Flood Frequency Analysis of Main Nara Valley

MANOHAR LAL*, BAKHSHAL KHAN LASHARI**, AND KHALIFA QASIM LAGHARI***

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ABSTRACT

This paper deals with the flood of 2007 and its frequency analysis at MNY (Main Nara Valley), and generally describe flood of 2010 in Sindh Pakistan. Heavy monsoon rain and cyclones cause the flood conditions in Sindh. The damages happened to the infrastructure of the MNVD from RD (Reduced Distance) 0-100 and the ecological impacts of the flood on the local region of Taluka Johi, District Dadu.

For flood risk assessment and its description, knowledge of extreme flood events and their return periods is important. This is achieved by regional flood frequency analysis, which deals with using flood information from different sites within a hydrologically homogeneous region. At the study area and its surroundings, information of previous 12 peak floods of 50 years have been collected and analyzed for flood frequency analysis. The Gumble's flood frequency and analytical methods have been used for obtaining the flood frequency. Generally, flood threat to this area is mainly from Nai Gaj River and rarely from flash floods from Balouchistan. The disastrous flood of 2007 and 2010 were the examples of the heavy floods in the last 50 years history at the study area. Analysis results suggest constructing small reservoirs in order to permanently solve the flood problems and to use the stored water for agricultural and other needs.

Key Words: **Flood Frequency Analysis, Main Nara Valley, Flood Disaster.**

1. INTRODUCTION

Two major flood events in Sindh occur from the Indus River and from Balochistan; the former is more predictable and allows enough time to prepare; however, the later characterizes heavy flow and leaves no time to retort. Heavy floods have smaller frequency and period but very high strength therefore impact is also sever. These floods normally occur in monsoon months of July and August when its catchment areas in Balochistan receive heavy rains. Western boundary of Sindh is connected with Balochistan through Khirthar hills. A series of ferocious torrents including Mula, Boolan, Khanji, Mazarani, Dillan, Buri, Salari, Shole, Gaj, Angai, Naing and Bandani bring gushing waters from high altitudes of Khirthar to Kachhi plains of Sindh. This flood requires entirely different management systems, institutional capacities and infrastructure. Floods of 1942, 1944, 1948, 1956, 1973, 1975, 1976, 1995, 2007, and 2010 have left several reminders. Among these floods, 1976,

* Senior Engineer (H & TED) National Engineering Services of Pakistan NESPAK, Lahore Pakistan

** Professor, Institute of Water Recources Engineering & Management, Mehran University of Engineering & Technology, Jamshoro, Sindh, Pakistan.

*** Associate Professor, Department of Civil Engineering, Mehran University of Engineering & Technology, Jamshoro, Sindh, Pakistan.

1995, 2007 floods were high in magnitude and caused greater devastation to the flood protection infrastructure and local communities.

The torrential rains occurred in June 2007 in Sindh and Balochistan provinces and were hit by the cyclone "Yemyin". The latter left vast areas of the two provinces flooded and damaged occurred which include 245 people died and 186 missed, Dadu district was amongst these areas [1].

The flash flood caused by this torrential rain, after devastating the vast areas of Balochistan province, entered in Sindh province and flooded Qamber Shahdad Kot district, Hamal Lake and Dadu district. This flood water was disposed off (drained off) through MNV Drain into Manchar Lake and finally to Indus River. Flood water caused the devastation on large scale to the irrigation and drainage system, people, crops and infrastructures.

Flood of 2010 reported by the NDMA (National Disaster Management Authority) that 20 million people as having been affected in Pakistan. The peak flood level at Guddu, Sukkar and Kotri Barrages were recorded 1170000, 1050000 and 580,000 respectively [2]. Continuing flooding occur around Manchar Lake, which straddles Sindh's Dadu and Jamshoro districts. While local authorities have managed to divert some of the water from the lake back into the Indus River, at least eight breaches were reported to have developed in the lake's embankments on 16 September 2010, inundating 75 villages, Sehwan airport and parts of Bubak town. Parts of the Indus highway were also flooded between the towns of Sehwan and Bhan, which lies between the lake and the Indus River.

