Spatial problem of water distribution in open channels

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Abstract. The article discusses the spatial problem of cold water movement in an open channel water distribution system through a door in a side wall. The formula for calculating the amount of cold water flowing through the channel is based on the cross-sectional area of the main channel. It is presented in terms of the velocity and depth of the water surface.

1 Introduction

In our republic, optimizing water resource allocation to users and efficiently using water distribution technologies, especially in agriculture, are critical for developing the national economy. The article addresses the optimization of water resource allocation and the efficient use of water distribution technologies, particularly in agriculture.

The issue of water distribution is currently being studied in terms of one-dimensional models, i.e., without considering the connection between the main channel and the water consumption points [1-3]. In some studies, water is considered a uniform flow in the main channel, and measurements are taken in the distribution channel [4, 5]. In conclusion, the water measurement methods developed so far can only measure the amount of water in the channel they are placed in. The fact that the amount of water sent to consumers from the main channel is not directly related to the water consumption, flow rate, and water level in the main channel can lead to errors in rational water distribution. Therefore, it is necessary to study the problem of water distribution to consumers from the main channel in the system of phase coordinates and the main channel's flow parameters. Although the formula for calculating the water flow in the main channel is complex, it provides the necessary accuracy. [16, 17]

2 Methods

For the experimental setup, an open main channel with an optional cross-section facilitates water flow through the weir installed on the side wall (Figure 1). We provide the water consumption formula for this process below. [18, 19]

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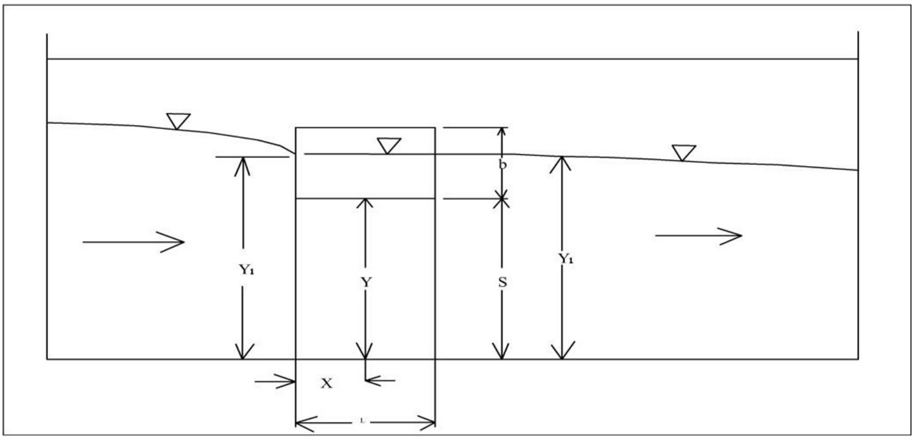

Fig. 1. Energy distribution along the longitudinal profile of the canal

The energy balance equation for the water flow in an open channel is written as follows [2, 13]:

$$H=z+y+\alpha\left(\frac{v^2}{2g}\right) \qquad (1)$$

Here: H represents the total energy; y is the height of the channel section above the horizontal plane; z is the depth of flow; v is the average velocity of the flow; α is a coefficient; (α- is approximated to 1 in most cases with a wide channel).[13,31]

Differentiating equation (1) with respect to the flow direction yields:

$$\frac{dH}{dx}=\frac{dZ}{dx}+\frac{dy}{dx}+\frac{d}{dx}\left(\frac{\alpha Q^2}{gA^2}\right) \qquad (2)$$

The result is obtained after differentiation.
If α x does not depend on the above

$$\frac{d}{dx}\left(\frac{\alpha Q^2}{2gA^2}\right)=\alpha\left[\left(\frac{Q}{gA^2}\right)\left(\frac{dQ}{dx}\right)-\left(\frac{Q^2B}{gA^2}\right)\frac{dy}{dx}\right] \qquad (3)$$

we create it.
Here: $B=\frac{dF}{dy}$ is the main channel has a wide range of coverage; F is the main channel is used for daily programs. Q is water consumption on the main channel; $\frac{dH}{dx}$ is energy gradient; $\frac{dZ}{dx}$ is gradient of the channel bed.

