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ORIGINAL ARTICLE

Calibration the area-reduction method in sediment distribution of Ekbatan reservoir dam using genetic algorithms

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Abstract Dam reservoirs usually play the most important role in the water resources systems and their optimal utilization in economic and social terms is indispensable. Sedimentation in dam's reservoirs is one of the destructive phenomena which leads to reduction of useful volume of reservoirs and also damages the installations and disturbs their functions. Area reduction method is the most common experimental method to measure the sediment distribution in reservoirs. In this method, reservoirs are geometrically divided into four types. Parameters obtained for each type are based on limited number of chosen reservoirs and consequently the results lead to large scale errors for accuracy of this method. Therefore choosing appropriate parameters can help us to have more acceptable accuracy. In this study, first based on area reduction method a model was made by using MATLAB software and optimized by GA. Error declined by 46.7 %. Then elevation–area–capacity curves for following years were predicted by best coefficients.

Keywords Area reduction method · Genetic algorithms · Sediment distribution · Optimization · Ekbatan dam

Introduction

Rivers have fascinated humanity for centuries. Most prosperous cities around the world have been founded along rivers (Pierre 2002). In ancient times, dams were built for the single purpose of water supply or irrigation. As civilizations developed, there was a greater need for water supply, irrigation, flood control, navigation, water quality, sediment control and energy. Building a dam on the river reduces water velocity and increases water level in dam's upstream. These factors have important effects on changing river morphology and increasing sediments in dam's reservoir.

Each year approximately 20 billion tons of sediment, moved by the world's rivers and waters, are resident deposits (Shafiee and Safamehr 2011). When the current velocity behind the dam reduces, transported sediments in river upstream start to settle in the reservoir. One of the destructive results of sedimentation in the reservoir is the reduction of its stability. Flood due to dam failure can cause catastrophic damage of properties and loss of life (Wu 2007). Sedimentation behind the dam will have negative effects on the exit installations and gates as well. These destructive effects endanger dam's safety (Mohammadzadeh Habili and Mousavi 2008). In sum, sedimentation in dam's reservoirs reduces the useful volume of the reservoir and consequently reduces dam's shelf life (Jain 2003). Therefore prediction and estimation of sediment transportation amount is very important (Shafai Bajestan 2011).

One of the most current methods of measuring the volume difference in a reservoir is using the elevation–area–capacity curves (Lara 1971). Experimental method of area reduction can be mentioned as one of the Elevation–area–capacity curves to distinguish the sediment distribution manner. Several studies have been conducted on experimental method. Area reduction method was evaluated by comparing resurvey data for a number of South African reservoirs with calculated values. The sediment which accumulated in these reservoirs varies from 1.14 to

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44.94 %, representing a wide range of conditions. The test was carried out for each reservoir by calculating the empirical sediment distribution of all four standard reservoir types, whereafter the type which most closely fitted the observed data was determined. This was accomplished by calculating the sum of the squares of the differences between the observed and empirical curves and taking the volume/depth and surface area/depth curves with the smallest sums as having the best fit (Annandale 1984). Ferrari estimated the sediment distribution of Prineville reservoir using area reduction method (Ferrari 1998).

Since the parameters used in the area reduction method are only based on information from limited numbers of dams in US and using this information is very important in accuracy of this method, hence it is possible that parameters used in this method can not be appropriate for prediction of sediment distributions in another reservoir elsewhere. Thus changing these parameters in every reservoir can help us to have more accurate prediction of sediment distribution. Having known the quality of sediment distribution and prediction, we can choose the policies of exploiting the reservoir and decision making about the problems caused by sediments with higher confidence. Sediment settlement is not uniform.

The area reduction method was manually calibrated for Golestan dam resulting to a 10 % reduction on error of estimation (Mohammadiha et al. 2010). The sediment distribution behind the Zayanderood dam was investigated using area increment and area reduction methods and comparing the results of models with the distribution of sediment settlement in the reservoir showed that Borland and Miller model of area reduction method has the highest similarity to real sediment distribution discrepancy (Mousavi et al. 2006). The exact data of elevation volume of Droodzan dam as well as the primary data were used to calibrate the parameters of the area reduction technique for the reservoir. Thus, through calibrating the parameter caused a 30 % reduction in the error of estimating the amount and profile of sediment distribution (Gharaghezlou et al. 2014). The area reduction method was calibrated using simulating annealing (SA) for Karaj dam and Error declined by 20 % (Emadi et al. 2012).

In order to estimate sediments distribution manner by area reduction parameters will be calculated carefully by optimization method. In recent years, some optimization methods that are conceptually different from the traditional mathematical programming techniques have been developed (Engelbrecht 2002). This methods are labeled as modern or nontraditional methods of optimization (Pelikan et al. 1999). One of these methods are genetic algorithms (GAs). GAs are well suited for solving such problems, and in must cases they can find the global optimum solution with a high probability. The genetic algorithm (GA) is an optimization and search technique based on the principles of genetics and natural selection (Vose 1999). A GA allows a population composed of many individuals to evolve under specified selection rules to a state that maximizes the "fitness" (i.e., minimizes the cost function). The method was developed by Holland (1975) over the course of the 1960s and 1970s and finally popularized by one of his students, David Goldberg. Philosophically, GAs are based on Darwin's theory of survival of the fittest (Haupt and Haupt 2004).

The aim of this research is to optimize area reduction method parameters by using genetic algorithms and to increase the accuracy of this method by in estimating sediment distribution in reservoirs for coming years.

In this study, first based on area reduction method a model was made by using MATLAB software and calibrated by GA. Then sediment distribution profile of 2012 was estimated through area reduction method before and after calibration.

Materials and methods

Study area

Ekbatan dam is one of the most important dams of the west region of Iran. It is situated 10 km southeast of Hamedan city on the Abshineh River after the confluence of Yalfan and Abro rivers (Fig. 1).

In order to provide Hamedan's drinking water, this dam started its operation in 1964. Table 1 shows the dam's characteristics.

In this research, by using data of the 2002 elevation–capacity–area curves of Ekbatan dam reservoir and through area reduction method, the sediment distribution profile was estimated for the year 2012.

Area reduction method

Experimental area-reduction method, first presented by Borland and Miller (1958) was subsequently revised by Moody (Blanton and Ferrari 1992). The aim of the Borland and Miller technique is to establish volume/surface area/depth relationships for reservoirs after sediment has been deposited therein (Annandale 1987). The calculation procedure of this empirical method was developed from resurvey data of 30 American reservoirs and consist of two main steps, viz. (Annandale 1984).

(a) Classification of a reservoir as one of four standard types, and
(b) An interactive calculations procedure to determine volume/surface area/depth relationships.