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Frequency Analysis of Low-Flows in the Large Karoun River Basin in Iran

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ABSTRACT: Frequency analysis is one of the suitable statistical methods in assessing the amounts of low-flow in various return periods which could be obtained using statistical distribution theories and choosing proper probability law or distribution function. The purpose of this study is a frequency analysis for low-flows of Karoun, Dez, and the Large Karoun river basin in Iran , find the dominant probability distribution functions and the low-flows' values until their behaviors in 1-day to 30-day periods could be determined. The observed statistics and information from three hydrometric stations were used in this investigation, namely, Polshaloo as the inflow to the Karoun-3 storage dam, Talezang as the inflow to the Dez storage dam, and Ahvaz as the performance location of the Large Karoun system. The results from this study showed the low-flow generation in Karoun basin (Polshaloo) and the Dez basin (Talezang) are closed together in low probabilities. Analysis of daily to monthly low-flows of the Large Karoun River in Ahvaz station varies between 190 to 250 m^3/s. These values for 80% frequencies are between 143 to 183 m^3/s. The time series analysis of 1-day to 30-day low-flows of this station shows that flow during the first 15-year period prior 1969 had been normal and during the following years it was affected by the basin's soil and water resources development plans.

Keywords*:* Frequency Analysis, Low-Flows, Water Shortage, Large Karoun River.

INTRODUCTION

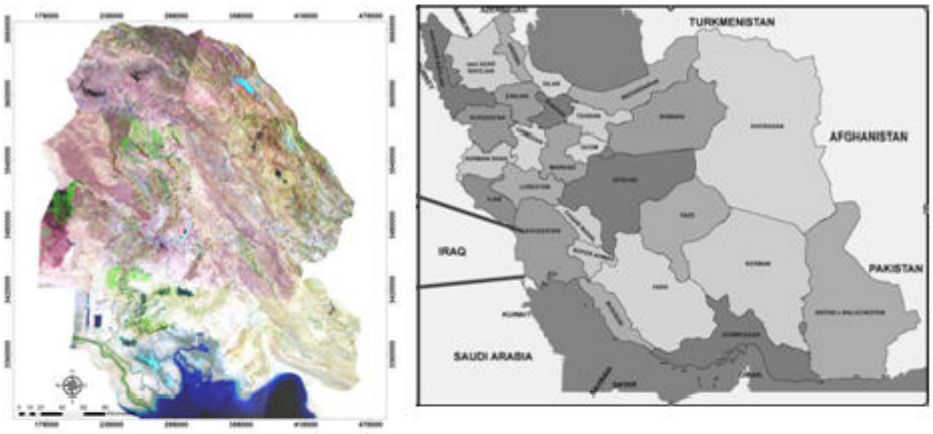
International glossary of hydrology defines low flow as 'flow of water in a stream during prolonged dry weather. This definition does not make a clear distinction between low flows and droughts. Low flows is a seasonal phenomenon, and an integral component of a flow regime of any river. Drought, on the other hand, is a natural event resulting from a less than normal precipitation for an extended period of time. McMahon and Arenas (1982) presented a compilation of methods used in different countries to compute low-flow characteristics, illustrated some of these methods with case studies and addressed some theoretical aspects of natural and man-induced factors affecting low flows. Smakhtin (2001) presented a paper with matter "Review Low flow hydrology" that further focuses on the techniques for low-flow estimation in ungauged river catchments. This paper presents a summary of recent international low-flow related research initiatives. The review is largely based on the research results reported during the last twenty years. Analyzing rivers discharge and flood water is one of the most important statistical topics in the field of the applied hydrology science. The observed data is a primary and substantial requirement for every frequency analysis. whenever there are sufficient statistical samples and the possibility to fit a proper distribution function, the frequency analysis is a suitable statistical method in assessing discharges in different return periods. Rao and Hamed (2000) for calculating the statistical parameters of density or distribution functions suggested several methods could be used including: method of moments, maximum likelihood, probability weighted moments, least squares, etc. Usually, the first three mentioned methods are common. The low-flow is the lowest mean flow in one day or 3, 5, 7, 30 or 60 consecutive days during one year. Modarres (2008) Stated the reason for calculating the low-flow for some consecutive days is to minimize the flow's small oscillations and variations. Tusker (1987) with using statistical distributions studied the hydrometric statistics of about 20 rivers in Virginia State of US. He suggested the 3-parameter Weibull and Log-Pearson distributions for analyzing the 7-day low-flow series. Yureklh and Kurunc (2005) properly used the low-flows

