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ASSESSMENT OF THE EFFICIENCY OF CHECK DAMS IN THE CONTROL OF STREAM SUSPENDED LOAD (CASE STUDY: MARMEH WATERSHED IN SOUTHERN IRAN)

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Each year more than 20 billion tons of sediments are carried away by rivers throughout the world. The rivers and streams in Iran carry large amounts of sediments due to poor land use practices. In this article, the effect of gabion check dams on the suspended load of streams in the Marmeh watershed is investigated. The suspended load of the entire basin in two periods of time - before and after check dam construction - were compared. There was no meaningful difference on a validated level of 95 %. Five gabion check dams ware selected in each sub-basin in order to examine their effects on the suspended load (after filling their reservoirs) at the present condition. During six phases, simultaneous samples were taken of the suspended load before and after the spillways of the dams. After the statistical tests, it was found that there was no meaningful difference at a validated level of 95 % in the Marmeh watershed. Gabion check dams intended to reduce the suspended load did not achieve the objective. In the management of watersheds and erosion-sediment control projects, we must recognize that gabion check dams may not be an effective control method.

INTRODUCTION

A watershed as a system includes several kinds of natural resources, soil, water, forests, pasture lands, and wildlife. In the management of watersheds we must have a comprehensive outlook, identify major watershed problems and plan properly in order to mitigate them. These problems differ from place to place. However, the erosion of watershed surfaces and sedimentary loads of streams are of the utmost importance. They cause sediments to accumulate in dams and reservoirs, decrease water quality, and finally intensify socioeconomic problems (Gellis, 2002). Each year, over 20 billion tons of sediments are transferred by rivers throughout the world. This causes severe damage to dams and the related foundations, irrigation canals and tunnels, and so on (Qadimi and Qodusi, 2000). Rivers in Iran carry a high load of sediments compared to the other parts of the world. This indicates a severity of erosion and an improper state of natural resources (e.g. high pressure on pasture lands, destruction of forests, and unsuitable practices in agriculture) in water basins (Alizadeh, 2002).

In order to control erosion and deposition, several methods have been used, each of which is used on the basis of regional limits and conditions. A very common physical method is the use of check dams in streams since the check dams are the most applicable construction for soil preservation and watershed management. To properly evaluate their operational costs, it is necessary to examine and analyze the expected aims and functions.

A review of the references shows that due to the smallness and simplicity of check dams, there has been a much research about them and we have thus paid attention to the limited relations offered in the books on check dam design. Piri Ardakani (2001) has examined optimization of distances and dimensions of the check dams and introduced their relations.

Javan (2001) offered the principles of design of check dams in the book titled "Gabion Constructions".

Brown (1994) in his studies called " Control of sediments for preventing the filling of reservoir dams" under the supervision of the US Watershed Management Association has stated that technical and mechanical constructions can be effective in controlling the sediment loads when the following conditions are satisfied in design, constructing and maintaining them:

a) They should be consistent with watershed characteristics. It is necessary to investigate topographic, physiographic, geologic, geomorphologic, climatic, soil, hydrologic, and vegetative features, territory applications, potential natural strengths, developmental facilities and exploitation of present resources, culture and methods of exploitation, current exploitation of soil and water resources and economic-social conditions.

b) Selective constructions consistent with water basin characteristics should be designed properly and on the basis of technical-engineering principles.

c) The designed constructions should be implemented while consistent with each of their characteristics.

d) Technical-engineering operation should be combined with biological implementations.

e) The constructions should not be considered only from the viewpoint of mitigating soil erosion and waste of water. They must have different effects and consequences so that watershed residents can take benefit from their innovations over the short-term period.

f) Constructions should be operationally simple, understandable, and applicable to water basin residents and consistent with their incomes economically, and provide the necessary costs with practical guidelines.

g) Preservation methods for pre-designs, facilities and requirements of watershed residents, and implemented tasks should be profitable and predictable.

