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Calibration of Area-Reduction Empirical Method for Dam Reservoir

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ABSTRACT

The mathematical model of Area-Reduction empirical method is written through MATLAB software. Three periods of the hydrologic survey are required to run, calibrate and validate the model. The Dez Dam, which is one of the most significant dams of the Middle East with three periods of hydrographic surveys in 1972, 2002 and 2011, has been chosen for the investigation. The annual average of the input sediment load to this reservoir was calculated by summation of the suspended load and bed load that were estimated through the sediment rating curve and experimental Karaushev curve, respectively. Upon running the model in order to predict the sediment distribution in 2002, the optimization was done by combining MATLAB and Genetic Algorithm models. The research was validated by comparing the results of the calibrated model in 2002 and 2011 with the measured data in the corresponding years. Additionally, Sediment distribution in the reservoir was predicted for 2032 and 2052 using the optimized model. Input data of the calibrated model can be changeable, so the calibrated method can be generalized for other reservoirs as well.

Keywords

Calibration; Genetic Algorithm; sedimentation; Dez Dam

1. Introduction

Sedimentation in dam 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. Thus, for various purposes of reservoir planning, such as economy promotion, operation effects, flood prevention, etc., the designer/planner needs the information on the pattern and distribution of sediment deposition in the reservoir (Vaibhav et al., 2008; Xiaoqing, 2003; Tadesse, 2013). On the account of this matter, several empirical and mathematical methods have been developed to predict the temporal sediment distribution in reservoirs. Among those empirical methods, area-reduction method is the most popular one (Sharad, 2009; Behrangi et al., 2014).

Initially, in order to calculate the sedimentation, it is necessary to estimate the annual average of sediment input (total sediment deposition) to the reservoir by summation of the suspended load and bed load. Sediment rating curve (USBR, 1962; Roshani et al., 2012) is the most common method to estimate the suspended load. There are several hydraulic and hydrological methods for bed load estimation (Farajzadeh et al., 2014; Heng et al., 2014). Considering the fact that usually there is no suitable bed load data for most of the dams, the Karaushev

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experimental curve has been used to determine the bed load to suspended load ratio based on the slope of the river (Georgiev, 1990; Karashuev, 1973). According to Karaushev theory the ratio changes in different rivers based on the topographic conditions. Studies show that Karaushev theory is applicable to Iran Rivers (Heidarnejad et al., 2006; Salimi et al., 2013).

Researches showed that the error of the area-reduction method is different in various cases (Rahmaninan et al., 2012). Annandale (1987) conducted research on fourteen reservoirs in South Africa and showed that just one out of fourteen area-reduction method results were consistent enough with the observation data through the suggested type of reservoir by that method. Thus, many researchers decided to reduce the error of area-reduction method predictions. For example, Gharaghezlou et al. (2014) reduced the error of this method by 30% through manual calibration for Droodzan Dam reservoir.

In the area-reduction method, reservoirs are geometrically divided into four types. There are specific parameters for each reservoir type, which are achieved based on an investigation of the limited number of reservoirs that lead to error in predicting the sedimentation in different reservoirs. By optimizing the mentioned parameters, the area-reduction method is calibrated by an accurate procedure, which can be trusted. Because of the requirement of at least three periods of hydrographic input data, this calibration was done using the Dez Dam measured data, which is one of the largest and the most significant dams in Iran even in the Middle East.

2. Materials and Methods

2.1. Case Study

The Dez Dam is a large hydroelectric dam built in 1963 in Iran. It started operation in 1972. The characteristics of the dam are summarized in Table 1. The current problem of the dam is the annual loss of reservoir capacity due to soil erosion in upstream areas. To estimate the sedimentation through the area-reduction method, data from the Telezang Hydrologic Station, which is a hydrometric and sedimentation monitoring station at the inlet of the Dez Dam, was used to calculate the average annual sediment load (Tagavifar et al., 2010). Location of the Dez Dam and its watershed in Iran, Telezang hydrometric station and considered rain stations of the Dez Dam watershed are shown in Fig. 1 (Emam-gholizadeh, et al., 2013; Meshkin-Nezhad, 2013).