This (3) equation expresses the variable head of the pump quickly. If there is no control valve in the main channel, $\frac{dH}{dx}$, $\frac{dZ}{dx}$ and $\frac{dy}{dx}$ will have the same value. It should be noted

that in areas where there are hydraulic contractions in the head [13, 14, 15].
$\frac{dy}{dx}$ cannot have a single value. Considering the above, we obtain the following expression from (3):

$$\frac{dy}{dx}=\frac{\alpha\frac{Q}{gA^2}\frac{dQ}{dx}}{\alpha\frac{Q^2B}{gA^3}-1} \tag{4}$$

In equatin (4), the loss of head due to friction is not taken into account. This means that the loss of energy in the x direction is compensated by the gravitational forces in that direction. [19, 20, 21].

For a horizontal channel, it is possible to consider $\frac{dH}{dx}=\frac{dZ}{dx}=0$ in equations (3) and (4). If $H-Z=E$ is specified, then for a horizontal channel $E=const$.

In the case of a non-horizontal canal, $\frac{dH}{dx}=\frac{dZ}{dx}$ is still used $H-Z$ remains unchanged. For steeply sloping channels $\frac{dH}{dx}\neq\frac{dZ}{dx}$ is used.

$$E=y+\alpha\frac{v^2}{2g} \tag{5}$$

if we specify

$$Q=F\sqrt{\frac{2g(E-y)}{\alpha}} \tag{6}$$

The change in water flow in a channel passing through the left wall can be as follows:

$$\frac{dQ_s}{dx}=C_d b\sqrt{2g\left(y-s-\frac{b}{2}\right)}\left[1-\frac{1}{96}\left(\frac{b}{y-s-\frac{b}{2}}\right)^2\right] \tag{7}$$

Here: Q_s is water consumption in the default channel; C_d is consumption coefficients b is door (valve) height; s is ratio of door pipe height to channel pipe height
From the condition of continuity of the flow, we obtain

$$\frac{dQ_s}{dx}=-\frac{dQ}{dx} \tag{8}$$

to obtain a balance.
"The differential equation is obtained from equations (4)-(6) with $\alpha=1$ as follows:

$$\frac{dy}{dx}=\frac{2C_d b\sqrt{(E-y)\left(y-s-b/2\right)}\left[1-\frac{1}{96}\left(\frac{b}{y-s-\frac{b}{2}}\right)^2\right]}{F-2B(E-y)} \tag{9}$$

The equation (9) [22] is calculated for the cross-sectional area of the main channel and the rectangular default channel, and it expresses the change of the free surface of the main channel concerning x. Below we present the formulas for calculating the cross-sectional areas of various types of main channels:

1. For a trapezoidal cross-section, $F = B\cdot y$
2. For a trapezoidal cross section $F = B_0 y + y^2 tg\theta$ (where B_0 - is the width of the channel tube and θ is the angle formed by the vertical wall of the channel).
3. For the parabolic cross-sectional area, use

$$F=B\left(y-\frac{dB^2}{12}\right); \qquad B=2\sqrt{\frac{y}{a}}\,.$$

For channels that are not rectangular, numerical methods can be used to calculate the equation (9). If we consider $\frac{1}{96}\left(\frac{b}{y-s-\frac{b}{2}}\right)$ to be very small compared to 1 in this equation and use it for a rectangular channel with a straight trapezoidal cross-section, we obtain the following simple form:

$$\frac{dy}{dx}=\frac{2C_d b\sqrt{(E-y)\left(y-s-b/2\right)}}{B(3y-2E)} \tag{10}$$

The solution of this equation is shown in the following form:

$$-\frac{C_d bx}{B}+const=\frac{1}{2}\left[E-3\left(s+\frac{b}{2}\right)\right]\arcsin\left(\sqrt{\frac{E-y}{E-s-b/2}}\right)-\frac{3}{2}\sqrt{(E-y)\left(y-s-\frac{b}{2}\right)} \tag{11}$$

The given equation is specified by the conditional statement $const\ y|_{x=0}=y$,

$$\frac{C_d bx}{B}=\frac{1}{2}\left[3\left(s+\frac{b}{2}\right)-E\right]\left[\arcsin\left(\sqrt{\frac{E-y}{E-s-b/2}}\right)-\arcsin\sqrt{\frac{(E-y_1)}{E-s-\frac{b}{2}}}\right]+$$
$$+\frac{3}{2}\left[\sqrt{(E-y_1)\left(y_1-s-\frac{b}{2}\right)}-\sqrt{(E-y)\left(y_1-s-\frac{b}{2}\right)}\right] \tag{12}$$

Given the water consumption in the main channel and the water level in the wall, it is

possible to calculate y_1 in the equation (12) when E, the height of the water is known. The slope of the main channel is expressed in terms of the level of the independent surface. The water consumed by the main channel Q_2 after the weir can be determined from formula (7) when the width α and y_2 of the weir are known [9].
In this case, the default water consumption from the channel is equal to

$$Q_1 = Q_0 - Q_S \tag{13}$$

The second figure shows a graph of the relative width of the default channel $\frac{b}{B}$ as a function of water consumption [10, 11].

