Journal of University of Duhok, Vol. 20,No.1(Pure and Eng. Sciences), Pp 762-775, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.66

HYDROLOGICAL STUDY AND ANALYSIS FOR PROPOSED SARTIK DAM PART 1: STREAM FLOW DATA ANALYSIS & FLOOD DISCHARGE CALCULATION

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ABSTRACT

This research is the part1 of hydrological study and analysis for proposed Sartik dam which located on the Lesser Zab River, the second largest tributary of Tigris River at 18 km northeast of Altun Kopri town, within Erbil governorate of Iraqi Kurdistan Region. In this part all collected meteorological data for the dam catchment area are presented and analyzed, also the mean monthly recorded stream flow data at the dam site for the period (1960-1999) were analyzed to find monthly and annual inflow into dam reservoir. The maximum flood of lesser Zab river at the dam site was studied and probable maximum flood (PMF) value was predicted in accordance with the obtained relation catchment area - specific runoff for all left Tigris river tributaries and was equal to (9100 m^3/sec). Enough data necessary for calculation of flood flows at the Sartik dam site was not available, therefore the flood flow values for return periods (25, 50, 100, and 1000) years for the Sartik Dam catchment were predicted in accordance with the obtained relation catchment area - specific runoff for different return periods prepared by (ITSC), and were (1990, 2330. 2850, and 4100) m^3/sec respectively. Hydrographs for PMF, and (25, 50, 100, and 1000) years return periods were prepared.

KEYWORDS: Meteorological Data, Stream Flow, Catchment Area, PMF, Specific Runoff, Flood Flow

1. INTRODUCTION

Kurdistan region of Iraq is frequently subjected to a severe drought, which causes shortages for the region population, as the available water resources to not satisfy water demands for domestic, livestock consumption, agriculture, tourism and environment requirements. Therefore, the water resources management becomes one of the most important issues at the same time intensive rain causes runoff at times that take substantial amounts away from where it falls and after lost. Water harvesting is a useful practice to capture runoff and utilize in situ for various uses especially supplemental irrigation during drought spells [3].

In order to satisfy water management of the area, investigations and studies started for water harvesting through the construction of small and medium dams everywhere feasible, that aims at collection of excess water and in conservation of the eroded soil, in addition to ground water recharge. Many locations in Erbil Governorate were proposed for conducting feasibility studies and design of small and medium dams in order to reclaim water resources of Erbil Governorate. Sartik location in Altun Kopri District is one of the areas was selected for the above object in order to reclaiming water resources of the area.

2. GENERAL DATA

2.1. LOCATION:

The Sartik proposed dam site is located on the Lesser Zab River, the second largest tributary of Tigris River after the Greater Zab River. It is at 18 km northeast of Altun Kopri town, within governorate of Erbil – Kurdistan Region, Iraq. The selected axis represents the narrowest part of the flood plain in the whole reach between Altun Kopri and Taq Taq towns.

The dam axis lies between Sartik village on the right bank of the river and about 2 km from Qara Salim village, which is located about (3km) away from the river course on the left bank as shown in the figure (1).

The following coordinates of UTM system bound the center line axis of the proposed dam: 3964698.5 - 3965201.5 N and 438323 - 438353 E. The left bank of the river at the proposed dam site is in form of continuous ridges, which rise up to elevation (400) m.a.s.l, while flood plain's general level is around (285) m.a.s.l. The right bank is

Journal of University of Duhok, Vol. 20,No.1(Pure and Eng. Sciences), Pp 762-775, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.66

undulating with elevations rises to (370) m.a.s.l. The river at the site forms two branches with an island in-between. The right bank flood plain extends gently over a distance of about (500)m until it reaches the hills on this side with elevation of (294) m.a.s.l. while the left bank flood plain extends almost horizontally over a distance of about 450 m until it reaches the rugged hill which rises up to elevation 400 m.a.s.l and above.

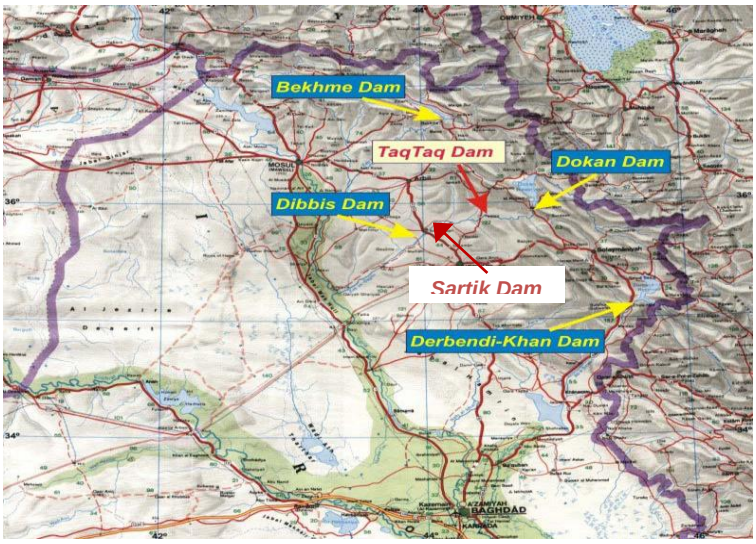

Fig. (1):- Sartik Proposed Dam Location

2.2. Climate:

Sartik reservoir area is located in the semi-arid zone, with hot summer and cold winter. The maximum daily temperature may reach 45 C^o on July and August and minimum daily temperature may reach 0 C^o on January and February. The rainfall occurs from October to May. All climatic data of this area have been taken from the available records of Kirkuk, Dokan and Sulaimani meteorological stations. The available records cover the period (1941-2006) these data are being compiled by the meteorological organization [14].

2.2.1. Relative Humidity:

The average, maximum and minimum Relative Humidity data record at Kirkuk, Sulaimani, and Dokan meteorological stations within the project area which cover the periods (1941–2001), (1971–1990) and (1973–2006) respectively are shown in the table (2-1). The average annual relative humidity within the project area is about 45 percent. In winter, the monthly average reaches 73 percent while it drops to 20 percent in the summer period.