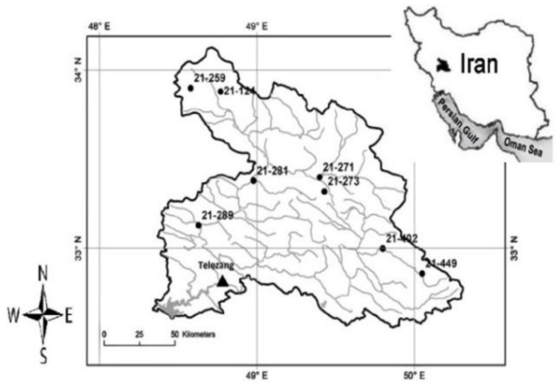

Fig.1. Location of Dez Dam and its watershed in Iran, Telezang hydrometric station and considered rain stations of the Dez Dam watershed

Table 1.Characteristics of the Dez Dam

River	Dam type	Crest width (m)	Height (m)	Height of arc (m)	Capacity of the reservoir (MCM)
Dez	Two arch Concrete thick layer dam	27	203	213	34.60

2.2. Sediment rating curve and total sediment load

The sediment rating curve is a common method of estimating total sediment discharge in the absence of hydraulic measurements. This method shows a relation between the flow discharge and sediment concentration. Sediment concentration (erosion rate) is directly related to the flow discharge. General equation of the sediment rating curve is:

$$Q_S = aQ_W b \quad (1)$$

where Q_S is weighted discharge of sediment (ton/day), $Q_W$is water flow discharge (m^3/s) and $a \& b$ are values for a particular stream and are determined from data via a linear regression between $\log(Q_s)$ and $\log(Q_W)$.

This relationship enables us to estimate the monthly mean and annual sediment rates (Douglas et al., 1998; Yang, 1996).

Total sediment load was determined by the summation of the bed and suspended loads. Then, the volume of the sediment was calculated by dividing the sediment mass to the average density of the sediments. Although there are several hydraulic and hydrological methods for bed load estimation, considering the fact that there are no suitable bed load data for the hydrometric stations, the Karaushev experimental curve has been used to determine the bed load to suspended load ratio based on the river slope of the specific hydrometric stations. Multiplying this ratio by the suspended load will yield the bed load, and the summation of both loads will yield the total sediment load estimation (Farajzadeh et al., 2014).

2.3 Area-Reduction Method

This method was first developed from data gathered in the resurvey of 30 reservoirs and was described by Borland and Miller (1960) with revisions by Lara (1962). This method classifies the reservoirs into four types (listed in Table 2). The reservoirs categorization is done based on the shape factor, M', which is defined by the relationship between reservoir depth and capacity (Livesey, 1975).

The substantial equation of the method is as follows:

$$S = \int_{0}^{Y_0} A\,dy + \int_{Y_0}^{H} K a\,dy \quad (2)$$

$$K = \frac{A_0}{a_0} \quad (3)$$

$$a' = mP^n (1-p)^c \quad (4)$$

where S is total volume of the deposited sediments, H is the initial depth of the reservoir, Y_0 is sediment depth behind the dam, A is reservoir level at different levels, dy is height component, K is the proportionality factor to convert the relative level of sediment to the real surface (Eq. 3), A_0 is the initial level in the reservoir Y_0, a_0 is the relative level of the reservoir level Y_0 and a' is the relative level of return for different values of the sediment depth that is calculated by relative depth "p" (Eq. 4). The parameters of relative area equation for each reservoir type by Lara (1962) and Borland and Miller (1960) are represented in Table 3.

Table 2. Classification of the reservoir shape using M' parameter (Yenigün et al., 2008)

Standard type	Tank type	Parameter M'
I	Normal Lake (Lake)	3.5-4.5
II	Flood plains hill (Flood Plain)	2.5-3.5
III	Foothills (Hill)	1.5-2.5
IV	Highland (Gorge)	1-1.5

Table 3.Parameters of sediment relative area relationships (USBR, 1962)

Tank Brigade	Parameters of sediment relative area relationship due to Lara method (1962)			Parameters of sediment relative area relationship due to Borland & Miller method (1960)		
	m	n	c	m	n	c
I	5.074	1.85	0.35	3.417	1.5	0.2
II	2.487	0.57	0.41	2.3247	0.5	0.4
III	16.967	1.15	2.32	15.882	1.1	2.3
IV	1.486	-0.25	1.34	4.232	0.1	2.5

The volume of the sedimentation between two different levels of the reservoir was calculated by multiplying the interval of the depth by the average surface area of sediment for the two levels. If the accumulated volume of sediment for all intervals between levels was equal to the probable volume of sediments, the new zero-capacity elevation was accepted. Otherwise, the ratio of the accumulated volume to the expected volume of sediment was multiplied by K and the computations were repeated using the new K (Eq. 3). This process continued until the volume of the distributed sediment in the reservoir became equal to the predicted volume of the sediment in the time period.

