The Team carried out continuous measurements for one week to obtain flood hydrographs at gauging stations No.604.5 and No.680 on the Arun and Sun Kosi rivers respectively in the rainy season of 1984. The resultant flood hydrographs are shown in FIG. 2-15 and 2-16.

3.3 Adapted Design Flood Discharge

Based on Study, the relationship between catchment area and design flood discharge was determined as shown in FIG. 2-17. Design flood discharges for each dam are tabulated below.

TABLE 2-13 **DESIGN FLOOD DISCHARGE**

Dam	C.A (km^2)	Design Flood Discharge (m^3/s)
Sun Kosi No. 1	16,200	22,500
" No. 2	10,396	17,300
" No. 3	5,520	11,600
Dudh Kosi No. 1	4,100	9,800
Indrawati No. 1	980	4,100
Tama Kosi No. 3	2,753	7,600
" No. 4	5,085	11,100
Tamur No. 1	5,085	11,100
" No. 3	4,000	9,600
Sapt Kosi High Dam	61,000	42,500

TABLE 2-2 METEOROLOGICAL STATIONS LIST

STATION NO.[1/]	STATION NAME	PERIOD OF RECORD	
(1) BAGMATI ZONE			
1001	TIMURU	1957 - 80	
1002	ARU GHAT CHAT DHODENI BAZAR	1957 - 80	
1003*	TRISULI	1955 - 80	
1004*	NUWAKOT	1956 - 80	
1005	DHADING	1956 - 80	
1006	GUMTHANG	1947 - 80	
1007*	KAKANI	1962 - 65	1972 - 80
1008	NAWALPUR	1959 - 80	
1009	CHAUTARA	1947 - 68	1971 - 80
1010	LATIPUR	1965 - 68	
1011	KATHMAMANDU USAID	1954 - 69	
1012	SUNDARIJAL POWER HOUSE	1940 - 80	
1013	SUNDARIJAL WATER RES	1940 - 80	
1014*	KATHMANDU I.E.	1942 - 70	
1015	THANKOT	1966 - 80	
1019	PANI PAUWA	1967 - 70	
1021	KIRTIPUR BAGBANI	1963 - 68	
1022*	GODAVARI	1952 - 80	
1023	DOLAL GHAT	1947 - 80	
1024	DHULIKHEL	1947 - 80	
1026	BUDOL BANEPA	1966 - 70	
1027	BAHRABISE	1965 - 80	
1028	PACHUWAR GHAT	1966 - 80	
1029*	KHUMALTAR	1967 - 80	
1030*	KATHMANDU AIRPORT	1949 - 80	
1031	KYANGJIN LANGTANG	1968 - 72	
1039*	KATHMANDU PANI POKARI	1971 - 80	

1/ Total Stations: 27

- Climatological: 8*
- Precipitation: 19

TABLE 2-2 (2 of 5)

METEOROLOGICAL STATIONS LIST

STATION NO.[1/]	STATION NAME	PERIOD OF RECORD	
(2) JANAKPUR ZONE			
1102	CHARIKOT	1959 - 80	
1103*	JIRI	1961 - 80	
1104	MELUNG	1959 - 80	
1106	REMECHHAP	1948 - 80	
1107	SINDHULI GADHI	1955 - 80	
1108	BAHUN TILPUNG	1958 - 66	1972 - 80
1109	PATTHARKOT EAST	1956 - 70	1972 - 80
1110	TULSI	1956 - 70	1973 - 80
1111*	JANAKPUR AIRPORT	1968 - 80	
1112	CHISAPANI BAZAR	1955 - 70	1972 - 80
1113	THODUNG	1961 - 69	
1114*	HARDINATH	1968 - 80	
1115	NEPALTHOK	1948 - 80	
1116	HARIHARPUR GADHI	1955 - 80	
1118	MANUSMARA	1979 - 80	
1119	GAUSALA	1979 - 80	

1/ Total Stations: 16
- Climatological: 3
- Precipitation: 13

METEOROLOGICAL STATIONS LIST

STATION NO.1/	STATION NAME	PERIOD OF RECORD	
(3) SAGARMATHA ZONE			
1201*	NAMCHE BAZAR	1948 - 80	
1202	CHAURI KHARK	1948 - 70	1972 - 80
1203	PAKARANS	1947 - 70	1973 - 80
1204	AISYEALU KHARK	1948 - 70	1973 - 80
1206*	OKHAL DHUNGA	1947 - 70	1972 - 80
1207	MANE BHANGYANG	1947 - 70	1973 - 80
1208	DWARAPA	1959 - 70	
1210	KURULE GHAT	1947 - 70	1972 - 80
1211	KHOTANG BAZAR	1959 - 70	1972 - 80
1212	PHATEPUR	1976 - 80	
1213	UDAYAPUR GADHI	1947 - 70	1972 - 80
1215	LAHAN	1955 - 70	1972 - 80
1216	SIRAHA	1947 - 70	1972 - 80
1217	KHUMJUNG	1966 - 80	
1218*	TENGBOCHE	1966 - 80	
1219	PHAPLU SALLERI	1947 - 62	1973 - 80
1220*	CHIALSA	1966 - 80	
1222	DIKTEL	1973 - 80	
1223	RAJBIRAJ	1971 - 80	
1224	SIRWA	1959 - 67	1973 - 80
1225*	SYANGBOCHE	1973 - 80	
1226	BARMAJHIYA	1975 - 80	

1/ Total Stations: 22
- Climatological: 5
- Precipitation: 17

METEOROLOGICAL STATIONS LIST

STATION NO.1/	STATION NAME	PERIOD OF RECORD	
(4) KOSI ZONE			
1301	NUM	1959 - 70	1973 - 80
1302	DUMUHAN	1947 - 70	1972 - 80
1303*	CHAINPUR EAST	1947 - 70	1972 - 80
1305	LEGUWA GHAT	1947 - 70	1972 - 80
1306	MUNGA	1947 - 70	1972 - 80
1307*	DHANKUTA	1947 - 80	
1308	MUL GHAT	1947 - 80	
1309	TRIBENI	1948 - 70	1972 - 80
1310*	BARAHKSHETRA	1947 - 70	
1311	DHARAN BAZAR	1947 - 70	1972 - 80
1312	HARAINCHA	1956 - 70	1972 - 80
1313	BIRATNAGAR	1948 - 69	
1314	TERHATHUM	1971 - 80	
1315	LALANTAR	1972 - 80	
1316	CHATARA	1948 - 70	1972 - 80
1317	CHEPUA	1959 - 70	1973 - 80
1318*	PARIPATLE	1971 - 80	
1319*	BIRTNAGAR AIRPORT	1971 - 80	
1320*	TARAHARA	1971 - 80	
1322	MACHUWA GHAT	1948 - 70	1972 - 80
1323*	DHARAN BRITISH CAMP	1971 - 80	
1324*	BHOJPUR	1954 - 70	1973 - 80
1325	DINGLA	1948 - 70	1973 - 80

