Journal homepage www.jzs.univsul.edu.iq
Journal of Zankoy Sulaimani
Part-A- (Pure and Applied Sciences)

Statistics and Variability of Darbandikhan and Dukan dam Inflow time series

Nawbahar F. Mustafa[1]

1 Irrigation Department, Engineering Faculty, Sulaimani University, Sulaimani, Iraq
nawbahar.mustafa@univsul.edu.iq

Article info

Original: 19 October 2016
Revised: 23 December 2016
Accepted: 9 January 2017
Published online: 20 June 2017

Key Words:
Low flow
Flow duration curve
Trend
Darbandikhan dam
Dukan dam

Abstract

Flow, low flow statistics, and variability of Darbandikhan and Dukan inflow time series have been analyzed. Darbandikhan and Dukan dams' inflow time series were best fitted with three parameter inverse Gaussian distribution. Long term, annual, and monthly flow duration curves (FDCs) are constructed. Two parameters logarithmic function appeared to be the most appropriate functions fitted to FDCs. Low flow percentiles are extracted from flow duration curves for 95, 90, 75, 70, 50, and 25 percentiles. Annual minimum 1-, 3-, 7-, 14-, 30-, 60-, and 90-day mean inflow with recurrence intervals of 2, 5, 10, 20, 30, and 50 years were estimated.

Base flows were separated from long-term inflow time series. Results indicated that a large amount of long-term inflow was supported by base flow for both Darbandikhan and Dukan dams' inflow time series. The discharges were generally less than their mean inflow with no large fluctuations.

The trend of monthly mean inflow discharge versus time have been analyzed using different methods. Results are indicating a significant negative monthly trends of 0.488 m^3/s and 0.593 m^3/s with reduction percentages of 0.0127 % and 0.0120% for Darbandikhan and Dukan dams' inflow time series; respectively. The results of current study were compared with USGS Data Series 540 results. All month's inflow defined a reduction that maximized in August. Comparison of low flow statistics are also referred to maximum reduction percentage in Q95% which is occurring commonly in summer. The larger reduction during summer months is indicating artificial water withdrawals from feeding streams of the dams during periods of no rain.

Introduction

A flow duration curve (FDC) is one of the most informative ways of displaying the complete range of river discharges, from low flows to flood events. Using average daily discharge data, flow duration curves are cumulative frequency distributions that show the percent of time that a specified discharge is equaled or exceeded during a period of interest [1].

Determining FDCs enables the regulatory authority to estimate that abstraction volume which is the maximum volume of water that can be abstracted from the river without resulting in an unacceptable deterioration in upstream ecology or an adverse impact on downstream water users [2].

Low flow characteristics determined from flow duration curve commonly are the basis of water-quality standards and minimum flow rate [3]. Knowledge of the magnitude and frequency of low flows for streams are important for water-supply planning and design, waste-load allocation, reservoir storage design, and maintenance of quantity and quality of water for irrigation, recreation, and wildlife conservation [4].

Base flow is an important component of streamflow generated from groundwater inflow or discharge. Estimation of base flow regime is important for development of catchment management strategies, especially for drought conditions.

It is necessary to know that the water resources trends in a river basin, identification of temporal changes in hydrological regimes of river basins are important topics in contemporary hydrology because of the potential impacts of climate change on river basin [5].

In the present study the previous, current and future water situation availability for Darbandikhan and Dukan inflow and low flow discharges were evaluated.

2 Material and methods

2.1 Study area

Darbandikhan and Dukan are the major and most important lakes in Kurdistan, northern Iraq which are impounded by Darbandikhan and Dukan dams; respectively. Darbandikhan dam is located at the coordinates (35°6'47.95") N & (45°42'22.85") E with 17,850 km^2 catchment area lies mainly in Iran, the two main feeding tributaries are the Tanjero River, which flows in from Iraq, and the Sirwan River, which flows in from Iran.

Dukan dam is located at the coordinates (35˚57'15") N & (44˚57'10") E with 11,690 km^2 catchment area lies mainly in Iraq ,the lake is fed by the Lesser Zab river from the northeast and the Hizop stream from the northwest. Darbandikhan Lake has total storage capacity of 3,000 Mm^3 while Dukan Lake has total storage capacity of 6800 Mm^3 [6 and 7].

Darbandikhan and Dukan reservoir inflow time series was obtained from Darbandikhan and Dukan dams' directorate, (during 1985 to 2015 for Darbandikhan and 1988 to 2015 for Dukan) and were used to construct the annual hydrographs. The annual hydrographs for Darbandikhan and Dukan reservoir inflow time series start from October to September. The highest mean monthly inflow takes place during March and the driest months are July, August, and September (Figure: 1).

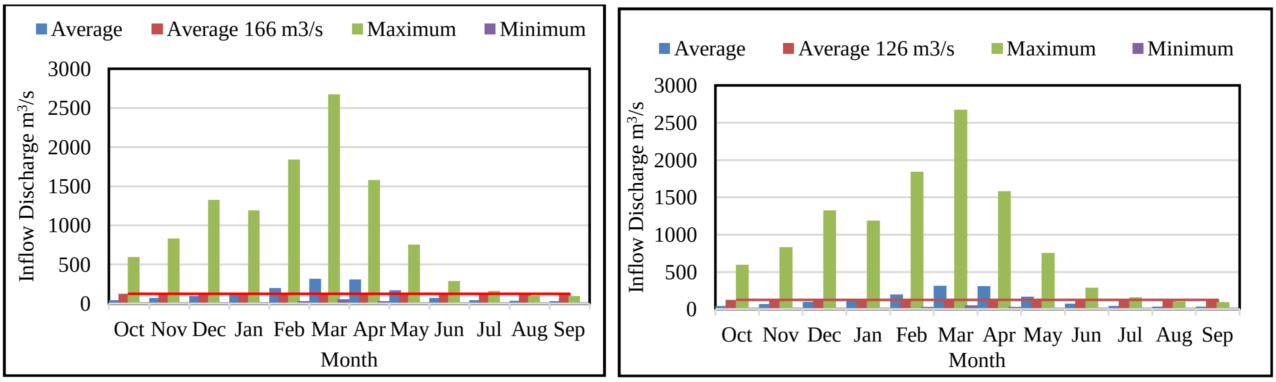

Figure- 1: Average, Maximum, and Minimum annual hydrograph for Darbandikhan and Dukan Lake inflow time series

The flow exceedance probability curve is developed using existing hydrologic flow data from a specified time period of interest, and can be formatted to fit daily, weekly or monthly data. To create the curve, flow values for the time period of interest are first ranked by magnitude. Then, exceedance probability is calculated by determining the percentage of time that the stream flow is likely to equal or exceed a specified value. Exceedance probabilities are plotted against flow values, and the curve reflects average flow characteristics of a stream throughout the range of discharge. [7]

FDCs may be determined for particular periods (defined by days, months, or group of months) of the year. For example, for irrigation abstraction, the growing season for a specific crop type may be define the most appropriate period for analysis. FDCs constructed on the basis of daily flow time series provide the most detailed way of examining duration characteristics of a river [8].

