International Journal of Water Resources and Environmental Engineering Vol.2 (1), pp. 001-008,January, 2010
Available online at http://www.academicjournals.org/ijwree

Full Length Research Paper

Determination of appropriate hydraulic conditions to decrease the negative impacts of Dez dam flushing operation on the downstream

H. Samadi-Boroujeni[1]*, A. H. Haghiabi[2] and E. Ardalan[3]

[1]Water Engineering Department, Shahrekord University and Water Recources Research Center, Iran.
[2]Water Engineering Department, Lorestan University, Iran
[3]Water Engineering Department, Shahrekord University, Iran, Msc Water Engineering Graduated from Shahrekord University, Iran

Accepted 8 November, 2009

The Dez dam is located in the Southwest Iran and was constructed in 1963, with a height of 203 m and an underground powerhouse of 520 MW, because of the high rate reservoir sedimentation, in recent years, therefore, performing flushing operations through the three irrigation gates of the dam has received great attention. Due to the release of high concentrations of sediments, on the other hand, performing such operations may cause considerable impacts downstream. The downstream limitations should, therefore, be taken into consideration during the flushing operations. In this paper, it has been tried to identify and introduce the downstream limitations of performing flushing operations for Dez dam, and to determine the most appropriate flushing hydraulic conditions in terms of discharge, concentration, and duration of such operations using model MIKE 11, so that the dam utilization system can perform these operations with the least damage to the downstream. Results show that if we take into consideration every factor involving the decision- making, then the flushing operations along with two stages of opening the irrigation gates (that is the evacuation of sediments) for 6 hours and the discharge of 30 m^3/s will be the best option. The interval between the two flushing operations should be at least 6 hours. Based on the results of this paper, appropriate conditions for hydraulic flushing can be determined. These conditions will be manipulated by the responsible administration as these operations would have the least damage and cost.

Key words: Dez dam, environmental impacts, sediment flushing, Mike 11 model.

INTRODUCTION

The Dez dam Project was constructed in the period from January 1960 to November 1962. The project is located in the Zagros Mountain range in the Southwest Iran and approximately 25 km north of Dezful city. The dominant foreseen elements of the project are the 203 m high double curvature arch dam and the 60 km long reservoir with the original volume of 3315 million m^3. The minimum and maximum control level is 300 and 352 m, respectively. An underground powerhouse contains eight 65 MW units for a total installed capacity of 520 MW has been generated an average of 2400 GWh/year energy production during last 46 years. Also Dezful re-regulating dam was constructed in 31 km downstream Dez dam to regulate the released water from Dez HEPP. A map of Dez project is shown in Figure 1.

Although the project has been well maintained, the project is now over 46 years old and the total amount of sediment accumulated on the dam reservoir amounts to 700 million cubic meters so it is reaching its mid-life period. Sedimentation in the Dez dam reservoir is one of the worth issues, which have assumed special importance in recent years, and the increased level of sediment behind the Dez dam body during the past years with a rate of 2 m/year has caused the sediment level to rise near the intake of Dez power plant. Another component of the project is Dezful re-regulating dam. The re-regulating dam with a height of 20 m is located in the vicinity of Dezful city and 31 km downstream of Dez dam.

*Corresponding author. E-mail: samadi153@yahoo.com.