The study area is flood affected areas of Johi, District Dadu. It includes the MNVD from RD 0-100, where huge damages and breaches occurred at many locations and flooded the villages of Dadani, Nawab Solangi, Khuda Bux, Radhani and other villages.

The MNVD was constructed at the same time as Sukkur Barrage, in 1932. MNVD connects the two natural depressions i.e. Hammal Lake (then called Mirza Khan Reservoir) to the north and Manchar Lake to the south. It was aimed to carry flood flows from Hammal Lake to Manchar Lake as well as escape flows from the canals. The total length of the drain is 64 miles (104 km). In its first 56 RDs, it runs in a single section, while beyond this point, it widens out considerably. In the wider portion of the drain the channels were constructed on the inside of each bank for the capacity of 750 cusces. Under North Dadu Project, the capacity of MNV Drain has been enhanced to 2160 cusecs. Presently the discharge carrying capacity of the drain is being increased to 3500 cusecs under the RBOD-1 (Right Bank Outfall Drain) Project [3].

1.1 Description of the Area along the MNV Drain from RD 0-100

MNV Drain (also called Chhandan Wah) from RD 0-100 is located in Talukka Johi District Dadu. Johi is situated in the western side of District Dadu and its 70% area is known as Kachha (beyond the FP (Flood Protecting)) Bund towards Khirther Range in west) and the rest of 30% known as Pacca (from FP Bund towards eastern side). Kachha areas usually face Monsoon floods in July-August month due to Nai Gaj flow, whereas the Pacca area is protected by FP Bund in the West.

The Pacca areas are irrigated through irrigation channels i.e. Johi branch, Dara distry, Lakha distry, Johi minor and Chinni minor. The lands are rich but the irrigation system is not healthy so the people do live with the limited sources. Cotton and rice are major crops of Kharif season, whereas wheat, pulses, oilseed are Rabi crops.

The study area has witnessed several floods in the previous years and has suffered severe losses, but in this study the main objective is to analyze the frequency factor of flood 2007. The study of flood damages can help to mitigate flood havocs. This involves the assessment of recurrence, resource, intensity, duration, and impact of the flood.

2. METHODOLOGY

2.1 Data Collection

The survey of the area produced first hand information through public meetings with local people, site visits of different areas, interviews with executive staff, consultants and contractors. During survey, a semi structured questionnaire was used to interview from 50 peoples of different villages to get the data for the environmental impacts on local people and land. The informatory data about MNVD has been collected from the office of RBOD-1 consultant office at Dadu. The data of floods in previous years have been collected from the office of Southern Dadu Division IPD (Irrigation & Power Department) Sindh [4]. The data of discharge measurement of Nai Gaj River have been collected from Hydrology Department, WAPDA (Water and Power Development Authority) Hyderabad.

The analysis of damages to MNV Drain have been investigated through site visits of the drain and by taking cross sections of the drain from RD 0-100, at the interval of 5 RD. However, some relevant details have been collected from the office of RBOD-1 consultant at Dadu.

2.1.1 Floods in the Previous Years

The catastrophic flood in June-July 2007 is the only example of the heavy flood from Balochistan in the previous 50 years history. Potentially, the greatest flood threat posed to this area is Gaj Nai River, having a catchment area of 2750 square miles, is the largest of the torrents.

The Hydrological records show that high flood occurred in the year 1942,1944, 1948, 1956, 1959, 1973, 1975, 1976, 1978, 1986, 1992 and 1995. All these floods were occurred due to Nai Gaj River flow [5].

The past history of FP Bund reveals that water collusion against the bund in-variably caused breaches, during each wet year resulting in heavy damages to the fertile lands of the Sukkur Barrage Right Bank command, and serious destruction of life and property, communication system etc. in Larkana and Dadu Districts.

2.2 Measurement of Discharges for Different Gauges for MNV

The calculations of discharges against different gauge readings have been carried out using by Manning's Equation (1) [6].

$$Q = A\left(\frac{1.486}{n}\right)R^{2/3}S^{1/2} \tag{1}$$

Where; A, is area of the flow (ft^2), (observed at the location), R, is hydraulic mean depth which is A/P (P, is wetted perimeter), S, is bed slope (dimension less) of the Nai Gaj River (which is observed at the location and found V:H 1:1550) and n, is roughness coefficient (dimension less).