Table 4. F and relative depths for each type of reservoir (Sharad, 2009)

p	F			
	type1	type2	type3	type4
0.01	996.7	10.568	12.03	0.2932
0.02	277.5	3.758	5.544	0.2911
0.05	51.49	2.233	2.057	0.2878
0.1	14.53	1.495	1.013	0.2796
0.15	66.971	1.169	0.6821	0.2781
0.2	4.145	0.9706	0.518	0.2556
0.25	2.766	0.8299	0.4178	0.2518
0.3	1.9	0.7212	0.3486	0.239
0.35	1.495	0.5565	0.2968	0.2365
0.4	1.109	0.49	0.2333	0.2197
0.45	0.9076	0.4303	0.2212	0.2033
0.5	0.7267	0.3768	0.1917	0.201
0.55	0.568	0.3623	0.1687	0.1826
0.6	0.4732	0.3253	0.1422	0.1636
0.65	0.3805	0.278	0.1207	0.1443
0.7	0.3026	0.2333	0.1008	0.1245
0.75	0.2359	0.1907	0.08204	0.1044
0.8	0.1777	0.15	0.06428	0.08397
0.85	0.1202	0.1107	0.04731	0.0633
0.9	0.08011	0.07276	0.03101	0.0423
0.95	0.0583	0.02698	0.01527	0.02123
0.98	0.01494	0.01425	0.006057	0.008534
0.99	0.007411	0.007109	0.00302	0.00247
1	0	0	0	0

F dimensionless function for different relative depths, " p ", is calculated as:

$$F = \frac{S - V_h}{HA_h} \tag{5}$$

where F is dimensionless function of the entire sediment deposition, capacity, depth and area, S is total sediment deposition, V_h is reservoir capacity at a given elevation, h, H is initial depth of the reservoir, A_h is reservoir area at a given elevation, h.

The relation between F and p is re-presented in Table 4. Then, the depth of the reservoir, the exiting sedimentation volume under zero level was determined by using the capacity curve, and after that, sedimentation volume in different depths was estimated (Mousavi et al., 2006; Khademi et al., 2010).

3. Results and discussion

Considering the majority of Dez sediment as fine sediments, which contains 45% clay and 55% silt, and the gravity of 1.2 (ton/m3), the entire suspended load was estimated using sediment rating curve according to the method results (Fig. 2). The average yearly suspended load was calculated about 13.167 (MCM). Bed load to suspended load ratio was estimated about two percent in Telezang Station due to Karaushev graph according to the Dez river slopes in the Telezang station. (Fig. 3) The yearly bed load was calculated about 2.63 (MCM) by multiplying this ratio by the suspended load. Then, using sum of the mentioned values, the average of the total annual sediment load was calculated about 15.8 (MCM). Thus, Due to the hydrographic survey in 1972 and according to the yearly average of whole logged sediment load as input data, sediment distribution in 2002 was predicted through the area-reduction Borland & Miller and Lara MATLAB model. At first, according to 1972 surveys, a logarithmic plot of the depth-capacity relationship in 1972 (Fig. 4) for Dez dam reservoir provided the shape factor (m'=2.65) for type classification, so the reservoir was classified as type II according to Table 2. The most important part of the mentioned model is estimation of the new initial level of the Dez reservoir after sedimentation and calculation of the sediment areas for each depth increment above the new zero elevation in 2002. These calculations were done by dividing the primary area (before sedimentation in 1972) at zero elevation using Eq. 4 considering the parameter values in Table 3 according to the reservoir types and a dimensionless function from the original capacity curves in 1972 for Dez dam reservoir using equation Eq.5 and Table 4. Then, the plot of data point's prediction was obtained by using Borland & Miller and Lara MATLAB model, which represented the volume-elevation of the reservoir in 2002. Comparison of the hydrographic survey results in 2002 is shown in Figs. 4 and 5. As it is observed, prediction and hydrographic survey curves did not overlap considerably. In addition, it was observed that empirical prediction error in lower reservoir elevations was much more than in higher elevations. For a more accurate comparison, the error percentage, the Root Mean Squared Error (RMSE) and determination coefficient (RSQ returns r2) of the mentioned methods and the new initial reservoir level after the sedimentation in 2002 are compared with the related observed data in the same year, as illustrated in Tables 6 and 7.