2.2 Applications of the FDC

The FDC is commonly used for the preliminary design of simple abstraction schemes in order to estimate the time percentage that a given abstraction can take place. It is a key element of the planning for proposed schemes and an assessment of water availability for defining the potential area that can be irrigated by the supply river. Seasonal FDCs can be used to compare potential demand with available water. The analysis of FDCs at gauged and ungauged sites can help to determine how much water can be abstracted for fish farming, ecosystem protection and amenities. It is also used to estimate the dilution of domestic or industrial discharge destined for a river. The FDC is also used to estimate the frequency of the availability of cooling water for large thermal power stations. If the discharge at critical navigation points is converted into a water depth, then the FDC can be used to estimate the percentage of time that the river is require a given navigation depth [8].

2.3 Low-flow statistics

- Mean flow: The mean flow is one of the most commonly used, it is normally calculated for complete calendar or hydrological years of data it can also be calculated for specific months or seasons.
- Low-flow percentiles from the FDC are often used as key indices of low-flow. Low flow indices derived from the FDC are the percentiles which indicate a high frequency of exceedance and therefore present the low flow period of a regime. Common percentiles used as low flow indices are the 95, 90 and 70 percentile, with discharge termed as *Q*95, *Q*90, and *Q*70 respectively, and can be derived from FDC for specific periods (day, month, group of months). In the present study monthly and annual percentiles of 95, 90, 75, 70, 50, and 25 are estimated from the inflow discharge time series.
- Mean annual minima: The annual minimum *n*-day discharge, *AM* (*n*-day) is the smallest average discharge of *n* consecutive days within one year. Common averaging interval, i.e. values of *n*, are 1-, 3-, 7-, 14-, 30-, 60-, and 90-day average flows. An AM (*n*-day) can easily be calculated by applying a moving-average filter of *n* days on a daily discharge series and subsequently selecting the minimum of the filtered series. The annual minimum time series can be estimated with recurrence intervals of 2, 5, 10, 20, 30, and 50 using the most suitable theoretical distribution [9].
- Mean annual minima of 7Q10 and 7Q2, mean annual 7-day minimum with return periods of 10 years and 2 years respectively, are indices of more extreme low-flow conditions which estimated from the annual series of flow minima. 7Q10 is usually used as a criterion to permit a specified quantity of waste effluent to be discharged to streams and to set permit limits for surface water withdrawals from streams. They include the 7 day average flow with return periods of 10 and 2 years (7Q10 and 7Q2) and the 7 day average MAM7 [3].
- The specific water-quality criteria applicable at the 7Q10 minimum flow condition includes the aquatic life criteria dissolved oxygen (DO), pH, temperature, turbidity, and toxics as well as the human health criteria for non-carcinogens [10].
- Base flow index BFI: Knowledge of base flow regime is important for development of catchment management strategies, especially for drought conditions. Base flow is an important component of streamflow generated from groundwater inflow or discharge. Base flow separation techniques use the time series record to derive the base flow signature [3].

2.4 Inflow Discharge Variability and Trend in Time

Reservoir inflow discharge in a specific geographical region is affected by rainfall, evaporation, topography, lithology, vegetation heterogeneity and other factors, including regional and global climatic fluctuations. Estimation of reservoir inflow discharge variability is important for many practical purposes, particularly in water resources management. These include reservoir operations, irrigation management, hydroelectric power generation, flood and drought control, and recreational sports. Specifically, knowledge of temporal variability in reservoir inflow discharge can be used to assess extreme events of floods and droughts [11]. Identification of temporal changes in hydrological regimes of river basins is an important topic in contemporary hydrology because of the potential impacts of climate change on river basin.

3 Results and Discussion

3.1 General

Darbandikhan and Dukan inflow time series are plotted against years *(Figures: 2 and 3)*. It can be conclude that for both time series, the driest and most wet years from all the rated years were the years 2008 and year 1988. The maximum inflow discharge is generally occurred up to 1994 during the first ten years of the time, while minimum inflow discharge occurred after 1999 to 2009. The inflow time series values of the discharges are generally less than their mean, and show short periods of large fluctuations.

Statistics of monthly and annual mean discharges computed *(Table: 1)* from the annual mean discharges for the period of record include (1) the maximum, minimum, and mean monthly discharges and (2) the maximum, minimum, and mean annual discharges. The years in which the maximum and minimum discharges occurred are listed with the respective values, and the standard deviation of the monthly and annual mean discharges are listed with the respective values. The percentage of the annual discharge that occurs each month is listed in the table for each station. Each monthly mean is the mean of the daily values for that month. The maximum monthly mean discharge is the maximum value of all monthly mean values for a given month for the period of record. Similarly, the minimum monthly mean discharge is the minimum value of all monthly mean values. The mean monthly discharge is the mean of all the monthly mean discharges for a given month for the period of record, and the standard deviation is a measure of the variability of the values. All the maximum monthly inflow discharges are occurred up to 1944 for both time series except in February and September for Dukan inflow time series. All the minimum inflow discharges occurred from 1999 to 2009. The period from up to 1999 can be set as wet period while the period from 1999 to the end of rated years as dry period with respect to mean inflow discharges.

Table- 1: Extremes and statistics for Darbandikhan and Dukan monthly and annual mean inflow discharges

Month	Maximum		Minimum		Statistics				Maximum		Minimum		Statistics			
	Discharge (m3/s)	Year of occurrence	Discharge (m3/s)	Year of occurrence	Mean discharge (m3/s)	Standard deviation (m3/s)	Coefficient of variation	Percentage of annual discharge	Discharge (m3/s)	Year of occurrence	Discharge (m3/s)	Year of occurrence	Mean discharge (m3/s)	Standard deviation (m3/s)	Coefficient of variation	Percentage of annual discharge
January	356	1994	26	2009	130	92	0.7	9	497	1994	32	2009	187	138	0.7	9
February	469	1985	59	2009	198	113	0.6	13	734	2006	53	2009	286	180	0.6	14
March	1115	1988	84	1999	315	229	0.7	21	1569	1988	100	1999	388	285	0.7	19
April	861	1992	53	2008	310	199	0.6	20	1086	1992	92	2008	391	244	0.6	20
May	513	1992	22	2008	169	107	0.6	11	797	1992	49	2008	244	168	0.7	12
June	207	1992	11	2008	73	47	0.6	5	354	1992	27	2008	113	89	0.8	6
July	116	1988	5	2000	45	28	0.6	3	162	1988	13	2008	54	37	0.7	3
August	84	1988	2	2000	35	22	0.6	2	84	1988	9	2008	36	20	0.6	2
September	86	1987	3	2000	33	24	0.7	2	274	2003	9	2008	42	50	1.2	2
October	228	1998	5	2001	45	45	1.0	3	93	1988	14	2001	39	23	0.6	2
November	317	1994	11	2001	70	61	0.9	5	344	1993	20	2000	88	83	0.9	4
December	291	1987	27	2008	99	72	0.7	6	382	1991	30	2008	131	101	0.8	7
Annual	289	1988	33	2008	126.9	69	0.5	100	402	1988	52	2008	166	93	0.6	100