Evaluation of 899 constructions for controlling erosion by Peterson and Branson (1962) in Arizona and New Mexico has indicated that over half have failed during a few years after establishment. They note that the percentage of failure in the designed constructions for the preservation of the walls of ditches is so high that their utility is doubtful. Sheng and Zhong (1998) have examined the effect of establishing check dams associated with tree vegetation to control erosion of steep streams in the southern part of China and concluded that the establishment of a series of check dams in the steep streams and providing vegetation upstream causes the stability of beds and control of erosion in the streams and reduction of the transferred sediments downstream. Gellis et al. (2001) have evaluated the constructions controlling erosion of the Rio Natria watershed in the US. And observed that about 60% of the earth dams and 22% brush-rock dams have failed and thus have stopped gathering sediments. The cause of the failure of these constructions is the occurrence of flood, bank erosion and widening of streams. Through examining three water basins in Greece, America and France, Kondolf et al. (2002) showed that establishing a series of check dams in streams provides the grounds for tree vegetation and stability of streams and a considerable volume of sediments is reduced.

Lenzi (2002) has studied the effect of making check dams on the stability of steep streams in China and reported that these check dams have stabilized streams against the floods with a restoration period of 20-25 years. Lenzi and Comiti (2003) have studied the scouring of check dams downstream in the mountainous streams of Italy and found that maximum depth of check dams downstream depends the depth of flow over the dam, distances between dams, and maximum modified gradients of streams. Rhoshani (2003) has offered his thesis on the effect of check dams over the control of floods in Kan watershed and concluded that these check dams cause an increase of concentration time and decrease of peak flow because of their influence on the modification of gradients. Through field examinations, Zhou et al. (2004) have found that establishment of a series of check dams in the gully is one of the most effective methods for the control of gully erosion and decrease of sediments carried downstream.

In Iran, gabion check dams are widely used because of flexibility against settlement, permeability with the natural environment, and ease of constructions in forest and mountainous regions. This study evaluates the utility of these constructions in the control of erosion and sediment load.

MATERIALS AND METHODS

In this article, we examine the effects of gabion constructions over the suspended Load of the Marmeh watershed. The geographical location of the watershed is 27° 58’ 00” to 28° 07’ 00” of northern latitude and 53° 44’ 00” to 53° 53’ 00” of eastern longitude with an area of 100.4 km^2. It is located in Fars province south of Larestan city including mountainous regions and part of northern Zagros mountain ranges (Figure 1). Some of the features of this watershed are presented in Table 1.

Vegetation of this watershed is diversified. Its forest vegetation includes types of wide leaf trees such as hornbeam, acorn and maple. In some regions forests are thinly scattered and been ruined because of excessive exploitations. Agricultural areas which are mostly located in the margins of Marmeh village have been dedicated to dry farming and have been created by removing forest. The Marmeh watershed is made up of six sub-basins called Suteh Rud, Abshar, Khalu Dare, Meidan, Sefidab and Natkeh through which several gabion and timber check dams have been created by the Assistance Department of Watershed Management of Fars province (Figure 2).

In this article we provide the statistics and necessary information related to the Marmeh watershed and the introductory maps were produced by the use of geographical informational system.

Furthermore, data such as the location of engineering constructions, their types and dimensions were provided by Fars Province Department of Watershed Management and the maps for the location of check dams were generated (Figure 2).

With regard to the years of their establishments and annual suspended load of Marmeh watershed, the amount of suspended load of the main stream was compared in two periods of time - before and after the establishment of check dams. In the next process through the implementation

