Algorithms for calculating limits in water management in irrigation systems

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Abstract. In this article, the algorithms for calculating the limits in water resources management in irrigation systems are carried out, and the water management problems of the basin management of irrigation systems are studied distances from each other.

1 Introduction

In the Republic of Uzbekistan, limited water use has been adopted, which depends on the availability of transboundary and local sources of water resources; on their basis, the basin management of irrigation systems for each period of vegetation and non-vegetation determines the limits of the main water withdrawals. Limits on transboundary sources are established considering the forecast hydrographs and following the adopted agreements for the joint use of water resources of these sources [1-4].

The head flow of the main canal, according to the allocated limit, usually differs from the required flow of water consumers. Hence, the task arises to clarify the requirements for water, considering the established limits for the growing and non-growing periods.

2 Methods and Results

The water supply of the main canal depends on the head required (planned) $Q^{HR}_{m_{\Gamma}n}$ consumption and water consumption limit $Q^{HLR}_{m_{\Gamma}n}$ for the head water intake of the main canal and is determined [1]

$$k^{LR}_{m_{\Gamma}n} = \frac{Q^{HLR}_{m_{\Gamma}n}}{Q^{HR}_{m_{\Gamma}n}} \qquad (1)$$

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where $k^{LR}_{m_\Gamma n}$ is the coefficient of the water supply of the limit from the required (planned) flow.

The water supply coefficient determines the deficit or the possibility of fully meeting the planned needs of the water resources of the main canal. If the coefficient of water supply is greater than one, then those with water resources fully cover the planned needs of agricultural and other consumers. If less than one, there is a shortage of water resources, and it is necessary to adjust the water distribution plan for consumers of the main canal. The principle of adjusting the planned water distribution depends on the level of deficit; if the deficit level is less than 10%, then the planned water distribution is not adjusted; if the deficit level is within 10% - 30%, then the planned water distribution is adjusted proportionally to all consumers. In the event of a deep shortage, i.e., more than 40–50%, the irrigated areas of agricultural crops and the needs of other consumers are specified, considering the most efficient use of available water resources. Further, based on the specified areas of agricultural crops and the needs of other consumers, the specified planned needs for water resources of consumers of the main canal are compiled. Depending on the value of the water availability coefficient, planned water supplies for agricultural consumers of canal outlets are adjusted according to the limit.

For agricultural consumers, you can enter the coefficient of refinement k^L of planned needs according to the established head water intake limit. The value of this coefficient is determined from the condition of a uniform decrease in the needs of agricultural water consumers in such a way that the allocated limits of the head water intake fully provide all consumers.

The corrected planned needs of the j -th water intake according to the limit on the site m, considering the refinement coefficient, will be written in the form [2,3]

$$Q^L_{mjn} = k^L\, Q^R_{0mjn} + q_{DRmjn}, \tag{2}$$

where Q^L_{mjn} is water consumption of the j -th water intake according to the limit in the area m.

Expression (1) means that the needs of agricultural consumers are proportionally reduced by the value of the refinement coefficient, and other water consumers of industry, energy, and public utilities are provided on demand.

To determine the planned needs of consumers of water resources, equations are compiled based on the water balance of sections of the main canal, taking into account (1) as follows

– for end sections of the main channel graph [4]

$$Q^{LE}_{nm_k} = k^L Q^R_{IWnm_k} + q_{DRnm_k}, \quad \forall m_k \in M_k, \quad \forall n \in N_W,$$

– for internal sections of the main canal [5]

$$Q^{LH}_{mn} = \frac{Q^{LE}_{mn} + k^L Q^R_{IWmn} + q_{DRmn} - Q^R_{Rmn}}{\eta_m}, \quad \forall m \in I_{iH}, \quad \forall n \in N_W, \tag{4}$$

– for a section of a channel connected to a group of graphs [6]

$$Q^{LE}_{n_{ijH}n} = \sum_{\kappa_{ijH} \in N_{ijH}} Q^{LH}_{\kappa_{ijH}n}, \quad \forall n_{ijH} \in I_{iH}, \ \forall n \in N_W. \tag{5}$$

Consistently, excluding $Q_{mn}{}^{LH}$ from the system of equations (3) - (6) with known limited water flow rates of the head water intake, we obtain equations for determining the coefficient for specifying the demand according to the established limit and the planned needs of crops from the water intakes of the canal section. The form of the equation for k^L depends on the structure of the main channel.
For example, consider a main canal consisting of three sections connected in series (Fig. 1).