Table (2-1):- Monthly Relative Humidity Recorded Data

Month	Kirkuk Meteorological Station For period (1941-2001)			Sulaimani Meteorological Station For period (1971-1990)			Dokan Meteorological Station For period (1973-2006)		
	Max. Avg.	Avg.	Min. Avg.	Max. Avg.	Avg.	Min. Avg.	Max. Avg.	Avg.	Min. Avg.
Jan.	89	72	46	80	64	48	80	64	48
Feb.	83	66	43	83	66	49	83	66	49
March	83	61	36	82	59	37	82	59	37
April	77	51	25	78	57	36	78	57	36
May	64	34	17	59	39	30	59	39	30
June	38	24	11	43	26	11	43	26	11
July	38	22	11	38	23	11	38	23	11
Aug.	33	23	11	37	24	12	37	24	12
Sept.	36	26	12	42	27	14	42	27	14
Oct.	52	38	17	64	46	28	64	46	28
Nov.	77	58	31	78	60	41	78	60	41
Dec.	84	72	46	77	60	43	77	60	43
Year	89	46	11	83	46	11	83	46	11

Journal of University of Duhok, Vol. 20,No.1(Pure and Eng. Sciences), Pp 762-775, 2017
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2.2.2. Temperature:

The air temperature records from Kirkuk meteorological station, which covers the period (1941–2001), from Sulaimani meteorological station for a period (1973–2006) and from Dokan meteorological station for a period (1979-2003) is shown in the table (2-2). The temperature varies considerably between summer and winter and between day and night.

The maximum monthly temperature at Kirkuk meteorological station is 49.50C^{o} occurs in July and a minimum temperature of -6.70C^{o} occurs in January and February, while the maximum monthly temperature at Sulaimani meteorological station is 44.20C^{o} occurs in August and a minimum temperature of -130C^{o} occurs in January, and the maximum monthly temperature at Dokan meteorological station is 460C^{o} occurs in August and a minimum temperature of -80C^{o} occurs in February.

Table (2-2): Air Temperature Recorded Data (C^{o})

Mon.	Kirkuk Meteorological Station For period (1941-2001)					Sulaimani Meteorological Station For period (1973-2006)					Dokan Meteorological Station For period (1979-2006)				
	Maximum		Avg.	Minimum		Maximum		Avg.	Minimum		Maximum		Avg.	Minimum	
	Abs. max	Avg. max		Abs. min	Avg. min	Abs. max	Avg. max		Abs. min	Avg. min	Abs. max	Avg. max		Abs. min	Avg. min
Jan.	37.5	12.7	9.0	- 6.7	5.1	13.2	9.3	5.5	-13	1.7	14	8.4	5.8	-5	3.2
Feb.	26.6	15.0	10.6	- 6.7	7.1	15.9	11.2	6.9	-11.4	2.7	19	9.6	6.7	-8	3.7
Mar.	34.6	18.3	14.4	- 5.6	9.6	19.9	15.8	11.2	-6.5	6.5	26	13.5	10.4	-7	7.2
Apr.	39.6	25.1	20.4	- 1.0	15.4	26.8	21.8	16.6	2.9	11.4	29	20.8	16.2	-1	11.6
May	43.3	31.4	26.9	6.7	19.7	31.6	28.4	22.4	6.5	16.4	37.5	28.1	22.8	4	17.5
June	47.8	37.5	32.8	13.9	27.2	41.3	34.9	28.6	13.5	22.4	40	35.3	29.2	15	23
July	49.5	41.4	36.2	20.0	29.9	43.0	39	32.8	18	26.5	45	39.1	33.0	15	26.8
Aug.	49.4	40.7	36.3	18.4	28.8	44.2	38.8	32.2	17.5	25.6	46	38.9	32.5	19	26.1
Sept.	46.6	36.7	31.3	9.4	25.7	40.8	34.8	28	13	21.3	42	35.5	29.0	10	22.4
Oct.	41.4	39.4	24.5	1.1	19.3	34.8	27.4	21.1	3.2	15.7	37	26.5	21.7	5	16.8
Nov.	33.4	21.8	16.9	- 2.0	10.5	24.6	18.2	13.5	-6	8.8	26	16.8	13.6	-1	10.4
Dec.	27.1	15.3	10.8	- 6.1	7.0	16.8	12	8	-10.5	4	19	10	7.6	-2	5.1
Year	49.5	27.1	22.4	- 6.7	17.1	44.2	24.3	18.9	-13	13.6	46	39.1	21.2	-8	3.2

2.2.3. Evaporation:

Evaporation losses represent a major factor of the total amount of water lost from the reservoir. The average monthly pan evaporation for the period (1967–2001) of Kirkuk Sulaimani and Dokan meteorological stations are given in table (2-3). The computed maximum average evaporation occurs in July, while the computed minimum average evaporation occurs in December. The yearly class (A) pan evaporation in the three above stations are 2347.7, 2290.5 and 2379.2 mm respectively and after multiplying the above values by Pan coefficient (Kp = 0.7) for Class A pan, the corresponding free water surface evaporation amounts were computed and were equal to 1642.9, 1602.9 and 1664.9 mm per year respectively. Estimated yearly class (A) pan evaporation in the project area is taken the average value of the three stations 2339.1 mm and the corresponding free water surface evaporation amount is to be1636.9 mm.

Journal of University of Duhok, Vol. 20,No.1(Pure and Eng. Sciences), Pp 762-775, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.66

Table (2-3): Average Monthly & Annual Evaporation Recorded Data

Month	Kirkuk Meteorological Station (1967-2001)		Sulaimani Meteorological Station (1973-2006)		Dokan Meteorological Station (1979-2006)	
	Class A pan evaporation (mm)	Free water Surface evaporation (mm)	Class A pan evaporation (mm)	Free water Surface evaporation (mm)	Class A pan evaporation (mm)	Free water Surface evaporation (mm)
Jan.	46.9	32.8	39.8	27.8	48.8	34.1
Feb.	60.6	42.4	55.7	39.0	58.6	41.0
March	101.0	70.7	86.3	60.4	94.8	66.4
April	152.1	106.4	128.3	89.8	141.3	98.8
May	262.9	184.0	225.6	157.9	228.7	160.1
June	353.1	247.1	386.1	270.2	369.6	258.7
July	398.8	279.1	417.3	292.0	431.3	301.8
Aug.	368.2	257.7	374.9	262.4	393.6	275.5
Sept.	288.8	202.1	285.7	199.9	301.1	210.7
Oct.	184.7	129.2	165.5	115.8	168.6	118.0
Nov.	84.3	59.0	77.1	54.0	88.3	61.8
Dec.	46.3	32.4	48.2	33.7	54.5	38.1
Year	2347.7	1642.9	2290.5	1602.9	2379.2	1664.9

2.2.4. Wind:

The wind directions prevailing in the project area as recorded in Kirkuk are between northeast and west. The average wind velocity is about 2.8 m/sec with minor variations during the year. During the extreme condition, the wind velocity reaches about 30 m/sec.

The computed average, maximum and minimum wind speed values at Kirkuk, Sulaimani, and Dokan meteorological stations are given in Table (2-4).

