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Calibrating the Experimental Area Reduction Method in Assessing the Distribution of Sediments in Droodzan Reservoir Dam in Iran

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ABSTRACT: The experimental area reduction method is a technique for predicting sediment distribution in dam's reservoir and its parameters (C, m, n) have been obtained by Borland and Miller on the information from a limited number of dams in America. These coefficients can be calibrated for any other reservoirs if there is hydrographic information from the reservoir and then more accurate coefficients can be produced for predictions and programs for water sources. In this research, is employed the primary and secondary hydrographic data of the reservoir to calibrate the area reduction coefficients for Droodzan reservoir. Therefore in utilizing these parameters, the sediment distribution has been predicted in the following years. The result demonstrates that calibrated parameters make 30% reduction on the amount of errors in predicting sediment distribution.

Keywords: Reservoir Sedimentation, Area Reduction Method, Droodzan Dam

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INTRODUCTION

The purposes of reservoirs are to store water in wet season and to consume it in dry season. Therefore, due to water decrease in speed and stagnancy, the sediments are gradually accumulated in the reservoir and decrease the volume of the reservoir and eventually their lifetime. Because of the high costs of reservoir dams and the related installation of water supply, this volume decrease cannot be ignored easily, and it should be prevented to extend the project's useful lifetime. Thus, a number of methods have been developed based on prevention and recycling reservoir volume, the requisites of which are to know the volume of input sediments and the distribution in the reservoir (Shafai Bejstan,2008).

The other problems related to the resident settlement cause are the decrease in the capacity of retarding flood water , increase in the risk of collapse , decrease in the performance of bottom outlets and disturbance in water taking , increase surface roughness and the possibility of capitation in water ways ,the erosion of downstream and putting the dam danger and lower quality of consumed water. Therefore, the issue of sediments should be considered in all the steps of dam construction and its maintenance (Yang,1996).

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. With the researches on 14 different reservoir dams done in India, the sediments often settle at the upper part of the reservoir where the water depth is 20 – 30 percent of the maximum reservoir depth (Houshmandzaeh et al. 2001). Because of the nonuniform and complex particles settlement, various methods have been developed for predicting sediment distribution in the different parts of the reservoir. These methods are based on presenting mathematical models, suggesting experimental and semi-experimental methods or they are based on making laboratory models, which are used only when there is a need for high accuracy since they are expensive and takes time to do it and are limited. Also, the presented mathematical models require several parameters most of which are hard to measure in most reservoirs or have not been measured accurately, but if they exist, they are highly accurate. Many experimental methods have been presented for calculating the feature of sediment distribution in dam reservoirs. However, area increment and area reduction methods are the most common (Amini et al .2010).

The base of both of which is the adjustment of the reservoir's primary due to the settlement of sediments. The cause of the advantages of these 2 methods over the others is that they need input data. But it has to be noted that these methods do not cover all the aspects of sediment settlement in the reservoir but they are economically justifiable because they are simple work and have low costs and high accuracy.

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. 2007).

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The area reduction method was manually calibrated for Golestan dam resulting to a 10 % reduction on error of estimation (Mohammadiha and Emadi, 2010).

The effect of choosing the type of lake on the accuracy of sediment distribution in the Experimental method of area Reduction method was investigated Reduction for Doroodzan dam, the results show that the proposed method by Borland and Miller in choosing reservoir type was not reliable for the dam (Gharahgezlou et al. 2010). Settlement in Sefidrood dam reservoir was investigated using area increment method, area reduction method, Gale and Evans experimental methods. The outputs in these methods are highly discrepant from hydrographic amounts and the methods need to be calibrated (Kargar and Sedghi, 2009). Of the most prominent problem in estimating and assessing the volume of settlement in the country's reservoir is the lack of experimental and semi – experimental methods attributed to reservoir calibration information

Since the parameters utilized in the experimental of area reduction method had been decreased have been obtained, according to information studied by Borland and Miller in 30 dams in America, choosing these parameters were highly influential in the accuracy of this method and since some reservoirs of country have been hydrographic in the years of exploitation, the above method can be calibrated accurately for every reservoir and every reservoir's specific coefficients are obtainable. The purpose of this research is to investigate the quality of sediments distribution in Droodzan dam reservoir using the experimental method of area reduction method and calibration. This method is used for a more accurate estimation and also its prediction for the following years according to calibrated parameters.

MATERIALS AND METHODS

Droodzan multipurpose rockfill dam is 100 km northwest of Shiraz on the Kore River in the longitude and latitude of 5'00'00, 23'00'00 near Marvdasht city (Figure.1). The construction began in 1959 and ended in 1963. The catchment area is 9650 km^2, the crest length is 700 m and it is 56 high.

Figure 1. Position of Droodzan reservoir dam.