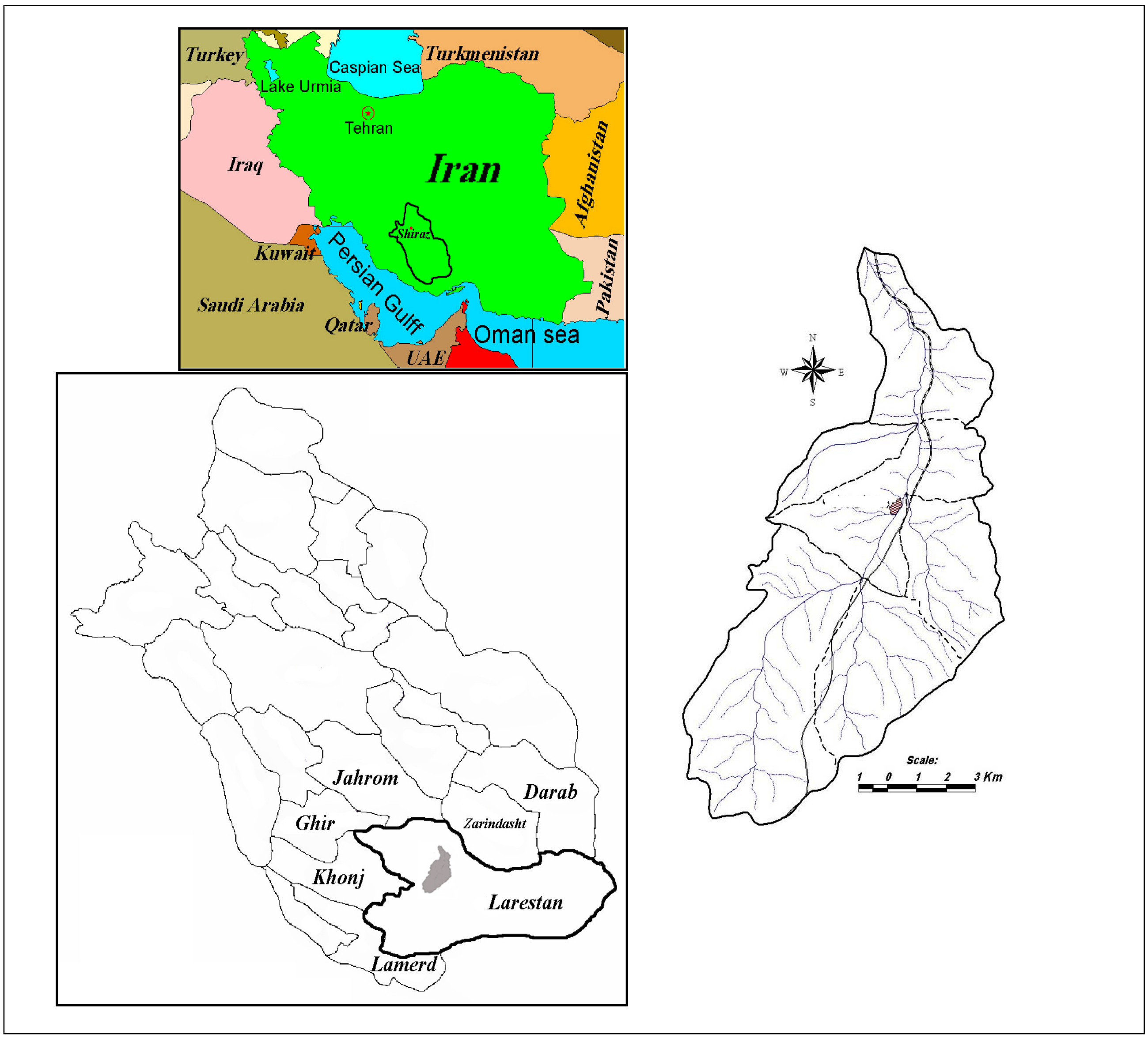

Figure 1. Location of Marmeh watershed in Iran and Fars province.

Table 1. Marmeh watershed features (Management Department of Fars province 1994).