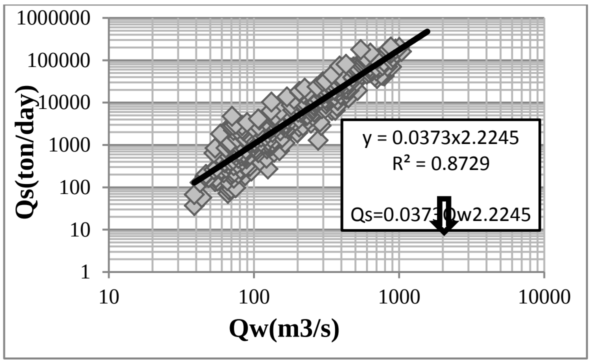

Fig.2. Dez Dam sediment rating curve (suspended load)

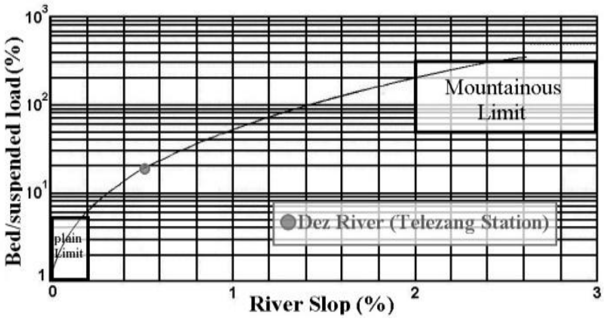

Fig.3. Karaushev Experimental Curve to estimate bed to suspended load ratio

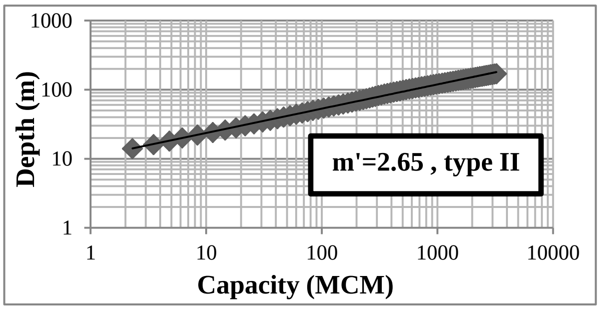

Fig.4. m' values and type of Dez Reservoir during the operation

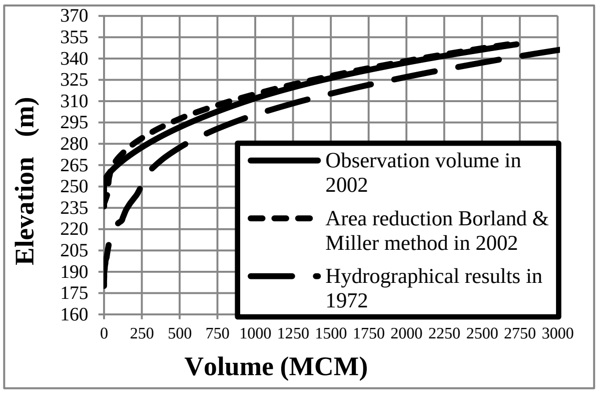

Fig.5. Running area-reduction Borland & Miller method in MATLAB model in 2002

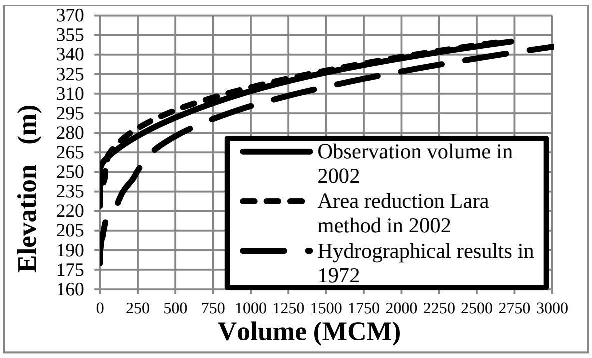

Fig.6. Running area-reduction Lara method in MATLAB model in 2002

Due to the undeniable values of RMSE and RSQ for Borland & Miller and Lara MATLAB models, calibration is necessary for more accuracy. For this purpose, the following relation was considered:

$$(I)\begin{cases} k=f(a,A), a'=f(m,n,c,p), p=f(Y,H) \xrightarrow[\text{are input observed data}]{A,H,Y,S} V_{ci}=f(m.n.c) \\ V_{ci}=f(K,p,S,H,A,a,Y) \end{cases}$$

where V_{ci} is the calculated volume at each elevation, all other parameters were explained in area-reduction method.

Borland & Miller (1960) and Lara (1962) directly related m, n and c parameters to the dam topographical conditions and their shape factors that were represented as the experimental results of studying a limited number of reservoirs. Therefore, it is obvious that they can be changed according to different climates and topographic conditions of dam reservoirs. Therefore, the calibration through the MATLAB and Genetic Algorithm combined method was done by considering m, n and c as the decision variables of the optimized model. Minimizing the RMSE was the objective function of this model that is represented in relation (II).

$$(II)\begin{cases} \text{Decision parameters} \rightarrow m,n,c \\ (\text{ObjectiveFunction} \rightarrow \text{MinimizingRMSE})\ RMSE=\sqrt{\dfrac{\sum_{i=1}^{n}(V_{oi}-V_{ci})^2}{n}} \end{cases}$$

where V_{oi} and V_{ci} are the observed and calculated volumes in each elevation, respect-tively.

Considering the hydrographic survey in 2002 as the observed volume and the predictions by Borland & Miller and Lara MATLAB model in 2002 as the calculated volume, the combined MATLAB & GA model performed until the least error of the objective function was obtained. The optimized parameters are shown in Table 5. According to the optimization process in the Genetic Algorithm, Fig. 7 represents the best, worst and mean score diagrams due to the generation in calibration of the three mentioned parameters.

The optimized parameters were used to produce the calibrated method; so the prediction of sedimentation in 2002 was done according to the hydrologic survey in 1972 through this method. Comparison of the optimized and observed curves (Fig. 8) showed that the overlapping considerably increased, and the RMSE decreased by 12.49 as illustrated in Table 6. Furthermore, the reduction of both RSQ and error percentages is shown in Tables 6 and 7.

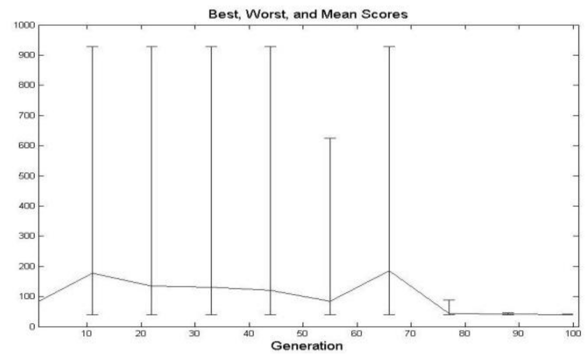

Fig.7. The best, worst and mean scores diagram due to the generation in calibration of the three parameters by GA

Table 5. Results of the combined MATLAB and Genetic Algorithm model

Objective function	Decision variables	m	n	C
Minimizing The RMSE	m, n, c	-0.116	0.402	0.769

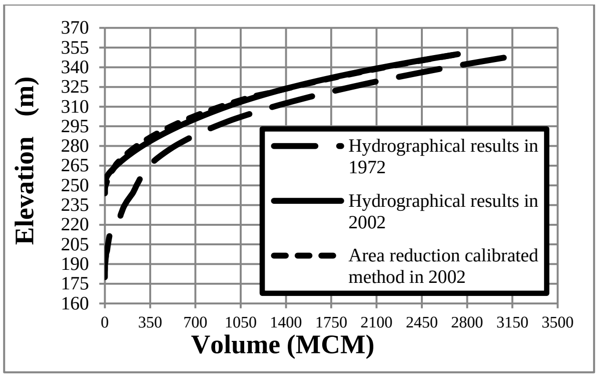

Fig.8. Running area-reduction calibration through MATLAB & GA Combined Model in 2002