1/ Total Stations: 23
- Climatological: 8*
- Precipitation: 15

METEOROLOGICAL STATIONS LIST

STATION NO.1/	STATION NAME	PERIOD OF RECORD
(5) MECHI ZONE		
1401*	OLANGCHUNG GOLA	1947 - 1970 73 - 80
1402	PANGTHUNG DOMA	1947 - 1970
1403	LUNGTHUNG	1947 - 1970 73 - 80
1404*	TAPLETHOK	1947 - 1970 72 - 80
1405*	TAPLEJUNG	1947 - 1970
1406	MEMENG JAGAT	1947 - 1970 72 - 80
1407*	ILAM BAZAR	1956 - 1970
1407	ILAM TEA ESTATE	1966 - 1980
1408	DAMAK	1961 - 1970 72 - 80
1409	ANARMANI BIRTA	1956 - 1970 72 - 80
1410	HIMAL GAUN	1968 - 1980
1411	SOKTIM TEA ESTATE	1966 - 1980
1412	CHANDRA GADHI	1971 - 1980
1413	KAMACHIN	1949 - 1954
1414	NUP	1948 - 1954
1415	SANISCHARE	1972 - 1980
1416*	KANYAM	1972 - 1980
1417*	JAURARI	1973 - 1980
1418	ANGBUNG	1947 - 1968

1/ Total Stations: 19
- Climatological: 6*
- Precipitation: 13

TABLE 2-8 (1 of 3) **RATING CURVE EQUATION FORMULA**

1. <u>G.S. No. 610</u>: Bhote Kosi

Jan. 1969 - Dec. 1969	$Q = -5.625 + 28.333H + 25.833H^2$
Jan. 1970 - Dec. 1970	$Q = -7.675 + 38.333H + 23.385H^2$
Jan. 1971 - Dec. 1973	$Q = 1.242 + 17.135H + 34.635H^2$
Jan. 1974 - Dec. 1978	$Q = 11.267 + 2.181H + 36.626H^2$

2. <u>G.S. NO. 620</u>: Balephi Kohla

Jan. 1969 - June 1970	$Q = 19.000 + 2.273H + 13.636H^2$
July 1970 - June 1971	$Q = 197.244 - 184.498 + 44.019H^2$
July 1971 - July 1974	$Q = 59.270 - 80.633H + 28.833H^2$
Aug. 1974 - Dec. 1978	$Q = 65.480 - 77.033H + 27.833\ H^2$

3. <u>G.S. No. 630</u>: Sun Kosi

Jan. 1966 - Sep. 1970	$Q = -16.600 + 42.333H + 43.333H^2$
Oct. 1970 - June 1971	$Q = -385.638 + 288.012H + 4.238H^2$
July 1971 - June 1972	$Q = -16.600 + 42.333H + 43.333H^2$
July 1972 - July 1974	$Q = 73.333 - 145.000H + 111.667H^2$
Aug. 1974 - Dec. 1975	$Q = 160.000 - 250.000H + 131.944H^2$

4. <u>G.S. No. 640</u>: Rosi Khola

Jan. 1969 - July 1969	$Q = 0.259 - 0.565H + 20.679H^2$
Aug. 1969 - July 1970	$Q = 0.574 - 7.090H + 26.449H^2$
Aug. 1970 - Dec. 1970	$Q = 0.493 + 1.300H + 17.667H^2$
Jan. 1971 - June 1978	$Q = -0.757 + 10.081H + 14.865H^2$
July 197 - Dec. 1978	$Q = 8.150 - 48.450H + 71.500H^2$ H = 0.50 (m) Below $Q = -28.606 + 68.929H - 16.234H^2$ H = 0.50 (m) Above

RATING CURVE EQUATION FORMULA

5. G.S. No. 647: Tama Kosi

Jan. 1971 - Aug. 1972	$Q = -22.662 + 39.156H + 34.189H^2$
Sep. 1972 - Mar. 1973	$Q = -28.087 + 61.363H + 32.446H^2$
Apr. 1973 - Jul. 1973	$Q = 0.947 + 17.486H + 41.967H^2$
Aug. 1973 - Dec. 1978	$Q = -15.871 + 68.063H + 26.355H^2$

6. G.S. No. 650: Khimte Khola

Jan. 1969 - June 1969	$Q = 1.171 + 11.300H + 16.714H^2$
July 1969 - June 1970	$Q = 3.740 - 6.683H + 42.404H^2$
July 1970 - May 1971	$Q = 6.749 - 23.423H + 50.879H^2$
June 1971 - Dec. 1978	$Q = 4.211 - 10.613H + 45.483H^2$

7. G.S. No. 652: Sun Kosi

Jan. 1968 - Sep. 1974	$Q = 15.918 + 17.242H + 61.165H^2$
Oct. 1974 - Dec. 1978	$Q = 5.924 + 11.674H + 62.034H^2$

8. G.S. No. 660: Likhu Khola

Jan. 1969 - July 1969	$Q = 2.219 + 8.135H + 30.168H^2$
Aug. 1969 - Dec. 1969	$Q = -6.019 + 14.681H + 22.210H^2$
Jan. 1970 - June 1973	$Q = -6.263 + 0.344H + 27.324H^2$
July 1973 - Aug. 1974	$Q = 48.715 - 102.943H + 65.104H^2$
Sep. 1974 - July 1975	$Q = 81.013 - 144.572H + 71.054H^2$
Aug. 1975 - June 1978	$Q = 43.433 - 93.560H + 58.669H^2$
July 1978 - Dec. 1978	$Q = 4.284 - 24.136H + 38.359H^2$

9. G.S. No. 670: Dudh Kosi

Jan. 1964 - June 1964	$Q = -2.739 + 58.133H + 69.525H^2$
July 1964 - Aug. 1965	$Q = 0.383 + 88.671H + 53.127H^2$
Sep. 1965 - July 1966	$Q = -10.824 + 81.036H + 58.559H^2$
Aug 1966 - July 1967	$Q = 16.277 + 196.793H + 4.393H^2$ H = 2.35 (m) Below $Q = 13.183 + 75.024H + 56.769H^2$ H = 2.35 (m) Above

