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INVESTIGATION OF DOMINANT DISCHARGE TRENDS IN THE GORGANROD WATERSHED, IRAN

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For the Gorganrod watershed, Iran, a tributary of the Caspian Sea, dominant discharge is important for calculation of suspended load values, design of hydraulic structures and determination of river optimal width. It is necessary to determine effective and bankful discharge, and the mean annual flood. The total suspended sediment curve is obtained using the suspended sediment curve and the histogram of daily output where the exponent is effective discharge. A value of bankful discharge is determined using sections of river width and finding the minimum surface width ratio. Statistics of river flooding in the Gorganrod were used to determine annual flood average. Since discharge was small in the 2.33-yr return period and its frequency was high, the discharge was not effective in transferring sediment. Effective discharge is introduced as the river dominant discharge that has sediment carrying capacity over the long term.

INTRODUCTION

Rivers as one of the main sources of surface waters conduct three actions of erosion, transport, and sedimentation at the same time. Artificial and natural environment changes in relation to rivers have one common point and that is the change of input discharge to the river and the amount of transitional sediment down river that finally causes a disturbance to the river system balance. Basically natural outlets like rivers have a tendency to coordinate themselves with hydrologic geometry changes. These changes will persist until the river can transfer water and sediment easily or in other words until the river reaches a balance (Hafez, 2000). Discharge is a master variable that controls many processes in stream ecosystems. However, there is uncertainty of which discharges are most important for driving particular ecological processes and thus how flow a regime may influence entire stream ecosystems (Doyle et al., 2005). Alluvial rivers adjust their channel and floodplain dimensions depending on the range of flows which are capable of mobilizing sediment from the bed and banks, and of transporting sediments delivered from upstream reaches (Lenzi, 2006). Four ways are used for estimating dominant discharge in rivers; bankful discharge, the average of the annual flood, discharge resulting from solution of sediment and movement equations, and quantity of established effective discharge (Inglish, 1974).

The results of Andrews (1980) research for establishment of effective discharge showed that effective discharge for general loads in catchment areas was a pretty frequent phenomenon. In stations under study in this research, on average the effective discharge was equal or more than 11 days in the study period of a year.

The results of Nash's (1994) research showed that by analyzing 55 rivers in America, there is a weak union between observed and predicted period of time for effective discharge, which is because the exponential function is a good estimation of the amount of transfer of sediment by use of discharge in some upper or limiting discharge. Wolman and Miller (1960) also showed a consistent correspondence between effective discharge and the bankful discharge in rivers. This has been further supported (Andrews, 1980; Torizzo and Pitlick, 2004). This perhaps indicates that alluvial channels adjust their boundaries to some maximum geomorphic work condition, although the exact processes of bankful dimensions corresponding to effective discharge remain unclear, and there are numerous examples of effective discharge not corresponding to bankful discharge (Doyle et al., 2007). In research done by Sichingable (1999) for determining the rate of suspended sediment transfer and its relation with effective discharge on the basis of curve of daily discharge, it was clear that the class of effective discharge included changes from 3 to 16.1 percent in the study period and on average, it happened in 8.4 percent of the study period. Also, he presents some equations for prediction of effective discharge from bankful discharge and drainage level. Studies by Esmaeili and Mahdavi (1381) examining effective discharge for transfer of suspended sediments in the catchment of the Zyanderoud Dam in Iran suggest that the effective discharge for all the studied tributaries include events with low values. Williams (1978) examining the correlation of dominant discharge with the related parameters of river (width, depth, granulometry of the side and bottom materials, and especially gradient) suggested this equation for bankful discharge value:

$$Q_b=4A_b^{1.21}S^{0.2} \tag{1}$$

where S = length slope of river (no dimension).

Dury (1973) in desert conditions noticed the relationship between meandering length of rivers with bankful discharge and width concerned the equation regimes on the basis of weekly discharge, in comparison with daily average discharge, and showed a better correlation, and suggested the following equation considering the meandering morphology of rivers:

$$Q_b=0.83A_bp \tag{2}$$

where Q_b = bankful discharge (m^2/s), A_b = the level of flow in brimful state (m^3), v = velocity (m/s).