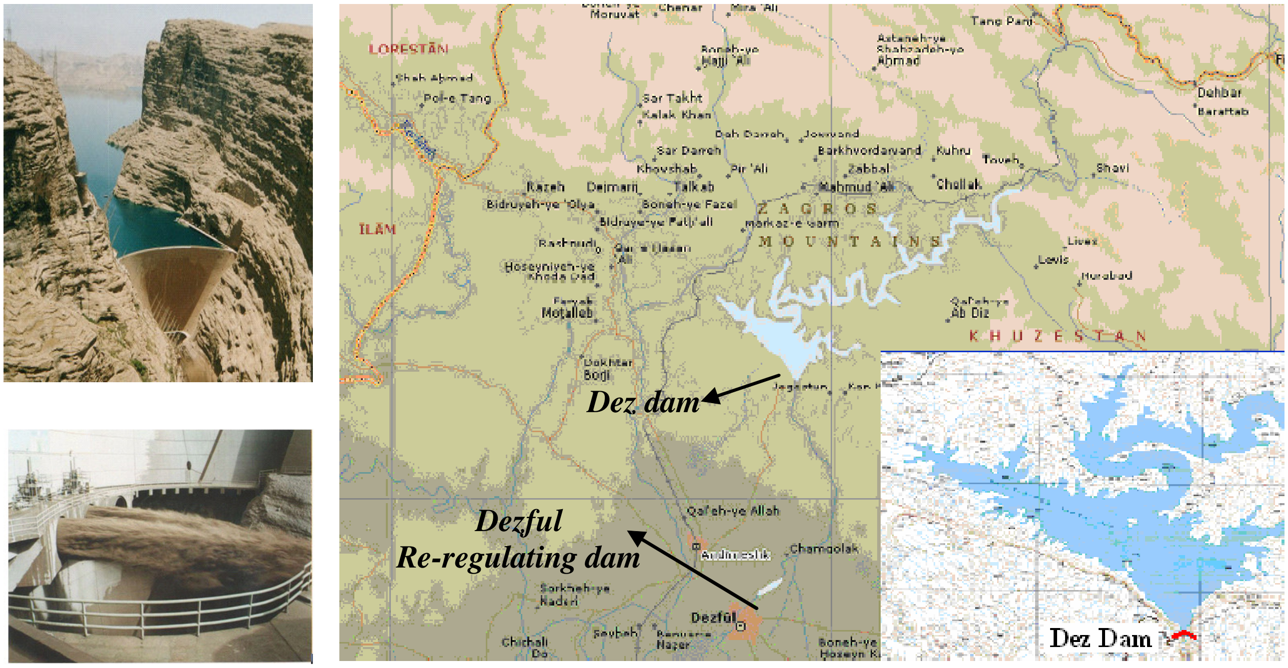

Figure 1. Map of Dez dam project and flushing br irrigation outlets.

It has been utilized since 1972 and the previous surveys show that 40% of the Dezful re-regulating dam reservoir capacity is already has been filled with sediment (Sadeghi, 2002).

Generally with particular regard to the elements affected by sedimentation, include:

- The reservoir, its remaining storage life and its ability to provide the degree of regulation originally envisaged for the project;
- elements already affected by the passage of water and sediment, including the irrigation outlets, and which may in the future be affected, including turbine equipment, particularly runners and wicket gates.
- Dezful re-regulating dam sedimentation. Since the main function of the re-regulating dam is to make regular release of water from Dez dam hydropower plant in downstream river, the useful storage volume is therefore, very important for this dam.

An overview of the reservoir sedimentation problem, its effects on the elements noted above, an indication of the impacts on the project, if remedial work is not implemented, and in this regards, one of the proposed measures to address the sediment management is the cone flushing of sediments through the dam irrigation outlets. Flushing of sediments has been conducted over the last few decades to augment irrigation flows as well as to remove the sediments that has accumulated immediately upstream of the irrigation outlets. This is surely has prompted the Khuzestan Water and Power Authority (KWPA) to consider performing the Dez dam flushing operations on the agenda. Predictions indicate that 1 - 1.5 million cubic meters of fine-grained sediments in the Dez dam reservoir will be discharged annually into the river downstream, in the next few years, as a result of performing flushing operations through the Dez dam irrigation outlets (Acres and Dezab, 2004). It should be noted that there are various important constraints during sediment flushing operation via the irrigation outlets such as environmental hazards downstream, loss of reservoir water storage, possibility of irrigation outlets clogging by large boulders, the effect of sediment spray around of the power house, and decreasing of power generation. Since the sedimentation in the re-regulating dam reservoir play an important role in Dez dam downstream flushing effects, it is essential that the sedimentation processes in the re-regulating dam reservoir to be simulated for surveying the negative impacts of Dez dam flushing operation on the downstream. It should be noted that sediments released from Dez irrigation outlets are mostly cohesive sediments therefore this matter should be considered for modeling of sediment transport processes in river downstream.