TABLE 2-8 **RATING CURVE EQUATION FORMULA**
(3 of 3)

Aug. 1967 - July 1969	$Q = 13.183 + 75.024H + 56.769H^2$
Aug. 1969 - Feb. 1970	$Q = 44.000 + 198.988H + 1.445H^2$
	H = 2.05 (m) Below
	$Q = 812.446 - 600.872H + 208.767H^2$
	H = 2.05 (m) Above
Mar. 1970 - Sep. 1970	$Q = 206.869 - 307.983H + 147.114H^2$
Oct. 1970 - Dec. 1970	$Q = 46.944 - 33.752H + 64.657H^2$
Jan. 1971 - June 1971	$Q = 8.809 + 44.464H + 33.780H^2$
July 1971 - Sep. 1972	$Q = 106.556 - 167.860H + 114.380H^2$
Oct. 1972 - Oct. 1974	$Q = 83.762 - 127.128H + 86.366H^2$
Nov. 1974 - Dec. 1975	$Q = 63.959 - 111.074H + 99.124H^2$

10. G.S. No. 680: Sun Kosi

Jan. 1966 - Nov. 1966	$Q = -17.042 - 33.955H + 59.238H^2$
Dec. 1966 - Apr. 1969	$Q = -90.413 - 10.003H + 57.566H^2$
May 1969 - Sep. 1970	$Q = 154.181 - 134.270H + 55.887H^2$
Oct. 1970 - July 1973	$Q = -78.280 - 47.267H + 43.701H^2$
Aug. 1973 - Sep. 1974	$Q = -97.004 - 12.776H + 39.986H^2$
Oct. 1974 - July 1975	$Q = -163.732 - 0.956H + 39.293H^2$
Aug. 1975 - Dec. 1977	$Q = -171.543 + 32.718H + 36.549H^2$

11. G.S. No. 690: Tamur

Jan. 1978 - Dec. 1978	$Q = 601.783 - 478.770H + 101.019H^2$

TABLE 2-9
(1 of 16)

MEAN MONTHLY DISCHARGE
Bhote Kosi River: No. 610 G.S. (C.A. 2,410km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1969	17.76	14.38	14.08	16.05	23.89	72.71	181.02	195.42	167.67	73.46	33.64	20.58	69.66
1970	15.23	12.92	12.61	15.53	20.20	77.69	191.92	228.65	129.10	71.46	35.81	21.32	69.89
1971	15.35	12.15	11.45	15.65	22.68	145.26	198.13	224.16	151.07	92.02	44.56	26.05	80.33
1972	16.95	15.46	15.34	15.40	39.29	79.49	190.81	215.90	169.01	63.22	39.37	27.85	74.47
1973	21.16	17.91	18.68	26.64	39.47	131.90	166.32	221.68	187.53	109.69	39.18	32.06	84.77
1974	25.56	18.34	17.88	24.40	30.70	93.04	230.55	240.10	172.00	83.44	39.99	26.38	84.08
1975	22.22	19.16	18.63	26.99	38.49	105.64	174.65	196.84	206.60	89.94	50.53	30.60	82.03
1976	21.98	19.82	17.67	21.43	31.38	104.85	147.16	185.68	139.71	61.97	39.20	24.17	68.22
1977	18.57	16.68	15.09	16.87	24.19	56.45	193.94	216.74	140.13	79.44	45.43	25.89	71.30
1978	20.44	16.83	16.12	23.55	53.47	120.43	199.58	239.61	131.87	76.82	42.54	29.80	81.66
Average	19.52	16.37	15.76	20.25	32.38	98.75	187.41	216.48	159.47	80.15	41.03	26.50	76.62

TABLE 2-9
(2 of 16)

MEAN MONTHLY DISCHARGE
Balephi Khola River: No. 620 G.S. (C.A. 629km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1969	11.32	9.07	8.70	9.40	12.10	34.04	118.50	142.77	128.77	48.28	21.30	14.28	46.83
1970	10.26	8.26	7.36	9.48	11.76	45.60	158.19	231.68	132.59	105.59	41.90	20.45	65.82
1971	11.12	7.00	6.43	11.83	21.77	169.44	136.39	174.42	103.63	66.32	31.30	18.46	67.72
1972	13.69	11.39	11.45	11.48	19.00	35.35	137.13	168.81	117.82	41.95	22.18	15.08	50.81
1973	11.64	10.40	10.92	12.22	15.69	78.34	107.17	170.35	139.50	66.48	25.04	13.95	55.42
1974	10.36	8.57	7.87	8.93	10.26	33.84	143.65	206.00	132.70	67.15	30.43	18.90	57.01
1975	14.59	12.33	11.16	13.07	16.98	59.50	148.76	140.03	143.03	69.17	25.26	15.05	56.08
1976	11.29	9.60	8.60	8.97	11.76	51.34	114.75	151.03	114.18	42.41	24.20	15.92	47.28
1977	12.44	10.90	10.15	11.32	13.86	30.63	139.86	185.87	99.44	52.32	28.00	18.88	51.56
1978	14.67	12.61	12.63	14.85	27.19	77.92	161.81	173.48	91.36	54.96	24.23	15.93	56.80
Average	12.14	10.01	9.53	11.16	16.02	61.60	136.57	174.44	120.31	61.46	27.42	16.69	55.57

TABLE 2-9
(3 of 16)

MEAN MONTHLY DISCHARGE
Sun Kosi River No. 630 G.S. (C.A. 4,920km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1968	50.78	40.94	44.85	45.58	72.31	233.42	676.26	667.71	466.77	295.90	129.52	83.63	235.72
1969	64.32	50.94	48.87	49.33	63.91	141.92	492.87	583.35	492.70	210.48	112.57	68.54	199.52
1970	47.16	41.71	41.03	49.62	66.70	197.42	575.03	823.19	436.60	245.42	128.27	85.74	229.97
1971	57.16	45.11	43.61	62.72	82.42	494.63	637.16	673.23	399.17	263.00	144.67	89.81	250.78
1972	57.94	46.80	46.05	44.38	78.18	145.22	652.00	749.29	568.33	203.65	122.12	82.44	234.71
1973	61.22	51.54	57.33	70.69	88.70	441.15	602.16	996.39	726.63	361.65	148.83	87.74	309.51
1974	66.21	52.16	46.29	55.83	64.50	193.21	813.97	1023.00	551.47	226.61	119.65	77.80	276.58
1975	59.08	50.89	43.84	59.55	85.58	279.65	652.45	660.87	694.20	311.97	124.54	74.50	259.45
Average	57.98	47.51	46.48	54.71	75.29	265.83	637.68	772.13	541.98	264.84	128.77	81.28	249.53