Inglish (1974) with use of a physical model in India's Puna concluded that rivers dynamically under some floods can reach their balance. He carried out this research on dominant discharge in 1947 and following the frequency test on physical models with sandy levels concluded that the amount of dominant discharge quantitatively is 80 percent of bankful discharge. He concludes that parameters such as width, depth, slope, and granulometry are relevant. The side and bottom materials depend on flow discharge and sediment discharge.

The purpose of this research is to establish the dominant discharge for the Gorganrod river on the basis of three methods. This discharge can have a significant role in designing river preservation structures, the design of river overpass structures, estimates and management of sediment transfer, and engineering of environmental and flood controls.

MATERIAL AND METHOD

The Study Area

The Gorganrod is one of the important rivers in the Caspian Sea Catchment (in Iran) that flows from the Narchi and Bili Mountains located 37 km northeast of Kollaleh City. The Gorganrod enters the Caspian Sea at the eastern bank of this sea after it irrigates the north area of the Gorgan Plain. The length of the Gorganrod to the Caspian Sea is about 325km. It is estimated the annual average discharge of the river in Basirabad Station over a 20 year period is 450 million m^3 year. It is estimated the maximum discharge of this river is about 3000 m^3/s (in the destructive flood that happened in 2001 in the east of Golestan Province). In this research for assessment and recognition of dominant discharge at first we choose three hydrometric stations at Tamer, Gonbad and Ghazagheli in the main branch. Figure 1 shows the location of study stations in Iran and Golestan Province.

METHODOLOGY

After the selection of stations, and using three methods of calculation, effective discharge, bankful discharge, and annual flood average discharge, as described below, we determine the dominant discharge of Gorganrod watershed.

Calculation of Effective Discharge

For better understanding of effective discharge calculation, we use the diagram in Figure 2. On the basis of shape if $f(Q)$ is the histogram curve for daily discharge and $S(Q)$ is a multiple of the measured sediment histogram of daily discharge, the peak of the curve of sediment transfer is effective discharge. This discharge corresponds to the with sediment transfer maximum in river.

For calculating effective discharge, it is needed to count the daily average discharge frequency histogram. For this, we used 20 year daily average discharge of the study stations from water years 1986-1987 to 2005-2006. The frequency of this discharge with attention to the number of classes

