DETERMINING OF REGIONAL COEFFICIENTS OF FULLER'S EMPIRICAL FORMULA TO ESTIMATE MAXIMUM INSTANTANEOUS DISCHARGES IN DASHT KAVIR BASIN, KALSHOUR SABZEVAR, IRAN

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Abstract

Estimation of the magnitude and frequency of maximum instantaneous discharges and hydrographs are used for a variety of purposes, such as the design of bridges, culverts, flood-control structures; and the management and regulation of floodplains. Fuller (1914), developed a flood-frequency formula based on analysis of flood peaks in hundred of streams to provide simple methods of estimating maximum instantaneous discharges, and sought to link maximum instantaneous discharges having various average return periods to the mean of the maximum annual discharges with a factor calibrated for different catchments. The aim of this study is the evaluation of the mentioned method in order to estimate maximum instantaneous discharge and calibrating its considered coefficients in Kaal Shour Sabzevar region. Therefore, the collected data from 10 hydrometric stations in the region were used in analysis and regional coefficient was obtained 0.041 and regional inundation coefficient is from 0.88 to 2.23 in 5 to 200-year return periods. The results showed that the discharge calculated by Fuller's empirical formula is less than values calculated by statistical distributions.

Key words: *Iran, Maximum discharge, Kalshour Sabzevar, regional coefficient, Fuller's empirical formula, statistical distribution.*

Introduction

Maximum instantaneous discharge is concerned not only as a hydrology parameter in a big basin, but also at sub-basins, and has been used as an indicator for water related plans.

Due to the lack of sufficient statistical data of flow type and its quantity, many various empirical methods has been proposed to determine relationship between maximum instantaneous discharge and climatic, management and edaphic features of basin. In most methods, area factor (the most important physical factor) is entered directly into equation and the effect of other factors (climatic, managerial and edaphic) is considered as coefficient and certainly these coefficients would be different from a region to another one. Therefore, it is necessary to calibrate coefficients used in these formulas with the statistical data of region stations.

Fuller empirical formula has been one of the methods which has been developed in eastern states of America by analysing hundreds of flood peaks and used widely for maximum flood peaks in different regions of the world. Their coefficients are calibrated for many regions. For example, frequency coefficient of annual inundation in this formula has been calculated for different basins in France as 0.8 to 2 and sometimes 7 (Gholami, 1991). The experts of Natural Resources Ministry of Canada studied the floods of Ontario by Fuller formula and corrected it for that region. Also, at United States of America, India and some other countries, maps have been prepared in which the quantity of regional basin coefficient rates is shown. These rates depend on the characteristics and circumstances of basin (Mahdavi, 1999).

Another study carried out in USA basins, Subramanya showed that regional coefficient varies from 0.18 to 4.5 (Subramanya, 1984). Leene also determined the regional coefficient for New Englands Stream equal to 0.96 and for very small rivers of South California up to 4.5. The United States Geological Survey (U.S.G.S) used Fuller formula to correct regression equation of 6^{th} and 10^{th} regions of Nevada (USGS, 1999). Fill and Steiner estimated the maximum instantaneous discharge using maximum daily discharge with Fuller formula and compared them with observational quantities. Their results showed that the Fuller Formula shows higher quantities ratio compared to observational quantities (Fill & Steiner, 2003).

Numerous applications of this method have been done in Iran and gained results have showed that Fuller formula provides more flood peaks at different return periods (Najmaee, 1990). Arab Khedri tested the quantity of maximum observational and estimated instantaneous discharge by Fuller formula in 21 sub basins of North Alborz watershed. The results showed the meaningful difference at 1% level between them (Arab Khedri, 1989). Gholami used the method for Mazandaran basin and determined regional coefficient between 0.03 to 12.3 and coefficient-frequency of annual inundation between 0.6 to 5.48 and for calculating of maximum instantaneous discharge using maximum daily discharge concluded that Fuller method by calibrated coefficients for the region, at return periods of more than 100 years and from humid regions to wetter places needs to be more conidered.