Verification of the optimized model was done through the combined MATLAB and GA model by considering the hydrographic survey in 2002 as input data and comparing the results of area-reduction by Borland & Miller and Lara and the calibrated method predictions with the hydrographic survey in 2011. The RMSE values of the comparisons are shown in Table 8, which shows the least value of RMSE for the calibrated method, so the accuracy of this method was also satisfying due to the considerable overlap of the observed and calculated curves using this method, as presented in Fig. 9. The error percentage and RMSE drastically decreased when calculating the new reservoir sedimentation level in 2011, as shown in Table 8.

Table 6. Errors of different methods in prediction of the new initial level of the Dez Reservoir in 2002

	Hydro-graphic data	Area-reduction calibrated method	Borland & Miller Area-reduction method	Lara Area-reduction method
New initial level of the reservoir	245.5	246	220.94	232
The error Percentage	–	0.2036	10. 000	5.499
RMSE		0.353	17.366	9.545

Table 7.Comparison of the errors of different methods in sedimentation prediction with Hydrographic Survey in 2011

	Area-reduction calibrated method	Lara Area-reduction method	Borland & Miller Area-reduction method
RMSE	11.16175	59.4979	60.2784
RSQ	0.9891	0.7853	0.7524

After verification, it is safe to predict the next year sedimentation of the reservoir through the calibrated method with the optimized parameter based on hydrographic data in 2002. Predicted sedimentation results for 30 and 50 years after 2002 are shown in Tables 9 and 10 as well as Fig.10.

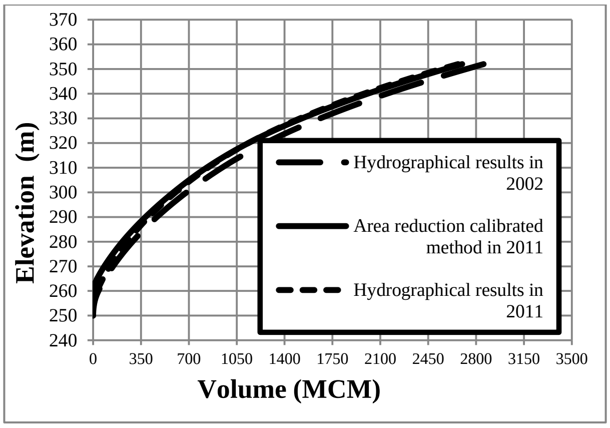

Fig.9. Running area-reduction calibrated through MATLAB & GA Combined Model in 2011

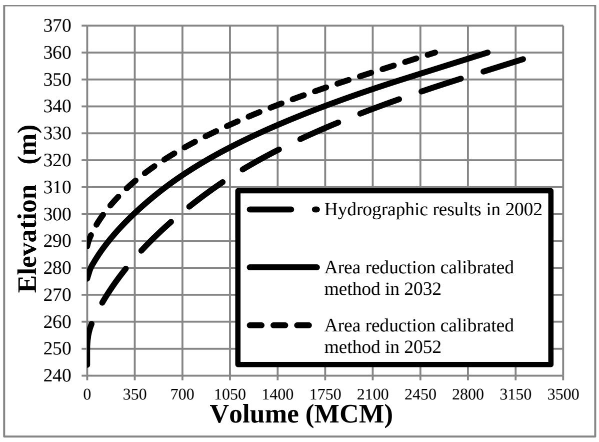

Fig. 10. Running the area-reduction calibrated MATLAB & GA Combined Model for 2032 and 2052

Table 8. Prediction of sediment volume and depths in next years

Sediment depth toward normal depth of dam	Reservoir sediment depth (m)	New initial level of the reservoir from sea level (m)	Sediment volume percentage below the new initial level toward total volume of sediment	Sediment volume below the zero elevation (MCM)	Total sediment volume of the reservoir (MCM)	years after 2002
		245.5				0
27.7	30.5	276	52.6	249.500	474	30
38.6	42.5	288	55.4	437.500	790	50

Table 9. Reservoir volume and percentage of the reservoir volume reduction in different years at two levels of 360 m and 350 m

