IMPROVING THE RELIABILITY AND EFFICIENCY OF WATER USE IN IRRIGATION CANALS UNDER VARIABLE HYDRAULIC FLOW PARAMETERS

UDC 626.81:532.5:519.6

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Abstract: The article investigates the reliable and efficient use of water in irrigation canals under variable hydraulic parameters. Using the Mirishkor Main Canal as an example, the effect of decreasing flow parameters on canal conveyance capacity is analyzed, and a one-dimensional mathematical model for controlling flow depth is developed.

Keywords: irrigation canals, hydraulic parameters, water flow, reliability, efficiency, water discharge, flow depth, mathematical modeling.

Аннотация: Мақолада гидравлик параметрлари ўзгарувчан шароитларда ирригация каналларида сувдан ишончли ва самарали фойдаланиш масаласи тадқиқ этилган. Миришкор магистрал канали мисолида сув оқими параметрларининг камайиши каналларнинг транспорт қобилиятига таъсири таҳлил қилинган ва оқим чуқурлигини бошқаришнинг бир ўлчамли математик модели ишлаб чиқилган.

Калит сўзлар: ирригация каналлари, гидравлик параметрлар, сув оқими,

ишончлилик, самарадорлик, сув сарфи, оқим чукурлиги, математик моделлаштириш.

Аннотация: В статье исследуется надёжное и эффективное использование воды в ирригационных каналах при изменяющихся гидравлических параметрах. На примере Миришкорского магистрального канала проанализировано влияние снижения параметров водного потока на пропускную способность каналов и разработана одномерная математическая модель управления глубиной потока.

Ключевые слова: ирригационные каналы, гидравлические параметры, водный поток, надёжность, эффективность, расход воды, глубина потока, математическое моделирование.

The analysis of scientific literature shows that numerous studies by foreign and national researchers have been devoted to the reliability and safety of irrigation systems[1, 2]. The scientific solutions obtained by these researchers have been reflected in the form of scientific recommendations and regulatory criteria. Nevertheless, despite the considerable amount of research conducted, certain problems related to the reliability and safety of irrigation structures remain unresolved. In particular, the issue of the reduction in the conveyance capacity of irrigation networks under variable parameters of water-flow elements has not yet been fully resolved [3].

It is well known that one of the main requirements for an irrigation network is to ensure the reliable delivery of irrigation water to all water consumers [4, 5]. At present, under conditions of water scarcity, many irrigation canals are unable to receive the required amount of water resources. As a result of the reduction in the values of the hydraulic parameters of the flow, the conveyance capacity of canals decreases significantly. Consequently, the reliability and efficiency of irrigation canals are reduced.

The research object of this study is the UR-10 inter-farm irrigation canals hydraulically connected to the Mirishkor Main Canal. The Mirishkor Main Canal

supplies water to more than 100,000 hectares of cultivated land in the Kashkadarya Region. The total length of the canal is 118 km, and 12 inter-farm irrigation canals are hydraulically connected to it. The canal receives water through its head structure from the section located between Pumping Stations No. 4 and No. 5 of the Karshi Main Canal and is highly dependent on the upstream water level. In other words, its operation is directly dependent on the operating regime of Pumping Station No. 4 of the Karshi Main Canal, as shown in Figures 1 and 2.