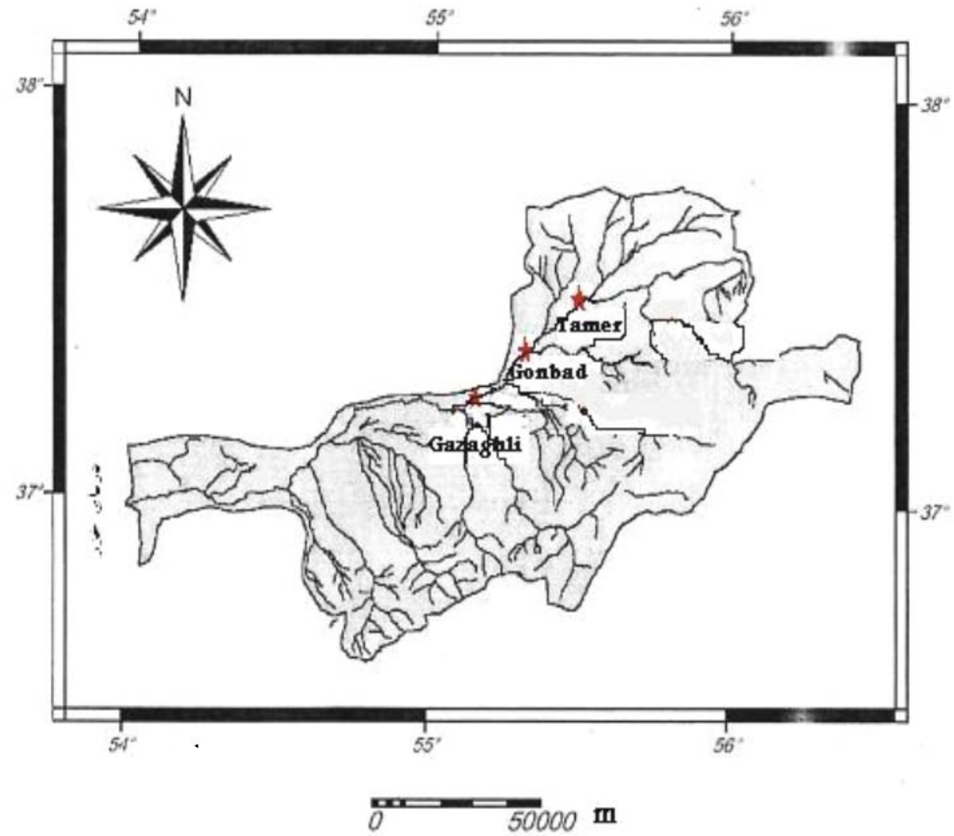

Figure 1. The location of study hydrometric stations in Iran and Golestan province.

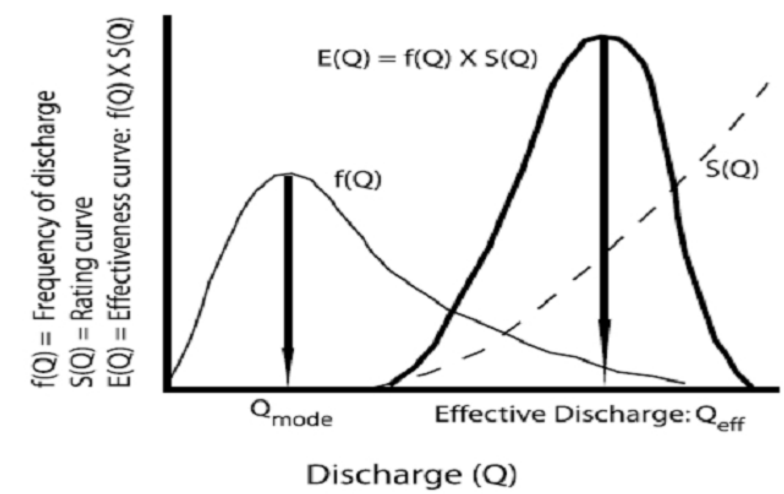

Figure 2. Components of effective discharge (Qeff). Adapted from Wolman and Miller (1960).

(twenty classes) was established and the histogram of frequency was made for counting of suspended load at the stations on the basis of a cubic equation, $Qs=aQ_w^{\ b}$, between the amount of flow discharge using a regression relation. In this equation Q_w is flow discharge, Q_s is sediment discharge and a and b are factors. The number of data corresponding to water and sediment discharge suspended in the hydrometric stations of Tamer, Gonbad and Ghazagheli were 128, 138 and 1300 respectively. After making the relation between flow and sediment discharge with the sediment measuring curve in the frequency histogram of daily discharge, the total sediment transfer curve was established. The climax peak of this curve indicates the effective discharge and this discharge corresponds with the maximum sediment transport in the river.

Calculation of Bankful Flow

The bankful flow is the flow in a river on the threshold of flooding the floodplain. To establish the bankful discharge in a river, we need the dimensions of river bankful and the staff gauge-discharge curve. In this research with the use of planning operations and examining the area under the course of Gorganrod River in some banks of river the width and depth of each banks is established and the minimum ratio of width of bank level to depth *W/D* and depth (*D*) in a coordinate system of height corresponding to bankful discharge. In the following phase the data of staff gauge-discharge is used to obtaining the staff gauge-discharge relation.