In addition, this method can't be used for forest basins less than 5oo Km^2 area (Gholami, 1991). Telvari calculated the coefficient of Fuller formula for homogeneous sub-basins of Karkhe basin (Asgahri, 1998). Sheikh used Fuller method to estimate maximum instantaneous discharge based on maximum daily discharge at 120 basins of Iran. This research calculated regional coefficients of Fuller formula and assessed this method in maximum instantaneous discharge estimation of Kal Shour of Sabzevar.

Materials and Methods

Studied area

The study area is Kaal Shour Sabzevar basin with 245000 Km^2 area at 56º 18´ to 58º 18´ east latitutue and 35º 26´ to 36º 32´ north longitude. Based on basin classification system (Jamab-1982), this basin is a part of major basin number 4 (Streams which ends to inner lakes, deserts and playa) and sub basin of Dasht Kavir (No 47).

The average precipitation of region, based on 27 years statistical data (1973-1999) is about 176 millimeters and its climate is affected by two important factors including geographical altitude and air mass, Siberian air flow, North west airflow, Mediterranean air mass and desert air mass). This condition provides semi-arid climate with the maximum precipitation in winter (Arab,1989).

Fuller empirical Method:

Fuller (1914) provided the first empirical formula for frequency analysis of maximum daily discharge (equation 1 & 2) which obtained from several investigation in east of the United States using common equation of hydrologic frequency analysis introduced by Chow (Chow,1951).

$$Q_{max}= Q_{ave} (1 + ß \log T) \quad (1)$$

$$Q_{ave}= CA^{0.8} \quad (2)$$

The following equation is also suggested to estimate maximum instantaneous discharge using maximum daily discharge:

$$Q_p= Q_{max} (1+2.66 A^{-0.3}) \quad (3)$$

Where:

Q_{ave}: The average maximum daily discharge of basin (m^3/s)

Q_{max}: The maximum daily discharges of T year return periods (m^3/s)

Q_p: The maximum instantaneous discharge of T year return periods (m^3/s)

A: Basin area (Km^2)

C: Regional coefficient which depends on climatic and geographical situations and characteristics of the basin:

ß: Regional inundation frequency coefficient

To approach the aim of current study, 10 hydrometric stations having regional maximum daily discharge data were selected to determine regional coefficient (C) and regional inundation frequency coefficient (ß). The location of stations is shown on the map (Figure 1).

Using the station available data and barographs, 1978 to 1999 periods, 22 years were considered as common statistical periods. The linear, exponential and logarithmic correlation models (using SPSS and Normal Ratio method) were applied to complete and improve lack of data of the stations and common functions distribution in hydrology (Normal distribution, 2 and 3 parametric log normal, Pearson type 3 and Pearson log type 3, two parametric gamma and Gumble distribution) were used to analysis frequency and selecting appropriate distribution done by HYFA software. The best fitted distribution in each station was identified based on common tests like K^2-square test and Smirnov-Kelmograph test, moments and maximum likelihood methods and then two parametric gamma distribution was selected as dominant regional distribution.

By selecting dominant regional distribution, the maximum daily discharge estimated for 2,5,10,20,25,50,100 and 200 years return period (Table 1). Then, homogeneity test of the stations were done by Longbein method (1947).