analysis for drought analyses. For study drought they applied the daily low-flow information and statistics of each month observed in three hydrometric stations located at the Cockrick basin in Turkey. The objective of this study is the frequency analysis of Karoun and Dez rivers low-flow at inflows to Karoun-3 and Dez dams reservoirs to while clarify probability distribution functions also to determine the low-flow amounts and their behavior during 1-day and 30-day periods. Also, the low-flow time series for Ahvaz hydrometric station at the large Karoun system is discussed.

MATERIALS AND METHODS

In this study, the information and statistics from three hydrometric stations located at large Karoun basins including Karoun-Polshaloo, Dez-Talezang, and large Karoun-Ahvaz were used. The observed flow in Polshaloo and Talezang hydrometric stations are as inflows to the reservoirs of Karoun-3 and Dez dams. The common statistical period for stations was 1957-2008. The aforementioned data were acquired from Ministry of Energy [Iran Water Resource Management Company and Khouzestan Water and Power Authority (KWPA)].The geographic coordinates for the selected hydrometric stations show in table (1).

The equipments and number of stations in during sampling were sufficient and ranked as grade 1 in terms of hydrometrics. Regularly, discharge measurement, sectioning, and water sampling for qualitative tests and sediments are performed in these stations. In 1955, the first sampling from Khouzestan surface water resources began at the Gotvand section, and during the following years, Polshaloo and Talezang hydrometric stations became operational. By oprating of Karoun-3 storage dam, the Polshaloo station was placed at the dam's reservoir (close to the dam's axis) where that the inflow is considered as the recorded flow in this station. In fact, recently, due to opration of the Karoun-4 storage dam, the flow normalization requires a series of hydrological modifications. The general characteristics of flows in studied hydrometric stations are appended to table and figure(1).



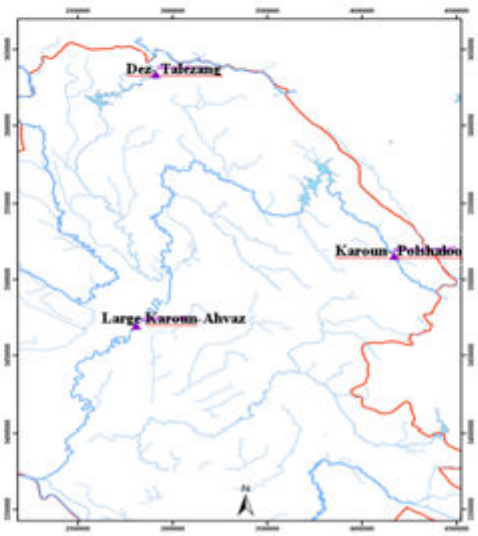


Figure1. Location of selected hydrometric stations.

Table 1. Coordinates and general characteristics of flows in selected hydrometric stations

River's name	Karoun	Dez	Large Karoun
Station's name	Polshaloo	Talezang	Ahvaz
Longitude (UTM)	417051.32	291061.3	280701.07
Latitude (UTM)	3515497.8	3633751	3469350
Height (m)	690	444	9.78
Statistical duration (Year)	50	53	54
Basin's area (km^2)	24210	16213	60737
Annual flow volume (million m^3)	9429	7852	19962
Annual flow variations coefficient	0.37	0.38	0.40

