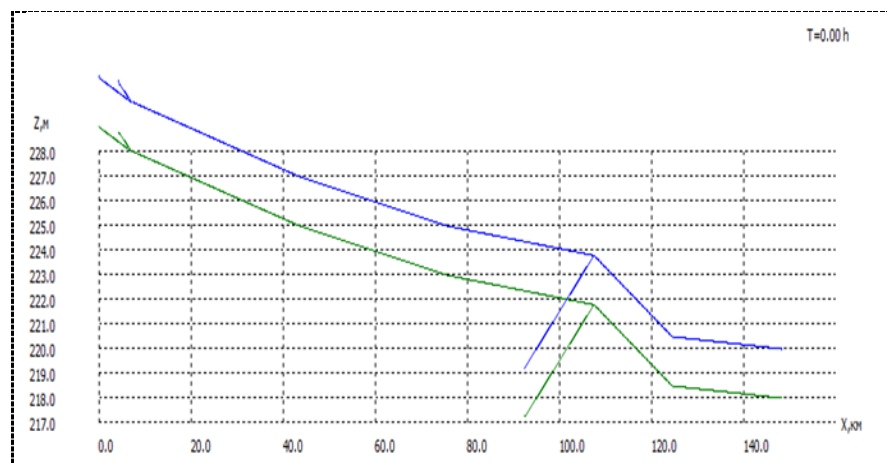


Figure 2. Hydrograph and bottom marks of the ABMCh [22]. The upper and lower lines, respectively, the water level and bottom marks ABMCh, time $T=0$;

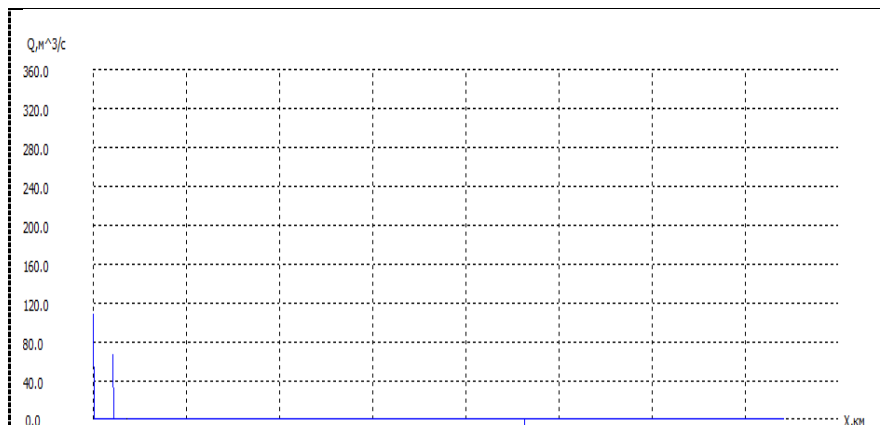


Figure 3. The supplied water flow in the channel of the irrigation and drainage system through the Head facility at the beginning of the calculation of the ABMCh [22]

According to the accepted calculation conditions, after every 20 km the calculation results with all hydrodynamic parameters were issued. In addition, with the help of a special program, it is possible to monitor the dynamics of hydrodynamic parameters in the intermediate sections of the ABMCh (Figure 4).