Annual Average Discharge

Because of the problem that there is in recognizing the flow bankful flow, many researches believed that formative discharge of stream associated with a discharge with specific return period. Bankful discharge in streams is about discharge with a return period estimated one to 2.5 years, and floods with return periods of 1.5 years is average index in many rivers. If floods are defined by Gumbel distribution, the probability of discharge exceedance from a determined amount is established in the following way:

$$P(Y \geq y) = 1 - e^{-e^{-y}} \tag{3}$$

and the maximum account variable with return period is from the following equation:

$$X_t = \overline{X} + (0.7797 Y_T - 0.45) S \tag{4}$$

where, Y = the probability that the named decreased variable that is reached from this equation:

$$y \quad Ln \quad Ln\ 1 \ \frac{1}{T} \tag{5}$$

where Y = the study parameter, X = the maximum value of variable with probability of concern occur, $\overline{X}$ = data average, S = standard deviation of data, T = return period

The average amount in this distribution when reach the amount of inside parentheses become zero, namely:

$$0.77977 Y_T - 0.45 = 0 \tag{6}$$

and or:

$$Y_T = 0.5772 \tag{7}$$

Replacing of the amount in Equation 8, the occurrence probability and return period is 2.33 years (Mahdavi, 2002).

RESULTS

Effective Discharge

In this research accounting for suspended load at study stations, we create a regression relation between flow discharge and sediment discharge on the basis of a cubic relation. This relation of water discharge and sediment discharge in studying hydrometric stations is given in Figure 3.