TABLE 2-9
(4 of 16)

MEAN MONTHLY DISCHARGE
Rosi Khola River: No. 640 G.S. (C.A. 87.2km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1969	1.18	0.93	0.81	0.80	0.90	0.83	3.15	5.62	4.06	2.66	1.61	1.33	2.00
1970	1.19	1.12	0.94	0.82	0.65	1.25	3.96	4.62	2.16	1.73	1.12	0.90	1.72
1971	0.79	0.71	0.69	0.85	1.33	8.57	5.09	8.91	3.74	2.76	1.84	1.44	3.07
1972	1.07	1.11	0.87	0.66	0.60	1.11	5.45	5.59	6.31	3.71	2.50	1.49	2.56
1973	1.16	1.08	1.06	0.75	0.99	5.35	6.16	9.85	8.25	10.59	3.19	2.16	4.24
1974	1.64	1.22	0.93	0.79	1.09	0.71	6.40	9.67	9.95	4.06	2.59	2.03	3.44
1975	1.65	1.42	1.04	0.67	0.83	1.30	10.66	9.38	8.19	4.78	2.71	2.16	3.77
1976	1.68	1.44	1.26	1.04	1.36	1.93	4.77	5.73	4.53	3.38	2.18	1.98	2.62
1977	1.68	1.44	1.26	1.04	1.36	1.93	4.77	5.73	4.53	3.38	2.18	1.98	2.62
1978	1.83	1.35	1.36	1.35	1.37	1.54	9.08	11.03	2.14	4.07	0.40	0.19	3.01
Average	1.38	1.18	1.02	0.88	1.05	2.45	5.95	7.62	5.39	4.11	2.03	1.57	2.99

TABLE 2-9
(5 of 16)

MEAN MONTHLY DISCHARGE
Tama Kosi River: No. 647 G.S. (C.A. 2,758km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1971	27.72	21.59	19.74	25.33	41.69	292.02	437.68	495.52	294.00	180.90	75.41	42.11	163.87
1972	28.65	22.95	22.25	23.54	75.96	143.77	383.26	460.77	341.67	141.69	75.08	44.63	148.05
1973	31.38	24.63	26.38	40.79	77.83	261.02	385.87	506.03	409.63	217.58	97.83	58.08	179.08
1974	40.20	29.73	27.85	40.10	68.02	167.38	460.77	496.55	304.43	156.35	71.42	42.52	159.98
1975	30.59	25.01	22.31	35.55	71.27	198.75	427.61	430.74	404.27	211.45	78.70	42.53	165.89
1976	28.12	22.09	18.52	20.59	46.40	179.43	307.42	410.26	286.63	103.42	52.71	35.15	126.65
1977	27.89	25.00	23.57	27.03	40.39	108.42	409.81	456.87	262.50	129.84	64.37	41.99	135.92
1978	32.51	27.97	28.09	34.06	91.45	210.73	430.06	462.16	256.70	132.39	62.18	40.07	151.82
Average	30.88	24.87	23.59	30.87	64.13	195.19	405.01	464.86	319.98	159.20	72.21	43.39	153.91

TABLE 2-9
(6 of 16)

MEAN MONTHLY DISCHARGE
Khimti Khola River: No. 650 G.S. (C.A. 313km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1969	5.90	4.89	4.61	4.42	6.47	17.35	49.41	51.81	43.63	17.25	9.48	7.00	18.63
1970	5.52	4.89	4.57	4.44	8.05	32.47	61.38	75.25	33.91	17.75	9.04	7.04	22.19
1971	5.45	4.77	4.46	5.51	8.72	65.21	73.46	78.14	47.04	19.36	11.95	6.69	27.70
1972	5.39	4.79	4.41	4.35	6.78	13.07	65.60	72.00	52.30	12.48	7.29	6.06	21.37
1973	4.80	4.26	4.07	3.87	8.55	74.35	74.33	96.54	65.91	26.96	8.31	6.79	31.71
1974	5.23	4.47	4.21	5.41	7.39	18.34	84.05	90.90	49.31	21.19	9.63	5.88	25.73
1975	6.18	5.54	4.47	4.59	6.37	30.53	122.50	87.34	92.18	38.08	14.21	7.45	35.24
1976	5.62	4.66	3.79	3.89	7.56	64.02	94.46	81.22	56.51	22.25	12.01	6.84	30.40
1977	5.00	3.89	3.55	6.67	7.06	13.95	84.58	79.76	39.15	17.32	12.82	7.14	23.63
1978	5.59	4.45	4.35	5.81	18.20	43.23	113.04	103.02	58.92	33.46	14.36	8.29	34.68
Average	5.45	4.66	4.28	4.90	8.52	37.25	82.28	81.60	53.89	22.61	10.91	6.92	27.13

TABLE 2-9
(7 of 16)

MEAN MONTHLY DISCHARGE
Sun Kosi River: No. 652 G.S. (C.A. 10,000km²)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1968	155.19	128.77	101.38	101.63	123.57	284.37	868.65	1802.00	2091.00	1037.00	625.90	265.52	634.79
1969	114.61	88.68	83.25	83.74	126.32	364.07	1173.00	1432.00	1063.00	367.10	171.70	109.74	434.41
1970	79.82	65.68	59.18	68.76	99.52	396.77	1472.00	1958.00	793.13	406.71	217.67	141.42	484.64
1971	103.07	80.70	77.52	104.89	147.16	1187.00	1519.00	1737.00	858.80	481.35	230.47	141.94	558.17
1972	118.23	101.20	96.37	94.82	176.68	305.60	1245.00	1462.00	988.00	404.94	221.97	146.71	450.25
1973	108.27	86.43	94.13	111.03	175.58	741.27	1177.00	1774.00	1428.00	718.35	284.47	174.16	576.16
1974	128.16	98.04	86.13	105.70	138.23	347.97	1428.00	1850.00	1201.00	476.19	226.90	147.48	523.64
1975	114.13	96.01	78.25	105.35	154.77	494.53	1470.00	1404.00	1431.00	727.39	274.27	168.23	546.60
Average	115.19	93.19	84.53	96.99	142.73	514.07	1294.08	1677.38	1231.10	577.38	281.73	161.90	526.08