Purpose of frequency analysis is obtaining the probable law of "density function" or "distribution function" dominant on the studied random variable according to the observed sample and calculating the return period or x_T occurrence value (Rao and Hamed, 2000). Generally, the frequency analysis is the probable investigation of the flow's random variable including: sample collection (minimum daily or more consecutive days discharge), sample data mending and completion, required statistical test such as random, independency, integrity, outliers and stationary, choosing proper statistical distribution (density function f(x) or distribution function F(x)), assessing the density function parameters and the required tests for density function fitting and also choosing the best function. In order to achieve the research's goal, including the low-flows in 1-day or more consecutive days of a year, hydrometric statistics from the above-mentioned stations were considered in daily scale for the statistical period mentioned in table (1). Provided the daily flow statistics of the mentioned sections for more than 50 years, the following steps were taken:

a) Using the daily discharge, the minimum daily discharge for each station-water year was determined. In this method the minimum discharge from among discharges of 365 days of each year was determined and considered for same year. Thus, for each hydrometric station a 50-years time series of low-flow was developed.

b) Since 3, 5, 7, 15, and 30 consecutive days low-flows are aimed in this study, using the daily discharge and the moving average technique, the discharge of 3, 5, 7, 15, and 30 consecutive days low-flows was determined for each station.

c) For the series frequency analysis, the Hydrological Frequency Analysis software(HYFA), and such statistical distribution as normal, log-normal (II), log-normal (III), gamma (II), Pearson (III), log Pearson (III) and Gumball were used. for calculate the distribution parameters, two methods were applied, namely, the moment and the maximum likelihood method. The best statistical distribution corresponding to data was selected based on the minimum mean relative deviations of the flow observed values and their calculated values in distribution, relative deviations mean square, K-square (K^2), and comparing the distribution fitting on observed data separately for each station. The low-flow with different return periods was determined based on this distribution.

RESULTS AND DISCUSSIONS

In this study, the minimum discharges of Karoun, Dez, and large Karoun rivers were considered. The statistical period is 52 year. First the preliminary analysis on time series of low-flows in one day or more consecutive days of each year including mean, maximum and minimum parameters, standard deviation, range and coefficient variations for each hydrometric station was conducted. The results are given in table (2). As shown in table(2), the time series ranges of one-day, three-day and … to monthly time series of Polshaloo and Talezang hydrometric stations have slightly changed. This is due to flow consistency in dry seasons. Moreover, the annual flow coefficient of variations for these stations are about 37%, while the low-flow time series coefficient of variations for Karoun River is 27% and for Dez River is 21%. The Ahvaz hydrometric station does not follow the above-mentioned trend due to regulate upstream flow and there is a significant difference between one-day and monthly time series flow.

The HYFA hydrology software was used for frequency analysis. The moments and maximum likelihood methods assessed the statistical distribution parameters. The best statistical distribution was determined based on the mean relative deviations of observed and calculated flows in the distribution, relative deviations mean squares, k-square and comparing the distribution fitting on observed data separately for each station and time series. The analysis results are presented in table (3).

Table 2. the preliminary analysis of low-flow time series of hydrometric stations (m3/s)- Pol shalo

Karoun river-pol shalo station						
Parameter/time series	1-day	3-day	5-day	7-day	15-day	Monthly
Mean	96	97	98	99	100	103
Maximum	164	166	168	168	169	179
Minimum	29	36	36	38	39	40
Standard deviation	26	27	26	29	27	27
Range	135	130	132	130	131	139
Coefficient of variations	0.27	0.27	0.27	0.29	0.27	0.27
Dez river-Talezang station						
Parameter/time series	1-day	3-day	5-day	7-day	15-day	Monthly
Mean	56	56	56	57	58	61
Maximum	101	101	101	101	102	104
Minimum	34	35	35	36	37	39
Standard deviation	12	12	12	12	12	13
Range	67	66	66	65	65	65
Coefficient of variations	0.22	0.21	0.21	0.21	0.21	0.22
Large Karoun river-Ahvaz station						
Parameter/time series	1-day	3-day	5-day	7-day	15-day	Monthly
Mean	189	199	209	215	232	250
Maximum	328	333	344	353	410	434
Minimum	86	90	91	92	100	107
Standard deviation	54	57	60	64	72	79
Range	242	244	253	261	310	327
Coefficient of variations	0.28	0.28	0.29	0.30	0.31	0.31

Table 3. The analysis results for frequency distribution functions fitting of low-flows in the studied hydrometric stations