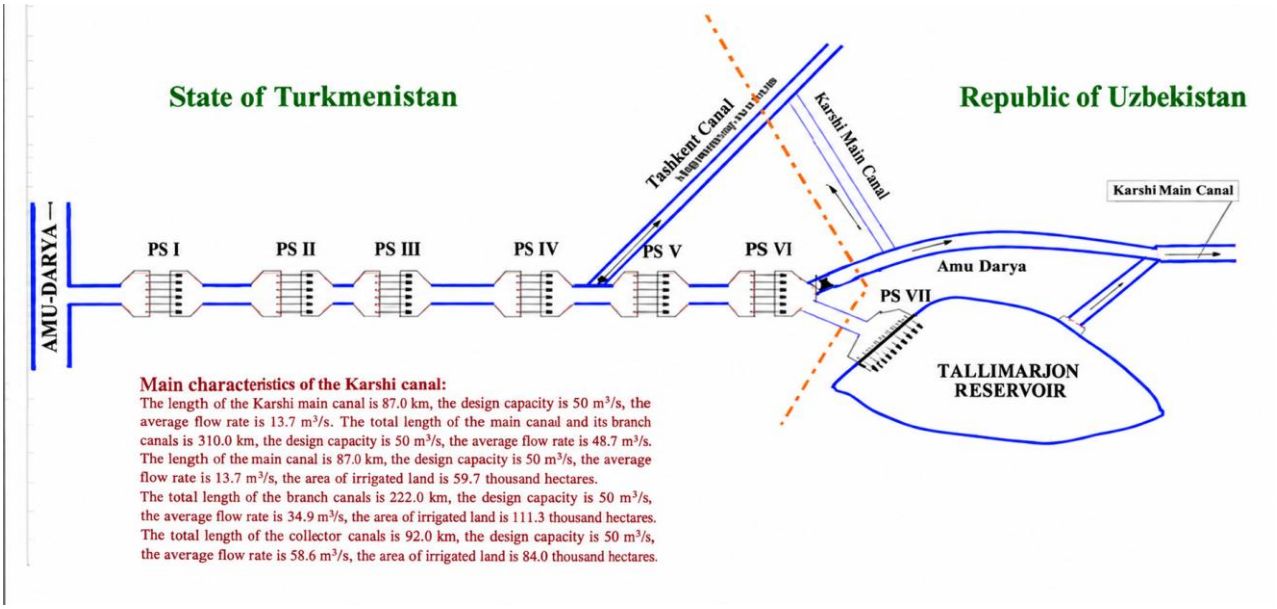


Figure 1. Schematic diagram of the beginning section of the Mirishkor Canal



Figure 2. Water intake structure of the Mirishkor Main Canal from the Karshi Main Canal at PK 0+00

Scientific studies have shown that when five units are operating at Pumping Station No. 4, a water discharge of 136 m³/s is supplied through the head structure. When four units are operating, the discharge is 83.2 m³/s, while with three operating units, the Mirishkor Canal receives 62.1 m³/s of water. Under such variable values of the water-flow parameters, four water-regulating structures operate along the Mirishkor Main Canal to address the problem of water conveyance along the canal.

However, when three units are operating at Pumping Station No. 4 of the Karshi Main Canal, the UR-2, UR-4, UR-6, UR-9, and UR-10 inter-farm irrigation canals receiving water from the Mirishkor Canal cannot obtain the required water discharge, and their conveyance capacity decreases sharply. In addition, most of the irrigation networks were constructed at the end of the last century. The canal elements were designed and constructed with reserve capacity in order to provide water to areas planned for future development. In turn, under current conditions of water scarcity, this situation is causing problems in delivering water to consumers in many irrigation networks.

Therefore, we set the objective of developing scientific and methodological

foundations for the efficient and reliable use of water under variable, particularly decreasing, water-flow conditions in irrigation canals. The relationships between the hydraulic parameters of flow under variable conditions can be determined using different approaches. In other words, when developing a model for establishing the hydraulic relationship between the discharge QQ and water depth hh in open channels, one of the three fundamental laws of fluid mechanics can be applied: the law of conservation of mass, the law of conservation of momentum, or the law of conservation of energy.

The one-dimensional Saint-Venant equations are widely used to describe unsteady flow in open channels. A number of scientific studies have been devoted to this subject. In our hydraulic modeling, we used the law of conservation of momentum. After performing the necessary mathematical operations, we obtained a one-dimensional hydraulic model describing the dynamics of changes in the flow velocity in irrigation canals under the exponential operating regime of pumping stations:

$$p(\tau)\frac{\partial u}{\partial \tau} = \frac{\partial^2 u}{\partial \bar{x}^2} - \mathrm{Re}\frac{\partial u}{\partial \bar{x}} \quad (1)$$

Where: $p(t) = e^{-\int_0^t \lambda dt}$ — reliability condition of the irrigation canal or probability of reliable operation; **Re** — Reynolds number.

After performing the necessary mathematical operations, we obtained the one-dimensional relationship describing the variation in flow velocity under the exponential laws of water discharge supplied to the canal:

$$+\left[\exp\left(\frac{\mathrm{Re}-\sqrt{D)}}{2}\hat{L}\right) - \exp\left(\frac{\mathrm{Re}+\sqrt{D)}}{2}\hat{L}\right)\right]\exp\left(\frac{\mathrm{Re}-\sqrt{D)}}{2}\hat{x}\right)\Bigg\} \quad (2)$$

According to the problem formulated above and based on control theory, we determine the control input $h_{\min} \prec h(\bar{x},\tau) \le h_{\max}$ that satisfies the condition $h(\bar{x},\tau)$ for Equation (2). For this purpose, Equation (2) is transformed into the following form:

$$+\left[\exp(\frac{\mathrm{Re}-\sqrt{D)}}{2}\hat{L})-\exp(\frac{\mathrm{Re}+\sqrt{D)}}{2}\hat{L})\right]\exp(\frac{\mathrm{Re}-\sqrt{D)}}{2}\hat{x})\Bigg\}(3)$$

We assume that the water discharge in the irrigation canal varies according to a decreasing exponential law.

$$Q(\bar{x},\tau)=Q^{0}{}_{np}(\bar{x})\exp(-\lambda t)\,(4)$$

Based on Equations (3) and (4), we obtain the equation for controlling the flow depth in an irrigation canal with a trapezoidal cross-section under variable values of the water-flow parameters:

$$+\left[\exp(\frac{\mathrm{Re}-\sqrt{D)}}{2}\hat{L})-\exp(\frac{\mathrm{Re}+\sqrt{D)}}{2}\hat{L})\right]\exp(\frac{\mathrm{Re}-\sqrt{D)}}{2}\hat{x})\Bigg\}^{-1}\,(5)$$

We obtained the equation for controlling the flow depth in an irrigation canal with a trapezoidal cross-section under variable values of the water-flow parameters. However, since our field studies have not yet been completed, it was not possible to determine the error of this model.

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