

# Management exploitation condition of Amu-Bukhara machine channel

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**Abstract.** In this article discussed current exploitation condition of the largest irrigation and drainage network of the Republic of Uzbekistan - Amu-Bukhara Machine Channel. Main importance of this work – is to develop of an intensive method for predicting emergencies arising during the exploitation condition during the vegetation period, the possibility of applying the method of mathematical modelling in controlling exploitation condition. The aim of the study is to develop a modern, convenient, simple and accessible mathematical tools, which will give reliable material for predicting the flow dynamics in the channel and making the right decision in emergency situations when complex exploitation of irrigation and drainage systems. The research methodology consists of a review of the existing systems of hydrodynamic equations which describes the flow motion, and adoption from them divergent system of equations. Have been developed mathematical model and a computer program which allows solve a wide spectre of tasks for modelling of flow in an irrigation and drainage system with various difficulties with taking account daily regulation.

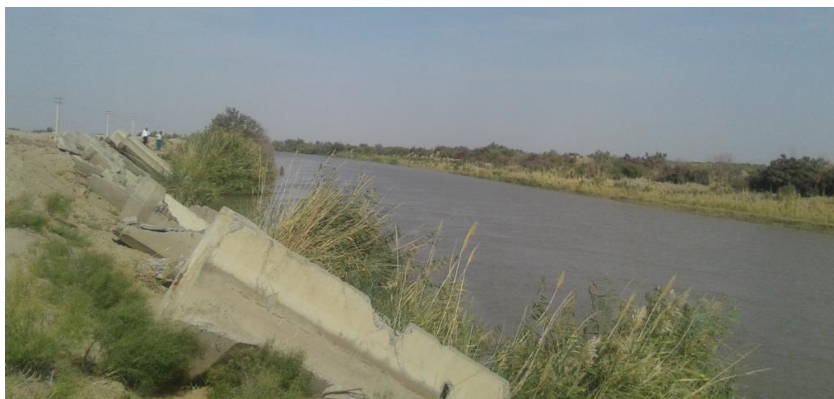
## 1 Introduction

Due to the dynamic expansion in irrigated area of Central Asian (CA) region, were built many irrigation systems. Only in Uzbekistan, over the last 40 years in the Amudarya river basin, irrigated areas have expanded from 1,469 thousand hectares to 2,490 thousand hectares, which indicates 70% of the dynamic growth of the irrigated areas of the republic. Generally, in the Amudarya basin of Central Asia, the dynamics of irrigated areas ranged from 2,704 thousand hectares to about 5,000 thousand hectares [1-3]. Therefore, to provide required volume of the irrigation water, were created corresponding irrigation and drainage systems. In particular, the most complicated irrigation and drainage system was created in Uzbekistan, including more than 180 thousand km of canal network, 140 thousand km. collector-drainage network, about 160 thousand hydrologic constructions, from them over 800 are big and 1588 pumping stations with an annual capacity of 8.2 billion kW, 55 reservoirs with a total capacity of 19.8 billion m<sup>3</sup> and more than 4100 wells [4]. During the

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many years of exploitation, all those devices and systems noticeably outdated. Naturally, this is reflected in a sharp deterioration in operating conditions, an increase in the number of accidents in the irrigation system, a decrease in system capacity, an increase in the intensity of channel processes in an unfavorable direction for operational services, etc. (see fig. 1) [5].



**Fig. 1.** Fortified shore of Amu-Bukhara Machine channel

With analysing above presented figure, one can assume undesirable bed processes in the Amu-Bukhara Machine Channel. In this cases, it is necessary to do emergency tasks to prevent serious consequences of accidents, which requires knowledge of the hydrodynamic characteristics of the flow moving in the channel bed, knowing the intensity of coastal deformation, the nature of the distribution of sediments and their movement, information about the flow time in the system, the level of water, possible volume of flow in the place of release, etc. This information should be obtained using a convenient and simple “tool” for predicting the calculation of the movement of water flow in the channel, which is the main goal of this work.

## 2 Method

To establish a forecast of possible problems with the adoption of emergency measures, in case of accidents, the operation of outdated irrigation and drainage systems, usually but two methods are used: experimental-physical and mathematical modelling [6-8]. The existing regime of water flow in case of emergency operation of the system moves to a dramatically changing. To predict the course of the channel process with uncontrolled flow, it is usually possible to conduct a physical experiment. But, in order to reproduce the real movement of water flow in large canals on a reduced scale of the laboratory model, more material costs, labor and enormous costs for measuring equipment, and model preparation are required. In addition to the above, there are many problems, without solving which the provision of a criterion for the similarity of model and nature is not possible [9-12].

## 3 Results and discussion

Problems of numerical and physical modelling of flow in channels mainly consist of finding the basic physical laws and developing a mathematical model (a closed system of equations) that would adequately describe the process we are considering with sufficient accuracy at the same time, a mathematical model can be stochastic and deterministic. After

creating such kind of model, the problems of both physical and numerical methods of modelling become completely different.

