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Scenarios for improvement of water distribution in Doroodzan irrigation network based on hydraulic simulation

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ABSTRACT

Considering the value of water and the high cost of its acquisition and distribution, goal-oriented utilization of water resources is necessary. One of the problems of water resources development in developing countries is the low-yield use of water in irrigation networks downstream of dams. Despite vast investments on construction of these networks in Iran, enough attention is not paid to the right method of their operation, which guarantees the success in achievement of primary goals of networks' construction. Therefore, most of irrigation networks are operated through experimental methods, without any scientific and planned basis. Considering the complex hydraulics of water conveyance and distribution in open networks as very extensive infrastructures, studying them with the aim of determination of a suitable and reliable operation method is not possible with the physical tests in laboratories or experimental approaches, and the mathematical models must be utilized. In the present study SOBEK hydrodynamic model was employed for provision of a suitable operation method for Doroodzan irrigation network, located downstream of Doroodzan dam in Iran. The best operation scenario, based on water distribution assessment indicators was offered after calibrating the model and vast study of available scenarios. In the present operation method water is distributed in the network with a steady distribution and a fixed discharge, and in the proposed method water is distributed through a continual distribution with variable discharge in each 15 days, to provide the water requirement for the present cropping pattern.

1. Introduction

Most of irrigated agricultural lands around the world cannot fully achieve their goals due to low efficiency. Investigating the performance of irrigation networks can have an important role in decision-making of policy makers and managers of the networks and increase the water productivity in agriculture. Many efforts have been done so far to increase the efficiency of irrigation water, and this issue is still one of the most important problems, considered by researchers. Investigating hydraulics of irrigation and drainage networks and their structures can be an effective step in determination of factors affecting the networks and the right management of the networks. Appropriate software can be utilized as powerful tools for studying irrigation networks and forecasting future potential events (Shahrokhnia and Javan, 2003). Choosing the right model which can lead to steady flow and unsteady flow models depends on irrigation network's hydraulic regime. Clemmens et al. (1993), Schuurmans (1993), Merkley and Rogers (1993), Holly and Parish (1993) and Rogers and Merkley (1993) utilized and assessed DUFLOW, MODIS, CANAL, CARIMA and USM hydraulic models respectively. Kasbdooz et al. (1998) assessed the water delivery strategies and operation methods in Qurichay irrigation network. For this network they proposed these operation scenarios: continuous flow with fixed rate, continuous flow with variable flow rate and rotational flow. In their study, assessment of selected operation scenarios was carried out by ICSS-POM hydraulic model, and continuous flow with variable flow rate was chosen as the superior option of operation. In their study, Santhi and Pundarikanthan (2000) developed a multi-criteria approach for planning and scheduling rotational water distribution. This model was utilized in an irrigation network in India in which rotational distribution method was utilized. Results revealed that the performance of water distribution systems utilizing the results of optimization by the model was better compared with the conventional planning method. Mishra et al. (2001) utilized MIKE 11 hydraulic model for examining the need for operation and management improvement in the Main canal of Kangsabati irrigation network, west of India. They utilized the observed and planned discharge ratios for assessing the degree of uniformity in water dis-

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tribution along the canal. A sharp decline in this ratio, from upstream to downstream of the canal was observed, the reason for which was overuse of water in the upper and middle offtakes. Also it was determined that sensitivity of canal's end section to canal discharge changes is more than upper and middle parts. Kumar et al. (2002) utilized CanalMan hydraulic model for performance assessment and operation improvement in RBMC canal located in KangSabati irrigation network, west of India. Hydraulic modeling showed that canal flow was about 13 percent (40 million cubic meters) more than the required amount which reveals over-irrigation in some parts upstream of the canal. Montazar et al. (2007) designed a new control algorithm for network management and utilized it in Narmada canal in India. In this study designed Algorithm was assessed using results of some operation scenarios modeling by SOBEK hydraulic model and performance assessment indicators. Results showed that this algorithm has a considerable accuracy and potential for flow control in this canal, and provides the possibility for realization of demand-based distribution and promotion of water distribution conditions. Tariq and Latif (2010) utilized SIC hydraulic model for hydraulic modeling and flexibility examination of Chowki canal of Swat irrigation network in Pakistan. Results showed that structures weak performance in the canal was due to inaccuracy in their construction.