TABLE 2-9
(8 of 16)

MEAN MONTHLY DISCHARGE
Likhu Khola No. 660 G.S. (C.A. 823km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1969	14.53	12.73	11.88	11.13	16.93	34.34	119.15	133.73	116.42	54.54	30.51	20.08	48.29
1970	14.36	12.56	11.40	11.76	12.80	56.59	148.40	178.35	92.25	53.74	28.83	18.15	53.67
1971	14.48	12.04	11.15	14.23	22.84	103.75	137.15	157.55	93.17	74.29	39.06	23.63	58.95
1972	16.89	13.77	12.47	12.24	19.62	38.39	115.26	128.52	110.10	58.14	32.70	20.97	48.54
1973	16.98	13.44	13.33	13.10	19.94	71.16	92.64	172.27	164.30	100.42	39.61	21.71	61.36
1974	15.12	11.06	10.19	13.12	16.25	40.40	177.28	187.77	124.83	56.60	26.30	16.66	58.42
1975	12.23	9.74	7.98	8.70	12.07	34.14	126.68	135.92	159.97	79.77	31.18	18.98	53.41
1976	13.88	11.36	8.79	7.91	13.72	66.57	137.23	155.94	118.69	49.55	25.89	16.63	52.49
1977	12.43	10.18	8.41	10.90	15.30	29.77	114.11	163.94	108.07	54.98	28.09	17.81	48.18
1978	13.20	10.74	10.49	12.38	27.04	79.15	171.06	199.58	129.77	76.12	38.54	24.55	66.53
Average	14.42	11.76	10.61	11.55	17.65	55.43	133.90	161.36	121.74	65.82	32.07	19.92	55.03

TABLE 2-9
(9 of 16)

MEAN MONTHLY DISCHARGE
Dudh Kosi River: No. 670 G.S. (C.A. 4,100km²)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1966	51.89	41.76	38.17	38.79	66.21	220.33	586.71	772.90	557.17	213.87	125.87	81.87	234.51
1967	53.55	39.07	36.84	56.27	98.90	267.83	466.71	467.42	303.23	139.36	68.65	46.75	171.42
1968	33.32	24.59	24.24	29.57	51.36	189.70	630.58	602.94	444.47	383.81	115.70	53.45	217.10
1969	33.83	24.32	23.00	24.12	59.28	268.80	524.84	555.19	471.50	245.23	135.93	83.10	205.34
1970	57.74	45.06	45.32	49.10	69.40	263.48	883.03	978.77	366.50	210.53	92.53	60.33	263.05
1971	45.54	35.20	33.79	54.34	90.61	576.77	761.94	843.74	377.53	306.10	110.01	72.33	277.59
1972	57.06	48.43	48.25	48.89	91.60	197.53	562.10	620.26	474.20	149.06	83.09	58.61	204.55
1973	47.40	41.12	44.57	50.83	82.40	308.29	431.65	673.68	451.87	337.65	119.59	74.57	223.34
1974	58.60	49.55	45.93	53.62	84.01	259.07	638.26	789.26	401.43	227.42	114.58	66.05	234.09
1975	46.29	36.17	32.05	42.55	66.81	321.20	725.77	481.03	632.23	338.45	113.89	67.88	273.33
Average	48.52	38.53	37.23	44.81	76.06	287.30	621.16	678.52	448.01	255.13	107.98	66.49	227.43

TABLE 2-9
(10 of 16)

MEAN MONTHLY DISCHARGE
Sun Kosi River: No. 680 G.S. (C.A. 17,600km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1966	194.19	170.11	147.29	153.70	204.10	591.33	1859.00	2881.00	1713.00	462.03	296.07	205.81	745.16
1967	161.45	140.89	137.94	155.07	205.16	416.90	1569.00	1999.00	1245.00	537.35	288.87	229.87	595.01
1968	158.42	138.61	139.13	142.07	182.10	608.67	2229.00	2890.00	1915.00	1415.00	417.40	286.19	884.22
1969	222.77	171.71	148.52	141.70	175.68	420.43	1548.00	1925.00	1443.00	516.58	296.00	245.03	608.52
1970	211.23	198.25	187.55	191.07	227.10	564.87	2227.00	2859.00	1272.00	627.71	310.30	213.00	764.04
1971	179.87	162.93	155.94	185.70	236.97	1570.00	2079.00	2304.00	1203.00	736.84	330.50	225.06	785.91
1972	173.94	146.50	140.13	136.07	222.39	434.47	1612.00	1862.00	1316.00	496.71	284.27	196.26	589.44
1973	157.68	131.93	137.42	147.40	217.39	948.83	1457.00	2146.00	1698.00	1016.00	429.07	275.65	734.44
1974	221.26	184.04	168.32	191.80	236.71	511.13	1888.00	2435.00	1631.00	701.77	344.97	235.19	734.32
1975	190.39	164.32	141.65	162.40	217.26	688.87	1903.00	1916.00	1937.00	1030.00	397.57	243.48	753.76
1976	198.77	170.43	141.71	149.20	211.45	764.47	1654.00	2099.00	1492.00	559.48	307.23	210.32	667.13
1977	168.74	143.39	129.19	160.50	191.52	387.27	1690.00	2215.00	1208.00	590.52	296.10	194.19	619.65
Average	186.56	160.26	147.90	159.72	210.65	658.94	1810.00	2294.25	1506.00	724.17	325.70	230.00	706.6[illegible]

TABLE 2-9
(11 of 16)