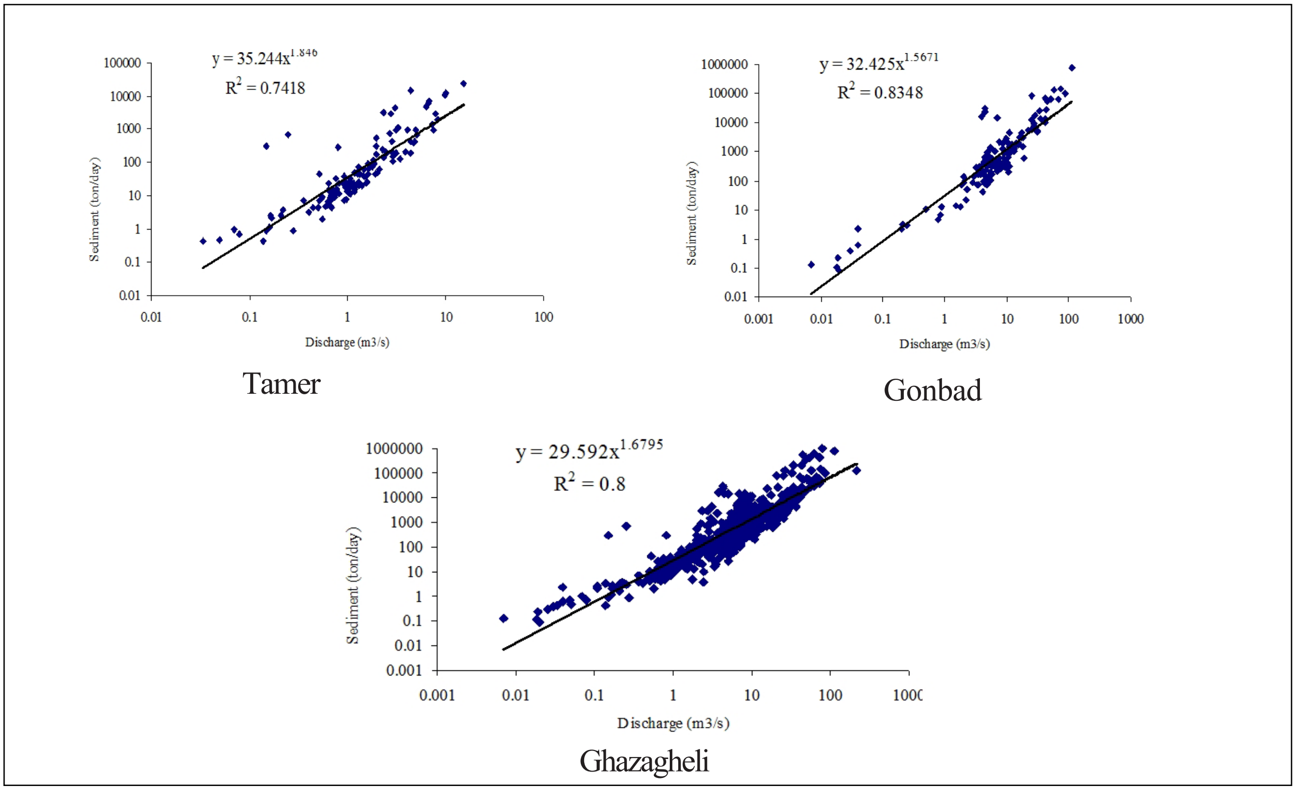

Figure 3. Sediment rating curves for Tamer, Gonbad, and Ghazagheli stations.

Considering sediment histogram in the station, and the maximum of sediment shown in Figure 4, the effective discharge at each station has bean calculated. The effective discharge and accompanying sediment transport is given in Table 1.

With attention to this conclusion in this section the amount of effective discharge of the river increases from Tamer Station downstream to Gonbad Station, then to Ghazagheli Station to reach the maximum amount. From Table 2 it can be concluded that the amount of sediment transport (*kg/s)* at the investigated stations was extracted from the multiple of sediment discharge in frequency to the division of this amount by the number of statistic years.

Bankful Discharge

For counting of bankful discharge with use of minimum bank level width of the ratio diagram to depth in appoint flow depth in opposite flow depth (*D*) correspond to height of Bankful along of Gorganrod is counted. After a counting of height correspond to bankful with use of Staff gauge discharge relation for each station in 2004-2005 year, the correspond discharge with height of bankful (bankful discharge) in Stations is according to Table 3.

Annual Average Discharge

The conclusions of annual flood average discharge with return period of 2.33 year is shown in Table 4.

CONCLUSION

The effective discharge of water in the Gorganrod River shows that the amount of sediment transfer from upstream (Tamer Station) to downstream (Ghazagheli Station) is increasing. Many tributary branches enter the Gorganrod River in this reach, and we conclude this is one of the main