Karoun river-pol shalo station					
Time series	Type of function	Method of assessment	K2	Sq.Rel.Dev	Rel.Dev
1-day	log Pearson (III)	Momentum	1.1	44.44	3.56
3-day	Normal	Momentum	0.9	13.70	2.12
5-day	Normal	Momentum	0.90	13.63	2.25
7-day	Normal	Momentum	1.91	18.57	2.43
15-day	Normal	Momentum	0.08	12.04	2.18
Monthly	Normal	Momentum	1.30	12.38	2.05
Dez river-Talezang station					
1-day	gamma(II)	maximum likelihood	4.45	12.09	2.14
3-day	Gumball(I)	maximum likelihood	2.00	8.76	1.96
5-day	log Normal(II)	Momentum	2.18	9.72	2.09
7-day	log Normal(II)	Momentum	2.75	8.69	2.75
15-day	Gumball(I)	maximum likelihood	0.87	6.28	1.70
Monthly	log pearson (III)	Momentum	2.00	4.27	1.65
Large Karoun river-Ahvaz station					
1-day	log Pearson (III)	Momentum	3.59	11.44	2.66
3-day	gamma(II)	maximum likelihood	1.74	16.17	2.39
5-day	log Normal(III)	Momentum	0.81	14.51	2.85
7-day	gamma(II)	maximum likelihood	1.37	18.96	2.67
15-day	log Normal(III)	Momentum	1.37	9.00	1.91
Monthly	log Pearson (III)	Momentum	0.63	9.70	2.00

According to the information provided in table (3) and also using the best distribution function, the low-flow discharge with various return periods was determined. Table (4) indicates the frequency analysis results for low-flows in the studied hydrometric stations.

The area of Karoun at Polshaloo and Dez at Talezang catchment-basin is 24210 and 16213 km^2, respectively. Hence, the area ratio of generating basin of Dez River flow to Karoun in the mentioned stations is equal to 0.67. But the mean ratio of Dez branch to Karoun annul flow is 80%. This ratio could be 58% for low-flows average discharges, which as the occurrence probability decreases, this ratio increases up to 96%. That is, the minimum flow generation of the Karoun basin (Polshaloo) gets closer to the Dez basin (Talezang). Analyzing the daily to monthly low-flows of Karoun-e-Bozorg River at the Ahvaz station varies between 190 and 250m^3/s.

These numbers for 80% frequencies are between 143 to 183m^3/s. It should be noted that the analyzed figures for Ahvaz station are related to regular and normal data for the last 50 years and the upstream consumptions as well as returned water are effective on them. Figures (2) to (4) compare the one-day and thirty-day time series of low-flows for studied hydrometric stations. As shown in these figures, these series are close to each other in Karoun (Polshaloo) and Dez (Talezang) rivers. This means that the low-flows for at least thirty days are consistent in each day. Indeed, this is slightly different for dry seasons. As shown in table (1), the applied statistical period in analyzing the large Karoun river at Ahvaz hydrometric station is 54 years. The

time series analysis of one-day and thirty-day low-flows of this stations shows that during the first 15 years of the statistical period before 1969 the flow was relatively normal and for the following years it was affected by basin's soil and water resources development plans figure (4).

Table 4. The results from frequency analysis of low-flows at the studied hydrometric stations (m^3/s)

Karoun river-pol shalo station										
Time sequence	Mean	50%	60%	70%	75%	80%	90%	95%	97.5%	99%
1-day	96	100	93	85	80	75	61	50	42	32
3-day	97	97	91	83	79	75	63	54	45	35
5-day	98	98	96	92	81	76	65	55	47	37
7-day	99	99	92	85	81	77	65	56	47	38
15-day	100	100	93	86	82	78	66	56	48	38
Monthly	103	103	96	89	85	80	68	58	49	39
Dez river-Talezang station										
1-day	56	55	52	49	47	46	41	38	35	32
3-day	56	54	51	49	47	46	43	40	38	36
5-day	56	55	52	49	48	46	42	39	37	34
7-day	57	56	55	53	48	47	43	39	37	34
15-day	58	56	54	51	50	48	45	42	40	38
Monthly	61	59	56	53	51	50	46	43	41	38
Large Karoun river-Ahvaz station										
1-day	189	185	172	158	151	143	123	108	95	81
3-day	199	194	180	166	159	151	131	117	105	92
5-day	209	205	190	175	167	158	135	117	102	85
7-day	215	209	194	178	170	161	139	123	110	96
15-day	232	226	209	191	182	172	146	126	110	92
Monthly	250	244	225	205	195	183	156	135	119	101