MEAN MONTHLY DISCHARGE
Arun River: No. 604.5 G.S. (C.A. 33,766 km²)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1976	111.55	107.39	113.55	132.67	237.32	778.03	869.84	925.87	673.03	363.68	228.70	162.03	393.64
1977	129.16	129.18	150.23	210.70	279.26	542.80	935.00	1124.00	706.07	486.87	281.57	186.35	432.52
1978	149.16	145.39	164.00	214.37	381.61	773.20	926.68	1045.00	761.33	432.74	247.70	170.74	452.99
1979	127.19	120.46	130.77	183.00	272.58	413.47	1012.00	952.74	748.83	494.94	239.23	176.16	408.42
1980	140.45	143.29	171.74	218.87	274.35	606.87	988.06	1479.00	1238.00	519.81	246.70	158.71	517.94
1981	121.32	134.82	150.94	216.40	322.52	689.00	1167.00	1180.00	810.63	300.19	178.00	131.58	452.62
1982	116.06	118.04	147.10	189.87	234.19	610.67	980.74	762.16	518.43	215.26	148.47	116.87	348.14
1983	102.81	100.72	119.74	129.47	234.61	453.53	991.32	794.55	1025.00	436.65	188.70	141.26	395.05
Average	124.71	124.91	143.50	186.91	279.55	608.44	983.83	1032.91	810.16	406.26	219.88	425.16	458.47

TABLE 2-9
(12 of 16)

MEAN MONTHLY DISCHARGE
Tamur River: No. 690 G.S. (C.A. 5,640km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1972	53.75	44.99	43.26	72.58	226.85	403.63	904.87	626.35	537.57	224.06	120.50	81.13	280.15
1973	61.66	49.76	49.22	65.39	177.37	716.07	675.87	992.29	730.57	597.45	186.90	109.06	369.62
1974	79.81	59.47	54.31	108.02	225.13	562.57	1314.00	1149.00	820.33	406.87	156.50	94.86	422.39
1975	67.23	53.86	44.01	65.87	146.47	583.10	1002.00	678.71	1052.00	445.74	151.97	90.85	366.66
1976	63.37	56.44	40.75	64.28	163.16	569.23	851.55	922.13	584.63	235.13	119.50	82.59	314.60
1977	53.49	42.04	38.89	101.21	212.63	363.60	723.87	1068.00	665.93	365.48	198.10	98.69	330.01
1978	72.37	52.65	51.77	92.12	229.68	663.07	925.10	870.65	596.97	318.52	114.09	76.34	340.65
1979	50.56	42.03	33.77	56.58	119.96	235.77	826.35	782.84	600.13	232.94	106.87	73.28	265.82
1980	81.88	70.13	77.61	101.76	192.16	401.23	718.94	712.48	578.03	217.13	127.63	87.24	282.01
1981	65.22	50.95	46.78	76.59	158.95	586.93	833.94	1177.00	639.57	242.16	121.99	75.39	325.43
Average	64.93	52.23	48.03	80.44	185.23	488.52	877.65	897.95	680.57	328.55	140.41	87.44	329.73

TABLE 2-9
(13 of 16)

MEAN MONTHLY DISCHARGE
Bagmati River: No. 550 G.S. (C.A. 585km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1962	-	-	-	-	-	-	36.120	67.940	44.030	11.800	6.332	3.939	-
1963	2.845	1.296	3.800	2.642	2.384	6.838	27.610	58.350	36.430	16.290	7.764	4.524	14.231
1964	2.668	1.559	1.045	1.742	2.297	6.863	32.470	41.450	34.640	11.910	5.869	3.503	12.168
1965	2.204	1.274	1.333	2.221	0.977	8.865	36.510	51.530	17.660	10.590	9.571	4.270	12.250
1966	3.796	2.277	0.956	0.336	1.276	2.891	29.730	66.240	23.300	7.898	4.842	3.503	12.254
1967	2.269	1.606	2.236	2.201	1.252	5.295	38.240	45.990	27.420	8.204	5.065	3.385	12.352
1968	2.702	2.096	1.239	0.771	1.342	9.679	53.170	49.230	18.810	26.750	6.539	3.463	14.634
1969	2.539	1.491	2.010	1.214	2.056	1.325	17.920	46.860	22.950	8.042	3.639	1.678	9.310
1970	1.105	1.051	0.771	0.596	0.852	7.345	57.640	58.750	43.070	19.770	8.311	3.495	16.896
1971	1.724	1.380	1.275	5.612	5.063	72.900	44.240	45.890	22.120	14.360	7.075	3.002	18.720
1972	1.535	2.119	2.453	1.681	0.735	7.875	94.520	35.990	38.830	16.380	9.673	4.744	18.045
1973	2.076	1.465	3.338	0.518	1.581	19.110	49.210	55.480	62.150	39.190	9.276	3.752	20.596
1974	1.604	0.721	0.714	1.142	4.263	2.282	47.290	79.820	61.560	15.090	7.180	4.912	18.882
Average	2.256	1.528	1.764	1.723	2.007	12.606	43.436	54.117	34.844	15.867	7.010	3.705	15.072

TABLE 2-9
(14 of 16)

MEAN MONTHLY DISCHARGE
Bagmati River: No. 590 G.S. (C.A. 2,720km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1965	8.71	7.41	11.45	23.39	25.60	243.50	670.10	655.30	288.60	49.39	61.13	24.98	172.46
1966	18.36	14.06	14.79	11.55	17.65	59.20	488.50	562.40	295.00	36.45	27.37	15.63	130.08
1967	18.24	13.43	16.78	18.54	16.00	110.90	522.00	457.70	400.90	141.00	32.86	20.82	147.43
1968	16.77	13.90	17.35	14.45	20.18	201.70	630.80	514.30	349.80	416.50	79.89	20.31	191.33
Average	15.52	12.20	15.09	16.98	19.86	153.83	577.85	547.43	333.58	160.84	50.31	20.44	160.33

TABLE 2-9
(15 of 16)

MEAN MONTHLY DISCHARGE
Kamla River at Tinmai (C.A. 1,470km^2)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1956	-	-	-	-	-	21.20	133.00	120.00	91.50	44.00	17.20	9.40	-
1957	8.40	4.60	2.90	1.50	1.20	24.00	61.50	84.80	37.50	19.60	5.80	6.00	21.48
1958	4.50	2.90	1.40	1.10	10.50	18.50	33.10	146.00	65.50	35.50	14.50	9.30	28.57
1959	7.20	6.30	3.30	3.30	4.70	53.00	39.10	53.20	50.00	51.00	16.70	9.40	24.77
1960	4.60	2.70	3.50	1.20	7.70	41.90	130.00	137.00	189.00	48.50	15.10	8.30	49.13
1961	4.50	5.60	3.60	1.40	3.90	44.60	33.80	124.00	62.60	42.90	13.90	8.30	29.09
1962	5.60	5.10	6.20	4.00	8.10	84.80	71.70	136.00	93.50	40.88	11.40	8.10	39.61
1963	4.90	3.30	2.60	5.20	26.10	75.10	135.00	102.00	42.90	56.20	22.30	15.70	40.94
1964	7.30	5.10	2.90	5.10	13.90	24.10	271.00	150.00	162.00	51.40	17.90	11.00	60.14
1965	6.10	4.40	3.30	1.90	11.70	38.20	319.00	375.00	139.00	58.50	33.40	13.50	83.67
1966	11.50	6.90	3.40	1.80	7.80	29.40	195.00	395.00	127.00	32.60	16.90	15.00	70.19
1967	9.40	5.90	6.00	4.60	3.20	34.50	143.00	88.10	136.00	33.80	11.10	11.00	40.55
1968	8.10	6.00	3.90	1.80	3.40	74.50	165.00	153.00	136.00	74.60	21.30	15.70	55.28
1969	9.00	4.80	3.70	3.50	4.40	50.70	88.80	138.00	89.90	37.50	17.20	12.40	46.66
1970	9.00	7.70	6.00	5.50	6.40	39.50	-	-	-	-	-	-	-
Average	7.15	5.09	3.53	2.99	9.42	43.60	129.93	157.29	108.74	44.78	16.76	10.94	45.02