It can be seen from the graph that the slope of the main channel increases, and the amount of water flowing out of the channel after the weir decreases (the weir surface does not change here)

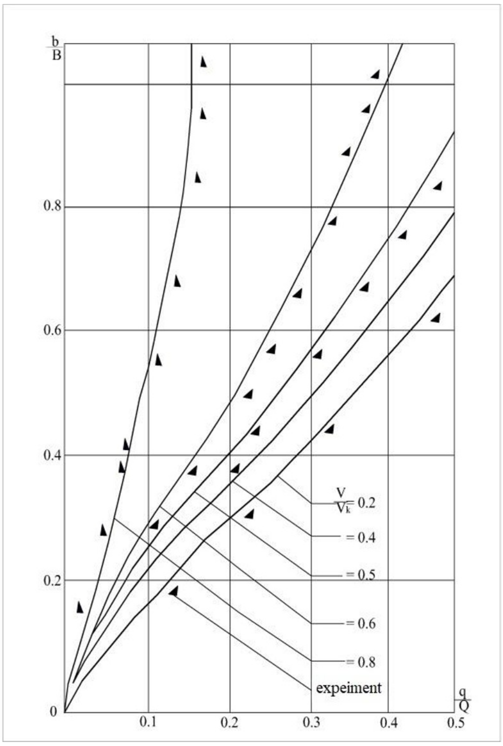

Fig. 2. Relation between slope increase and flow amount beyone the weir

In this model, one of the main characteristics that is of practical importance is the calculation of the coefficient of friction of the channel's bed, which is expressed by the following formula:

$$k = \frac{V}{V_k} \cdot \frac{q}{Q} / (b / B)$$

Here: V_k is velocity of water in the default channel; Q and q are correspondingly, the flow rate and width of the main and default channels; B and b are correspondingly, the depth of the main and default channels.

In Figure 2.3, the graph of k as a function of $\frac{q}{Q}$, $\frac{V}{V_k}$ is depicted

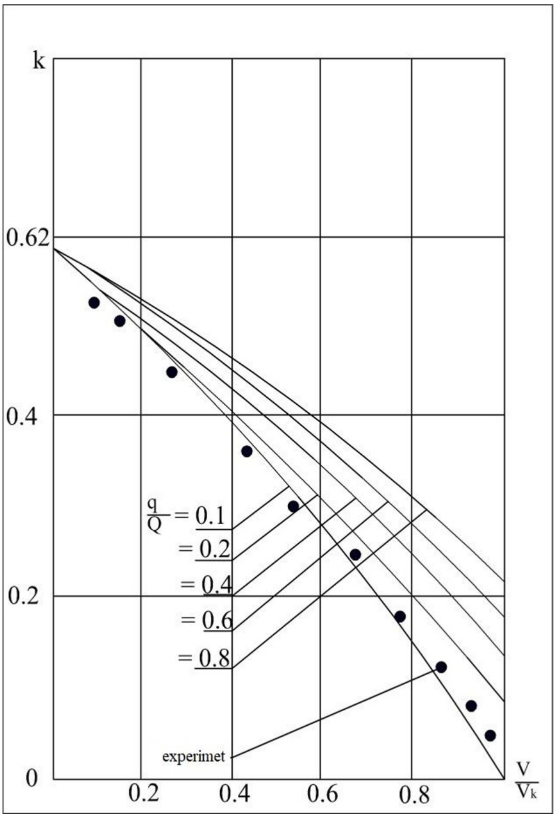

Fig. 3. Graph of dependence of flow coefficient – k of the channel on $\frac{q}{Q}$, $\frac{V}{V_k}$

3 Conclusions

Based on the 2nd diagram, it can be observed that the increase in flow velocity in the main channel is related to the decrease in the amount of water in the default channel. The graph also shows how the depth of the default channel varies with different flow velocities in the main channel [12, 13].

In the third figure, the graph of dependence of the coefficient of discharge – k on the parameter $\frac{V}{V_k}$ is shown for various values of $\frac{q}{Q}$ is shown for various of $\frac{q}{Q}$ when water enters the default channel from the main channel due to the reduction in the amount of water used in the main channel and the change in the coefficient of the discharge as a result of this reduction.

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