Area (km^2)	Slope (%)	Average Precipitation (mm)	Land use (ha)			
			Forest	Range land	Agriculture	Residential
100.4	41.1	732.8	6161	2543	1298	38

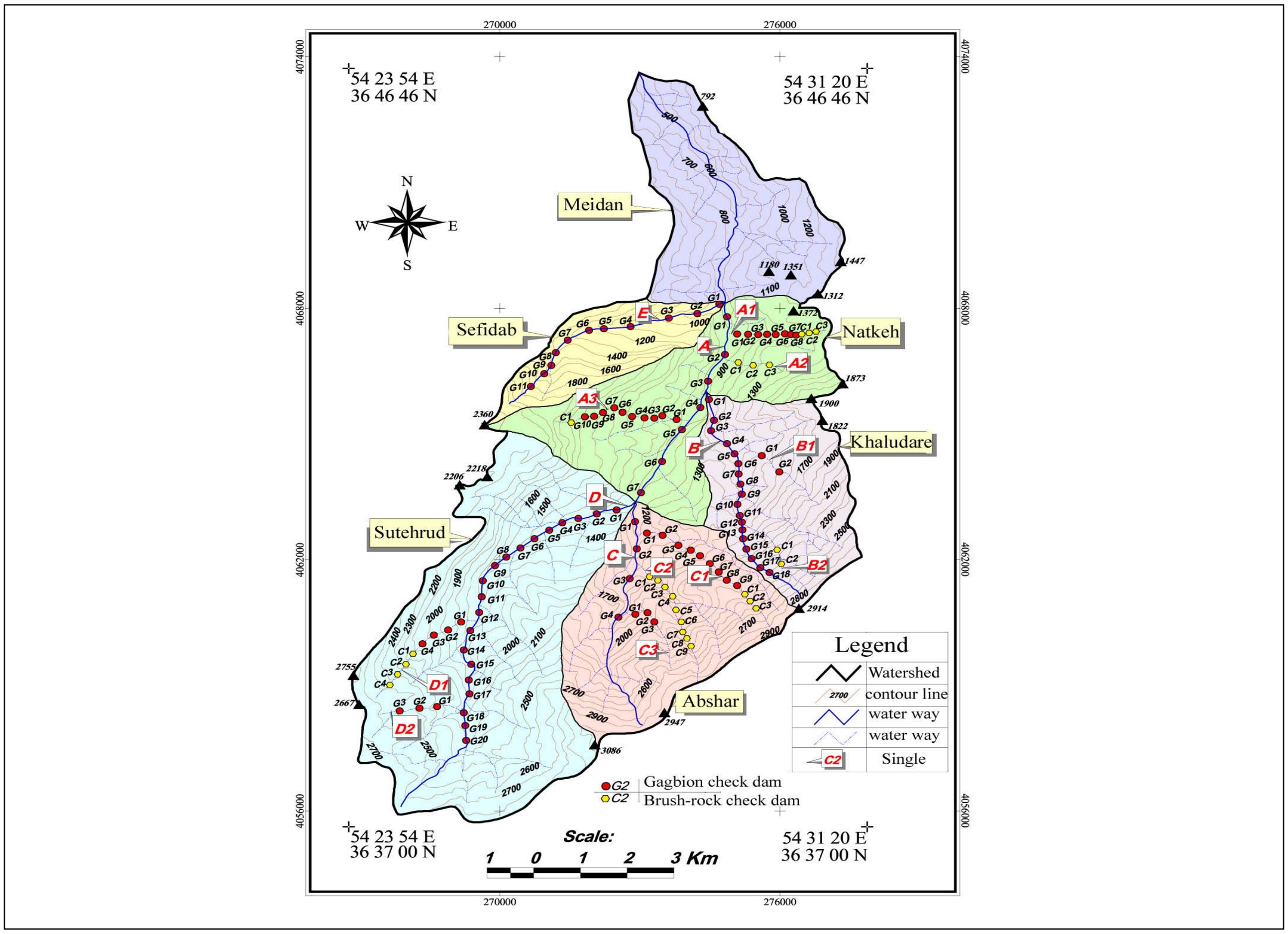

Figure 2. The location of established check dams in Marmeh water basin.

of field operational visits to the catchments and established constructions, five gabion check dams, all of which had been established in the main stream of each sub-basin, were selected.