Elevation (m)	year						To Explain
	2052	2032	2011	2002	1972	1962	
350	1.934	2.322	2.59	2.728	3.253	3.316	Reservoir volume (billion cubic meter)
	41.68	29.98	21.89	17.73	1.90	0	The percentage of the reservoir capacity reduction in comparison with the operation year in 1962
360	2.558	2.951	3.17	3.36			Reservoir volume Billion cubic meter)
	23.87	12.17	5.65	0			The percentage of the reservoir capacity reduction in comparison with 2002

4. Discussion

The large value of the total annual sediment load estimation about 15.8 (MCM) in Dez Dam Reservoir due to the calculated suspended and bed load of its basin (as shown in Figs 2 & 3) caused the useful reservoir volume to decrease gradually. Thus, the importance of sediment distribution study by an accurate method was more highlighted. Lara and Borland & Miller area-reduction methods are the best empirical methods. However, parameters of those methods were obtained by experimental study of 30 dams in America, so the parameters may not be applicable to different climates and regions. With the purpose of obtaining the most convenient prediction, calibration and validation of the area-reduction method was done by the combined MATLAB and GA model due to three periods of the hydrologic surveys in 1972, 2002 and 2011 that were investigated by specific methodologies due to the Geometric sections and the changing sedimentation. Validation is the most important stage after the calibration, and if the study is done without validation, the results of the calibrated method will have no accuracy for further investigations, and it will just overlap for a particular year. Because of the error reduction in comparison with the hydrographic and the calculated data after calibration and validation, the investigation showed that the calibrated method is a convenient accurate method for prediction of the sediment distribution. In previous years, due to the lack of hydrographic data and low accuracy, calculations led to serious damages to the reservoirs because of the big problems for the water resource management and water exploitation due to the sedimentation. Overall, predictions by the calibrated method illustrated a considerable capacity loss of the Dez Dam reservoir gradually and the new initial level increment, which is represented in Table 9, will cause unavoidable problems in opening the lower valves and operation of hydroelectric turbines. Furthermore, as shown in Table 10, after 90 years since the operation time, about 50 percent of the reservoir capacity will be lost because of the sedimentation indicating the short service life of the dam (Table 10). In fact, it is undeniable that the reservoir would not be efficient after some years. Thus, by using the accurate calibrated method further investigations such as estimating useful life of the dams will be done correctly. Therefore, these calculations emphasize the necessity of the reservoir flushing and taking effective measurement of the dam operation. Now, this can be achieved by the calibrated method, and more precise predictions of the sedimentation trend at different levels, in particular, years can be achieved.

It is worth mentioning that the input data of the calibrated model were not described just for Dez Dam; they are changeable so that the model can be used for other dams with at least three periods of hydrographic surveys. Therefore, the results will be more confident and further measurements can be done wisely, before the dam reservoir being filled with the sediments at the critical period.

Nomenclature

Q_S	weighted discharge of sediment (ton/day)
Q_W	water flow discharge (m^3/s)
S	total volume of the deposited sediments (m^3)
H	initial depth of the reservoir (m)
Y_0	sediment depth behind the dam (m)
A_0	initial level in the reservoir (m)
h	elevation (m)
A_h	reservoir area at a given elevation h (m^2)
V_h	reservoir capacity at a given elevation h(m^3)
p	relative depth

Subscripts

MCM	Million Cubic Meters
M'	Shpe factor of the reservoir
m,n,c	Parameters of the sediment relative area
a,b	values for a particular stream
F	dimensionless function of the entire sediment deposition

References

Annandale G.W., (1987), Reservoir Sedimentation, Elsevier Science Publishers. New York.

Behrangi F., Banihashemi M.A., Mahani Sh., and Rahmanian M.R., (2014), Sediment settling in the Latian Dam in Iran. International Journal of Sediment Research, 29(2), 208–217.

Douglas B. M., and Peter J. W., (1998), Annual hysteresis in bed load rating curves. Water Resources Research journal, 34(9), 2393-2399.

Emamgholizadeh S., Golabkesh F., Kazemasare E., and Golabkesh M. M., (2013), Sediment transport estimation of Sabily water intake in the Dez River with Sharc model. Journal of Applied Sciences in Environmental Sanitation, 8(1), 11-16.