In this research, by using data of the primary elevation – the volume and area curves of Doroodzan dam reservoir and through area reduction method, the sediment distribution profile was estimated for the year 2004 with the common parameters of C,m,n. then the parameters C,m,n were calibrated based on the 2004 reservoir hydrographic data via a program written in the MATLAB environment, and it was compared to the real (hydrographic) amount and the discrepancy and standard deviation were obtained through the relations. Then, by using the calibrated parameters based on the hydrographic information, sediment distribution was predicted for 3 time periods of (2024, 2044 and 2064) (Figure 2).

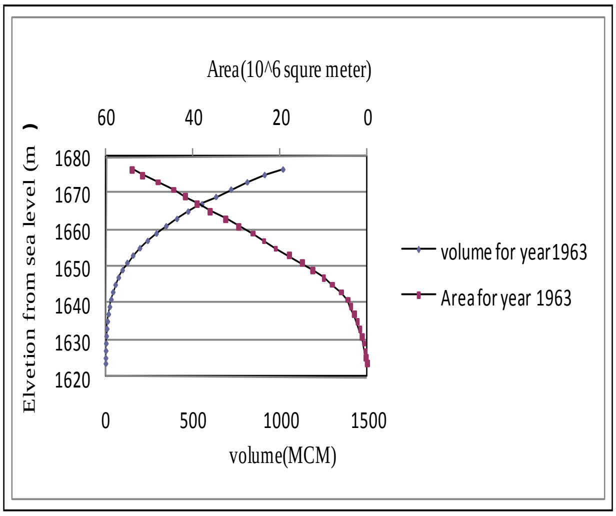

Figure 2. Elevation- volume and area curves of Doroodzan dam

Area Reduction method simulation

The area reduction method is a mathematical method based on observation principles in reservoirs in which the accumulation and distribution of sediments in the different levels have a specific relation with reservoir's shape.

The reservoir shape is defined and categorized according to the height and volume of the reservoir. In this method according to table 1, the reservoirs are divided into 4 types.

Table 1. Types of reservoir in Area Reduction method (Borland and Miller 1958; Muterja 1986).

M	Reservoir Shape	Type
3.5 – 4.5	Lake	I
2.5 - 3.5	Floodplain	II
1.5 – 2.5	Hill and Gorge	III
1 – 1.5	Gorge	IV

The basis of categorizing the reservoirs is M factor which is converse of the didivity of the best drawing line of reservoir height versus reservoir capacity which is drawn on a full logarithm paper where the depth is on the vertical axis and volume is on the horizontal one.

The main equation in this method is: (Borland and Miller, 1971)

$$S = \int_{0}^{y_0} A dy + \int_{y_0}^{H} K a dy \qquad [1]$$

In which S is the total input sediments to the reservoir during life span of reservoir and the bottom and above limits of the first integral count for the primary level of the river bed at the place of construction before and after sediment settlement, respectively. A is the reservoir area in the different elevations.

dy is height increment, H is the reservoir height at normal water level. a is the approximate area of sediments which is measurable according to a difference, for the approximate of p , and k is the proportion coefficient to change the sediment in the approximate area into the real area obtained from Equation 2.

$$K = \frac{A_0}{a_0} \qquad [2]$$

In which A_0 is the reservoir area in height h_0 . a_0 is the sediment in the approximate area in the new height zero . The approximate area is obtained through formula 3.

$$a_p = Cp^m (1-p)^n \qquad [3]$$

Where the measures C, m and n are fixed coefficients determined according to the type of reservoir from table 2. Of course, these measures are Borland and Miller: corrected measures which can be calibrated for each reservoir.

Table 2. Values C, m and N on type of reservoir

Type	C	m	n
I	5.074	1.85	0.36
II	2.487	0.57	0.41
III	16.967	-1.15	2.32
IV	1.486	-0.25	1.34

In the area reduction method, for determining the profile of sediment distribution, the following steps should be taken.(Yang, 1996).

Step1: The depth of reservoir is drawn against its capacity in a logarithmic paper, to determine the reservoir shape factor (M) and then, the reservoir type is determined accordingly from table 2.

Step 2: The measures of dimensionless function h (p) for the different measures of approximate depth of p are calculated from Equation (4).

$$h'(p) = \frac{S - V(y)}{H \times A(y)} \qquad [4]$$

Where h (p) is the dimensionless function of the whole settled sediments, and the capacity depth and area of reservoir. S is the total volume of settled sediments.

V(y) is the reservoir capacity in level y and A(y) in the reservoir area in level of y.

Step 3: Based on the relative depth p and also F – p relation obtained from the graph in Figure 3, the value/s of h(p) is/are drawn in the Cartesian system, where these two curves cross is the new zero level in dam.

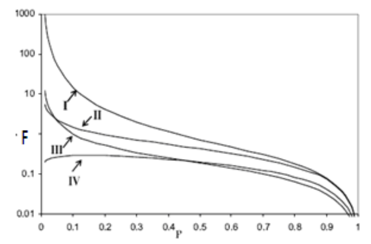

Figure 3. Curves to determine the depth of sediment of dams (Strand and Pemberton, 1982).