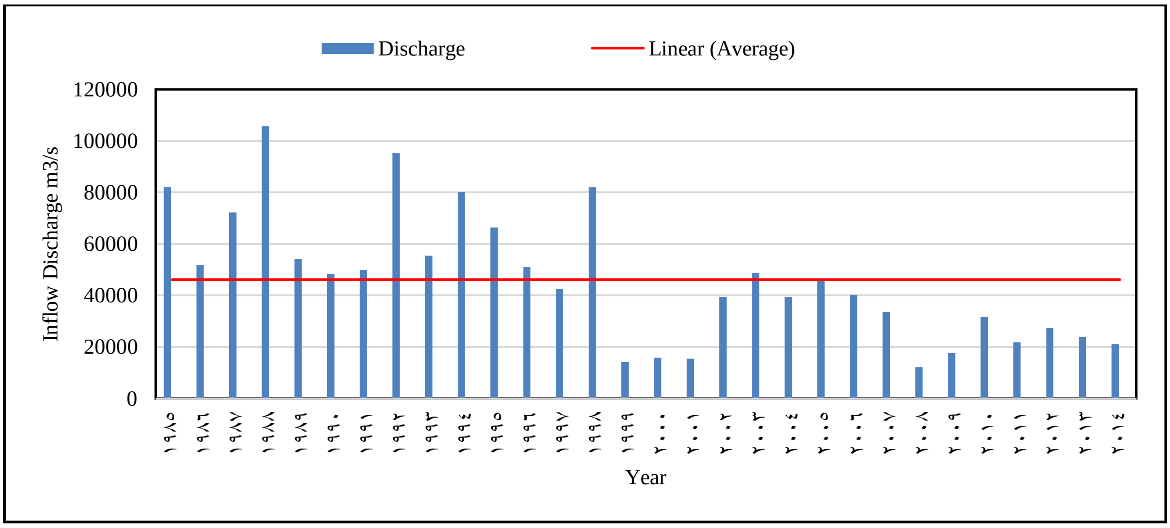

Figure- 2: Darbandikhan annual inflow discharge from 1985 to 2014

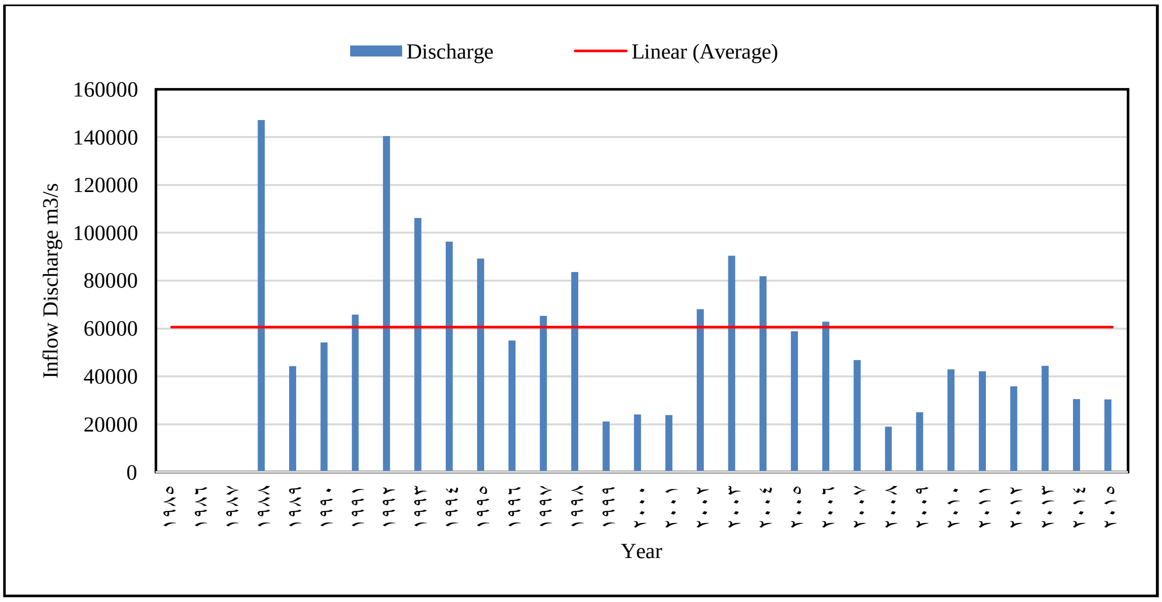

Figure- 3: Dukan annual inflow discharge from 1988 to 2015

Darbandikhan and Dukan dams' inflow time series were fitted to several theoretical probability distributions and Log-Normal distribution was found to provide the best overall fit based on Kolmogorov Smirnov test.

3.2 Flow duration curves FDCs and Low-flow percentiles

Long term, annual, and monthly flow duration curves are constructed *(Figures: 4, 5, 6 and 7)*, the low flow percentiles from long term FDC was abstracted and given in *(Tables: 2 and 3)*. the percentiles ranges from minimum in August and September to maximum in March and April as expected. The slope of the Figure: is small at the low-flow part of the FDCs, therefore it can be concluded that groundwater flow contribution is normally significant and low-flows are sustainable for Darbandikhan and Dukan inflow discharges.

Full percentage and the lower three-quarter section (25% to the end) of developed FDCs were fitted. A 2-parameter logarithmic function appears to be the most appropriate one fitted to the FDCs data (among: power, exponential, linear, and logarithm functions) with R-squared values equal to 0.93 and 0.99 respectively as shown by (Figures: 4 and 5).