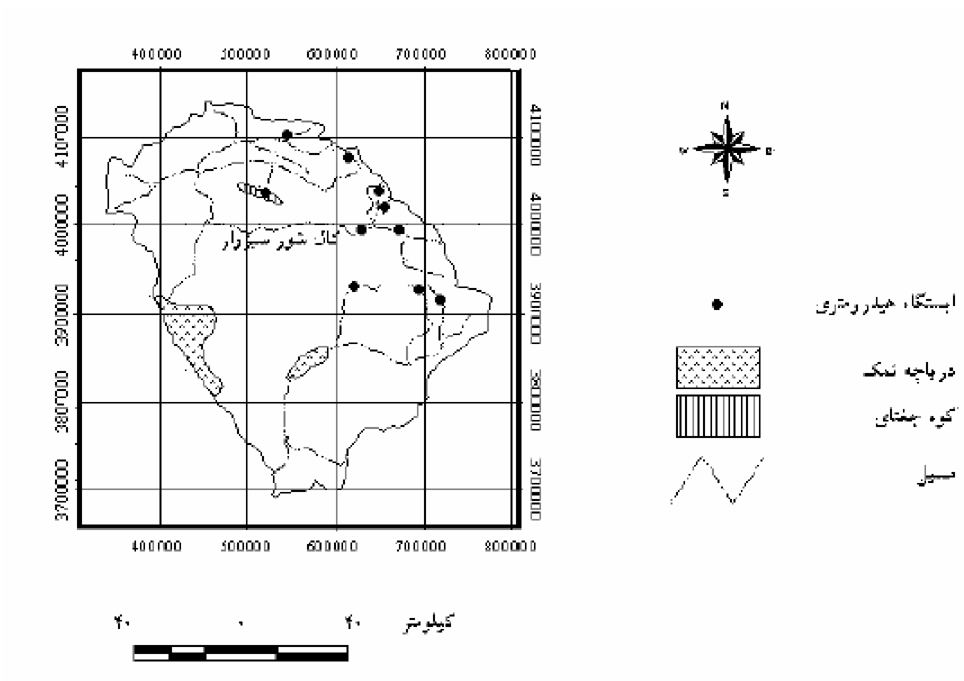

Figure 1- Location map of the studied station

Table 1: Estimated maximum daily discharge of stations for different return periods

Station code	(Km^2)Area	Maximum daily discharge of different return periods							
		2	5	10	20	25	50	100	200
47-039	4309	13.07	45.5	74.39	105.8	116.42	150.6	186.56	224.1
47-043	119	5.34	8.9	11.4	13.75	14.5	16	19.3	21.7
47-045	5134	23.2	58.23	85.8	114.3	123.6	153.2	183.4	214.4
47-049	90	.76	2.09	3.28	4.55	5.01	6.42	7.45	9.45
47-051	71	1.92	4.4	6.3	8.16	8.8	10.7	12.7	14.7
47-053	92	9.76	26.45	41.84	59.25	65.25	84.9	106	128.3
47-059	515	11.84	27.35	41.4	75.55	63.23	82.4	103.84	127.7
47-069	2070	19	42.95	60.07	75.5	80.8	94.8	107.4	118.64
47-071	152	9.34	23.07	33.8	44.8	48.4	59.8	71.5	83.4
47-073	810	7.32	12.1	15.25	18.28	19.24	22.2	25.1	28.07

Determination of regional coefficients:

Using the maximum daily discharge estimation at different return periods for 10 homogeneous stations of the region, the regional coefficient (C) and regional inundation frequency coefficient (ß) for return periods were conducted using equations 1 & 2 which were calibrated for stations and whole of the region (Using Solver programme of Excel)

The relation between maximum instantaneous and daily discharge of six stations data were analysed (four stations were omitted because of insufficient data about maximum instantaneous discharge) and for 27 years statistical period, maximum instantaneous discharge was calculated with two method of statistical distributions and Fuller empirical method at different return periods.

Results and Discussion

The values of c and ß coefficients estimated for 10 homogenous hydrologic stations with different basin area varying from 119 to 5134 Km^2 for basin regional coefficient (C) was 0.035-0.45 while regional inundation frequency coefficient (ß) was 0.62-2.99 which vary based on return period and stations (Table 2).

Table 2: Basin coefficient (C) and regional inundation frequency coefficient (ß) in stations of region