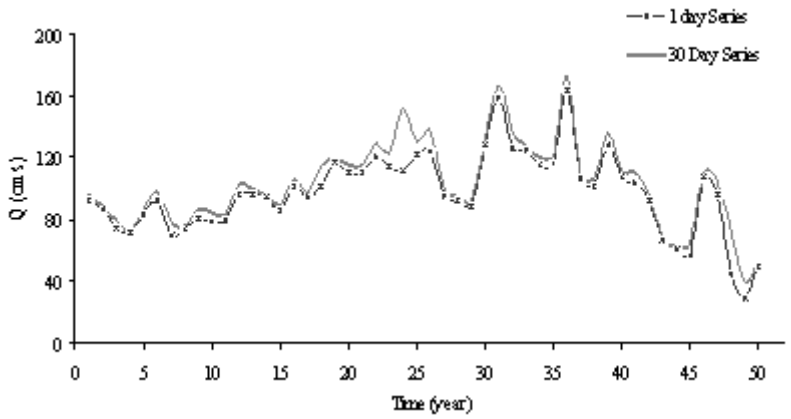


Figure 2. Time series comparison of low-flows – Karoun River – Polshaloo

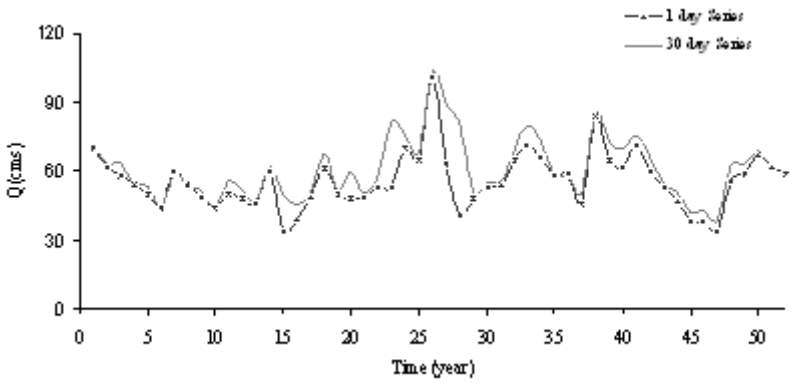


Figure 3. Time series comparison of low-flows – Dez River – Talezang

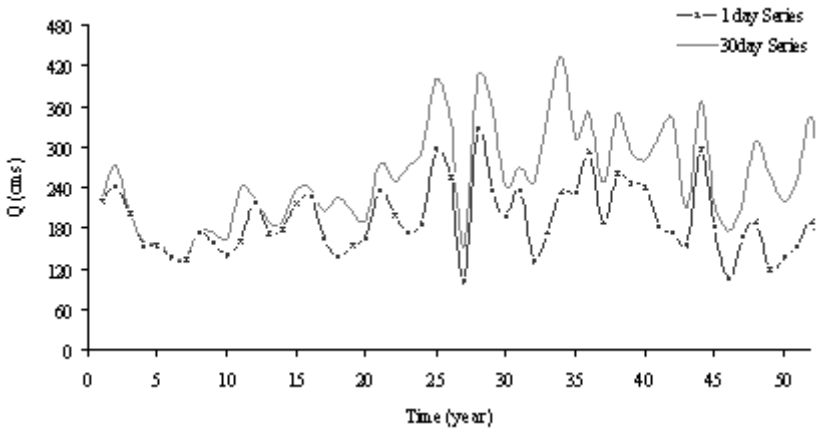


Figure 4. Time series comparison of low-flows –large Karoun– Ahvaz

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