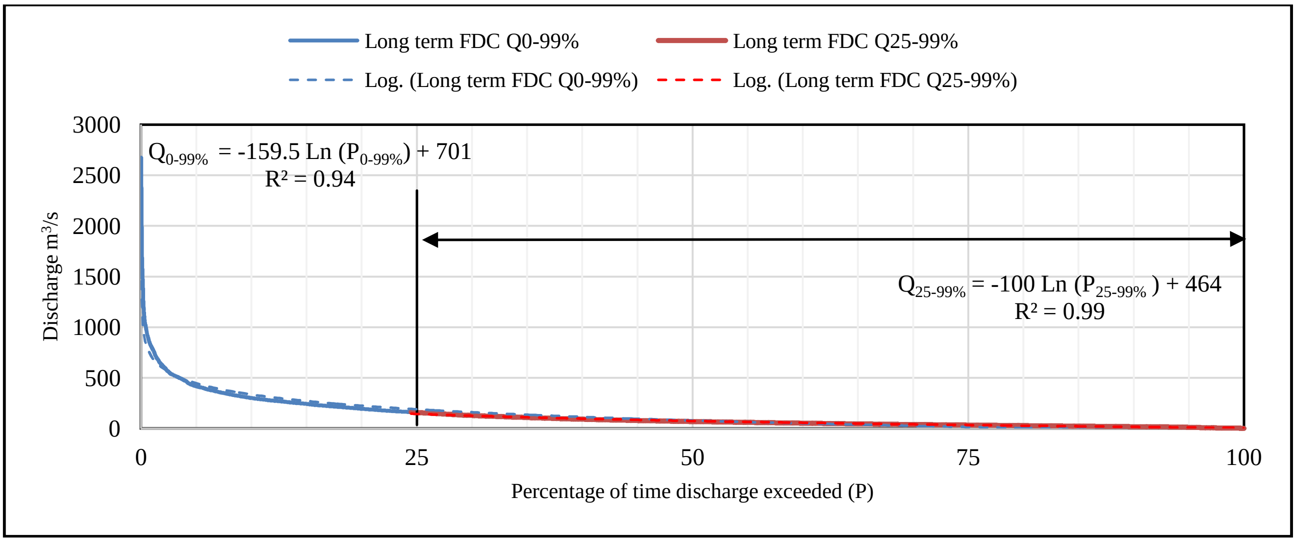

Figure- 4: Darbandikhan inflow Long term flow duration curve

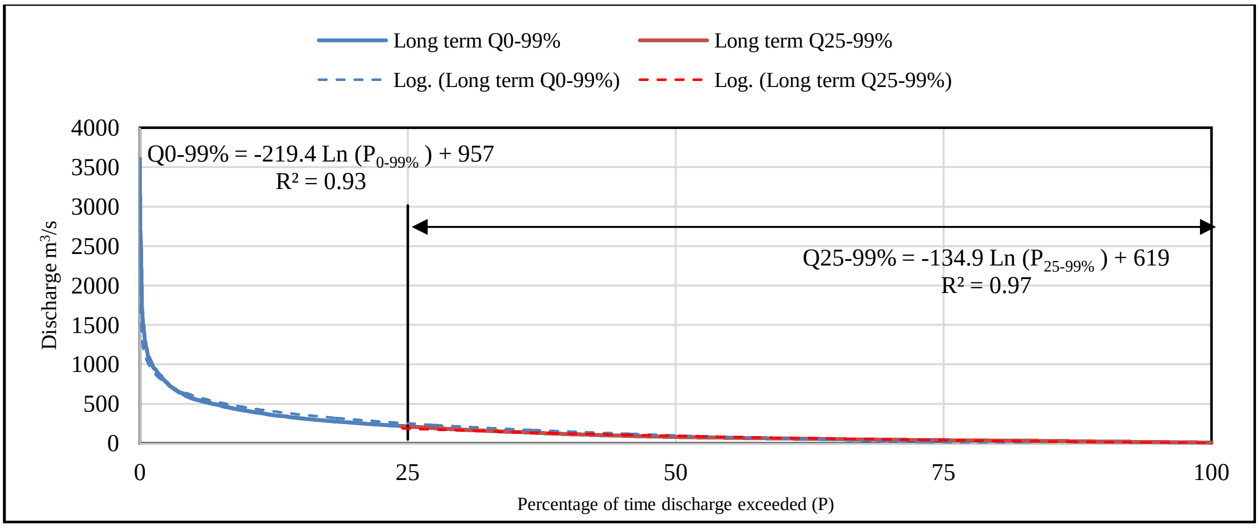

Figure- 5: Dukan inflow Long term flow duration curve

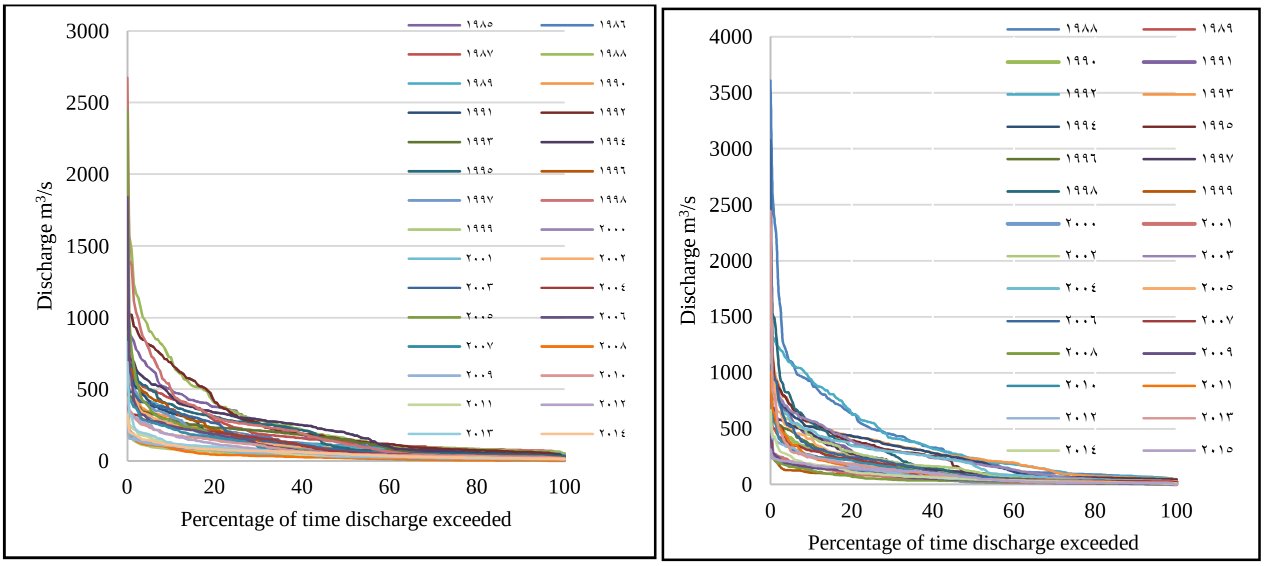

Figure- 6: Darbandikhan and Dukan inflow Annual flow duration curve

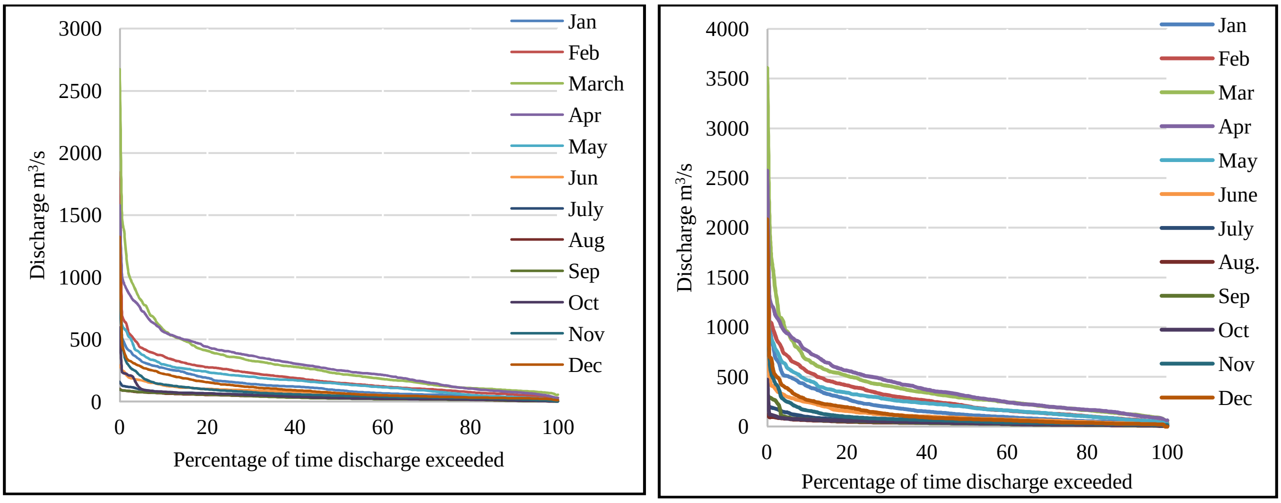

Figure- 7: Monthly flow duration curve for Darbandikhan and Dukan inflow time series