Abdelmoaty (2013) simulated a part of Ibrahemia canal (one of the longest irrigation canals in Egypt) using one dimension mathematical model (SOBEK 1D) to predict the change of hydraulic parameters of the studied reach. It was simulated after the execution of the suggested training programs to improve the hydraulic efficiency of the studied reach and to reduce the water loss and also to insure that the reach is capable of passing the required discharge to downstream reaches. Finally, four maintenance scenarios were suggested and evaluated hydraulically in selected reach.

Huge investments on construction of agricultural conveyance and distribution networks, downstream of dams have been done in Iran, but their operation is mostly performed through traditional, experimental or trial and error methods. In fact, the scientific and logical method of operation, to be adopted considering special conditions of structures and social conditions of water resources and annual cropping patterns which guarantees the successful work of the networks, is not offered both at the time of design and after their construction. Doroodzan irrigation and drainage network located southwest of Iran in Fars province is also one of these networks. Therefore the need for assessment of the present conditions of operation, and finally providing a new strategy for promotion of network performance is fully felt. The aim of this study was first to investigate about the present conditions of water distribution in a part of irrigation and drainage network of Doroodzan in Fars province (construction unit 1) based on hydraulic indicators. For this purpose irrigation network modeling and SOBEK model calibration were performed for the present conditions. Then some operation scenarios were defined in the network with consideration of problems and weak points of current method of water distribution. Also we try to define acceptable and practical scenarios for water users respecting the local agronomy condition and talking to farmers and Operation Company. The best possible option for water distribution in the considered part of the irrigation network was offered through simulation of these methods and comparing them with hydraulic indicators.

2. Materials and methods

2.1. SOBEK hydrodynamic model

Hydraulic models which were developed specifically for irrigation canals network are few. One of the modules of SOBEK is exclusively applied for simulation of irrigation networks. It is verified in some researches and case studies and it seems to have a high ability to consider the several types of structures. SOBEK is a strong software package which has the possibility of being utilized in different management areas of water conveyance, distribution canals and rivers. SOBEK hydrodynamic model was utilized to simulate hydraulic behavior of the irrigation network in the considered area. This model was developed in the framework of a commercial model in 2000 by WL/Delft Hydraulics with cooperation of TUDelft University of Technology of the Netherlands.

2.2. Performance assessment indicators

For water distribution assessment in irrigation networks, in this study the distribution indicators of adequacy, equity and surplus water were utilized. Distribution adequacy (P_A) is an indicator expressing the capability degree of the operation method in water delivery to provide for the needs:

$$P_A = \frac{1}{T}\sum_T\left[\frac{1}{R}\sum_R(P_a)\right] \quad (1)$$

$$P_a = \frac{Q_d}{Q_r} \leqslant 1 \quad (2)$$

In these equations P_A is the distribution adequacy, P_a is the point performance function related to adequacy, Q_d (Delivery Amount of Water) and Q_r (Required Amount of Water) are attributes of the actual amount of water delivered and the amount of water required for X branch respectively, in t time period. Symbols $\frac{1}{T}\sum_T()$ and $\frac{1}{R}\sum_R()$ show the average of time and place respectively. Distribution equity (P_E) is an indicator that assesses the amount of the existing ratio between the delivered amounts and the required amounts of water in different branches and time periods:

$$P_E = \frac{1}{T}\sum_R CV_R\left(\frac{Q_d}{Q_r}\right) \quad (3)$$

In which CV_R shows the coefficient of place change. Adequacy and equity indicators of distribution were given by Molden and Gates (1990). Table 1 shows these proposed standards.

Surplus water indicator (SW) is also utilized to express the receipt of more water than required in each offtake (Bakhoda Bishegahi, 2012):

$$SW = PA - 1 \quad (4)$$

For intervals with adequacy indicators less than or equal to one the value of Surplus water indicator equals zero. Zero is the ideal value for this indicator and when this indicator is closer is to zero; less water surplus enters the lower degree canal. This indicator is important because studies and observations show that in most open irrigation canals in Iran some offtakes receive more water than required, and the downstream offtakes become deprived of water with the same proportion (Bakhoda Bishegahi, 2012). In both cases the plants become damaged and in some cases surplus water initiates the waterlogged lands.

Table 1
Performance standard classes (Molden and Gates, 1990).

Indicator	Performance classes		
	Good	Mediocre	Poor
P_A	0.9–1.0	0.80–0.89	<0.8
P_E	0–0.1	0.11–0.25	>0.25