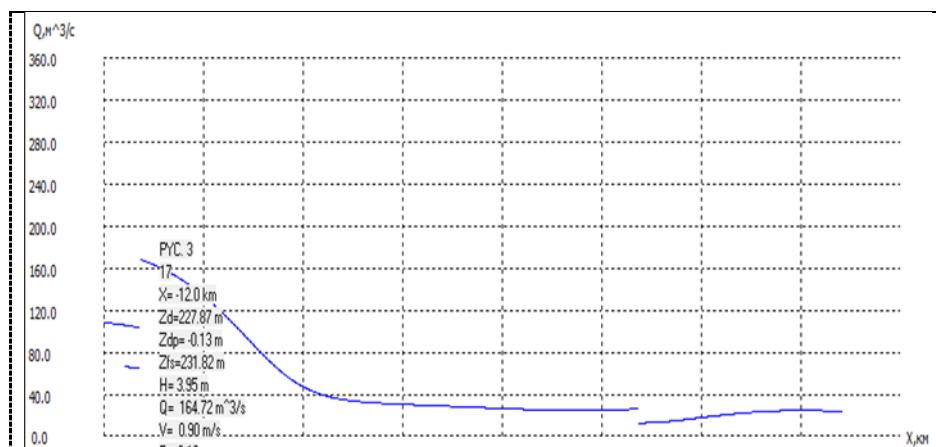
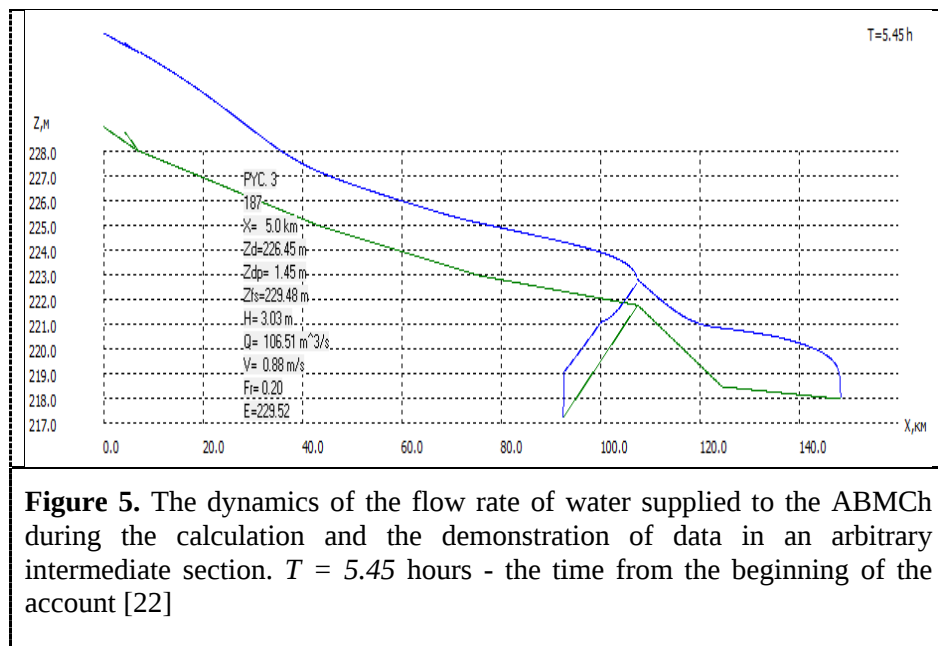


Figure 4. The hydrograph of the bottom of the channel, a demonstration of the calculation data in an arbitrary intermediate alignment [22]

ABMCh Upper and lower lines, respectively, water level and bottom marks ABMCh, time $T = 5.45$ hours, X is the distance from the head structure, Z_d , Z_i are marks of the free surface of the stream and the bottom of the channel, H is the depth in m, Q is flow in m^3/s , V is the average flow rate, Fr is Froude number, E is the specific energy of the flow, $T = 5.45$ hours is the time from the beginning of the calculation.



At the inlet boundary, the supply hydrograph was set concerning the incoming flow rate and the clarified flow ($S = 0$). The parameters of the numerical model and were selected in the calculation process from the condition of the best coincidence of the calculated profile of the natural object with the numerical model. The calculation results are presented in (Figure 6).