Table- 2: Darbandikhan inflow monthly and annual- long term- low flow percentiles from flow duration curves

Percentages of discharge equaled or exceeded	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Annual*
95	*29*	*48*	*78*	*61*	*27*	*12*	*5*	*3*	*3*	*6*	*13*	*24*	*10*
90	*35*	*57*	*88*	*76*	*36*	*17*	*9*	*5*	*5*	*9*	*21*	*27*	*18*
75	*127*	*69*	*31*	*23*	*17*	*15*	*19*	*32*	*36*	*52*	*90*	*121*	*32*
70	*56*	*101*	*142*	*155*	*89*	*39*	*26*	*19*	*17*	*20*	*34*	*42*	*39*
50	*251*	*144*	*64*	*38*	*32*	*24*	*28*	*47*	*67*	*90*	*151*	*224*	*67*
25	*159*	*257*	*360*	*404*	*214*	*94*	*61*	*49*	*52*	*61*	*86*	*134*	*150*

Table- 3: Dukan inflow monthly and annual- long term- low flow percentiles from flow duration curves

Percentages of discharge equaled or exceeded	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Annual*
95	*35*	*57*	*102*	*97*	*55*	*22*	*13*	*9*	*9*	*10*	*20*	*26*	*15*
90	*39*	*73*	*125*	*122*	*67*	*29*	*15*	*12*	*11*	*13*	*22*	*30*	*21*
75	*60*	*121*	*183*	*182*	*113*	*50*	*27*	*21*	*16*	*17*	*31*	*42*	*39*
70	*72*	*132*	*200*	*201*	*134*	*58*	*34*	*25*	*17*	*19*	*35*	*48*	*44*
50	*115*	*204*	*285*	*306*	*197*	*82*	*45*	*33*	*30*	*33*	*54*	*76*	*81*
25	*226*	*363*	*450*	*506*	*304*	*135*	*64*	*43*	*48*	*53*	*84*	*159*	*218*

The Annual minimum 1-, 3-, 7-, 14-, 30-, 60-, and 90-day Darbandikhan and Dukan mean flows with recurrence intervals of 2, 5, 10, 20, 30, and 50 years were computed using Log-Pearson Type III distribution distributions [11 and 12] *(Figure: 8).*

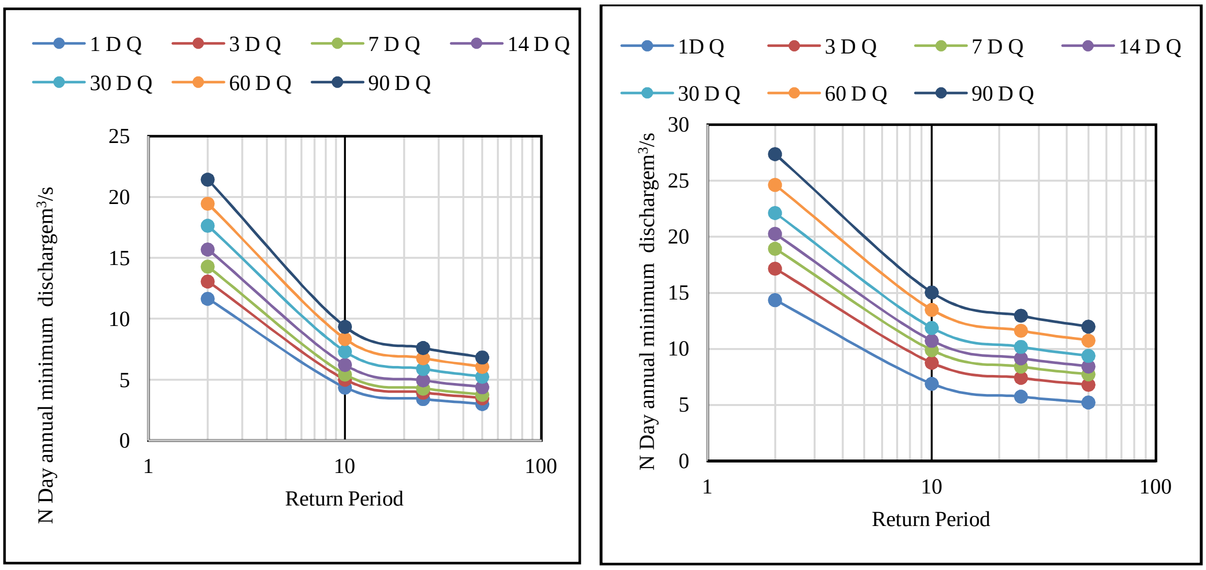

Figure- 8: Darbandikhan and Dukan inflow non-exceedance probability of minimum mean discharge for selected numbers of consecutive days

3.3 Base Flow

Various approaches exist for base flow separation; however, in the present study base flow was separated from long-term streamflow records using the Web-based Hydrograph Analysis Tool (WHAT), *(Figures: 9 and 10)* present the results of the base flow and direct flow for the daily inflow discharge calculated by Local minimum, one parameter digital filter, and two-parameter digital filter parameter methods. Results indicated that a large amount of long-term streamflow was likely supported by base flow. Darbandikhan inflow base flow index ranges between 82% and 84% and Dukan inflow base flow index ranges between 78% and 80% using the three methods. The estimated Base flow index (BFI_{max}) was 87% for two parameters method and for both time series. In absence of reliable information to determine groundwater discharge in streams and rivers, these indexes can be used to estimate annual base flow [13]. The large catchment areas and the long travel times to the catchment outlets resulted in the large amount and long-term of base flow.