2.3 Methods of Flood Frequency Analysis

Flood frequencies and their probabilities can be evaluated graphically by plotting magnitudes of hydrologic variables. Floods discharge verses frequencies (with which they have been equaled or exceeded) and fitting their smooth curve through the plotted points and assuming the same as representative of future possibilities [7]. To standardize the basis for fitting a curve, the concept of theoretical distribution is employed. It is assumed that the recorded data constitute a random sample of their population and fit into a theoretical distribution. Through statistical analysis the most probable nature of the distribution from which the data derived can be evaluated.

A number of empirical equations are used for plotting the probability of the observed events on probability paper. However, following equation being relatively more logical and widely used eminent research institutions have been adopted in this study to estimate Tr is, recurrence interval (year) [8]. The Equation (2) in its simplest form is given as:

$$T_r = \frac{N+1}{m} \tag{2}$$

Where N, is total number of statistical events (dimension less), m, is rank of events (dimension less) arranged in decreasing order and P, is probability (Percent) and its Equation (3) is given as:

$$P = \frac{1}{T_r} \times 100 \tag{3}$$

The methods based on frequency factors involve a generalized equation used for hydrologic frequency analysis in Equation (4) is:

$$Q = Q' + K \times s \tag{4}$$

Where Q, is flood magnitude of given return period, Q', is mean of recorded observed floods, K, is frequency factor (dimension less), and s, is standard deviation (cusecs) of recorded/observed floods.

It may be noted that in this method it is not necessary to plot the observed data. Yet this may be done for comparison purpose i.e. to see how closely the estimated frequency time fits the observed data.

Gumbel's frequency factor method involves the magnitude of flood (Q) for the desired return period (Tr) of years can be estimated from Equation (4) provided that the value of K is known as Q' and s can be estimated from the observed flood data. The value of K from Gumbel's distribution has been taken from Table 1. The stepwise procedure to determine the flood magnitude of the desired return period given below:

The Gumble's method include following main steps [9]:

(1) List the annual maximum floods magnitude

(2) To compute mean recorded flood and standard deviation of recorded flood as Equations (5-6):

$$Q' = \frac{\sum Q}{N} \tag{5}$$

$$s = \sqrt{\left[\left(\frac{\sum Q^2}{N}\right) - \left(\frac{\sum Q}{N}\right)^2\right]} \tag{6}$$

2.4 Gumbel's Analytical Method

Gumbel's analytical method is a simple and handy when the table of frequency factors is not available. It involves the Equations (7-10) given as:

$$P = e^{\left(-e^{-y}\right)} \tag{7}$$

$$T_r = \frac{1}{1-P} \tag{8}$$

TABLE 1. EXTREME VALUE FREQUENCY FACTORS (K) USED IN GUMBLE'S METHOD

Sample Size	Recurrence Interval (Tr) Year							
	5	10	20	25 50	75	100	1000	
15	0.967	1.703	2.410	2.632	3.321	3.721	4.005	6.265
20	0.919	1.625	2.302	2.517	3.179	3.563	3.836	6.006
25	0.888	1.575	2.235	2.444	3.088	3.463	3.792	5.842
30	0.866	1.541	2.188	2.393	3.026	3.393	3.653	5.727
40	0.838	1.495	2.126	2.326	2.943	3.301	3.554	5.476
50	0.820	1.466	2.086	2.283	2.889	3.241	3.491	5.478
60	0.807	1.446	2.059	2.253	2.852	3.200	3.446	
70	0.797	1.430	2.038	2.230	2.824	3.169	3.413	5.359
75	0.792	1.423	2.029	2.220	2.822	3.155	3.400	
100	0.779	1.401	1.998	2.187	2.770	3.109	3.349	5.261

$$y = \frac{Q - Q' - (0.45)s}{(0.7797)s} \tag{9}$$

$$Q = Q' + 0.45s - (0.7797)s \times \ln\left[-\ln\left(\frac{T_r - 1}{T_r}\right)\right] \tag{10}$$

Knowing Gumble Variate (y), Q', and s from the analysis of the hydrologic data of the Nai Gaj, the probable flood discharge is estimated for the selected values of Tr using Equation (10) and flood frequency curve can be drawn on extreme value with probability paper.