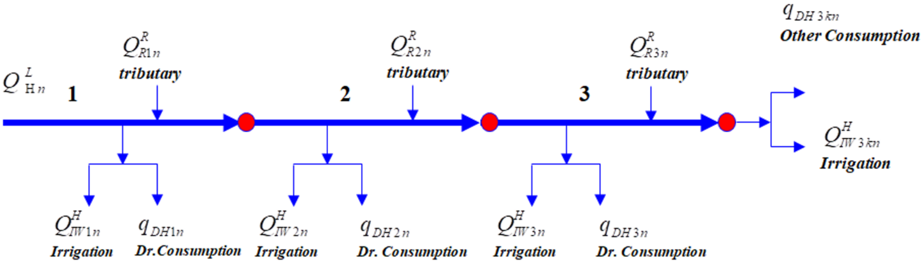

Fig. 1. Structure of main channel consisting of three sections connected in series

The system of equations for this case has the form [7-9]

$$Q^{LH}_{2n} = \frac{Q^{LE}_{2n}+k^L Q^R_{IW2n}+q_{DR2n}-Q^R_{R2n}}{\eta_2}, \qquad \forall n \in N_W \tag{6}$$

$$Q^{\mathrm{LH}}_{3n} = \frac{Q^{LE}_{3n}+k^L Q^R_{IW3n}+q_{DR3n}-Q^R_{R3n}}{\eta_3}, \qquad \forall n \in N_W \tag{7}$$

$$Q^{LE}_{1n} = Q^{\mathrm{LH}}_{2n}, \qquad \forall n \in N_W \tag{8}$$

$$Q^{LE}_{2n} = Q^{\mathrm{LH}}_{3n}, \qquad \forall n \in N_W \tag{9}$$

$$Q^{\mathrm{LH}}_{1n} = Q^{L}_{1Hn}, \qquad \forall n \in N_W \tag{10}$$

Eliminating sequentially from (6) - (7) $Q_{2n}{}^{LE}$, $Q_{3n}{}^{LE}$ and substituting their value in Q^{LH}_{1n}, we get [10]

$$Q^L_{1\Gamma n} = \frac{\dfrac{\dfrac{Q^{LE}_{3n}+k^L Q^R_{IW3n}+q_{DR3n}-Q^R_{R3n}}{\eta_3}+k^L Q^R_{IW2n}+q_{DR2n}-Q^R_{R2n}}{\eta_2}+k^L Q^R_{IW1n}+q_{DR1n}-Q^R_{R1n}}{\eta_1} \tag{11}$$

Substituting into (11) the value of $Q_{3n}{}^{LE}$, after simple transformations, we obtain the following equation for the refinement coefficient [11]

$$Q^L_{1\Gamma n} = \frac{k^L Q^R_{I3kn} + q_{DR3kn} + k^L Q^R_{IW3n} + q_{DR3n} - Q^R_{R3n}}{\eta_1\eta_2\eta_3} +$$

$$+\frac{k^L Q^L_{IW2n}+q_{DR2n}-Q^R_{R2n}}{\eta_1\eta_2} + \frac{k^L Q^R_{IW1n}+q_{DR1n}-Q^R_{R1n}}{\eta_1}, \tag{12}$$

From (12), it can be seen that the head flow of the main canal is the sum of the flow rates of the sections, considering the efficiency of his plots.

Solving (12) concerning the refinement coefficient, we obtain the following expression [12]:

$$k^L = \frac{\eta_1\eta_2\eta_3 Q_{1\Gamma n}^L - (q_{DR1n} - Q_{R1n}^R)\,\eta_2\eta_3 - (q_{DR2n} - Q_{R2n}^R)\,\eta_3 - q_{DR3kn} + q_{DR3n} - Q_{R3n}^R}{Q_{I3kn}^R + Q_{IW3n}^R + Q_{IW2n}^R\,\eta_3 + Q_{IW1n}^R\,\eta_2\eta_3} \tag{13}$$

Similarly, we will obtain the following expressions for the head flow of the Suenli channel, considering its structure [13-16].

$$Q_{1\Gamma n}^L = \frac{k^L Q_{IW1n}^R + q_{DR1n} - Q_{R1n}^R}{\eta_1} + \frac{k^l Q_{I2kn}^R + q_{DR2kn} + k^L Q_{IW2n}^R + q_{DR2n} - Q_{R2n}^R}{\eta_2} +$$

$$+ \frac{k^L Q_{I3kn}^R + q_{DR3kn} + k^L Q_{IW3n}^R + q_{DR3n} - Q_{R3n}^R}{\eta_1\eta_3} + \frac{k^L Q_{IW4n}^R + q_{DR4n} - Q_{R4n}^R}{\eta_1\eta_4} +$$