Physical modelling is based on finding the communication conditions between a model and nature, becoming from the analysis of the studied model of equations. This analysis is related with:

- using such a similarity transformation, which shows that a process happens on a smaller scale (on a model) is equivalent to a process that is being implemented on a larger scale (in nature);
- finding basis modelling criteria;
- identifying areas of self-similarity according to various criteria, if they actually exist [9].

The results of numerous researches on the prediction of such a situation [7, 9] clearly demonstrated the advantageous aspects of the use of mathematical modeling, which requires much less material costs than physical modeling, and revealed the possibility of modeling such processes that could not be modeled using traditional methods. It allows conducting several serial calculations about chosen problem. According to the results of research in the field of computational hydraulics [8,12-14], was chosen second research method based on the numerical solution of Saint-Venant hydrodynamic equations.

Analysis of existing systems of hydrodynamic equations which describes the movement of water flow in the channels (Reynolds, Navier-Stokes, Gromeki-Lyamb, MacAveev, Boussinesq et all) allowed to choose the most convenient divergent system of hydrodynamic equations as the basis of the mathematical model of the movement of water flow in the hydro-ameliorative system with the difficult scheme and with large extent. As a such kind of system was adopted one-dimensional equations Saint-Venant in [7,14,17,23]:

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x} \cdot \left( QU + \frac{1}{2} g \int_{y_n}^{y_b} h^2 dy \right) = gi\omega - \lambda \cdot \frac{Q^2}{2\omega R} + F, \quad (1)$$

$$\left. \frac{\partial \omega}{\partial t} \right|_{z_n = \text{const}} + \frac{\partial Q}{\partial x} = q, \quad (2)$$

$$\frac{\partial \omega S}{\partial t} + \frac{\partial QS}{\partial x} = -K \cdot (S - S_n) \cdot \frac{\omega}{R}, \quad (3)$$

$$(1-p) \cdot \left. \frac{\partial \omega}{\partial t} \right|_{\zeta = \text{const}} = -K \cdot (S - S_n) \cdot \frac{\omega}{R}. \quad (4)$$

There,  $Q$  – is the total volume discharge of water and sediment in the channel;  $t$  – time;  $U = Q/\omega$  – average flow velocity;  $\omega$  – area of the section of the stream;  $g$  – gravitational acceleration;  $y_b, y_n$  – coordinates of the gaps on the left and right bank, respectively;  $h = \zeta - z_n$  – flow depth;  $\zeta$  – mark of the free surface of the water (not dependent on the Y coordinate);  $z_n$  – bottom mark;  $i = \sin \alpha \approx \alpha$  – tilt of the OX axis to the horizon ( $\alpha$  is the angle between OX and the horizontal plane);  $\lambda$  – coefficient of hydraulic friction;  $R = \omega/\chi$  – hydraulic radius;  $\chi$  – wetted perimeter of the bottom of the watercourse;  $F$  – specific force (per unit length), related to density, due to unprincipled channel;  $q$  – is the specific

(per unit length of the channel) lateral flow;  $S$  – volume concentration of sediment particles in the stream;  $S_n$  – equilibrium concentration of particles (saturation concentration);  $K$  – coefficient of the intensity of the exchange of sediment between the bottom and the flow;

$p$  – soil porosity (the ratio of pore volume to total soil volume).

For the closure of system (1-4), it is necessary to specify the form of the functions  $\lambda$ ,  $F$ ,  $K$ ,  $S_n$ , and also the connections of  $R$  and  $h$  with  $\omega$ , which are determined by the shape of the channel.

The coefficient of hydraulic friction of Manning:

$$\lambda = 2gn^2 R^{-1/3}, \quad (5)$$

there,  $n = n(x, h)$  – roughness coefficient of the channel surface.

The loss of momentum due to the unprincipled channel [16,17] can be represented as:

$$F = - \int_{y_n}^{y_n} gh \cdot \frac{\partial z_n}{\partial x} dy \quad (6)$$

Suppose that  $z_d = z_d(x, y, t)$  is a single-valued function of  $y$  and  $|\partial z_n / \partial y| \ll 1$ . For the coefficient of the intensity of the exchange of sediment in the vertical direction, one can take the formula:

$$K = \gamma U_* \cdot \left( 1 + \frac{\beta W}{U_*} \right) \quad (7)$$

there,  $U_* = \sqrt{gnUR}^{-1/6}$  – dynamic speed;  $W$  – hydraulic size of the sediment;  $\gamma, \beta$  – numerical coefficients.

In the works [18,19,22] of A.V. Karasheva [20] with using the model of sediment transport obtained another, more difficult expression for  $K$ , which is not considered there. It should be noted that the question of the relationship between  $K$  and the main parameters of the flow and sediment for a particular object requires further study.