TABLE 2-9
(16 of 16)

MEAN MONTHLY DISCHARGE
Kankai River No. 770 G.S. (C.A. 1,150km²)

unit: (m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1964	-	-	-	-	-	-	-	-	-	50.04	41.25	21.42	-
1965	12.54	10.15	8.17	8.92	15.87	44.92	79.13	193.10	94.47	38.81	29.44	16.47	46.00
1966	15.69	9.86	6.38	4.69	6.04	12.01	142.40	191.30	127.20	35.37	15.03	8.97	47.91
1967	7.07	6.26	6.69	5.83	9.08	25.97	218.60	90.94	96.18	33.95	21.14	17.54	44.94
1968	10.00	5.96	5.01	5.25	9.01	34.46	177.20	160.60	157.60	259.30	28.98	22.36	72.98
1969	14.45	10.76	9.12	7.05	12.66	24.37	132.80	140.80	135.70	42.60	31.33	19.05	48.39
Average	11.95	8.60	7.07	6.35	10.53	28.35	150.03	155.35	122.23	76.68	27.86	17.63	51.89

TABLE 2-12 MAXIMUM PEAK FLOOD DISCHARGE
(1 of 3)

I. Gauging Station No. 670 Catchment Area: 4,100km^2 River Name: Dudh Kosi at Rabuwa Bazar		Gauging Station No. 680 Catchment Area: 17,600km^2 River Name: Sun Kosi at Kampu Ghat	
Year	Discharge (m^3/sec)	Year	Discharge (m^3/sec)
1964	1,540	1965	3,910
1965	1,480	1966	5,940
1966	1,580	1967	4,280
1967	1,150	1968	9,390
1968	1,450	1969	3,460
1969	1,590	1970	7,360
1970	2,450	1971	5,500
1971	2,000	1972	4,600
1972	1,760	1973	3,830
1973	1,900	1974	5,460
1974	2,700	1975	4,890
		1976	3,620
		1977	3,340

TABLE 2-12 (2 of 3) MAXIMUM PEAK FLOOD DISCHARGE

II. Gauging Station No. 690 Catchment Area: 5,640 km^2 River Name: Tamur River at Mulghat		Gauging Station No. 965 Catchment Area: 61.000 km^2 River Name: Sapt Kosi at Barakshetra	
Year	Discharge (m^3/sec)	Year	Discharge (m^3/sec)
1970	3,900	1948	13,547
		1949	11,203
1971	2,450	1950	9,646
		1951	7,257
1972	4,100	1952	8,677
		1953	5,420
1973	4,400	1954	24,217
		1955	7,079
1974	5,450	1956	5,437
		1957	7,532
1975	2,400	1958	10,562
		1959	5,975
1976	2,400	1960	7,192
		1961	8,297
1977	3,020	1962	10,505
		1963	7,645
1978	3,400	1964	10,760
		1965	6,654
		1966	10,816
		1967	8,835
		1968	25,853
		1969	8,136
		1970	13,869
		1971	12,176
		1972	10,709
		1973	9,850
		1974	11,420
		1975	9,201
		1976	9,481
		1977	7,777
		1978	9,829

TABLE 2-12 MAXIMUM PEAK FLOOD DISCHARGE
(3 of 3)

III. Gauging Station No. 630 Catchment Area: 4,920km^2 River Name: Sun Kosi at Panchuwar Ghat		Gauging Station No. 652 Catchment Area: 10,000km^2 River Name: Sun Kosi at Khur Kot	
Year	Discharge (m^3/sec)	Year	Discharge (m^3/sec)
1964	1,210	1967	1,890
1965	1,260	1968	5,000
1966	2,240	1969	2,660
1967	1,760	1970	6,600
1968	1,150	1971	5,550
1969	1,250	1972	3,850
1970	1,935	1973	3,310
1971	1,660	1974	5,000
1972	3,410		
1973	3,770		
1974	5,100		