In order to study the degree of the effect of check dams in the control of the suspended load we took samples of the suspended load before and after constructions. This was done in a six-week period of field operation. After each phase of sample-taking, samples were transferred to the hydraulic sediment laboratory in one-liter plastic containers and at the same time the weights of the testing samples were measured by a digital scale after passing the content of each container through a filter-paper and drying it. After finishing field and laboratory operations, the data were analyzed by different statistical tests and the effects of selected check dams in the control of the amount of suspended load of streams were identified and the effects of each construction in all the sub-basins were compared.

RESULTS AND DISCUSSION

1) Comparison of the suspended load – before and after the establishment of gabion check dams.

Establishment of gabions in the Marmeh watershed started in 2000. The years 1982 to 2000 are considered as the periods before the establishment of constructions and the years 2001 to 2005 are regarded as the periods after their establishment and the amounts of their suspended load have been compared. According to the correlation between sediment water discharge, the annual suspended load on the basis of ten per year is shown in Table 2. For comparison, we have used a sample T-test and statistical presumptions are as follows:

Ho: $\mu_a = \mu_b$

H1: $\mu_a < \mu_b$

Where, μ_a is the average of annual suspended sediment after the establishment of gabion check dams (12078.75 tons per year) and μ_b is the average of annual suspended sediment before the establishment of gabion check dams (15440.87 tons per year).

The above test has been carried out in the "Minitab" software and the p-value has been found to be 0.11 which is greater than α=0.05, Ho is accepted and thus on a validated level of 95%, there is no meaningful difference between the suspended loads of Marmeh river in the two periods of time - before and after the establishment of gabion check dams. Of course, with regard to the short length of statistical period after the establishment of construction (5 years) as wall as the role of climatic changes, especially precipitation, it is necessary to start new studies in the future after several years of the establishment of constructions in order to make a strict judgment in this area.

2) Assessment of the effects of gabion check dams on the suspended load of streams at the present condition

Table 2. Annual suspended load of Marmeh watershed before and after the establishment of check dams.

periods	years	suspended load (ton/year)
Before	1982	7873.10
	1983	5506.85
	1984	3503.17
	1985	27346.03
	1986	3738.01
	1987	3538.86
	1989	10682.43
	1990	7222.95
	1991	13130.97
	1992	9582.07
	1993	6593.95
	1994	61743.47
	1995	3037.03
	1996	3883.65
	1997	88474.95
	1998	10258.01
	1999	5164.75
	2000	6608.40
After	2001	10277.61
	2002	13466.03
	2003	15547.05
	2004	17257.34
	2005	3845.74

As usual it is expected that after the establishment of subsequent check dams, stream beds take a step-like shape and deposition behind the dam reaches the bottom of the next dam upstream while for most of the present constructions part of the construction upstream is also buried under the sediments and generally a new bed is created in the stream in addition to the fact that their reservoirs have been filled with sediments reaching the bottom of the next construction upstream. In such conditions, five gabion check dams were selected in each sub-basin in order to study the effect of the constructions on the suspended load and this load was determined before and after the spillways (10 sections of stream) in six phases of time (6 repetitions) by the use of field sample-taking and one section before the constructions as a control.

For instance, results of measurements and statistical tests are illustrated in the case of Suteh Rud sub-basin.

3) Comparison of the suspended load before and after the spillway of gabion check dams

By the use of paired-simples-T test, we compared the suspended load of the river before and after the spillway of gabion check dams and the statistical assumptions and applied relation are as follows:

H_0: $\mu_a = \mu_b$

H_1: $\mu_a \neq \mu_b$

Where, μ_a is the suspended load after construction and μ_b is suspended load before construction.

$$T = \frac{D - \mu D}{\left(\frac{SD}{0.5 \times n}\right)} \tag{1}$$

Where t is test statistic, D is the average of coupled differential of the samples, μD is the average of differentials, SD is the standard deviation of pair differential of samples and n is the number of pairs. This test was carried out in the environment of SPSS software and the p-value was found to be 0.419 which is greater then a = 0.05, and H_0 is accepted on a validated level of 95%, there is no meaningful difference between the suspended loads of Marmeh river before and after the spillway of gabion check dams.