$$+ \frac{k^L Q_{I5kn}^R + q_{DR5kn} + k^L Q_{IW5n}^R + q_{DR5n} - Q_{R5n}^R}{\eta_1\eta_4\eta_5} + \frac{k^L Q_{IW6n}^R + q_{DR6n} - Q_{R6n}^R}{\eta_1\eta_4\eta_6} +$$

$$+ \frac{k^L Q_{I7kn}^R + q_{DR7kn} + k^L Q_{IW7n}^R + q_{DR7n} - Q_{R7n}^R}{\eta_1\eta_4\eta_6\eta_7} + \tag{14}$$

$$k^L = \frac{\eta_1\eta_2\eta_3\eta_4\eta_5\eta_6\eta_7 Q_{1\Gamma n}^L - \eta_2\eta_3\eta_4\eta_5\eta_6\eta_7\left(q_{D\Pi 1n} - Q_{\Pi 1n}^{\Pi}\right) -}{(\eta_2\eta_3\eta_4\eta_5\eta_6\eta_7 Q_{IW1n}^R + \eta_1\eta_3\eta_4\eta_5\eta_6\eta_7(Q_{I2kn}^R + Q_{IW2n}^R) +}$$

$$\frac{\eta_1\eta_3\eta_4\eta_5\eta_6\eta_7(q_{DR2kn} + q_{DR2n} - Q_{R2n}^R) - \eta_2\eta_4\eta_5\eta_6\eta_7(q_{DR3kn} + q_{DR3n} - Q_{R3n}^R) -}{+\eta_2\eta_4\eta_5\eta_6\eta_7(Q_{I3kn}^R + Q_{IW3n}^R) + \eta_2\eta_3\eta_5\eta_6\eta_7 Q_{IW4n}^R +}$$

$$\frac{-\eta_2\eta_3\eta_5\eta_6\eta_7(q_{DR4n} - Q_{R4n}^R) - \eta_2\eta_3\eta_6\eta_7(q_{DR5kn} + q_{DR5n} - Q_{R5n}^R)}{+\eta_2\eta_3\eta_6\eta_7(Q_{I5kn}^R + Q_{IW5n}^R) +}$$

$$\frac{-\eta_2\eta_3\eta_5\eta_7(q_{DR6n} - Q_{R6n}^R) - (q_{DR7kn} + q_{DR7n} - Q_{R7n}^R)\eta_2\eta_3\eta_5}{+\eta_2\eta_3\eta_5\eta_7 Q_{IW6n}^R + \eta_2\eta_3\eta_5\left(Q_{I7kn}^R + Q_{IW7n}^R\right)\Big)} \tag{15}$$

After calculating the refinement coefficient by expression (15), the refined needs of consumers of sections of the main canal are calculated considering the established limit as follows [17,18]

$$Q_{Wmn}^L = \sum_{j \in J_m^{\text{В}}} \left(k^L Q_{IWmjn}^R + q_{DRmjn}\right) = k^L Q_{IWmn}^R + q_{DRmn}\,, \quad \forall m \in I_{i\Gamma}, \quad \forall n \in N, \tag{16}$$

$$Q_{IWmn}^L = k^L \sum_{j \in J_m^W} Q_{IWmjn}^R\,, \quad \forall m \in I_{i\Gamma}, \quad \forall n \in N_W. \tag{17}$$

Thus, from the planned operation modes of the sections of the main canal adjusted according to the established head water intake limit, the limited needs of all consumers are determined by the following set [19-23]

$$\Omega_M^{WL} = \{[m,\ Q_{mn}^{BL}, Q_{mn}^{EL}, Q_{Wmn}^{L},\ Q_{Rmn}^{R},\ Q_{IWmn}^{L}, q_{DRmn}^{R},\ S_{mn}^{L}],\quad \forall m \in M, \forall n \in N_W\}. \quad (18)$$

Here Q^{LB}_{mn} , Q^{LE}_{mn} are the water consumption at the beginning and end of the plot, Q^{L}_{Wmn}, Q^{R}_{Rmn} are the total water discharges of water intakes and tributaries, Q^{L}_{IWmn}, q^{R}_{DRmn} are the total water discharges for irrigation and other consumers by the limit, S^{L}_{mn} are the irrigated areas of agricultural crops suspended on the plot m for a decade n.

3 Conclusions

As a result of the research, algorithms for basin management of irrigation systems have been developed:

algorithms for calculating the modes of operational management of water resources on irrigation canals have been developed

It should be noted that this developed algorithm allows for increasing the level of operation and quality of water resources management of the basin management of irrigation systems, facilitating the work of operational personnel, and will increase the efficiency of water resources management in a particular system by improving information security.

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