3. RESULTS AND DISCUSSION

3.1 Discharge Computation

The discharge computations for different gauge reading of Nai Gaj River at Gaj diversion bund (Gaj Banglow) location have been carried out by using Equation (1), and Plotted along with the observed discharges (Fig. 1).

The observed and the calculated discharge values are in good agreement (Fig. 1). Therefore approach for estimation of discharges for other higher gauges is acceptable and hence adopted.

The discharges for the gauges from 1-28 feet calculated by Equation (1) and placed in Table 2. From the table it is obvious that the discharge of about 172400 and 295200 cusecs are obtained for 22 and 28 feet gauges respectively.

It is worthwhile to mention that the unprecedented heavy rainfall in the catchments of the Gaj in 1995, an ever-maximum flow of over 300,000 cusecs was recorded, which surpassed previous maximum flashy discharge of 170,000 cusecs. The relationship of discharge with respect to the gauge reading of Nai Gaj River is shown in Fig. 2.

The maximum discharges of Nai Gaj River from 1970-2008 were calculated which are given in Table 3.

Table 3 shows that the peak discharges occurred in the year 1976, 1995 and 2007, the minimum discharges were in the year 1997, 2000, 2002 and the average discharge for 39 years is about 71000 cusecs. All these data have been viewed graphical in Fig. 3.

The abnormal heavy rains during 1976 brought huge quantum of storm water and Nai Gaj River recorded the ever maximum gauge of 22 feet, having flashy discharge of about 172,400 cusecs.

Country-wide extreme rain events during 1995, resulted in record floods ever. The Nai Gaj recorded an ever maximum gauge of 28 ft. at Gaj diversion bund (Gaj Banglow), which was almost 300,000 cusecs, where as bund was designed to face about 250,000 cusecs. In 2007 unexpectedly flash flood appeared from Balouchistan and was of 230,300 cusecs which also brought havoc in the area of MNV.