Farajzadeh S., Salajegheh A., Ahmadi H., and Hosseini S. A., (2014), Determining the Best Method for Estimating the Bed Load through HEC-RAS Model (A Case Study for Taleghan Dam). Bulletin of Environment, Pharmacology and Life Sciences, 3(3), 20-27.

Georgiev B. V., (1990), Reliability of bed load measurement in mountain rivers. International Association of Hydro-logical Sciences (IAHS), 193, 263-270.

Gharaghezlou M., Masoudian M., and Fendereski R., (2014), Calibrating the experimental area reduction method in assessing the distribution of Sediments in Droodzan Reservoir Dam in Iran. Journal of Civil Engineering and Urbanism, 4(1), 54-58.

Heidarnejad M., Golmaee S.H., Mosaedi A., and Ahmadi M.Z., (2006), Estimation of sediment volume in Karaj Dam Reservoir (Iran) by hydrometry method and a comparison with hydrography method. Lake and Reservoir Management, 22(3), 233-239.

Heng S., Suetsugi T., (2014), Comparison of regionalization approaches in parameterizing sediment rating curve in ungauged catchments for subsequent instantaneous sediment yield prediction, Journal of Hydrology, 512, 240-253.

Karaushev A. V., (1973), Computation of reservoirs sedimentation. AISH Publication, 108, 199-205.

Livesey R. H., (1975), Corps of Engineers methods for predicting sediment yields. Present and Prospective Technology for Predicting Sediment Yields and Sources. U. S. Dep. of Agr., Washington D. C., ARS-S-40, 16-32.

MeshkinNezhad S., Mashal M., and Hedayat N., (2013), Simulation of the climate change impact on run off in Dez dam area. International Journal of Agriculture and Crop Sciences, 6(3), 121-126.

Miller C. R., (1951), Analysis of flow duration sediment rating curve method of computing sediment yield, report. United States Department of Interior, U.S Bureau of Reclamation (USBR), 55 pages.

Rahmanian M. R., and Banihashemi M.A., (2012), Introduction of a new empirical reservoir shape function to define sediment distribution pattern in dam redervoirs. IJST, Transactions of Civil Engineering, 36(C1), 79-92.

Roshani A., Mosaedi A., Sedghi H., Babazadeh H., and Mohmmad M., (2012), Estimation of sedimentation in Karaj and Torogh Dam Reservoirs (Iran) by hydro-logical models and comparison with actual sediment. Ecology, Environment and Conservation.18(4), 835-847.

Salimi M., Hassanzadeh Y., Daneshfaraz R., and Salimi M., (2013), Sedimentation Estimation Study Using Artificial Neural Network for Karaj Dam Reservoir in Iran. Journal of Basic and Applied Scientific Research, 3(8), 185-193.

Yang C.T., (1996), Sediment Transport Theory and Practice. McGraw Hill. New York, 369.

Sharad S. K., Jain Sanjay K., Jain, AnjuChaudhry and P. K. Agarwal, (2009), Empirical Area Reduction Method of Reservoir Sedimentation Assessment–Coefficients for Indian Reservoirs. Joint International Convention of 8th IAHS Scientific Assembly and 37th IAH Congress, September 6-12, Hyderabad, India.

Tadesse T. B., (2013), Sedimentation and Sustainability of Hydropower Reservoirs Cases of Grand Ethiopian Renaissance Dam on the Blue Nile River in Ethiopia. Norwegian University of Science and Technology Department of Hydraulic and Environmental Engineering, master thesis.

Tagavifar A., and Adib A., (2010), Evaluation of sedimentation and flushing by mathematical model in reservoirs of the successive Dez stream dams in Iran. WFL Publisher Science and Technology, Journal of Food, Agriculture & Environment, 8(2), 980-987.

United State Bureau of reclamation (USBR), (1962), Revision of the procedure to compute sediment distribution in large reservoirs, Sedimentation section and Hydrology branch.

Vaibhav G., and Jothiprakash V., (2008), Estimation of useful life of a reservoir using sediment trap efficiency. Journal of Spatial Hydrology. 8(2), 1-14.

Xiaoqing Y., (2003), Manual on sediment management and measurement. Secretariat of the world metrological organization, Switzerland.

Yenigün K., Gümüş V., and Bulut H., (2008), Trends in stream flow of Euphrates Basin. Turkey.Proceedings of the ICE - Water Management journal. 161(4), 189–198.