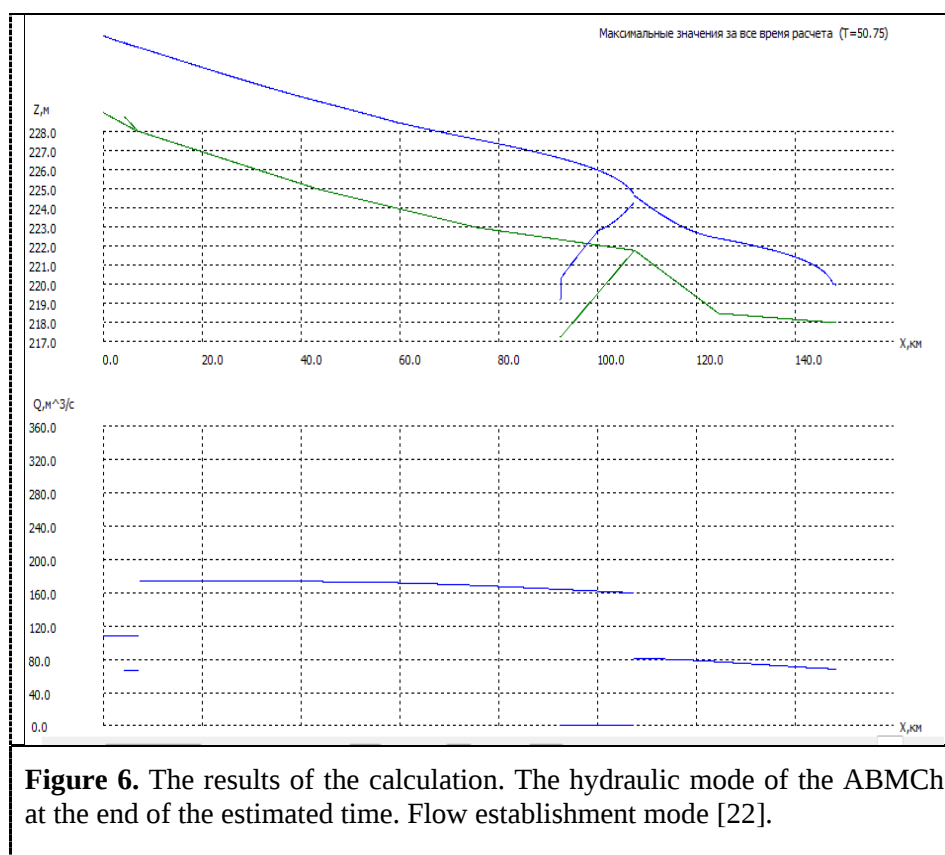


Figure 6. The results of the calculation. The hydraulic mode of the ABMCh at the end of the estimated time. Flow establishment mode [22].

The calculation results on Figure 6 show, that the specified hydrological regime is established in the system within 50 hours, which means - in case of a problem with the control equipment, the time it takes for the changed flow to reach the end of the system is slightly more than two days.

After the main construction of the first and second phases of the ABMCh in the channels, the water stream flows at a speed (0.88 m/s more than the maximum permissible velocity for the soil component of the watercourse). As a result of this hydraulic regime, the flow leads to erosion of the channel of the machine channel and due to the absence of sedimentation tanks in the area of approaches to the pumping stations, a saturated with sediments of various fractions water flow is observed (Figure 7).



Figure 7. Supply channels ABMCh-1 and ABMCh-2 [22]

This all contributes to the flow of saturated turbidity to the units of the pumping station. As a result of a long operation of pumping units with a constant flow of turbid flow, the impellers of the pumps wear. This is confirmed by the results of visual observations taken from the pump impellers of the ABMCh - I pumping units (Figure 8).



Figure 8. Condition of the impeller of the pumping unit ABMCh – I after one year of operation

It should be noted that such a violation will lead to large operational costs.

In addition, it can be established when the identified deficiency affects the operating modes of the waterworks and pumping stations of ABMCh [22].

4. Conclusions

In conclusion, it should be noted that a new one-dimensional model has been developed that describes the unsteady movement of the water flow in the channel of the channel with complex morphometry based on the divergent form of the Saint-Venant hydrodynamic equations. The calculation according to the developed mathematical model practically allows us to solve a wide range of problems in modeling flows in the ABMCh, taking into account the daily regulation and lateral flow from the system to the system due to reverse filtration. This makes it possible to identify and take measures in advance:

- Determine the time the flow reaches the channel of the machine channels;
- Establish sections of channels subjected to channel deformations;
- Develop measures to ensure a uniform flow pattern in the channel of the machine channel;
- Develop measures to ensure the entry of more clarified water into pump chambers of pumping stations;
- Set the characteristics and volume of water flow in an arbitrary section of the network at the required time;
- Take emergency measures to regulate the incoming residual volume of water after stopping its supply to the network, in case of malfunctions in the equipment of pumping stations;
- At the request of the operating personnel, it is possible to accept the possibility of possible malfunctions in the ABMCh pumping station and to predict the effect of this change along with the flow and against the flow in the machine channel;

- Minimize the negative consequences of emergencies, such as damage to regulatory or head structures;
- Reasonably prevent the development of systemic accidents;
- Prevent flooding of structures, irrigated areas located in the area of ABMCh;
- Prevent washing out of poles and damage to power lines, transport routes, water pipelines and gas pipelines passing through the considered section of ABMCh, etc.;
- Take measures for the installation of additional facilities, ensuring full clarification of the flow of water entering the pump chamber of the pump room.