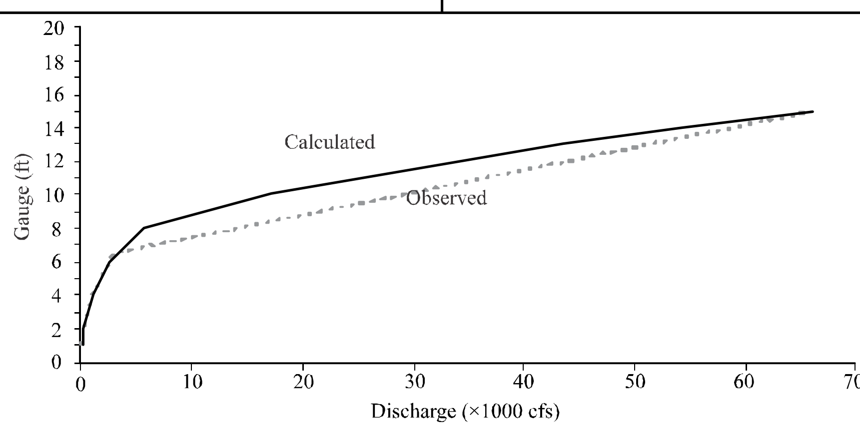

FIG. 1. GRAPH SHOWING THE CALCULATED AND OBSERVED DISCHARGES UP TO 15 FEET GAUGES

TABLE 2. DISCHARGES CALCULATED BY MANNING'S EQUATION FOR THE DIFFERENT GAUGES OF NAI GAJ RIVER

Gauge Reading (ft)	Width of Flow (ft)	Area of Flow (ft^2)	Mean Velocity (ft/s)	Discharge (ft^3/s)	Gauge Reading (ft)	Width of Flow (ft)	Area of Flow (ft^2)	Mean Velocity (ft/s)	Discharge (ft^3/s)
1	47	41	0.83	34	17	1432	15,187	6.09	92,489
2	112	142	1.58	225	18	1454	16,641	6.39	106,336
3	128	256	2.5	640	19	1467	18,105	6.71	121,485
4	143	385	2.74	1,055	20	1480	19,570	7.04	137,773
6	187	673	3.58	2,415	21	1495	21,058	7.35	154,776
8	1333	2,745	2.04	5,600	22	1510	22,547	7.65	172,394
10	1410	5,433	3.18	17,277	23	1525	24,084	7.93	190,986
12	1377	8,165	4.13	33,738	24	1540	25,620	8.21	210,340
13	1388	9,547	4.56	43,534	25	1555	27,155	8.48	230,274
14	1399	10,941	4.97	54,377	26	1570	28,735	8.75	251,431
15	1410	12,345	5.35	66,046	27	1585	30,323	9.00	272,907
16	1421	13,760	5.73	78,845	28	1600	31,910	9.25	295,168

TABLE 3. MAXIMUM DISCHARGES OF NAI GAJ FROM 1970-2008

Year	Gauge (ft)	Discharge (cusecs)	Year	Gauge (ft)	Discharge (cusecs)	Year	Gauge (ft)	Discharge (cusecs)	Year	Gauge (ft)	Discharge (cusecs)
1970	13	43,500	1981	12	33,700	1992	18	106,300	2003	21	154,800
1971	11.5	29,600	1982	17	92,500	1993	8	5,600	2004	9	11,400
1972	8	5,600	1983	18	106,300	1994	16	78,800	2005	12.5	38,000
1973	12	33,700	1984	17	92,500	1995	28	295,000	2006	15	66,000
1974	9	11,400	1985	18	106,300	1996	8.5	8,500	2007	25	230,300
1975	18	106,300	1986	20	137,800	1997	7	5,000	2008	15	66,000
1976	22	172,400	1987	12	33,700	1998	9.7	13,000			
1977	18	106,300	1988	18	106,300	1999	10	17,300			
1978	16	78,800	1989	16	78,800	2000	6	2,400			
1979	10	17,300	1990	16	78,800	2001	17	92,500			
1980	12	33,700	1991	15	66,000	2002	5	2,000			

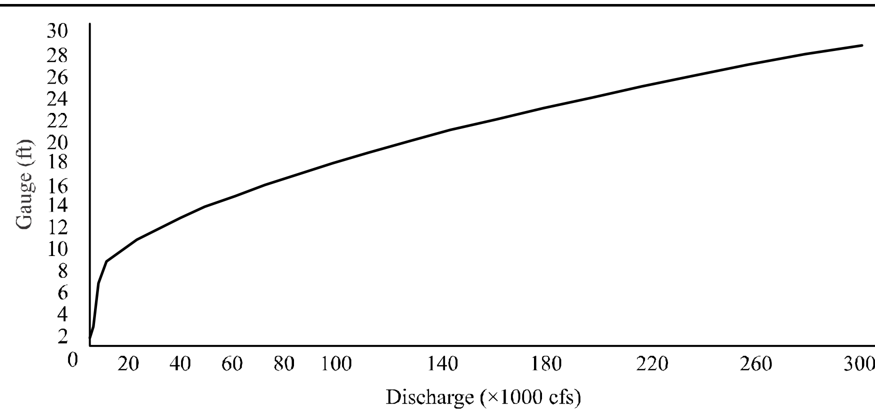

FIG. 2. RELATIONSHIP OF DISCHARGE WITH RESPECT TO GAUGES

3.2 Flood Frequency Analysis

The peak flood data of the Nai Gaj River at Gaj Banglow location for the last 39 years (1970-2008) have been used for flood frequency analysis. Theoretical flood frequency curves have also been derived by adopting Gumble methods. Hydrologic data of the Nai Gaj is compiled and analyzed by the methods narrated above and the results thus obtained are discussed in subsequent paragraphs.

3.2.1 Estimation of Recurrence Interval

Peak flood discharge data of 12 years recorded in 39 years has been arranged in descending order in Table 4 from column 1-3. Tr computed by eq. (2) listed in column 4. P is computed by Equation (3) listed in column 5.