Table (2-4):- Monthly average wind velocity (m/sec) Recorded Data

Month	Kirkuk Meteorological Station For period (1941-2001)		Sulaimani Meteorological Station For period (1971-1990)		Dokan Meteorological Station For period (1973-2006)	
	Abs. max	Avg.	Abs. max	Avg.	Abs. max	Avg.
Jan.	25	2.7	20	2.9	23	2.1
Feb.	27.5	3.1	21	2.8	24	2.4
March	22.5	3	20	2.7	16	2.8
April	26.5	3.1	20	2	12	2.6
May	30	3.3	20	2.2	22	2.5
June	25	3	20	2.4	19	3
July	18	2.8	20	3	21	2.6
Aug.	20	2.4	20	2.6	18	2.6
Sept.	15	2.7	20	2.1	17	2.3
Oct.	20	2.5	21	2.4	23	2
Nov.	16	2.4	16.5	2.3	15	2.1
Dec.	17.5	2.3	20	2.6	17	2.2
Year	30	2.8	21	2.5	24	2.4

2.2.5. Rainfall:

The average yearly rainfall varies considerably in the area. In the mountainous region, it fluctuates between 800 mm and 1600 mm, where as in the lower parts of the catchment area it varies between 400 mm and 700 mm.

The rainfall records at Dokan metrological station are assumed to be representative of the area since it is located within the catchment area. The measured average, maximum and minimum monthly precipitation values at Kirkuk, Dokan and Sulaimani meteorological stations are given in table (2-5).

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Table (2-5): Average, Maximum and Minimum Monthly Rainfall Recorded Data in mm

Month	Kirkuk Meteorological Station for period (1941–2001)			Dokan Meteorological Station for period (1958-2008)			Sulaimani Meteorological Station for period (1951–2006)		
	Max	Avg.	Min	max	Avg.	Min	max	Avg.	Min
Jan.	161.9	68.2	1.3	422.3	127.0	0.0	266.0	125.0	17.2
Feb.	155.8	66.2	3.3	383.4	125.0	0.0	224.3	108.2	13.5
March	286.6	52.9	4.0	378.0	123.6	0.0	423.7	105.6	29.0
April	144.4	39	0.0	345.5	102.2	0.0	440.3	102.0	1.1
May	149.2	13.1	0.0	198.0	31.3	0.0	124.3	39.7	0.0
June	3.1	0.2	0.0	0.0	0.0	0.0	7.1	1.6	0.0
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sept.	8.2	0.8	0.0	0.0	0.0	0.0	6.7	1.1	0.0
Oct.	76.9	16	0.0	184.0	27.1	0.0	146.2	27.5	0.0
Nov.	157.9	51	0.0	251.5	90.1	0.0	230.1	81.7	0.5
Dec.	162.4	59.9	2.4	393.5	128.5	0.0	285.1	120.6	18.0
Year	286.6	367.3	0.0	393.5	754.8	0.0	440.3	713.0	0.0

The maximum daily (24 hr) rainfall values at Kirkuk, Dokan and Sulaimani meteorological station are given in table (2-6).

Table (2-6): Maximum Daily (24hr) Rainfall Recorded Data in mm

Month	Kirkuk Meteorological Station	Dokan Meteorological Station	Sulaimani Meteorological Station
Jan.	48.1	73	60.8
Feb.	61.4	82.5	80.0
March	97.6	106.6	80.0
April	49.0	100	80.0
May	52.5	70.7	79.2
June	2.7	11.5	4.5
July	0.3	0	0.0
Aug.	0.2	0	0.0
Sept.	3.2	0	0.6
Oct.	38.2	52	92.3
Nov.	52.2	116	126.0
Dec.	67.0	84	60.0
Year	97.6	106.6	126.0

3. STREAM FLOW

3.1. General:

The Lesser-Zab River is one of three main tributaries of the river Tigris inside Iraq and has its sources in the mountains border regions between Iraq and Iran. It is the second largest tributary joining Tigris River from the left. The Lesser Zab River originates in the system of Zagros ridge at the altitude about 3000m, within the territory of Iraq the river runs along the plain area, which is called the Raniya Valley. Lesser Zab River length 450 km, average slope 1.1%, catchment area 22,250 km^2, Elevation 200 to 3000 m.a.s.l., and has average annual runoff 7.4 km^3 as shown in figure (2) [15].

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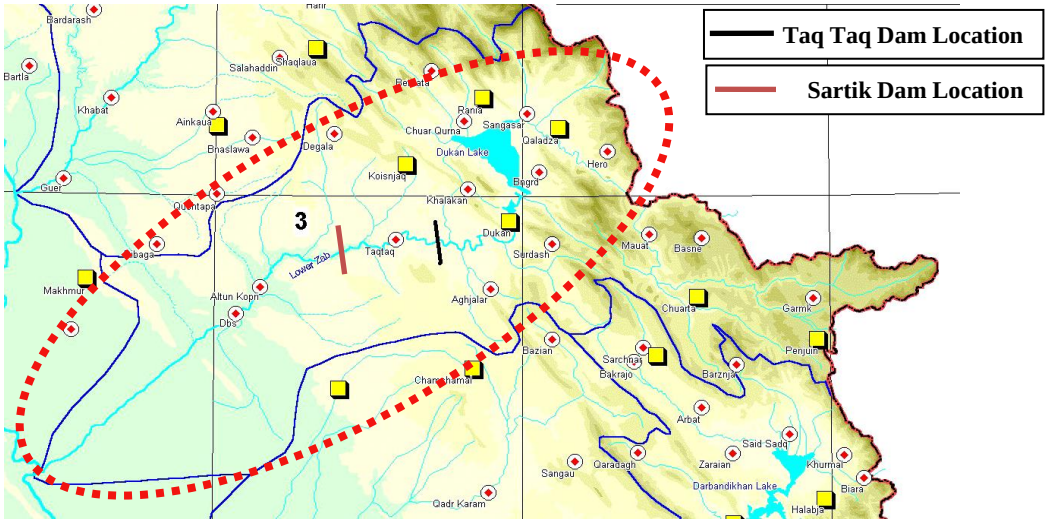

Fig. (2):- Lesser Zab River Catchment

The arc concrete dam was constructed in 1959 in the upper reaches of the river at the 233 km from the outfall near Dokan called Dokan Dam. Dokan dam Catchment area is 11,700 km^2, average annual inflow is 206 m^3/s, gross storage volume is 6.8 km^3, and normal water level 511 m.a.s.l [2].

The area is controlled now by Dokan dam at the end of the upper catchment and by a Dam at the end of the middle catchment at Dibbis District called Dibbis Dam at 140 km downstream of Dokan dam and at 100 km upstream of point of confluence of Lesser Zab with Tigress river, having gross storage volume of 50.2 million m^3, and normal water level 253 m.a.s.l [13].

In 2009, the Rock fill dam with clay core was proposed and designed on the Lesser Zab River at 50 km downstream of Dokan dam at Taq Taq District called Taq Taq Dam, the catchment area between Dokan and Taq Taq is 1850 km^2, average annual inflow is 217 m^3/s, gross storage volume is 2.86 km^3, and normal water level 415 m.a.s.l [7].