4) Comparison of the suspended load of different sections of stream with the total average of reach

Table 3. Suspended load in different sections of waterway in Suteh Rud sub-basin (g/l).

Check dams No.	Sample condition	Time of sample-taking					
		2005/2/5	2005/2/19	2005/2/26	2005/3/3	2005/3/10	2005/3/17
1	Before spillway	0.6	5.8	3.8	2.3	1.6	1.2
	After spillway	0.06	6.4	3.7	2.4	1.7	0.9
2	Before spillway	0.7	6.1	3.9	2.2	1.8	1
	After spillway	0.6	5.9	3.6	2.5	1.6	1.1
3	Before spillway	0.5	5.4	4	2.6	1.8	1.1
	After spillway	0.6	6.5	4.3	2.4	1.6	1.2
4	Before spillway	0.7	6	3.7	2.4	1.4	1.1
	After spillway	0.8	6	4.3	2.5	1.6	1.1
5	Before spillway	0.7	7.7	3.8	2.4	1.6	1.1
	After spillway	0.8	7.3	4.1	2.6	1.4	0.9
Control section		-	8.7	3.9	3	1.6	0.8

The average of the suspended load of each section of the sample was completed with the total average of reach and the statistical presumptions are as follows:

H0: $\mu_I = \mu_m$

H1: $\mu_I \neq \mu_m$

Where, μ_I is the average of the suspended load of each section of the sample and μ_m is the total average of the suspended load of reach. This comparison was implemented by the use of a one-sample T-test in the Minitab software and the amounts of p-value are presented in Table 4. It was found that there is no meaningful difference between them. Moreover, the control section suspended load average (3.6 g/l) was compared with that of reach (2.67 g/l) and through this test it was found that on a validated level of 95% there is no meaningful difference between them and both of them have the same trend of erosion and deposition.

5) Comparison of the functions of gabion constructions with each other

In order to study the differences between the functions of gabion check dams with each other, we used a Randomized Complete Block Design and each of the constructions was considered as a block and the place of sample-takings (before and after the spillway of constructions) as treatment. The input data to the Minitab software are shown in Table 5 and the results in Table 6. It was found that on a validated level of 95%, there is no meaningful difference between the function of the constructions with each other as well as between treatments and on the whole constructions are ineffective to control the suspended load of stream in the present condition.

Table 4. A comparison between the suspended loads of different sections of waterway with the total average of reach in Suteh roud sub-basin.

Section	T	p-value	Considerations
Before the construction No.1	-0.15	0.88	No meaningful difference
After the construction No.1	-0.06	0.95	No meaningful difference
Before the construction No.2	-0.03	0.97	No meaningful difference
After the construction No.2	-0.15	0.88	No meaningful difference
Before the construction No.3	-0.14	0.89	No meaningful difference
After the construction No.3	0.1	0.92	No meaningful difference
Before the construction No.4	-0.15	0.88	No meaningful difference
After the construction No.4	0.05	0.96	No meaningful difference
Before the construction No.5	0.19	0.85	No meaningful difference
After the construction No.5	0.17	0.87	No meaningful difference
Control section	0.66	0.54	No meaningful difference

Table 5. Suspended load overage related to each treatment in each construction (Block) on a scale of gram per liter.

Checkdam No. (block)	Treatments	
	Before the spillway of the Check dam	After the spillway of the Check dam
1	2.55	2.61
2	2.70	2.55
3	2.56	2.76
4	2.55	2.71
5	2.88	2.85

Table 6. Analysis of data variances of Table 5.