Estimated flood frequencies are plotted on extreme probability paper shown in Fig. 4. The observed flood frequency has also been plotted on same paper which shows a good agreement between observed and calculated value of frequency events.

3.2.2.1 Gumble's Frequency Factor Method

Table 5 presents the constructions of flood frequency curve for the Nai Gaj by Gumble's frequency factor method and shown in Fig. 4.

TABLE 4. FLOOD FREQUENCY ANALYSIS OF NAI GAJ AT GAJ BANGLOW BY GUMBLE'S METHOD

Order Number (m)	Year	Flood Discharge (Q)x1000 cusecs	Recurrence Interval (Tr) Year	Probability (P) (%)	(Q^2)
1	1995	295.00	40.00	2.50	87025.00
2	2007	230.30	20.00	5.00	53038.09
3	1976	172.40	13.33	7.50	29721.76
4	2003	154.80	10.00	10.00	23963.04
5	1986	137.80	8.00	12.50	18988.84
6	1975	106.30	6.67	15.00	11299.69
7	1977	106.30	5.71	17.50	11299.69
8	1983	106.30	5.00	20.00	11299.69
9	1985	106.30	4.44	22.50	11299.69
10	1988	106.30	4.00	25.00	11299.69
11	1992	106.30	3.64	27.50	11299.69
12	1982	92.50	3.33	30.00	8556.25

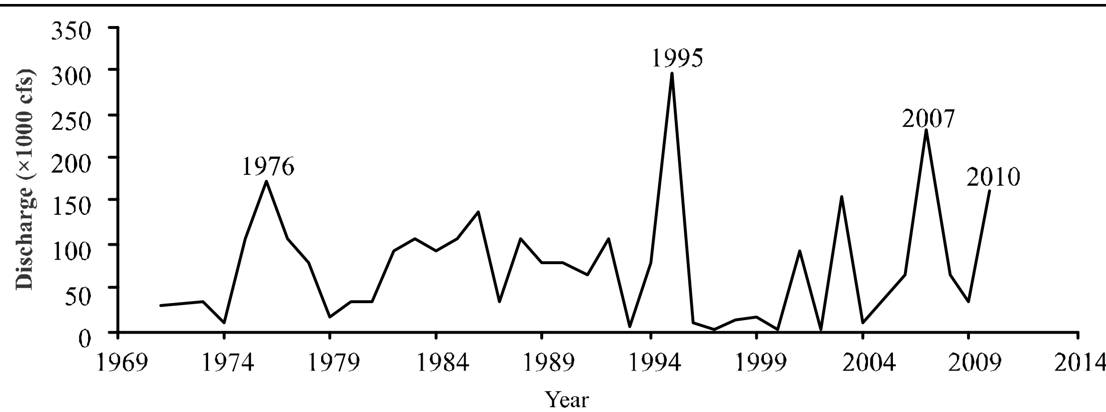

FIG. 3. SHOWING THE GRAPHICAL PRESENTATION OF PEAK FLOODS OF NAI GAJ RIVER FROM 1970-2007

3.3 Gumble's Analytical Method

Table 6 shows the computation of flood frequency curve by Gumble's analytical method. Column 1 & 2 represents the selected values of P and Tr. Computation of an event/variable is given in column 3 and the values of flood flows are given in column 4. Flood frequency curve for the Nai Gaj by Gumble's analytical method is shown in Fig. 5.

The computed flood frequency along with observed flood frequency are plotted on the same probability paper as shown in Figs. 4-5 that are closed which shows good correlation between computed and observed values.