Besides, a well-developed mathematical model has been developed that allows in real conditions and in real-time to help in the operational management of actions in emergencies and in choosing the most effective measures for each moment to minimize the consequences of random situations in the channel.

Such studies are necessary for the design and construction of channels to increase their reliability and safe operation. For such problems, mathematical modeling of the flow in the channel of the machine channels is the main solution, since laboratory modeling of very long sections of the channel is difficult and expensive.

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References

- [1] Bazarov D Shodiev B Norkulov B Kurbanova U and Ashirov B 2019 Aspects of the extension of forty exploitation of bulk reservoirs for irrigation and hydropower purposes in *E3S Web of Conferences* **97**
- [2] Krutov A Bazarov D Norkulov B Obidov B and Nazarov B 2019 Experience of employment of computational models for water quality modelling *E3S Web of Conferences* **97**
- [3] Mamajonov M Bazarov D Uralov B Djumabaeva G and Rahmatov N 2019 The impact of hydro-wear parts of pumps for operational efficiency of the pumping station,” *J. Phys. Conf. Ser.*, **1425** 012123
- [4] Militeev A and Bazarov D 1999 A two-dimensional mathematical model of the horizontal deformations of river channels *Water Resour.*, 26(1) pp 17–21
- [5] Kwon V I 1967 *On friction resistance during unsteady motion of an open fluid flow in a channel (Novosibirsk)*
- [6] Zhidkikh V 1966 Calculation of the coefficient of turbulent exchange in reservoirs during wind waves *Collection of reports on hydraulic engineering* **7**
- [7] Militeev A 1982 *Solving the problems of hydraulics in shallow reservoirs and hydroelectric reservoirs using numerical methods (Moscow)*
- [8] Kasyanova N D 1974 *The effects of channeling slopes of channels on the kinematics of flow and pressure loss (Kiev)* pp 24
- [9] Kan E and Ikramov N 2019 Effect of parallel connection of pumping units on operating costs of pumping station 05008
- [10] Neronova L 1976 Patterns of hydraulic resistance in rectangular channels of various widths *Hydraul. Hydraul. Eng.*, **22** pp 17–21
- [11] Glovatskiy O Djavburiyev T and Urazmukhamedova Z 2019 Interconnection of influent

- channel and pumping station units **97** 5008
- [12] Shkolnikov SY 1999 Transformation of flood waves propagating in a dry channel *Hydraul. Eng.*, n # 7
 - [13] Shkolnikov S Y Lyatkher V M 1981 Tensor structure of hydraulic friction coefficient *Water Resour.*, 5
 - [14] Kartvelishvili N A 1973 *Flows in undeformable channels* (Moscow)
 - [16] Shkolnikov S Y 1980 *The study of currents in rivers and lakes by numerical methods* (Moscow)
 - [17] Militeev A N and Bazarov D R 1997 A mathematical model for calculating two-dimensional (in terms of) channel deformations *Appl. Math. Community* pp 9–17
 - [18] Militeev A N and Bazarov D R 1997 Three-dimensional mathematical model for streams with a washout bottom *Appl. Math. Community* pp. 23–46,.
 - [19] Kuchkarov M 2017 Research of channel processes at ABMCh and development of an event to improve the conditions of damless water intake at ABMCh
 - [20] Kosichenko Y M 1988 Ensuring antifiltration efficiency and reliability of the lining of irrigation channels
 - [21] Gurin K G 2001 Inhomogeneous roughness of partially facing channels of large channels.
 - [22] Artikbekova F K 2020 *Estimating the processes in inlet channel with the consideration of the operational features of pump stations*. (Tashkent
 - [23] Bazarov DR, Vokhidov OF, Lutsenko LA, and Sultanov S **2019** Restrictions Applied When Solving One-Dimensional Hydrodynamic Equations *Proc. EECE 2019, Lect. Notes Civ. Eng.* **70**. pp 299–305
 - [24] Vatin N, Lavrov N, and Loginov G **2016** Processes at Water Intake from Mountain Rivers into Hydropower and Irrigation Systems *MATEC Web Conf.* **EDP Sciences**