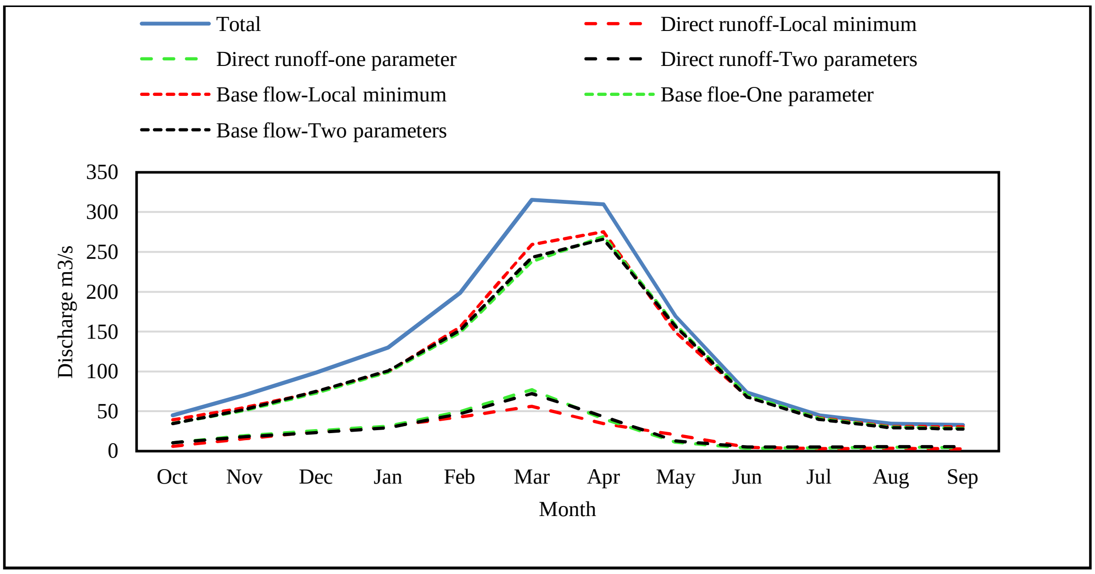

Figure- 9: Darbandikhan Total, Direct, and base flow hydrograph

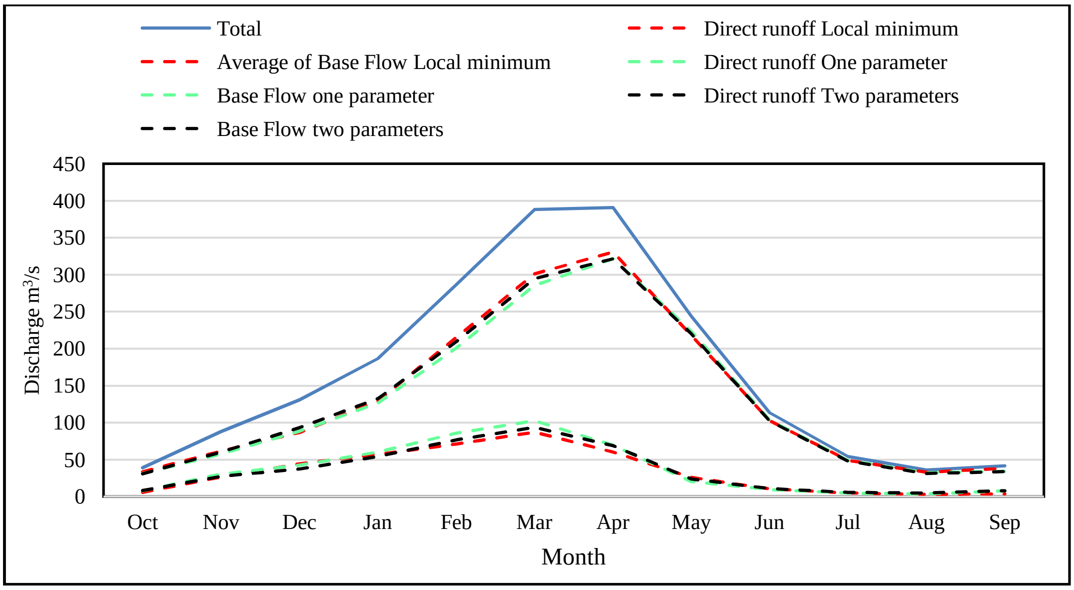

Figure 10: Dukan Total, Direct, and base flow hydrograph

3.4 Trend Analysis

Darbandikhan and Dukan inflow discharges were used to generate the trend lines of the discharge versus time. To compute reduction (or increase) in the inflow; the average monthly discharge was used to develop the trend lines using Excel program *(Figures: 11and 12)*. The slope of these lines were used to estimate the annual flow reduction with time, positive values of the slope show increasing trends, while negative values of the slope indicate decreasing trends. The Mann-Kendall test was used to detect the significant trends. Annual flow reduction is also calculated using average of successive ten years, the average of each ten years is calculated. Then the discharge reduction between two ten successive years is calculated, the average of the discharge reductions represents the ten years discharge reduction from which annual discharge reduction is calculated by dividing by ten. Results exhibited significant negative trend at a 99% confidence level during the period considered for both Darbandikhan and Dukan inflow time series, annual discharge reduction rate was 0.0127 %, and 0.0120% which equal average daily of 0.0000014 km^3 and 0.00000168 km^3 for Darbandikhan and Dukan inflow time series respectively *(Table: 3)*.