The data of environmental impacts have been collected through the questionnaire from 50 local people and

TABLE 5. COMPUTATION OF FLOOD FREQUENCY CURVE FOR THE NAI GAJ AT GAJ BANGLOW BY GUMBLE FREQUENCY FACTOR METHOD

Probability (P) (%)	Recurrence Interval (Tr) Year	Mean Flood Discharge (Q')x1000 cfs	Standard Deviation (s)x1000cfs	Frequency Factor (K)	(Ks)x1000 cfs	Estimated Flood Flow (Q)x1000 cfs	Computation of Events
20	5	70.93	63.62	0.838	53.32	124.25	Q=Q'+Kxs
10	10	70.93	63.62	1.495	95.11	166.04	
5	20	70.93	63.62	2.126	135.26	206.19	
2	50	70.93	63.62	2.943	187.24	258.17	
1	100	70.93	63.62	3.554	226.11	297.04	

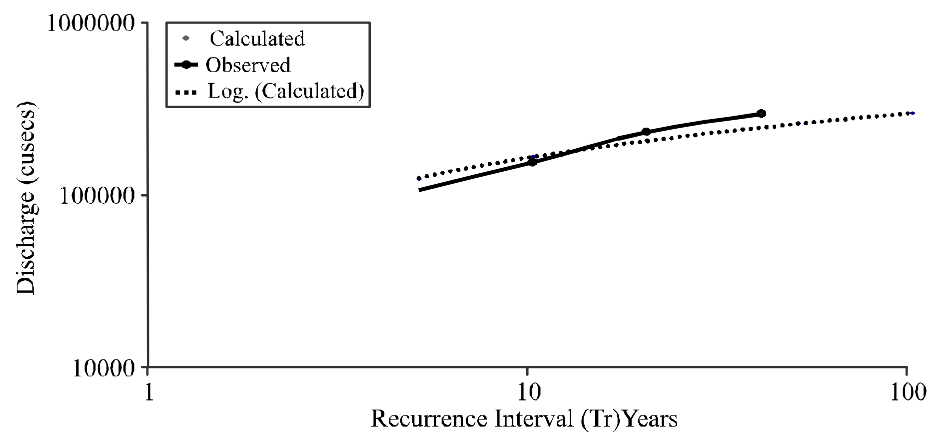

FIG. 4. FLOOD FREQUENCY CURVE FOR THE NAI GAJ BY GUMBLE'S FREQUENCY FACTOR METHOD

TABLE 6. COMPUTATION OF FLOOD FREQUENCY CURVE FOR THE NAI GAJ AT GAJ BANGLOW BY GUMBLE'S ANALYTICAL METHOD

Probability (P) (%)	Recurrence Interval (Tr) Year	Mean Flood Discharge (Q')x1000 cfs	Standard Deviation (s)x1000cfs	Ln(-Ln(Tr-1/Tr)	Estimated Flood Flow (Q)x1000 cfs	Computation of Events
20	5	70.93	63.62	-1.50	173.966	Estimated Flood Flow (Q) $Q = Q' + 0.45s - (0.7797)s \times \ln\left[-\ln\left(\frac{T_r - 1}{T_r}\right)\right]$
10	10	70.93	63.62	-2.25	211.170	
5	20	70.93	63.62	-2.97	246.885	
2	50	70.93	63.62	-3.90	293.017	
1	100	70.93	63.62	-4.60	327.740	

observed by visiting of the local area. The data revealed that 5 people died, 44 houses completely damaged, 78 houses partially damaged, the crop of rice and cotton on the area of 9000 acres completely damaged during the flood. The agricultural land became waterlogged and saline; hence the cropping intensity reduced in two consecutive crop seasons after the flood. The metallic road from Bhan to Chinni villages (5km) and the metallic road from Khuda bux Solangi to Chhaper Jamali village (4km) damaged. Dara Distributary from RD 18-32 silted by 1.0-2.0 feet and banks damaged. Lakha Distributary from RD 35-45 silted by 1.0-2.0 feet and banks damaged. Chinni Minor from RD 26-RD 33 silted by 1.0-2.0 feet and banks damaged. Watercourses 9 silted by 1.0-2.0 feet. Box culvert 5 and Pipe culvert 4 partially damaged. FP Bund leaked at RD 54 and RD 113, also from RD 0-33 outer slope of bund was wave washed due to flood water.

4. CONCLUSIONS

Flood threat to study area is mainly from Nai Gaj River and rarely from flash floods from Balochistan. The catastrophic flood of June-July 2007 was the only example of the heavy floods from Balochistan in the last 50 years history. Flood frequency analysis estimates the highest flood of 258,000 cusecs to occur in a 50 years period. The available structure like FP Bund may with hold flood up to 250,000 cusecs if FP Bund is regularly maintained.