The total catchment area for the Lesser-Zab up to the confluence with Tigris may be divided from topographic and morphologic points of view in to:

1. Upper catchment, which comprises the Zagros range down to Dokan dam (11700 sq. km.) with annual precipitation between (1200mm – 800 mm).

2. The middle catchment between Dokan dam and Dibbis (4100 sq. km.) which is characterized by lower ranges of mountains and hills with much less snowfall and precipitation, with average annual precipitation off (400-800 mm).

3. The lower catchment, which is the remaining area which lies between Dibbis dam and the confluence with the Tigris. It has undulated topography and flat areas and precipitation between (400-200 mm).

The site of proposed Sartik dam is located about (18 km.) to the northeast of Altun-Kopri town, the Dam is approximately 88.5 km downstream of Dokan existing dam and 33.5 km downstream of the Taq Taq Proposed dam, and. some 56.5 km upstream of the existing Dibbis Dam. These dams distribution along the river course is presented in Figure 4.

The purpose of the Sartik Dam will be irrigation, flood control for the downstream area, hydro-electric power generation. Sartik Dam will also serve as the regulating dam for waters released from the power station of Taq Taq proposed dam. The catchment area between Dokan dam and Taq Taq proposed dam site is (1850 km^2) and the catchment area between Dokan dam and Satik proposed dam site is (2400 km^2), this means that the catchment area between Taq Taq and Sartik proposed dams is (550 km^2).

Since 1959 the Lesser-Zab River had been regulated by means of Dokan reservoir created by the construction of the Dokan dam. The normal operating level of Dokan reservoir is +511.0 m.a.s.1 at capacity of 6.8 Milliard cubic meters. The maximum flood control reserve is 1.5 Milliard cubic meters.

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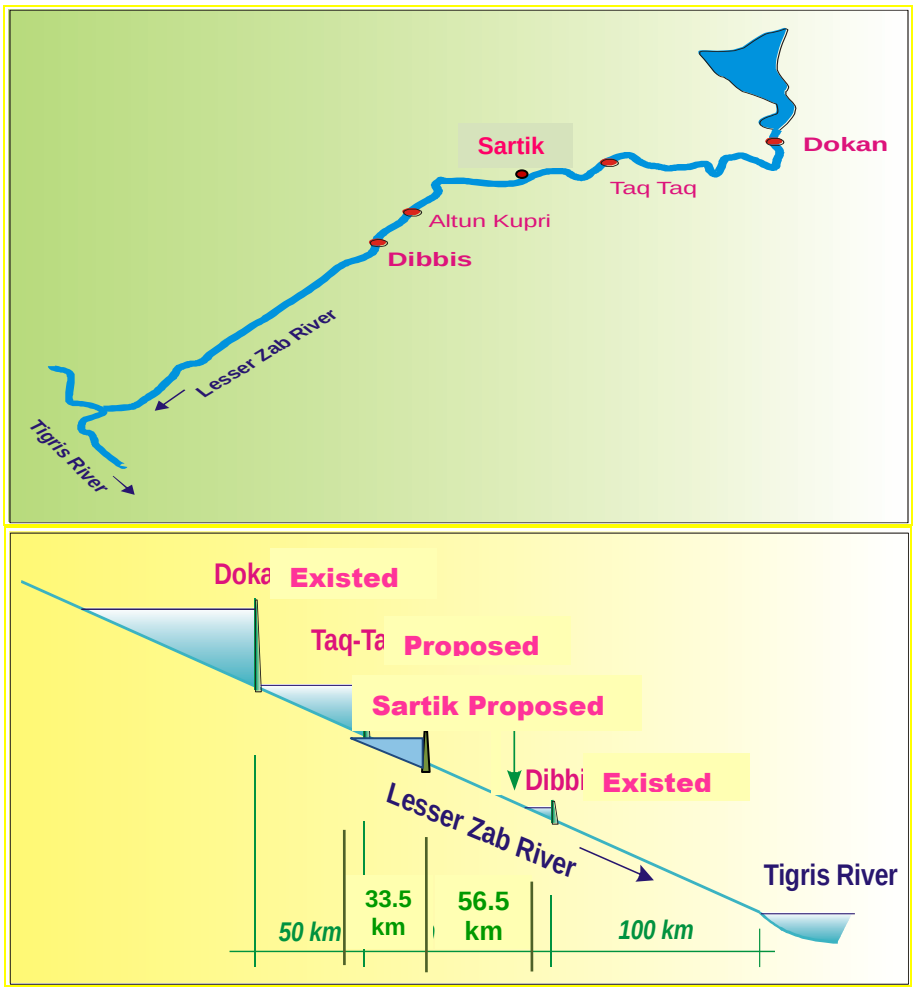

Fig.(4) :-Locations of Proposed and Existing Dams on Lesser Zab River

3.2. Discharge Measurement And Characteristics:

Stage records and discharge measurements in the Lesser-Zab River have been taken since 1932. Non-regulated discharge values exist at Altun-Kopri/Goma Zerdala station for the period (1932-1959). But for Dokan Ferry for the period (1951-1959) and from January 1959 onwards all discharges values from the two gauges stations refer to regulated conditions due to the construction of the Dokan dam. The non-regulated and the regulated monthly and annual discharge values for the gauging stations are given in tables (3-1) to (3-4) [15].

3.2.1. Analysis Of Existing Stream Flow Data:

A. At Dokan Ferry:

Complete stage records and discharge measurement in the Lesser-Zab River have been taken since 1932. Non-regulated discharge values are available for Dokan Ferry for the period (1932-1999) whose catchment area of (11700 sq. km.). Onwards all discharges values from Dokan Ferry are regulated due to the construction of Dokan dam. The non-regulated and regulated monthly and annual discharge values for the gauging station are given n in tables (3-1) to (3-2).

Table (3-1): Mean Monthly Inflow to Dokan Reservoir (m^3/sec) for period (1932-1999)

Month	Oct.	Nov.	Dec	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Annual
Avg. Q (m^3/sec)	57	89	142	194	315	466	491	306	146	85	64	61	201
Min. Q (m^3/sec)	27	24	48	55	51	48	40	67	32	16	11	14	66
Max. Q (m^3/sec)	108	343	627	513	741	1544	1501	789	351	211	265	260	505

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eISSN: 2521-4861 & pISSN: 1812-7568
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Table (3-2): Mean Monthly outflow from Dokan Reservoir (m^3/sec) at Dokan Ferry for Period (1960-1999)

Month	Oct.	Nov.	Dec	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Annual
Avg. Q (m^3/sec)	240	201	186	170	165	177	159	157	158	246	317	292	206
Min. Q (m^3/sec)	88	42	20	29	20	20	21	21	23	88	84	58	97
Max. Q (m^3/sec)	400	369	352	412	486	1124	1380	775	555	664	690	524	507

B. At Altun-Kopri/ Goma Zerdala Gauging Station (Sartik Dam Site):

Complete stage records and discharge measurements in the Lesser-Zab River at Altun-Kopri/Goma Zerdala gauging station have been taken since 1932. Non-regulated discharge values of Altun-Kopri whose catchment area (15600 km^2) for the periods (1932-1959) are given in table (3-3).