Step 4: By using the reservoir's capacity – depth curve, the volume of the existing sediments under zero level is determined and then according to Equation1, the sediment volume in the different depths are calculated.

It should be noticed that this method is a trial and error and if the obtained sediment volume has a high discrepancy with input sediments, the proportion coefficient is calculated again from Equation 5.

$$K_2 = K_1 \frac{S}{S_1} \qquad [5]$$

Where k_2 is the new proportion coefficient and k_1 is the previous proportion coefficient and s_1 is the accumulative volume of sediments.

Then, these measures are compared to those obtained from hydrograph and the amount of error and standard deviation are calculated according to Equations 6 and 7.

$$e = \sqrt{\sum_{i=1}^{n} (v_i - \overline{v_i})^2} \qquad [6]$$

$$\sigma = \sqrt{\sum_{i=1}^{n} (v_i - \overline{v_i})^2 / (n-1)} \qquad [7]$$

In which v_i and $\overline{v_i}$ are the measured volume and real volume of reservoir in the different levels, respectively. σ is the standard deviation and e is the amount of error.

RESULTS AND DISCUSSION

Table 3 shows the amounts of error and standard deviation for sediment distribution using the Area Reduction method before and after calibrating parameters (C, m, n) for the sediment distribution in Doroodzan dam. According to the table after calibration, the error decreased around 30%.

Table 3. Comparing the parameters of Area Reduction method before and after calibration

	C	M	n	Error(%)	$\overline{v_i}$ standard deviation
Befor Calibrated	2.487	0.57	0.41	77	14.82
After Calibrated	2.487	1.6	0.05	46.22	8.9

Figure 4 shows the amounts of reservoir's volume and height in 3 modes of the measured, calculated with common parameter and calibrated. As observed from the figure, the obtained volume – height graph by calibrated matches the measured amounts better. This concord is higher in upper levels and is less in lower levels, which is related to calculating the new zero level in the area reduction method. The inability of the method of area reduction method in predicting the new zero level will be found out here.

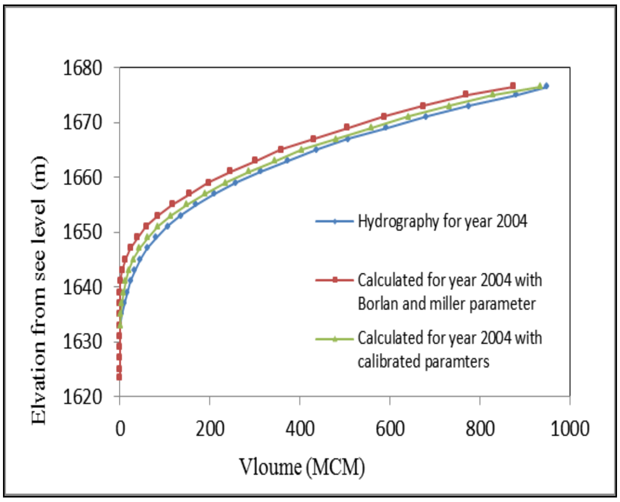

Figure 4. Measured and calculated of sediments' distribution profiles

Figure 5 depicts the prediction for the sediment quality of distribution in reservoir for the years 2024, 2044 and 2064 by using calibrated parameters based on the information of volume, area and height in 2004. It is seen in the graph that the input reservoir sedimentation is little.

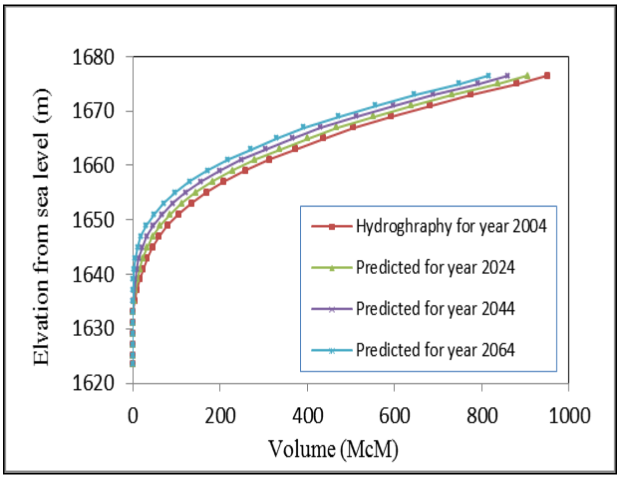

Figure 5. Predicted of sediment distribution profiles

CONCLUSION

The exact data of elevation volume (measured at 2004) as well as the primary data are used to calibrate the parameters of the area reduction technique for the reservoir. Thus, through calibrating the parameter caused a 30 percent reduction in the error of estimating the amount and profile of sediment distribution. Also, the amount of sediments and its distribution in the reservoir was predicted for following years (3 time periods of 2024, 2044 and 2064). Based on the result of this study, the discrepancy of deviation of estimation before and after calibration in this method should be calibrated for the other dams that have hydrographic data during the operation to find the accurate equations to estimate the amount and distribution of sediments and set programs for water resources.

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