Since the hydraulic of flow in rivers is very complex and man has not managed to give a real explanation of this phenomenon yet, it is necessary, therefore, to carry out a lot of experiments and measurements to ascertain the conditions of flow. Accordingly, researchers and scientists have tried to apply mathematical methods and computer-aided facilities in order to develop mathematical models, so that they could be used to facilitate the measurements and experiments as far as possible and in order to give a simulation for the flow under various conditions. Recently, these models were developed to solve more difficult problems, such as the simulation of sediment movements. Generally, the basics for the development of hydro-mathematical models are the famous equations of Navier-Stokes and the mass transport equations. For open channel flows (canals and rivers), these equations have been replaced with Sant Venant equations and the sediment transport equation. Although these equations do not have analytical solutions for real problems, one can solve them with an acceptable precision through the application of numerical techniques (Scarlatos and Lin Li, 1997). In this respect, many mathematical models have been developed, and one of the most famous is MIKE11 Model, which was developed by Denmark Hydraulic Institute in 1992 which simulates the flow in an unsteady and one-dimensional state (DHI, 2000). The MIKE 11 computational modules with particular relevance to sediment transport studies besides the main module are AD (advection-dispersion module), ACS (advanced cohesive sediment module), ST (sediment transport module), GST (graded sediment transport module), XZ (sediment transport in stratified flow). The MIKE 11 Sediment transport modules are used for simulation of one-dimensional free surface flow and sediment transport in rivers where stratification can be neglected. The AD module for transport modeling (advection and dispersion) is based on the one-dimensional equation of conservation of mass of a dissolved or suspended material (e.g., sult or fine sediments). The module requires output from the hydrodynamic module (HD module), that is discharge and water level, cross-sectional area and hydraulic radius. This model can numerically solve the general form of the mass transport equations as follows:

$$\frac{\partial c}{\partial t}+\frac{\partial}{\partial x}\left[u(x,t).C-D(x,t)\frac{\partial c}{\partial x}\right]+\sum_{i=1}^{i=n}\left[w_i(1-\frac{\tau_b}{\tau_{di}})\frac{1}{h}\right]C_i=C_e.e^{-\beta.t} \quad (1)$$

Where u(x, t) is the water velocity (m/sec), C_e is the coefficient of erodibility, β is the non- dimensional exponent of erodibility, w is the settling velocity of particle (m/sec), τ_d and τ_b are the shear stress for the beginning of sedimentation and the shear stress of bed respectively (N/m^2), h is the depth of water (m), C_i is the concentration of suspended sediments related to its group (Kg/m^3), C is the concentration of suspended sediments (Kg/m^3), D(x, t) is the coefficient of diffusion (m^2/sec), x is the distance (m), and t is time (sec).

MATERIALS AND METHODS

Data collection

In this study, the following information and data were collected: Statistics and information concerning the Dez River cross–sections, the discharge-stage relationships of the project's hydrometery stations, the data of discharge and sediments in the project's hydrometery stations (including the stations of Dez dam, Dast-Mashan and Dezful), and the information concerning the Dez dam flushing operations (Samadi Boroujeni and Galay, 2005). The cross-sections used in this study were carried out in the area between the Dez dam and the Dezful re-regulating dam in 1991 and 2001 by Khuzestan Water and Power Authority (Samadi-Boroujeni, 2004).

For the formulation of scenarios, the information concerning the utilization of the Dez dam and the Dezful re-regulating dam, and the information concerning the environment of river were used.

Based on the collected information, the input file of MIKE11 was provided for 31 km of Dez River, in the area occurring between Dez dam and Dezful re-regulating dam.