Station code	River	Station	A(km^2)	Basin Coefficient (c)	Regional inundation frequency coefficient (ß) in return period							
					2	5	10	20	25	50	100	200
47-039	Kal shour	Roh abad	4309	0.035	0	0.86	1.62	2.09	2.22	2.53	2.78	2.99
47-043	Bar	Arieh(chahar bagh)	119	0.113	0	0.66	0.87	0.96	0.98	0.98	1.08	1.11
47-045	Kal shou	Hossein abad gangal	5134	0.039	0	0.88	1.38	1.67	1.7	1.92	2.05	2.16
47-049	Kal yangejeh	Yangejeh abshar	90	0.038	0	0.74	1.38	1.76	1.88	2.15	2.36	2.5
47-051	Nashib	Nashib	71	0.091	0	0.86	1.3	1.51	1.57	1.7	1.8	1.9
47-053	Kamayestan	Hatiteh	92	0.45	0	0.83	1.5	1.95	2.07	2.4	2.66	2.9
47-059	Bidvaz	Esfarayen	515	0.12	0	0.77	1.33	1.7	1.8	2.14	2.43	2.7
47-069	Kal salar	Jafar mashhadi	2070	0.057	0	0.97	1.35	1.5	1.55	1.6	1.6	1.6
47-071	Shast darreh	Senovbar	152	0.256	0	0.88	1.37	1.64	1.71	1.88	2	1.2
47-073	Sheshtaraz	Kariz	810	0.04	0	0.62	0.8	0.89	0.91	0.96	0.98	1
Total area			-	0.041	0	0.88	1.43	1.76	1.84	2.04	2.2	2.32

The comparison of maximum instantaneous discharge values estimated by two methods including statistical distributions and Fuller in different return periods shows that the obtained results of maximum instantaneous discharge using Fuller empirical method is less than statistical distributions method (Table 3).

Therefore, 2.66 and -0.3 coefficients of equation No 3 of Fuller formula for the region was calibrated and changed for all return periods at meaningful level of 1% and coefficient correlation (R^2=0.88) using the formula:

$$Q_p=Q_{max}\,(1+11.63\,A^{-0.31278})$$

Conclusion

Based on the results, ß and C coefficients were near to other obtained coefficients limits in other regions conducted by Fuller, Sangal, Subramanay, Gholami, Telvari and Sheikh.

But there is a recognizable difference between coefficients determining before application. In the other hand, different results obtained for maximum instantaneous discharge estimation by the method and Fuller coefficient.

Table 3. The comparison of maximum instantaneous discharge of two methods

Station code	Maximum instantaneous discharge estimation method	Return period							
		2	5	10	20	25	50	100	200
47-039	P_e*	31.8	78.6	115.35	153.14	165.52	204.62	224.67	285.62
	P_f**	18.86	58.52	88.24	121.97	133.22	169.16	206.56	245.3
	P_f/P_e	0.6	0.75	0.76	0.79	0.8	0.82	0.84	0.85
47-043	P_e	17.4	38.85	58.78	79.7	81.48	117.6	149.65	186.1
	P_f	8.95	15.9	20.66	25.23	26.7	31.14	35.6	39.95
	P_f/P_e	0.51	0.41	0.35	0.31	0.33	0.26	0.24	0.21
47-045	P_e	46.7	112.74	117.72	258.4	288.14	393.4	520.4	672.05
	P_f	28.64	80.83	131.1	189.8	210.45	279.44	355.5	437.9
	P_f/P_e	0.61	0.72	0.74	0.73	0.73	0.71	0.68	0.65
47-059	P_e	43.07	92.06	128.3	164.5	176.2	212.8	249.73	278.06
	P_f	18.72	39.52	54.8	70.1	75.03	90.37	105.9	121.6
	P_f/P_e	0.43	0.43	0.43	0.43	0.43	0.43	0.42	0.42
47-069	P_e	91.9	164.4	210	252.3	265.5	305.6	344.8	383.5
	P_f	26.6	53.4	72	88.7	93.7	108.2	121.3	132.95
	P_f/P_e	0.29	0.32	0.34	0.35	0.35	0.35	0.35	0.34
47-071	P_e	19.73	48.21	76.57	112.05	125.2	171.84	228.45	296.38
	P_f	11.6	28.37	45	65.62	73.18	100.04	132.5	171.2
	P_f/P_e	0.59	0.59	0.59	0.59	0.58	0.58	0.58	0.58

x estimated maximum instantaneous discharge by statistical distribution method.

xx estimated maximum instantaneous discharge by fullers empirical formula.

As concluded by Canadian Ministry of Natural Resources experts and Fill and Steiner have gained higher values and Sangal has gained lower values than the estimations of current research. Telvari and Sheikh approved the results for some sub-basins while have reported lower values than estimated ones.

The results of this study also show lower value than real. But this ratio, has no considerable differences at different return periods which make it possible to use for all return periods for the whole of the region without any limitation.

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