From January 1959 onwards the discharge values at Atlun-Kopri gauging station are referred to regulate conditions due to the construction of Dokan dam are given in table (3-4).

Table (3-3): Mean Monthly Non-Regulated Discharges at Altun Kopri in (m3/sec) for Period (1932-1959)

Month	Oct.	Nov.	Dec	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Annual
Avg. Q (m^3/sec)	44	77	130	243	427	561	558	374	190	99	57	43	234
Min. Q (m^3/sec)	29	35	57	75	106	239	180	141	86	41	25	20	118
Max. Q (m^3/sec)	73	156	289	495	893	1270	1220	683	332	178	100	73	418

Table (3-4): Mean Monthly Regulated Discharges at Altun Kopri (m^3/sec) for Period (1959-1999)

Month	Oct.	Nov.	Dec	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Annual
Avg. Q (m^3/sec)	243	214	214	202	213	235	191	195	172	248	313	296	228
Min. Q (m^3/sec)	87	70	21	26	23	25	24	22	22	75	85	71	97
Max. Q (m^3/sec)	447	372	401	520	572	1433	1110	964	505	604	640	539	544

Analyzing the discharges of Dokan Ferry and Altun-Kopri which are given in tables (3-1) to (3-4). It can conclude the following:

1- The non-regulated average monthly discharges to Dokan dam site for the period (1932-1999) varies between 11 m^3/sec in August 1999 and 1544 m^3/sec in March 1988. The corresponding discharges at Altun-Kopri for the period (1932-1959) are 20 m^3/sec in September 1951 and 1270 m^3/sec in March 1954.

2- The recorded average yearly discharge at Dokan Ferry for the period (1960-1999) is 206 m^3/sec and the one at Altun-Kopri is 234 m^3/sec and 228 m^3/sec for the periods (1932-1959) and (1960-1999) respectively. The regulated average monthly discharge, i.e. from January 1960, at Dokan Ferry varies between 157 m^3/sec in May to 317 m^3/sec in August. The corresponding discharges for Altun-Kopri are 172 m^3/sec in June and 313m^3/sec in August respectively.

3- The average yearly-regulated discharge is 206 m^3/sec at Dokan Ferry (1960-1999).The annual non-regulated discharge at Sartik dam site varies between 118m^3/sec and 418 m^3/sec with an average value of 234 m^3/sec, but the corresponding values for regulated conditions are 97 m^3/sec, 544 m^3/sec and 228 m^3/sec respectively. It has to be noted that the values for regulated conditions are affected by increased evaporation and initial impounding in Dokan regulated conditions. These effects amount to approximately 6 m^3/sec as a yearly average.

3.3 Floods:

3.3.1. Observed Flood Peaks:

Major Flood peaks occur in Iraq during March and April as a result of insensitive rainfall and melting snow in the upper catchments. Flood peaks are often reduced by the accidental willful breaking of dikes, especially in the lower reaches of the Tigris River. Furthermore, from 1959 onwards all floods at Altun Kopri/Goma Zerdala gauging station are influenced by damping effects of the Dokan reservoir.

The maximum flows in the Lesser-Zab River occurred fortunately after the construction of Dokan dam in 1969, 1974 and 1988, the reductions of floods by the dam were in the order of 1380 m^3/sec, 700 m^3/sec and 1124 m^3/sec monthly averages, respectively.

The characteristic non-regulated and regulated flood peaks recorded at Dokan Ferry and Altun Kopri / Goma Zerdala is given in table (3-5) [15].

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https://doi.org/10.26682/sjuod.2017.20.1.66

Table (3-5):- Characteristic discharge values of recorded flood peaks at Altun Kopri and Dokan Ferry in (m^3/sec)

Station	Conditions	Period of records	Maximum Daily Q (m^3/sec)	Minimum Daily Q (m^3/sec)	Average Daily Q (m^3/sec)
Dokan Ferry	Non– Regulated	1932-1959	3440	521	1940
Dokan Ferry	Regulated	1960-1980	1800	218	449
Altun Kopri	Non– Regulated	1932-1959	3420	566	1759
Altun Kopri	Regulated	1960-1980	1350	686	686

Table (3-6):- gives maximum observed flood discharges together with the date of their occurrence at the Altun Kupri gauging station on Lesser Zab, in the period 1932-1958 (non- regulated period) [15].

Table (3-6): Maximum (Non-Regulated) Recorded Flood Flow of Lesser Zab River at Altun Kopri Gauging, for Period 1932-1958

No.	Max. Q (m^3/sec)	Date	No.	Max. Q (m^3/sec)	Date	No.	Max. Q (m^3/sec)	Date
1	900	25/02/1932	10	3400	11/02/1941	19	2250	08/03/1950
2	1120	14/03/1933	11	1820	08/03/1942	20	1680	20/02/1951
3	1600	22/12/1934	12	1490	26/03/1943	21	2520	11/02/1952
4	1540	16/021935	13	1160	30/03/1944	22	2980	20/02/1953
5	1140	02/04/1936	14	1510	21/01/1945	23	3420	25/03/1954
6	1740	13/04/1937	15	2660	14/03/1946	24	660	10/04/1955
7	1720	24/02/1938	16	852	02/02/1947	25	1940	13/04/1956
8	1520	02/01/1939	17	758	01/05/1948	26	1880	08/03/1957
9	1920	31/01/1940	18	2740	26/03/1949	27	566	01/02/1958

3.3.2. Probable Maximum Flood (Pmf):

The uncontrolled probable maximum flood (PMF) at Dokan was estimated in the (HIS) report to be (18000 m^3/sec). Binnie and partners (1959) had calculated the probable maximum flood (PMF) in the intermediate catchment between Dokan dam and Dibbis dam to be (8400 m^3/sec) measured at Dibbis dam site. ITSC (2006) had calculated the probable maximum flood (PMF) in the catchment between Dokan dam and Taq Taq dam to be (8700 m^3/sec).

PMF value for the Sartik Dam catchment is predicted in accordance with the obtained relation catchment area - specific runoff for all left Tigris river tributaries, table (3-7) and figure (5) below taken from Taq Taq dam hydrological report prepared by (ITSC) [7].