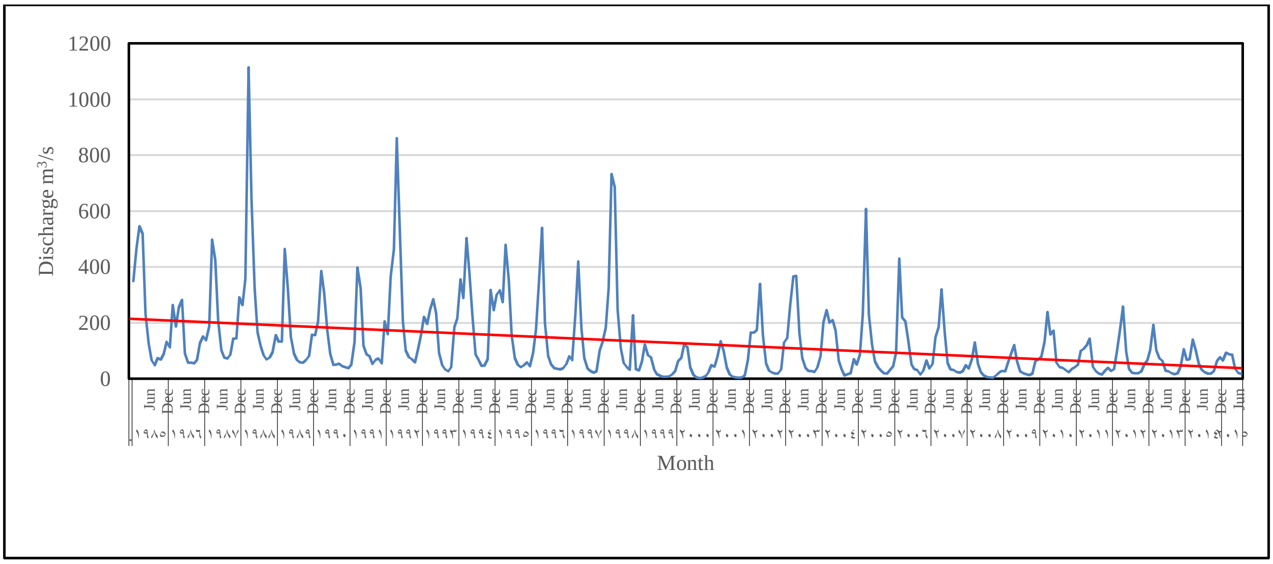

Figure- 11: Average monthly inflow of Darbandikhan dam inflow discharge

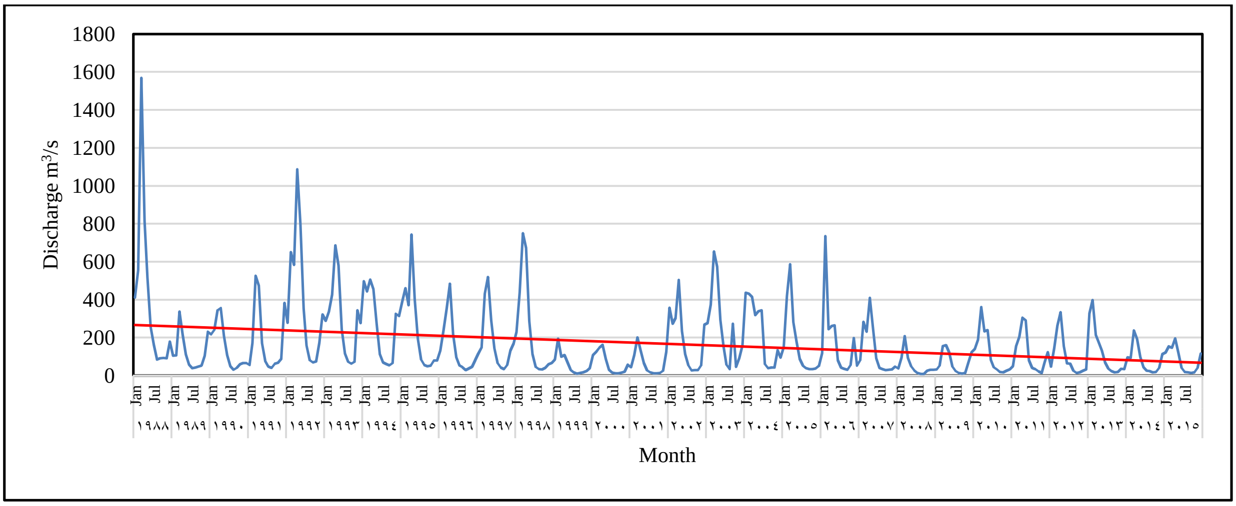

Figure- 12: Average monthly inflow of Dukan dam inflow discharge

Table- 2: Annual percentages of reduction in Darbandikhan and Dukan inflow discharge

Site	*Average Annual inflow m3/sec*	*Km3*	*Average water reduction m3/sec*	*Km3*	*Annual percentage reduction %*
Darbandikhan	*126*	*0.011*	*0.0163*	*0.0000014*	*0.0127*
Dukan	*166*	*0.014*	*0.0194*	*0.00000168*	*0.0120*

3.5 Comparison with Previously Published Low-Flow Statistics

Low-flow frequency statistics are influenced by length of record, hydrologic regime under which the data were collected, analytical techniques used, and other factors, such as urbanization, diversions, and droughts that may have occurred in the basin**.** The current study results were compared with the previously published low flow statistic results, namely USGS Data Series 540 [14] in which Darbandikhan and Dukan inflow time series of 75 years (1931-2004) were used to estimate inflow and low flow statistics. Histograms of average monthly inflow discharges of both studies are presented in *(Figures: 13 and 14)*. Monthly difference percentages for all month's inflow discharge defined a reduction that maximized during June to August, while minimized during October to December.

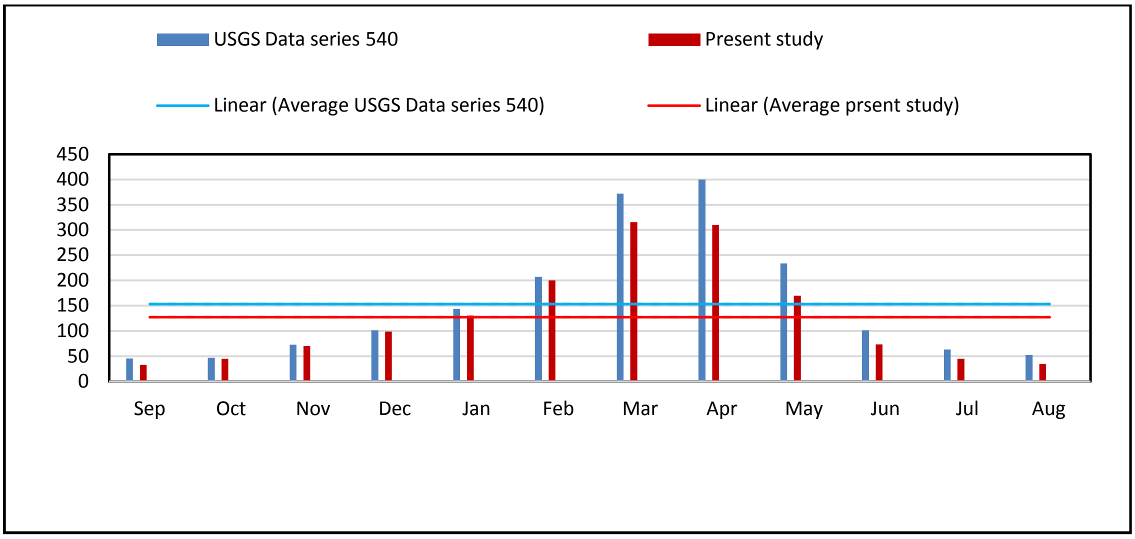

Figure- 13: Monthly reduction percentages between USGS Data series 540 and present study-Darbandikhan

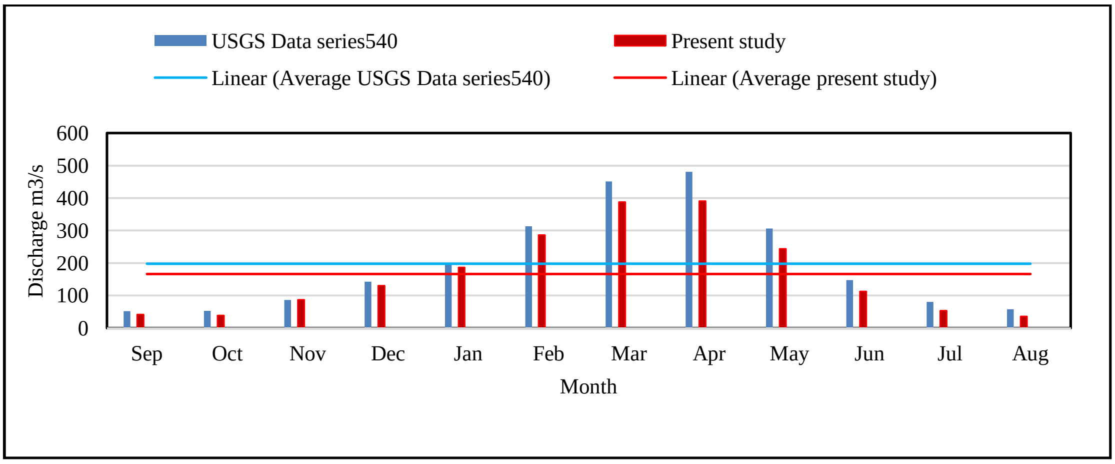

Figure- 14: Comparative annual hydrograph between USGS Data series 540 and present study-Dukan

Comparison of low flow statistics is also performed and the results *(Tables: 4 and 5)* referred to maximum reduction percentage in Q95% which is significant low flow parameter during periods of no rain. The larger reduction during summer months indicates artificial water withdrawals at the upstream sites during the considered time period and the results support the estimation that Iraq rivers discharge will continue to decrease with time [15].