Based on flood frequency analysis it is suggested that small reservoirs having various capacities to be constructed so that the flood problem can be permanently solved and the stored water can be utilized for agriculture and domestic purpose.

Environmental impacts assessment revealed that the crop of rice and cotton on the area of 9000 acres were completely damaged during the floods of 2007 and 2010. The agricultural land become waterlogged and saline and consequently the future cultivation will be affected, if the proper measures are not taken.

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REFERENCES

[1] Oxfam, G.B., "Report on Flood Damages in Cyclon Yemyin in Sindh and Balouchistan", Oxfam England and Wales (No 202918) and Scotland (SC039042), Oxfam International, UK, 2007.

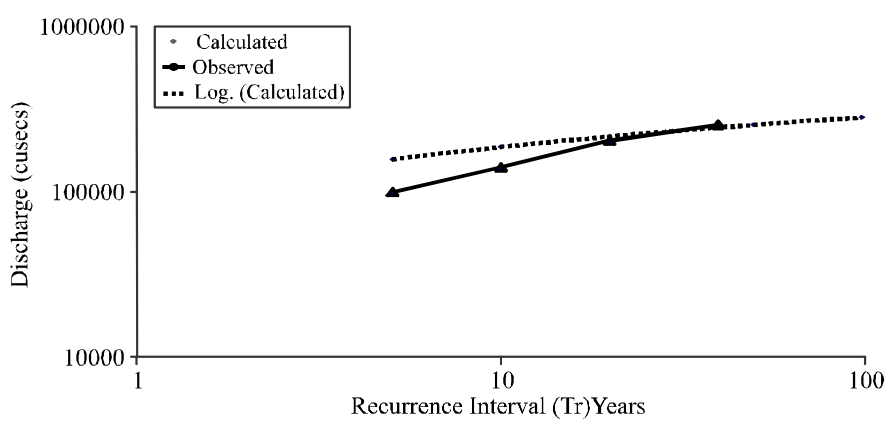

FIG. 5. FLOOD FREQUENCY CURVE FOR THE NAI GAJ BY GUMBLE'S ANALYTICAL METHOD

[2] Wilson, "Pakistan Flood Updates", The Institute of Hazard, Risk and Resilience, Department of Geography, Durham University, 2010.

[3] WAPDA, "Right Bank Outfall Drain (RBOD) Project-1, Revised PC-1", Annual Report-1 of Water and Power Development Authority of Pakistan, 2005.

[4] Irrigation and Power Department Sindh, Progress Report-1, Main Nara District Dadu, Sindh Pakistan, 2010.

[5] Memon, N. "Environmental Degradation of Manchar Lake", Daily 'Dawn', July 21 and 23, Karachi Pakistan, 2000.

[6] Siddiqui, I.H., "Irrigation and Drainage Engineering", A Text Book, Published by Oxford University Press [ISBN 978-0-19-547356-8], Karachi, Pakistan, 2007.

[7] Yue, S., Ouarda, TBMJ., Bobée, B., Legendre, P., and Bruneau, P., "The Gumbel Mixed Model for Flood Frequency Analysis", Journal of Hydrology, Volume 228, Nos. 3-4, pp. 228, Canada, 2000.

[8] Flynn, K.M., Hummel, P.R., Lumb, A.M., and Kittle, J.L., "User's Manual for Program PeakFQ, Annual Flood-Frequency Analysis", A Computer Program for Hydrologic Data Management, US Geological Survey Water-Resources Investigations Report 95-4085, pp. 211, USA, 2010, http://water.usgs.gov/software/annie.html

[9] Ladislav, G., Silvia, K., and Ján, S., "Revisiting Regional Flood Frequency Analysis in Slovakia: The Region-of-Influence Method vs Traditional Regional Approaches", EGU-GA, Department of Land and Water Resources Management, Slovak University of Technology, Bratislava, Slovakia, Volume 12, EGU2010-13693-2, Czech Republic, 2010.