Table (3-7):- Relation between PMF values and specific runoff for all left Tigris river tributaries

No	Profile	River	F (km^2)	PMF (m^3/s)	q (m^3/s/km^2)
1	Altun Kupri - Dokan	Lesser Zab	2,400	4,900	2.04
2	Dibis - Dokan	Lesser Zab	4,100	8,400	2.05
3	Dokan dam	Lesser Zab	11,700	18,000	1.54
4	Altun Kupri	Lesser Zab	14,100	22,900	1.62
5	Bekhme Dam	Greater Zab	16,600	25,850	1.56
6	Derbend-i-Khan Dam	Diyala	17,800	25,000	1.40
7	Diyala weir	Diyala	29,700	36,000	1.21
8	Eski Mosul Dam	Tigris	50,200	30,000	0.60

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eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.66

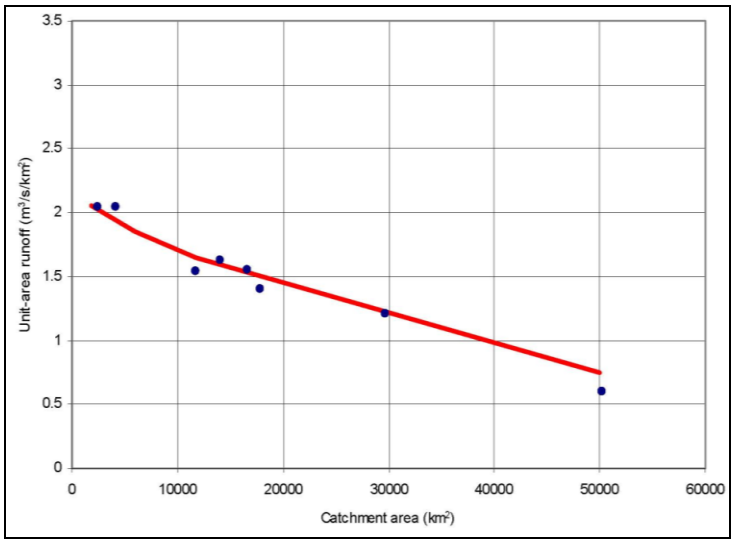

Fig. (5):- Relation between PMF values and specific runoff for all left Tigris river tributaries [7]

To predict PMF of Sartik dam two scenarios were used:

1- Without impact of Taq Taq and Dokan dams: The area controlled by Sartik dam without Dokan and Taq Taq dams is (14100 km^2), and the corresponding specific runoff from figure (5) is (1.575 $m^3/sec/km^2$) .this means that the natural (non –regulated) PMF at Sartik dam site would be about (22200 m^3/sec), then the PMF of Sartik dam is difference in PMF between Sartik and Dokan dams is (22200-18000 =4200 m^3/sec). The maximum discharge release from Dokan Dam is (4900 m^3/sec), then the expected value of PMF for Sartik dam site will be (4900 + 4200 = 9100 m^3/sec).

2- With Impact of Taq Taq dam : Taq Taq dam PMF and specific runoff according to Taq Taq dam hydrological report prepared by (ITSC) are (21800 m^3/sec) and (1.61 $m^3/sec/km^2$) respectively .The difference in PMF between Sartik and Taq Taq dams is (22200-21800 =400 m^3/sec) and the maximum release from Taq Taq dam according to Taq Taq dam hydrological report prepared by (ITSC)is (4300 m^3/sec), then the expected value of PMF for Sartik dam site will be (4300 + 400= 4700 m^3/sec).The table (3-8) below shows PMF flood flows and volumes at the considered profiles for both scenarios:

Table (3-8): PMF flood flows and volumes at the considered profiles for both scenarios

1- Without impact of Taq Taq dam :			
PMF	**Sartik**	**Dokan**	**Between Dokan and Sartik**
Flood Peaks (m^3/sec)	**22200**	**18000**	**4200**
Flood Volume (km^3)	**3.34**	**2.71**	**0.63**
2- With impact of Taq Taq dam:			
PMF	**Sartik**	**Taq Taq**	**Between Taq Taq and Sartik**
Flood Peaks (m^3/sec)	**22200**	**21800**	**400**
Flood Volume (km^3)	**3.34**	**3.28**	**0.06**

So by taking the first scenario in the account because Taq Taq dam is not built till now, then the total expected value of PMF for Sartik dam site will be (4900 + 4200 = 9100 m^3/sec).

It may be concluded that the probable maximum flood at the proposed site of Sartik dam which originates from the middle catchment, if one assumes that the PMF of the upper catchment coincides with the PMF of the intermediate catchment at the site.

Table (3-9) below shows the coordinates of PMF hydrographs for Dokan, Sartik (without Dokan) and between Dokan and Sartik, and figure (6) shows the graphical interpretation of the hydrographs.

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https://doi.org/10.26682/sjuod.2017.20.1.66

Table (3-9):-Coordinates of PMF hydrographs

	PMF hydrograph		
time	Dokan	Sartik	Between Dokan and Sartik
hr	Q (m^3/sec)	Q (m^3/sec)	Q (m^3/sec)
0	200	200	0
6	500	500	0
12	1200	1200	0
18	5000	6200	1200
24	11500	14200	2700
30	16600	20500	3900
36	18000	22200	4200
42	17000	21000	4000
48	14500	17900	3400
54	11500	14200	2700
60	8900	11000	2100
66	6500	8000	1500
72	4900	6050	1150
78	3300	4100	800
84	2300	2850	550
90	1600	1980	380
96	1050	1300	250
102	800	1000	200
108	600	750	150
114	400	500	100
120	100	100	0