Information concerning the Dez dam reservoir flushing

Following the over-accumulation of sediments behind the Dez dam body, flushing operations were performed for the first time in 1994, through opening of the dam irrigation outlets. However, these operations were subsequently repeated annually. As the flushing for the Dez dam is carried out without the discharge of reservoir, it is called flushing under pressure, where this type of flushing is repeated annually during the following years. As the flushing for the Dez dam is carried out without the discharge of the reservoir, called 'flushing under pressure'; in this type of flushing, parts of the reservoir sediment are discharged by opening the depth outlets for a relatively short time (less than 1 or 2 days); a hole in the shape of the cone is created behind the dam body, so after the formation of this hole, the outflow from depth discharge becomes clear (Morris and Fan, 1998). The previous observations of the Dez dam flushing operations have shown that these operations had a considerable contribution for the decreased level of sediment in front of the power plant intake. Accordingly, Khuzestan Water and Power Authority began the rehabilitation operations for the dam's irrigation outlets in 2004 (as they are the only outlets for sediments discharge) in order to perform these operations periodically. Accordingly, a schedule was provided for the regular flushing operations, 3 - 5 flushing operations for each year until the outlets are completely rehabilitated. It is predicted, therefore, that 1 - 1.5 million cubic meters of fine-grained sediments will be debouched into the downstream river annually (Acres and Dezab, 2004). It is worth mentioning that the sediments behind the dam body consist of 40% clay and 60% silt (Samadi Boroujeni et al, 2009). These sediments are cohesive, due to their properties, and they flocculate and deposit when they reach the reservoir of Dezful re-regulating dam during any flushing operation. The rate of sedimentation in the reservoir of re-regulating dam highly depends on the way a flushing operation is performed (i.e. the opening of irrigation outlets) and on the concentration of sediment released from the dam. The concentration of sediment release from the dam at the downstream cross-section of the dam (C_{River}) is obtained from the following relation, given the outflow discharge from the dam (Q):

$$C_{River}=\frac{\sum Q_i.C_i}{\sum Q_i}=\frac{Q_{Irr}.C_{Gate}+Q_{Tur}.C_{Tur}+Q_{Spill}.C_{Spill}}{Q_{Irr}+Q_{Tur}+Q_{Spill}}=\frac{Q_{Irr}.C_{Gate}}{Q_{Total}} \quad (2)$$

Where Spill, Tur, Irr and Gate indices belong to the spillway, the turbine outflow, and the irrigation outlets, respectively. The concentration of outflow from the irrigation outlets is more than 500 gm/l at the beginning of outlet opening (flushing) and then, finally, within one day, it becomes clear. The clear outflow of turbines and spillways, however, causes the concentration of sediment to

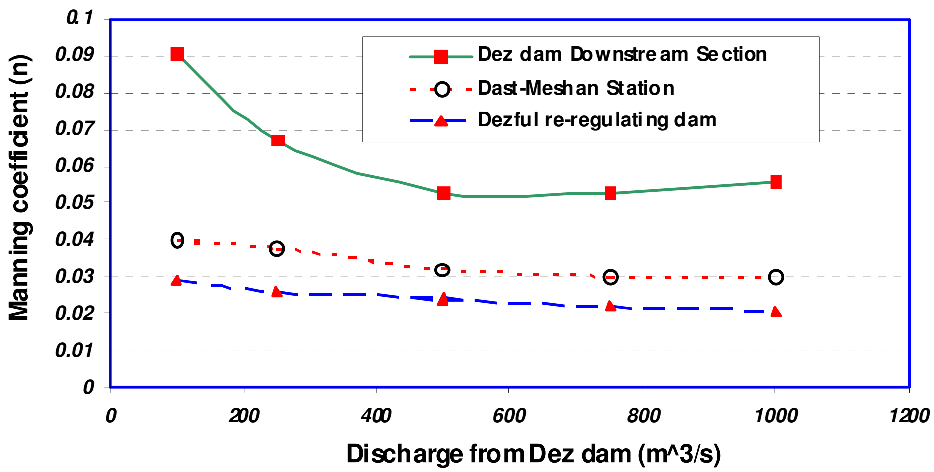

Figure 2. Calibrated Manning coefficient values via discharge in Dez River.

decrease at the downstream of the dam.

Calibration of MIKE 11 model

The model calibration is the most important part of the model running. In this study, two parts; the hydrodynamic and cohesive sediments transport in the model are used. the calibration of the model's hydrodynamic part is achieved through the selection of the coefficient of resistance (Manning coefficient), and the calibration of cohesive sediment transport model is achieved through the selection of the model's diffusion coefficient and the sedimentation and erosion extent rates.