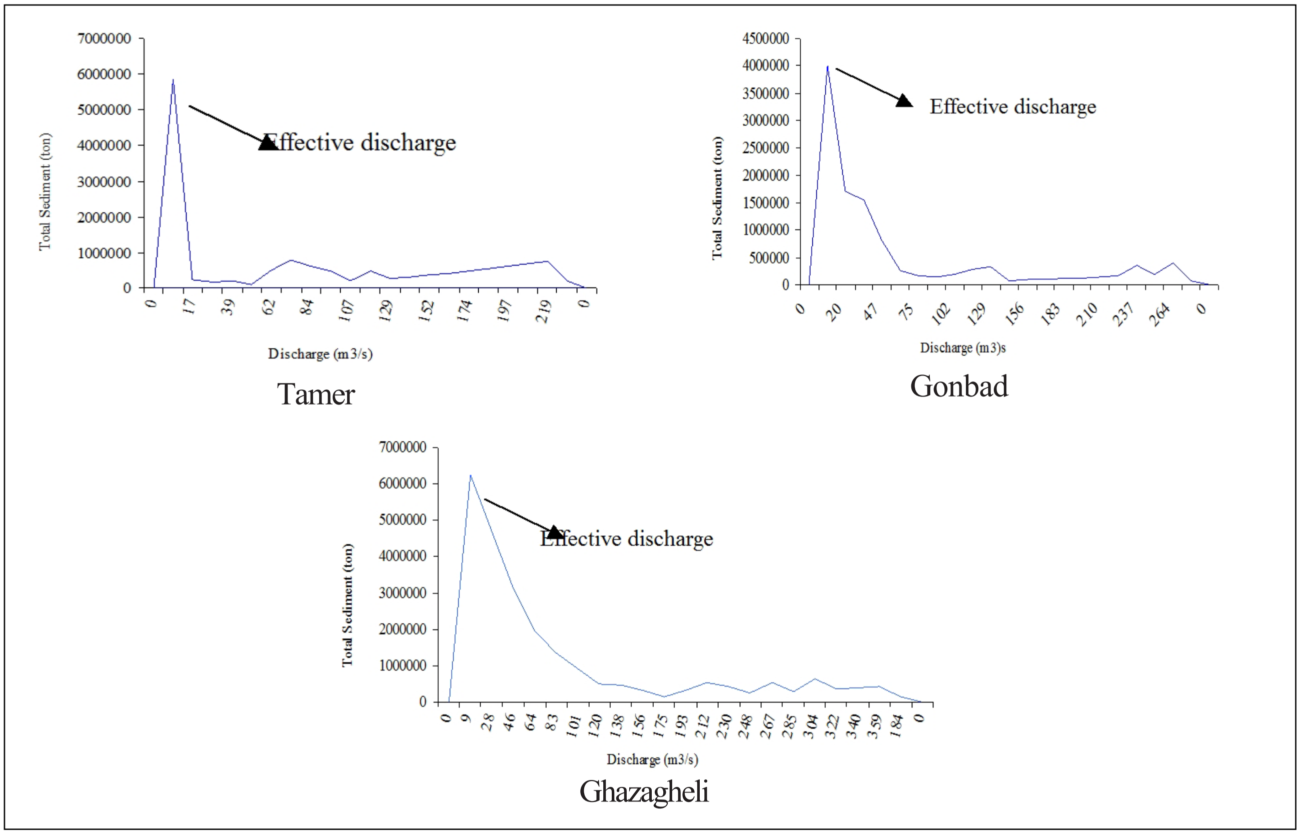

Figure 4. Suspended load discharges for Tamer, Gonbad, and Ghazagheli stations.

Table 1. Estimate of effective discharge and sediment transfer.

Station	Effective Discharge(m3/s)	Sediment(T)
Tamer	5.62	5858937
Gonbad	6.77	4013231
Ghazagheli	9.2	6266247

Table 2. The annual average of passing sediment at the study station.

Stations	$\sum Q_s f(Q)(ton)$	$\frac{\sum Q_s f(Q)}{n}\left(\frac{ton}{year}\right)$	Transit Sediment (kg/s)
Tamer	14311132	715556	22.69
Gonbad	11259110	562255	17.85
Ghazagheli	2397122	1198656	38

Table 3. Estimate of bankful discharge annual average discharge.

Station	Bankful	Bankful Discharge	Staff -gauge Equation	R^2
Tamer	3.86	43.82	$Q_w = 8.9291h^{1.1778}$	.91
Gonbad	4.9	52.06	$Q_w = 1.4665h^{2.2481}$	.7
Ghazagheli	6.97	85.8	$Q_w = 0.9177h^{2.3272}$	.99

Table 4. Discharge with return period 2.33 year.

Station	Discharge with return period of 2.33 year
Tamer	1.236
Gonbad	1.91
Ghazagheli	2.123

causes of increase of effective discharge of Gorganrod River. Also, the cubic discharge relation in those stations is greater than one. We conclude that suspended sediment load of the river is high and consists primarily of sand.

Discharge with return period 2.33 year is a small discharge with great frequency but it can transfer much sediment (Table 5). On the other hand bankful discharge at three stations was a great discharge, but this frequency was small and for transferring much sediment over a long period it wasn't effective. So effective discharge in this research has a frequency and enough transfer power through time as the dominant flow of Gorganrod River.

Table 5. Bankful discharge, effective discharge and annual average discharge.

Stations	Bankful Discharge	Effective Discharge	Discharge with return period of 2.33 year
Tamer	43.82	5.62	1.236
Gonbad	52.06	6.77	1.91
Ghazagheli	85.8	9.2	2.123

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