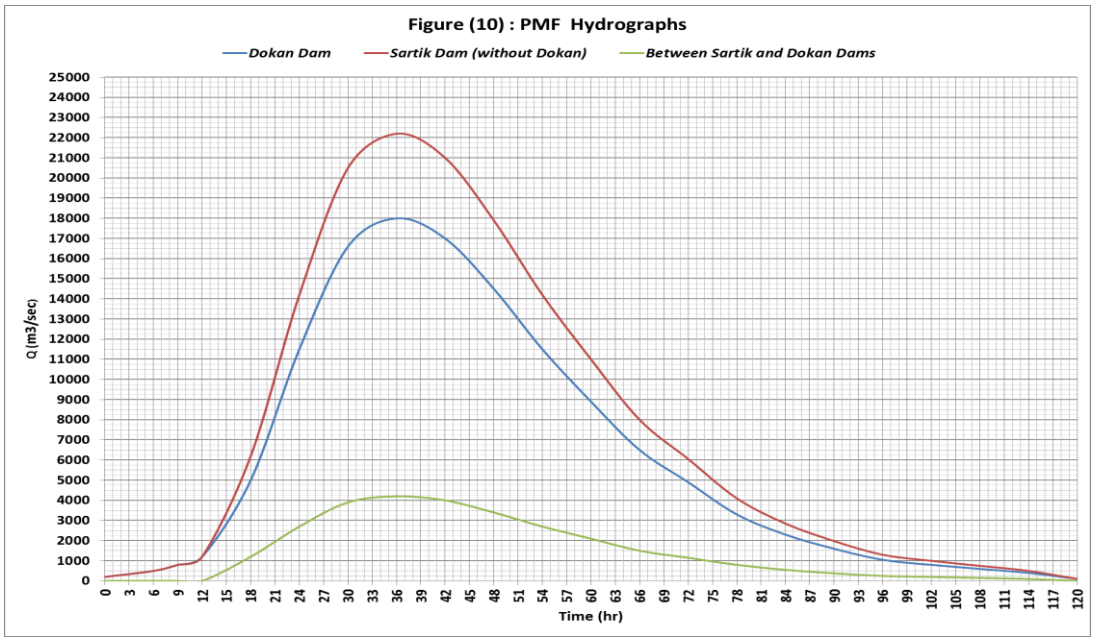

Fig. (6):- PMF hydrographs

3.3.3. Floods With Various Return Periods; Design Floods (Peak Discharges):

In The General Scheme of Water resources in Iraq stage I, the (Selkhozpromexport,1975) determined by means of statistical methods, the peak discharges with a return period of up to 1000 years for Dokan dam site. The results of this frequency analysis are shown in the table (3-10).

In the Harza report, "Hydrological survey of Iraq "July 1963, probable maximum flood hydrograph is prepared for Dokan dam site. This hydrograph was computed by combining runoff from a maximized rainstorm and maximum occurrence snowmelt runoff, and base flow .The maximized rainstorm was assumed to occur during the period (1-4)April.The resulting PMF discharge and the volume of this flood are given in the table(3-10) [5].

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eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.66

Table (3-10) : Flood peak and six days Flood volume for Dokan dam site.

	Return periods		
	100 yrs.	1000 yrs.	PMF
Flood peak (m3/sec)	5700	8000	18000
Six days volume (MCM)	710	1040	2350

Data necessary for the calculation of natural (non-regulated) flood flows at the Sartik dam site was not available, the non-regulated records from Altun Kupri in the table (3-6) cover 27 years only, which is a too short period to allow prediction of flood peaks of long return periods with high accuracy.

Flood flow values of return periods (25,50,100,and 1000) year for the Sartik Dam catchment were predicted in accordance to the obtained relation catchment area - specific runoff for different return periods, figure (7) below taken from Taq Taq dam hydrological report prepared by (ITSC) [7].

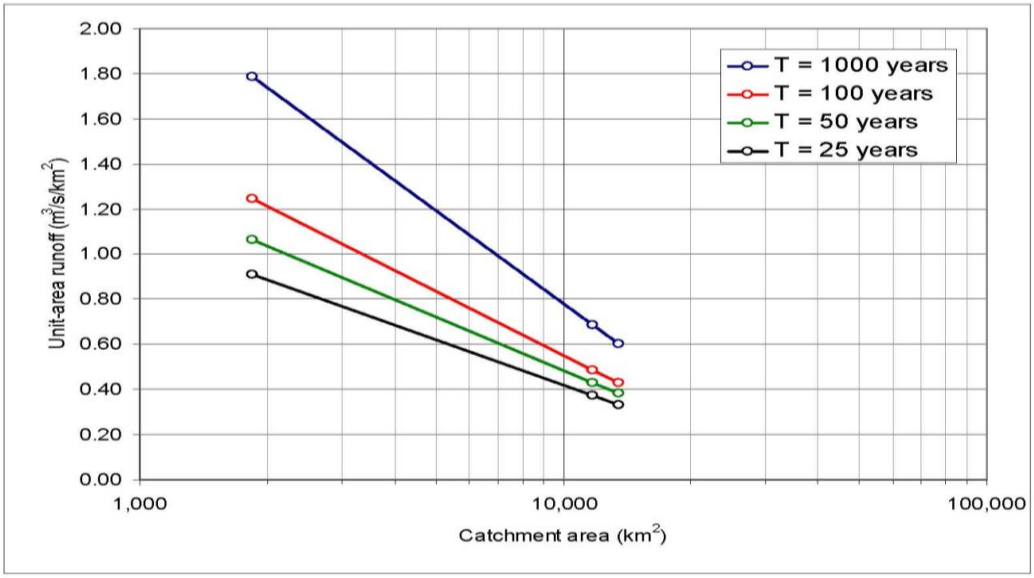

Fig.(7):- Relation catchment area - specific runoff for different return periods

The catchment area of Sartik dam is (2400 km^2), and from above figure the specific runoff (Unit area runoff) for return periods (1000, 100, 50, and 25) years were obtained from, and the corresponding peak discharges were calculated for each return period by multiplying the specific runoff to the catchment area (2400 km^2) as shown in table (3-11) below.

Table (3-11): Peak discharges of flood hydrographs for Sartik Dam

Return period (year)	**Specific Area ($m^3/sec/km^2$)**	**Catchment area (km^2)**	**Peak Q (m^3/sec)**
25	**0.829**	**2400**	**1990**
50	**0.971**	**2400**	**2330**
100	**1.1875**	**2400**	**2850**
1000	**1.7083**	**2400**	**4100**

Flood peaks for Dokan and the local flood flow between Dokan and Sartik were taken from the SWECO study, figure (8) shows the predicted different time periods flood hydrographs for Sartik dam and table (3-12) shows the coordinates of the hydrographs.

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eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.66

Table (3-12):- Coordinates of flood hydrographs for Sartik Dam

time	PMF	1000 yr flood hydrograph	100 yr flood hydrograph	50 yr flood hydrograph	25 yr flood hydrograph
hr	Q (m^3/sec)	Q (m^3/sec)	Q (m^3/sec)	Q (m^3/sec)	Q (m^3/sec)
0	523	100	100	95	90
6	628	200	150	190	105
12	889	360	300	280	190
18	2092	1100	750	560	470
24	5753	2560	1800	1435	1230
30	8368	3800	2600	2130	1820
36	9100	4100	2850	2330	1990
42	8472	3900	2700	2175	1865
48	7322	3280	2300	1850	1590
54	5962	2620	1825	1435	1275
60	4393	2050	1430	1110	955
66	3452	1520	1050	835	685
72	2406	1075	700	580	500
78	1674	770	500	395	365
84	1151	540	350	280	260
90	732	400	250	190	185
96	523	260	180	120	100
102	314	165	100	95	80
108	209	110	80	70	45
114	157	90	50	35	35
120	105	50	25	25	25