Determination of the calibrated manning coefficient was achieved on the basis of the discharge–stage relationship of the downstream stations (i.e. stations of Dezful, Dast-Mashan, and Dez dam tail water). The results of model calibration are shown in Figure 2 for parts of hydrodynamic (Samadi-Boroujeni, 2004). These results show that amount of Manning coefficient “n” has low sensitivity to discharge changes. Accordingly, average amounts of manning coefficient, i.e. 0.064, 0.034 and 0.024 were used respectively for the Dez dam downstream section, Dast-Mashan station and Dezful station, in this paper. High variability of the n values refers to the river bed material properties.

The calibration of cohesive sediment transport part (TD model) was achieved by validation of measurement results obtained during the Dez dam flushing operation in 2000. The sediment flushing operation in 2000 took time of about one day and during it, maximum concentration at Dez dam downstream section, inflow to re-regulating dam reservoir and re-regulating dam outflow was measured to 51, 33 and 4.5 gm/l, respectively. Based on these data, MIKE 11 model was calibrated and diffusion coefficient and erodability coefficient of the model were calibrated as 30 m^2/s and 0.02 $kg/m^2/s$, respectively. Other parameters of the model were determined based on the performed measurements, such as settling velocity of the sediments, grain size and fluid viscosity (Fathi Moghadam et al., 2009).

Scenarios for running the model

In the study, different scenarios have been proposed for performing the flushing operations in the Dez dam, taking into consideration every important factor associated with these operations (Table 1). According to these options, maximum concentration of sediment at the Dez dam downstream section was considered to be 40 gm/l, given the environmental limitations. Considering the following relation one can determine the sediment concentration at the Dez dam downstream:

$$Q_{t,s} = C_G(\frac{Q_G}{C_0}) - Q_G \qquad (3)$$

$$Q_o = Q_{t,s} + Q_G \qquad (4)$$

Where; $Q_{t,s}$ is the total outflow discharge from turbines and spillways, C_G is the concentration of outflow from the irrigation outlets, C_o is the concentration of outflow from the dam at the downstream, and Q_G is the discharge from the irrigation outlets and Q_o is total outflow discharge from the dam. In this study, it has been estimated that the concentration of outflow from the irrigation outlets is on the average of 500 gm/l, and the discharge of outflow from the turbines is 250 m^3/s during the flushing operation. For safety precautions, it was assumed that two outlets at most, out of three irrigation outlets in the Dez dam, should be on manever simultaneously, where the maximum discharge for each outlet was considered to be 45 m^3/s.

For the environmental considerations of the river, the flushing duration is considered to be 12 h at maximum, and, in some options, the flushing is to be performed intermittently, where the duration for flushing is 4 h each time. In such case the interval between the two flushings will be at least 6 h finally, MIKE 11 model was run for each scenario. To run the model, the hydrograph has been envisaged at the upstream border (the Dez dam downstream) on the basis of the following rules:

- Up to half an hour before the beginning of flushing, the flow will begin from the spillway in amounts specified in Table 2.
- Up to half an hour after the flushing, the outflow from the spillway will continue in order to maintain the river's environment (Table 2).
- When the irrigation outlets are closed, the outflow discharge from the dam has been assumed to be equal to the outflow discharge from the turbines. The total hours of flushing, in all alternatives, has been assumed to be 30 h.

For example, the hydrograph of flow and sediments obtained from by using MIKE 11 model for option G2-40 -30 is given in Figure 3.

Table 1. Different scenarios of the Dez dam flushing to run MIKE 11 model.