For saturation concentration,  $S_n$  can be taken depending on different authors. We mainly used the formula of R. Bagnold [15,16], which has a physical basement, simple structure and not giving much "falling out" points in the analysis of field data:

$$S_n = 0,4 \cdot \frac{U_*^2}{gR} \cdot \left( \frac{0,13}{tg\varphi} + 0,01 \cdot \frac{U}{W} \right), \quad (8)$$

there,  $\varphi$  – angle of internal friction of the soil in water ( $tg \varphi \approx 0,6$ ).

For the channel form, consider the following schematization:

A) A rectangular cross section of the channel.

In this case, the channel width along the top  $B = B(x, t)$ , the bottom elevation  $z_n = z_n(x, t)$  and the local depth, which coincides with the average  $h = h(x, t) = \zeta(x, t) - z_n(x, t)$ , do not depend on the transverse coordinate  $y$ ;

$$\omega = B \cdot h, \quad R = \omega / (B + 2h), \quad h = h_{cp}. \quad (9)$$

B) The channel of an arbitrary cross section.

In this case, the bottom in the section is assumed to be given at points in pairs of numbers  $(y_l, z_l)$ ,  $l=1, \dots, m$  sequentially from the left bank to the right bank. Then, at a known level of the free surface  $\zeta$  (and the calculation algorithm initially contains exactly  $\zeta$ ) it is easy to find  $\omega$  (for example, by the trapezium rule), and also  $\chi$ , as the sum of the lengths of distances between points  $(y_l, z_l)$  from the left edge to the right one.

In the receipt of a system of hydrodynamic equations of the presented type, based on the laws of conservation of mass and momentum, the following basic assumptions were made:

- the depth of the flow must be less than the linear dimensions that are essential for this engineering task, the features of the flow along the length of the channel:

$$h \ll L, \quad (4)$$

- there,  $h$  – depth of the stream;  $L$  – characteristic horizontal linear size of the problem being solved;
- planned (two-dimensional) effects do not affect the flow (but local energy losses can still be taken into account due to sharp turns and changes in the shape of the channel in the plan; to account for such losses, increased local hydraulic resistances are introduced in local sections of the channel);
- the curvature of the jets in the vertical sections of the stream is small, which allows the hypothesis of hydrostatic pressure distribution over the depth to be used;
- the slope of the free surface of the water in the direction perpendicular to the flow is small; between the mark of the free surface of the water and pressure there is a functional relationship;
- in the flow should not occur density stratification; in river flows, density stratification is rare, but in some cases, its presence takes place (an example known to us is density stratification in a lowland river at the bottom water intake of a thermal power plant that discharges partially cooled water into the same river above the water intake);
- in studies of non-stationary processes in rivers, it is permissible to use formulas for hydraulic friction coefficients of Darcy-Weisbach or Shezi, derived for conditions of steady motion in channels, for example, Maning or Forchheimer formulas (situations are known when this hypothesis was not true);
- correction of the amount of movement  $\alpha$  is close to 1, (the velocity diagram is almost uniform across the entire range), this hypothesis is not quite correct, even in a wide rectangular channel, when only the shape of the epurea in the depth of the stream affects the magnitude of the adjustment [15-16].

The developed mathematical model and the compiled program for its implementation allows to carry out calculations of water bodies of great length (typical for the irrigation and drainage network of the region) with complex bathymetry and outlines in terms of structures [21] (roads, bridges, water distributors, adjustment structures, bank dams and etc., which are used in the irrigation and drainage systems of the region)

When using a one-dimensional technique, as a rule, the collection of baseline information is greatly simplified and the conduct of relevant research is accelerated, the requirements for the qualifications of research specialists in the field of computational hydraulics are reduced.

## 4 Conclusion

In conclusion, it should be noted that the calculation based on the developed mathematical model and computer program practically allows solving a wide range of tasks for modeling

currents in an irrigation system of various difficulties, taking into account daily regulation and lateral flow from the system. This makes it possible to identify and take action in advance:

- determining the time to reach the stream using an irrigation and drainage system;
- establishing the volume of water flow in an arbitrary section of the system;
- the adoption of emergency measures to regulate the incoming residual volume of water after its termination into the system, in the event of an accident;
- minimizing the negative consequences of emergency situations, such as damage to regulatory or head facilities;
- justification for preventing the development of systemic accidents;
- prevention of flooding of buildings, irrigated areas located in the area of the irrigation and drainage system;
- prevention of undermining of supports and damage to power lines, flooding of distribution substations, etc.

In addition, the developed and investigated new mathematical model allows real-world and real-time assistance in the operational management of actions in emergency situations and the selection of the most effective at each point in time measures to minimize the consequences. Consequently, the developed mathematical model can be used to do numerical calculations for large irrigation and drainage systems — the Amu-Bukhara Machine Channel or Karshi Main channel, or other complex irrigation and drainage systems in the region, which have difficulties at various levels, which is a further task of research in this direction.

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