Table- 3: Comparison of low flow statistics and reduction percentages for Darbandikhan inflow discharge

Percentages of time discharge equaled or exceeded	***USGS Data series 540***	***Present study***	***Reduction %***
25	*191*	*157*	*18*
50	*89*	*68*	*24*
75	*47*	*33*	*29*
95	*21*	*11*	*48*

Table- 4: Comparison of low flow statistics and reduction percentages for Dukan inflow discharge

Percentages of time discharge equaled or exceeded	***USGS Data series 540***	***Present study***	***Reduction %***
25	*253*	*217*	*14*
50	*111*	*80*	*28*
75	*58*	*38*	*34*
95	*28*	*15*	*46*

Conclusions

1. Analyzing of Darbandikhan and Dukan inflow time series showed that the period from 1985 to 1999 can be set as a wet period while the period from 1999 to 2015 years as a dry period via mean inflow discharges.
2. Darbandikhan and Dukan dam inflow time series are fitted to several theoretical probability distributions and Log-Normal distribution was found to provide the best overall fit based on Kolmogorov Smirnov test.
1. Long term, annual, and monthly flow duration curves are constructed using inflow time series. Low flow percentiles are extracted from monthly and long term flow duration curves for 95, 90, 75, 70, 50, and 25 percentages.
2. Two parameter logarithmic function appears to be the most appropriate functions fitted to the inflow time series with full percentage and the lower three-quarter percentage (25% to the end) of developed FDC. The equations of Darbandikhan were: $\{Q = -159.5\ Ln\ (P_{0\text{-}99\%}) + 701\}$ and $\{Q = -100\ Ln\ (P_{0\text{-}99\%}) + 464\}$ with R-squared values equal to 0.94 and 0.99 respectively. The equations of Dukan were: $\{Q = -219.4\ Ln\ (P_{0\text{-}99\%}) + 957\}$ and $\{Q = -134\ Ln\ (P_{0\text{-}99\%}) + 619\}$ with R-squared values equal to 0.93 and 0.97 respectively.

3. Annual minimum 1-, 3-, 7-, 14-, 30-, 60-, and 90-day average inflow discharge with recurrence intervals of 2, 5, 10, 20, 30, and 50 years were estimated using Log-Pearson Type III distribution.
4. Base flow was separated from long-term inflow time series using Local minimum, one parameter digital filter, and two-parameter digital filter parameter methods. Results indicated that a large amount of long-term inflow was likely supported by base flow, the values of the discharge are generally less than their mean and there are short periods of large fluctuations. Darbandikhan inflow base flow index ranged between 82% and 84% and Dukan inflow base flow index ranged between 78% and 80% using the three methods. The estimated Base flow index BFI_{max} was 87% for two parameters method and for both time series. In absence of reliable information to determine groundwater discharge in streams and rivers, these indexes can be used to estimate annual base flow.
5. The trend of the average monthly inflow discharge versus time have been analyzed using Excel program. Results indicated negative trends at a significant confidence level of 99% using Man-Kendall test during the period considered for both Darbandikhan and Dukan inflow time series, annual discharge reduction rate was 0.0127 %, and 0.0120% which equal average daily of 0.0000014 km^3 and 0.00000168 km^3 for Darbandikhan and Dukan inflow time series respectively.
6. The current study results were compared with USGS Data Series 540 in which Darbandikhan and Dukan inflow time series of 75 years (1931-2004) were used to estimate inflow and low flow statistics. All month's inflow defined a reduction that maximized during June to August. Low flow statistics comparison is also referred to maximum reduction percentage in Q95%.
7. The larger reduction during summer months indicates artificial water withdrawals from feeding streams during periods of no rain.

Acknowledgment

The Directorate of Darbandikhan dam and Directorate of Dukan dam are acknowledged with thanks for providing the meteorological data for this study.

References

[1] Smakhtin V.U. *"Low flow hydrology: a review"*, Journal of Hydrology Vol. 240, pp. 147–186, (2001).

[2] Gustard A., et.al. *"Low f low estimation in the United Kingdom"*, Institute of Hydrology Report No. 108, (1992).

[3] JAMES K.S. *"Flow-Duration Curves"*, Manual of Hydrology, Part 2. Low-Flow Techniques, Geological survey water-supply paper 1542-A, (1959).

[4] Pamela A.T. *"Techniques for estimating 7-day, 10-year low flow characteristics for ungagged sites on streams in Mississippi"*, U.S. geological survey water-resources investigations report 91-4130, Jackson, Mississippi (1992).

[5] *"Shared tributaries of the Tigris River*", Inventory of Shared Water Resources in Western Asia. Beirut. (2013).

[6] Korsh A., et.al *"Preliminary Field & Lab Report Darbandikhan lake poisoning event"*, Nature Iraq Sulaimani, Kurdistan, Iraq September (2008).

[7] Hassan R. et.al,*"Dukan Dam Reservoir Bed Sediment, Kurdistan"*, Journal of Engineering Iraq, Vol. 8, pp. 582-596, (2016).http://dx.doi.org/10.4236/eng.2016.89054

[8] Candice N. H. *"Standard Operating Procedure for Flow Duration Analysis in California*", California Department of Fish and Wildlife Instream Flow Program Sacramento, California, (2013).

[9] *"Manual on Low-flow Estimation and Prediction"*, Operation Hydrology Report, No. 50.WMO 1029

[10] Toby D. F. and Wade M. C. *"The 7Q10 in South Carolina water-quality regulation: Nearly fifty years later*", South Carolina Water Resources Conference, Columbia Metropolitan Convention Center, (2010).

[11] Asok K. S., et.al. *"Statistical Characteristics of River flow Variability in the Odra River Basin, Southwestern Poland"*, Polish J. of Environ. Stud. Vol. 19, No. 2, pp. 387-397, (2010).

[12] Toby D. Feaster and Wladmir B. Guimaraes *"Low-Flow Frequency and Flow Duration of Selected South Carolina Streams in the Catawba-Wateree and Santee River Basins"*, U.S. Department of the Interior U.S. Geological Survey, (2014).

[13] Zhang Y., et.al. *"Regression Modeling of Baseflow and Baseflow Index for Michigan USA*" Journal of Water,Vol. 5, pp. 1797-1815, (2013).

[14] Dina K. Saleh, *"Stream Gage Descriptions and Streamflow Statistics for Sites in the Tigris River and Euphrates River Basins, Iraq"*, Data Series 540 U.S. Department of the Interior, U.S. Geological Survey.

[15] Al-Ansari N., et.al. *"Iraq Water Resources Planning: Perspectives and Prognoses"*, Jeddah Saudi Arabia Jan 26-27, (2015), 13 (01) Part XIII.