Source of variations	(DF)	(SS)	(MS)	F test
Block	4	98913	24728	2.37 (NS)
treatment	1	6248	6248	
error	4	41676	10419	0.6 (NS)
total	9	146337	-	
NS: NO meaningful difference				

CONCLUSIONS

Considering this study it was found that:

There is no meaningful difference in the suspended load average of Marmeh River in two periods of time - before and after the establishment of gabion check dams.

- In the present condition, there is no meaningful difference between the suspended loads of the stream of before and after dam constructions

- There is no meaningful difference between the average suspended loads of with the suspended load average of the control section.

- There is no meaningful difference between the interactions of gabion check dams with each other.

With regard to the similarity of the above results for all the sub-basins in which gabion check dams have been established, we can say that in the Marmeh watershed gabion check dams only affect on the bottom load of the stream and the bed has been filled with sediments by the occurrence of several floods after their establishment. They are not efficient for the reduction of the suspended load of stream. The suspended load of streams is due to the erosion of watershed surface because of the destruction of vegetation, improper land use, and geologic features. Hence, in the planning of watershed management and erosion control projects, first, only mechanical operations and construction establishments cannot be used as guidelines and second, we should be careful in the selection of a proper modification procedure. Furthermore, more attention should be paid to the reestablishment of vegetation and improving watershed land use with a comprehensive outlook and different biological functions.

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REFERENCES

Alizadeh, A. 2002. Principles of Applied Hydrology. University of Mashhad-Iran. 625 p.

Brown, A.G. 1994. Hierarchical structures and hydraulic properties of fracture network in the Causse of Larzac. J. Hydrology, Vol. 187, pp. 237–258.

Gellis, A.C. 2002. Effects of vegetation cover and precipitation on the process of sediment produced by erosion in a small watershed of loess region. Acta Ecological Sinica, Vol. 26 (1), pp. 1–8.

Gellis, A.C., A. Cheama, and S. Lalio. 2001. Developing a geomorphic approach for ranking watersheds for rehabilitation. Zuni Indian Reservation, New Mexico, J. Geomorphology, Vol. 3, pp. 105-134.

Javan, M.N. 2001. Design of Gabion Check Dams. Department of Soil and Water Conservation, Fars Province.

Kondolf, G.M., H. Piegay, and N. Landon. 2002. Channel response to increased and decreased bed-load supply from land use change: contrasts between two catchments. J. Geomorphology, Vol. 45(2), pp. 35-51.

Lenzi, M.A. 2002. Stream bed stabilization using boulder check dams that mimic step-pool morphology features in Northern Italy. J. Geomorphology, Vol. 45(4), pp. 243-260.

Lenzi, M.A., and F. Comiti. 2003. Local scouring and morphological adjustments in steep channels with check-dam sequences. J. Geomorphology, Vol. 55(4), pp. 97-109.

Peterson, H.V., and F.A. Branson. 1962. Effects of land treatments on erosion and vegetation on rangelands in parts of Arizona and New Mexico. J. Range Management, Vol. 15, pp. 220-232.

Piri Ardakani, M. 2001. Optimization of the distance and dimensions of check dams. MSc Thesis, University of Ghazvin- Iran. 120 p.

Qadimi, A.M., and J. Qodusi. 2000. Analysis of Suspended load in Namak lake watershed. Journal of research and construction, Vol. 45, pp. 282–290.

Roshani, R. 2003. Evaluating the effect of check dams on flood peaks to optimize the flood control measures (Kan case study in Iran). MSc Thesis, ITC. 132 p.

Sheng, J., and L. An-Zhong. 1997. Erosion control in south China, CATENA, Vol. 29(2), pp. 211-221.

Zhou, X.X., H.W. Zhang, and O. Zhang. 2004. Development of check-dam systems in gullies on the Loess Plateau, China. Environmental Science & Policy, Vol. 7(2), pp. 79-86.

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