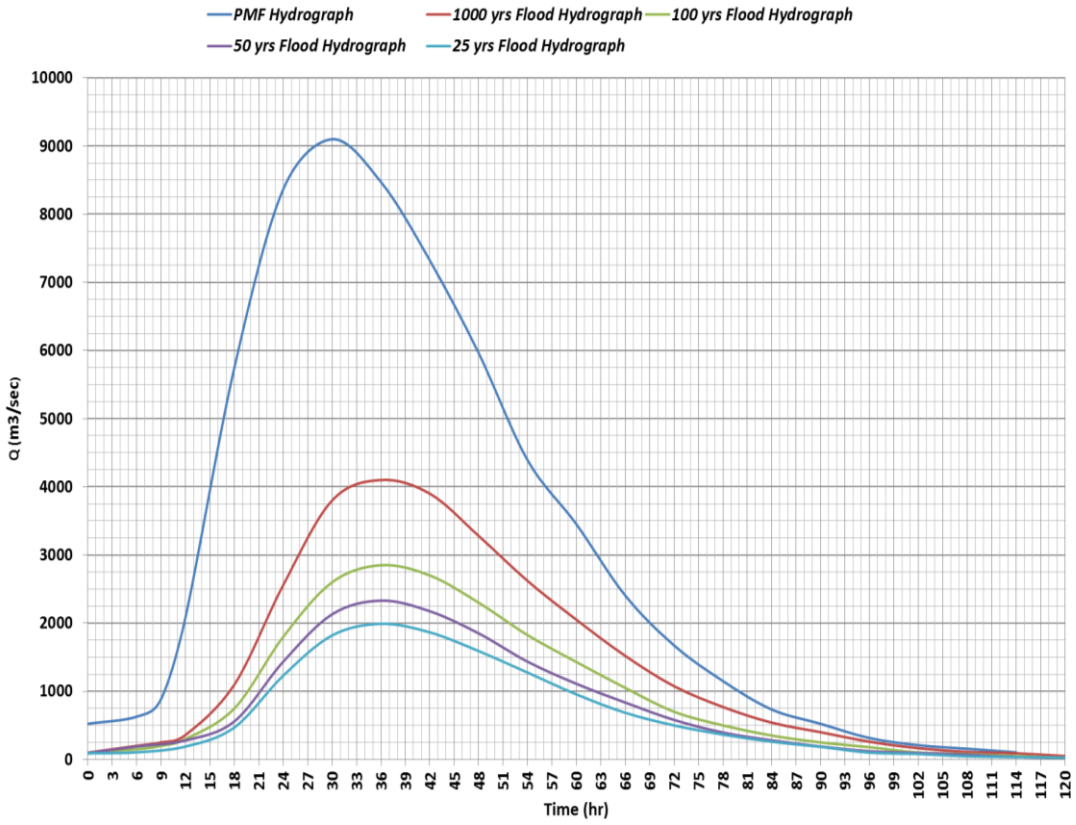

Fig. (8):- Sartik Dam Flood Hydrograghs

4. CONCLUSIONS

1- The Sartik proposed dam site is located on the Lesser Zab River, the second largest tributary of Tigris River after the Greater Zab River. It is at 18 km northeast of Altun Kopri town, within governorate of Erbil. The selected axis represents the narrowest part of the flood plain in the whole reach between Altun Kopri and Taq Taq towns. UTM system bound the center line axis of the proposed dam: 3964698.5 - 3965201.5 N and 438323 - 438353 E. The purpose of Construction of the Sartik Dam will be irrigation, flood control for downstream area, hydro-electric power generation. Sartik Dam will also serve as the regulating dam for waters released from the power station of Taq Taq proposed dam. The catchment area between Dokan dam and Satik dam site is

(2400 km^2) and the catchment area between Taq Taq proposed dam and Satik dam site is (550 km^2).

2- Complete stage records and discharge measurements in the Lesser-Zab River at the dam site at Goma Zerdala gauging station have been analyzed, the annual non-regulated Lesser Zab river discharge at Sartik dam site varies between 118m^3/sec and 418 m^3/sec with an average value of 234 m^3/sec, but the corresponding values for regulated conditions are 97 m^3/sec, 544 m^3/sec and 228 m^3/sec respectively.

3- PMF value for the Sartik Dam catchment is predicted in accordance with the obtained relation catchment area - PMF specific runoff for all left Tigris river tributaries, the predicted value of PMF was equal to 9100 m^3/sec, also the coordinates of PMF hydrographs for Dokan, Sartik (without Dokan) and between Dokan and Sartik were calculated.

4- Data necessary for the calculation of natural (non-regulated) flood flows at the Sartik dam site was not available. Flood flow values of return periods (25, 50, 100, and 1000) year for the Sartik Dam catchment were predicted in accordance with the obtained relation catchment area - specific runoff for different return periods, and were equal to 1990, 2330, 2850, and 4100 m^3/sec respectively.

5. REFERENCES

1.Al-Furat Co., "Altun Kopri Dam Project, Preliminary selection of structures sites," 2003.

2.Binnie, Deacon and Gourley: "The Dokan Dam Project Report", London 1959.

3.David R. Maiment, "Hand Book of Hydrology" Published by McGRAW-HILL, 1993.

4.D.L. VISHER & W.H. HAGER, "Dam Hydraulics", Published by by John Willey & Sons, 1998.

5.Harza, Binnie & Partners: "Hydrological Survey of Iraq", July 1963.

6.Ishaq, M. B., "Optimum Operation Rules for Tigris-Euphrates system in Iraq," Ph. D. Thesis, University of Baghdad, College of Engineering, Iraq, April 1998.

7.ITSC HYDRO ENGINEERING and STUCKY-SWITZERLAND "Taq Taq Dam Project Hydrology Report", 2006

8.Mark J. Hammer & Kenneth A., Hydrology and quality of water resources, published by John Willey & Sons, 1981.

9.Rasheed, M. M., "Optimum Operation for Saddam and Dokan Reservoirs and their Effects on Tigris River," M. Sc. Thesis, University of Baghdad, College of Engineering, Iraq, December 1998.

10. Richardson, Harvey, unpublished document, Massachusetts Soil Conservation Service, 1969.

11. Soil Conservation Service, Hydrology, Sec. 4 of National Engineering Handbook, U.S. Dept. of Agriculture, Washington, D.C., 1972.

12. Selkhozpromexport: "General Scheme of Water Resources and Land Development in Iraq", Baghdad-Moscow, 1975.

13.SWECO: "Lesser-Zab Regulation Project", Feasibility Report, Stockholm 1982.

14. The General Commission of Meteorology: "Records of Kirkuk, Sulaimani and Dokan stations".

15. The General Commission of Dams and Reservoirs: "Hydrological records of Lesser Zab-River".

16. White W.R.-Milli,"SedimentTransport Theories A review", Proc.Inst.Civ.Eng., part2,1975.

17. Sando P. Nikolov, "Rainfall Erosion in Northern Iraq an Aid to Soil Conservation", Baghdad, 1983.

18. Vector Miguel Ponce, "Engineering Hydrology Principles and Practice" Pub. by McGRAW-HILL.