Row	Scenario Code	Q_G (m^3/s)	Released sediment concentration (gm/l)	Total Flushing time (h)	Times of Flushing for each operation	Duration of flushing each time (h)	$Q_{t,s}$ (m^3/s)	Q_o^* (m^3/s)
1	G1-20-30	30	20	12	1	12	720	750
2	G1-30-30	30	30	12	1	12	470	500
3	G1-40-30	30	40	12	1	12	335	365
4	G2-20-30	30	20	12	2	6	720	750
5	G2-30-30	30	30	12	2	6	470	500
6	G2-40-30	30	40	12	2	6	335	365
7	G3-20-30	30	20	12	3	4	720	750
8	G3-30-30	30	30	12	3	4	470	500
9	G3-40-30	30	40	12	3	4	335	365
10	G1-20-45	45	20	8	1	8	1105	1150
11	G1-30-45	45	30	8	1	8	720	765
12	G1-40-45	45	40	8	1	8	523	568
13	G2-20-45	45	20	8	2	4	1105	1150
14	G2-30-45	45	30	8	2	4	720	765
15	G2-40-45	45	40	8	2	4	523	568
16	G1-20-90	90	20	4	1	4	2230	2320
17	G1-30-90	90	30	4	1	4	1470	1560
18	G1-40-90	90	40	4	1	4	1085	1175

*Total discharge of release from the dam. It should be noted that the safe discharge at downstream river is about 1100 m3/s (Samadi Boroujeni, 2004)

Table 2. Results obtained from MIKE 11 model simulation.

Scenario Code	$C_{o\text{-}max}$ (gm/l)	$C_{1\text{-}max}$ (gm/l)	$C_{2\text{-}max}$ (gm/l)	Amount of the sediments discharged (ton)			Te (%)
				Dez dam outflow	re-regulation dam reservoir inflow	Re-regulation dam outflow	
G1-20-30	20	17.6	6.9	674768	606492	229448	61
G1-30-30	30	18.6	8.6	674514	418776	188872	54
G1-40-30	40	23.6	9.8	656233	388387	154886	58
G2-20-30	20	13.2	6.9	701147	463671	239266	47
G2-30-30	30	18.6	8.8	700850	435576	195009	53
G2-40-30	40	23.6	9.8	681581	403434	159077	59
G3-20-30	20	13.2	7.1	727460	474934	236131	46
G3-30-30	30	21.6	8.8	772934	540766	201247	59
G3-40-30	40	24.3	9.8	706595	415347	159151	60
G1-20-45	20	13.9	8.2	703465	492375	285784	42
G1-30-45	30	19.8	10.4	701555	463239	240831	47
G1-40-45	40	25.2	12.2	694075	438806	206861	52
G2-20-45	20	14.2	8.3	743908	515924	289738	42
G2-30-45	30	20.2	10.6	727578	473178	234535	48
G2-40-45	40	25.9	12.4	733202	457981	206375	52
G1-20-90	20	15.3	9.9	750890	570698	366002	36
G1-30-90	30	21.6	13.5	756729	545640	331491	38
G1-40-90	40	27.8	16.6	759327	528881	303500	40

$C_{o\text{-}max}$: maximum concentration of sediment at Dez dam outflow.
$C_{1\text{-}max}$: maximum concentration of sediment at the re-regulation dam reservoir inflow.
$C_{2\text{-}max}$: maximum concentration of sediment at the re-regulation dam outflow.

$$T_e = \frac{(C_{1-\max} - C_{2-\max})}{C_{1-\max}} \times 100$$

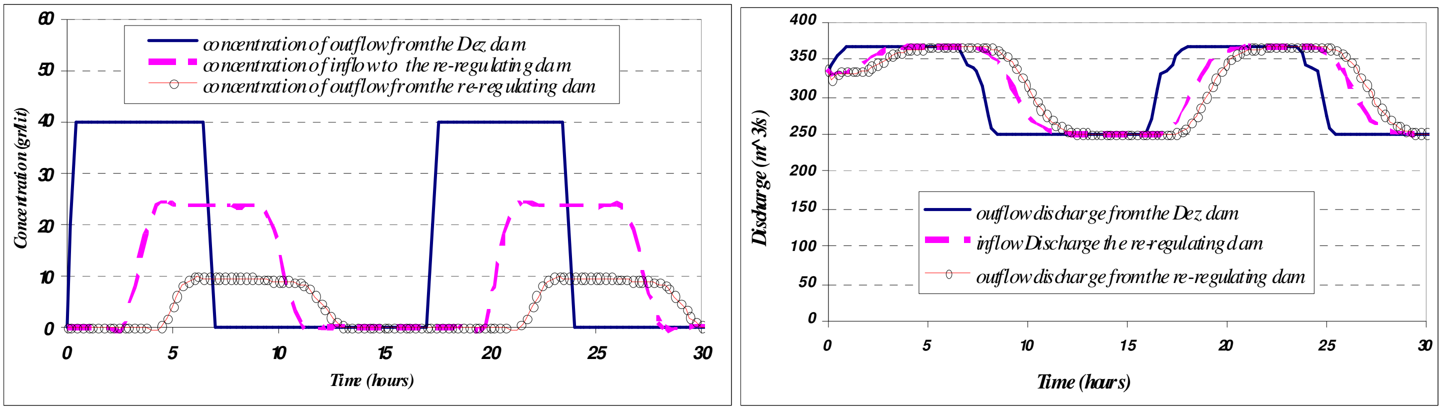

Figure 3. Hydrograph of flow and sediment concentration of the Dez River for the option G2-40 30 based on the model results.

Table 3. Introducing and ranking of criteria for the flushing operations in terms of scores.

Criterion	Degree of impact				
	Very high (0 points)	**High (2.5 points)**	**Moderate (5 points)**	**Low (7.5 points)**	**Very low (10 points)**
Ratio of water loss	W > 45	35< W<45	25< W<35	15< W<25	W<15
Threat of flooding downstream	Q_m2000<	<2000 Q_m1500<	<1500 Q_m1200<	<1200 Q_m1000<	Q_m<1000
Concentration at downstream (environmental aspect)	C_o > 12	12< C_o <10	10< C_o <8	8< C_o <6	C_o<6
re-regulating dam reservoir Sedimentation	T_e > 60	50< T_e <60	40< T_e <50	30< T_e <40	30 >T_e
Opening risk of the outlets	4 times opening	3 times opening	2 times opening	1 time opening	No opening

W: Ratio of Dez dam water outflow to the amount of sediment discharged during the flushing (million cubic meters of water /ton of sediment),
Q_m: Maximum discharge of outflow from the dam (m^3/s),
C_o: Maximum concentration of sediment at re-regulating dam outflow (gm/l),
Te: Percentage of trap efficiency of Dezful re-regulating dam reservoir.

RESULTS AND DISCUSSION

MIKE 11 model was run for different options, according to the scenarios given in Table 1. To meet the conditions of model stability, time-step calculations at the hydro-dynamic part equal to one minute and at the cohesive sediment transport section as equal to 0.1 min were selected. Table 2 shows the important results obtained from using the model. Results show that travel time of flow between the Dez dam and the Dezful re-regulating dam is, on the average, 4 h. In the studied scenarios, on the average, 70% of the sediments released from the dam find their ways into the reservoir of Dezful re-regulating dam. The same results show that for the options under study, the trap efficiency (T_e) of the sediments is, on the average, 50% in the reservoir of Dezful re-regulating dam. It can be seen, sedimentation in the reservoir of Dezful re-regulating dam is one of the important consequences of flushing in the Dez dam. Although this is undesirable in terms of decreased useful capacity of the re-regulating dam reservoir, one may consider it as useful in terms of environmental considerations since the concentration of suspended sediments in the downstream river is decreased up to an allowable concentration level (which is 8 gm/l in the Dez River, given the natural regime of the river sediments). Obviously, the consequence of this is to dredge the reservoir of re-regulating dam.

It should be noted that the Dez dam flushing causes various negative impacts on the downstream, so it is necessary to select the best option in terms of every important associated factor and consequence. Accordingly, one needs criteria to rank options in accordance with priorities. Surveys show that until now, unfortunately, quantitative criteria for flushing operations in the Dez River have not been set. Therefore, given the results of previous studies and the experiences of the present authors, and after various consultations, the important criteria for the Dez dam flushing have been determined quantitatively and along with points or marks in Table 3. This table has been worked out tentatively by the authors. in other words, it is a preliminary determination. it is necessary to consider the degree of importance for each factor in terms of the conditions for the location. Given the great importance of environment, for example, it is necessary to multiply the mark of environment by an incremental coefficient. During the years of abundant water, the mark related to the loss of water should be

Table 4. The criteria scores for each flushing option.

Scenario Code	Score of ratio of water loss	Score of threat of downstream flooding	score of environmental aspects	score of re-regulating dam reservoir sedimentation	score of opening risk of the outlets	Sum of scores for each option
G1-20-30	7.5	10	7.5	0	7.5	32.5
G1-30-30	7.5	10	5	2.5	7.5	32.5
G1-40-30	10	10	5	0	7.5	32.5
G2-20-30	2.5	10	7.5	5	5	30
G2-30-30	7.5	10	5	2.5	5	30
G2-40-30	10	10	5	0	5	30
G3-20-30	2.5	10	7.5	2.5	2.5	25
G3-30-30	7.5	10	5	0	2.5	25
G3-40-30	10	10	5	0	2.5	27.5
G1-20-45	0	7.5	5	5	7.5	25
G1-30-45	5	10	2.5	5	7.5	30
G1-40-45	7.5	10	0	2.5	7.5	27.5
G2-20-45	0	7.5	5	5	5	22.5
G2-30-45	5	10	2.5	2.5	5	25
G2-40-45	7.5	10	0	2.5	5	25
G1-20-90	0	0	5	7.5	7.5	20
G1-30-90	5	2.5	0	7.5	7.5	22.5
G1-40-90	7.5	7.5	0	5	7.5	27.5

multiplied by a minimal coefficient, and in case the dam's irrigation outlets have difficulties, the mark related to the maneuver risk of outlets should be multiplied by an incremental coefficient. In this study, as shown in Table 4, it was tried to calculate the marks or 'points' of each option without considering the incremental or minimal coefficients in order to achieve a preliminary result. Option with minimum scores can be introduced as the best option for performing flushing. Results showed that the options G1-20-30, G1-30-30, and G1-40-30 had the highest scores, and the option G1-20-9 had the lowest score. At the same time, option G3-30-30, which had the lowest trapped sediments in the re-regulating dam reservoir, has got 25 as the total score, while the option G2-20-30, which had the lowest environmental damages, has gained 30 points. it can be seen, therefore, that it is necessary to take the incremental or minimal coefficient into consideration in each criterion. Accordingly, to decide which option the best is flushing, the beneficiary administration should calculate the total score for each option, while paying attention to the dominant conditions and taking the relevant incremental as well as minimal coefficients into consideration.

Conclusion

Based on the present study, the important results are as follows:

- Results obtained from the use of MIKE 11 model, in this study, showed that this model, which is able to solve the equation of mass transport, can be used for the simulation of cohesive sediment transport in the reservoir.
- Results obtained from MIKE 11 model showed that manner of carrying out the flushing for the Dez dam sediments influences the trapping efficiency of re-regulating dam reservoir and one can, therefore, reduce the sedimentation in the re-regulating dam reservoir through proper management at the Dez dam flushing. The same results indicate that lesser the duration of flushing operations at the Dez dam and more the discharge, lesser the trapping efficiency in the re-regulating dam reservoir. This, however, causes the concentration of outflow from the re-regulating dam to be more than the allowable level of concentration at the downstream river.
- If all factors are involved in decision-making, such as the loss of Dez reservoir water storage, threat of flooding downstream, sedimentation in the reservoir of re-regulating dam, downstream environment, and risk of opening the Dez dam outlets are considered to have equal degrees of impact, the option G2-20-30 will gain the lowest impacts and therefore, it will be the most appropriate option. In this option, the irrigation outlets (sediments discharge) are opened for two times with a total discharge of 30 m^3/s, the duration of performing the flushing operation being 6 h each time at a minimum 6-hour interval between two flushing operations. In the years of excess flooding, the option G2-20-45 may create better conditions. In this option, the flushing is performed

two times, at a minimum of 6-hour interval between the two flushing operations, with a duration of each flushing (the opening of irrigation outlets) being 4 h, and the discharge of sediment outlets being 45 m^3/s in this option.
- To decide which option is the best flushing alternative, the beneficiary administration needs to pay attention to the relevant conditions and to consider the incremental as well as the minimal coefficients for each criterion, and to calculate the total scores of each option.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Khuzestan Water and Power Authority for their assistance and guidance provided in the preparation of this paper.

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