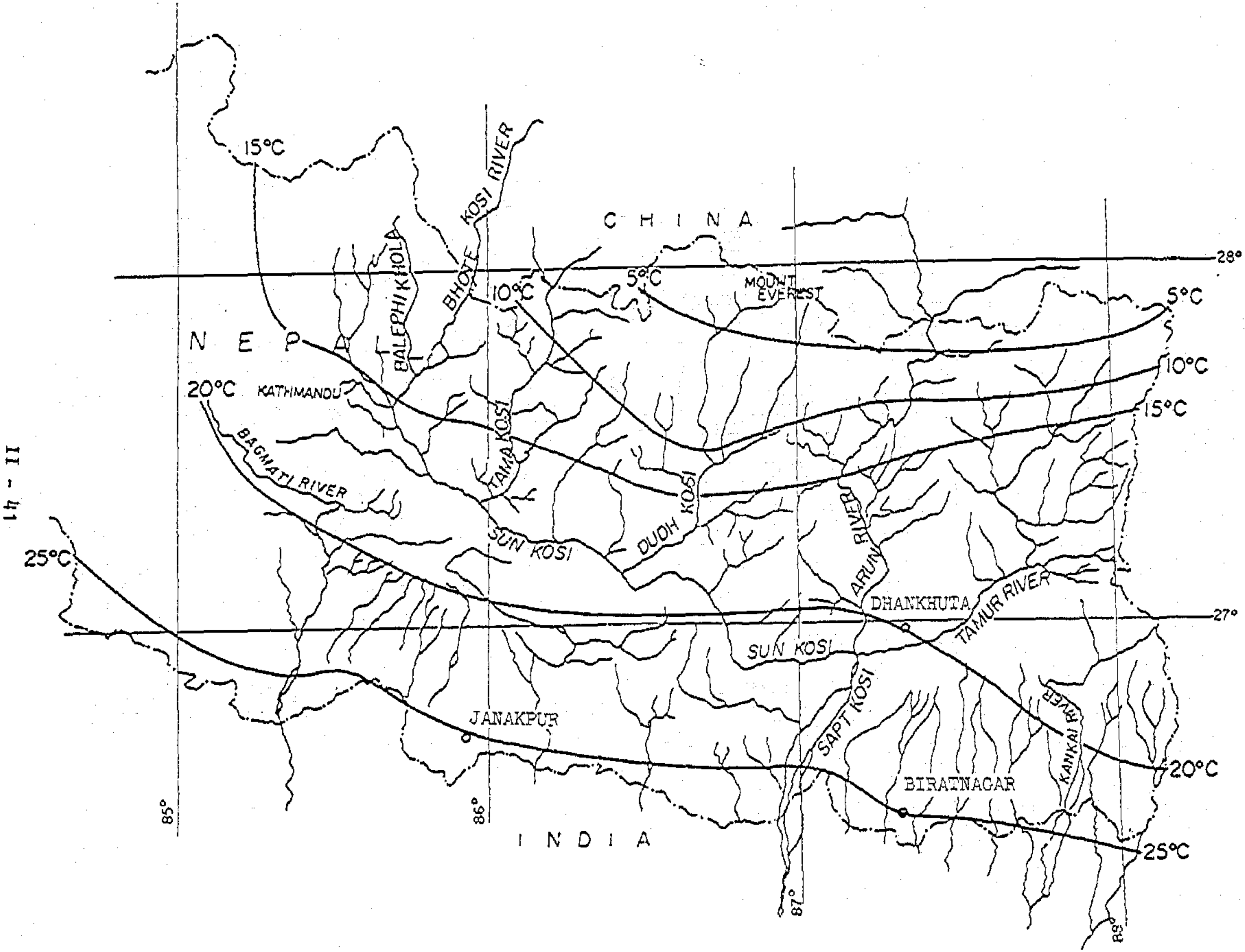


FIG. 2-1 ISOTHERMAL MAP (1970-1980)

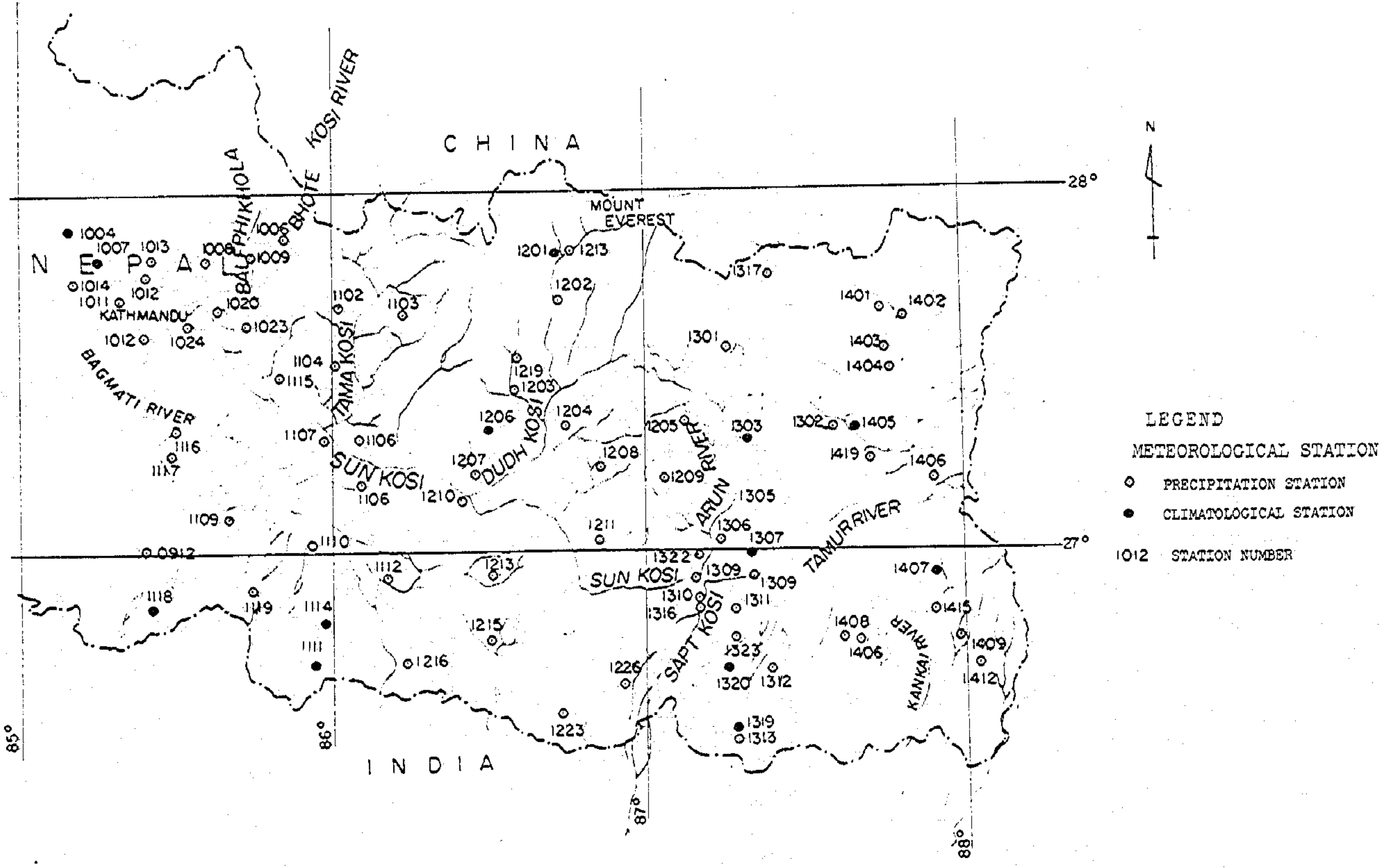


FIG. 2-3 METEOROLOGICAL STATIONS IN THE STUDY AREA

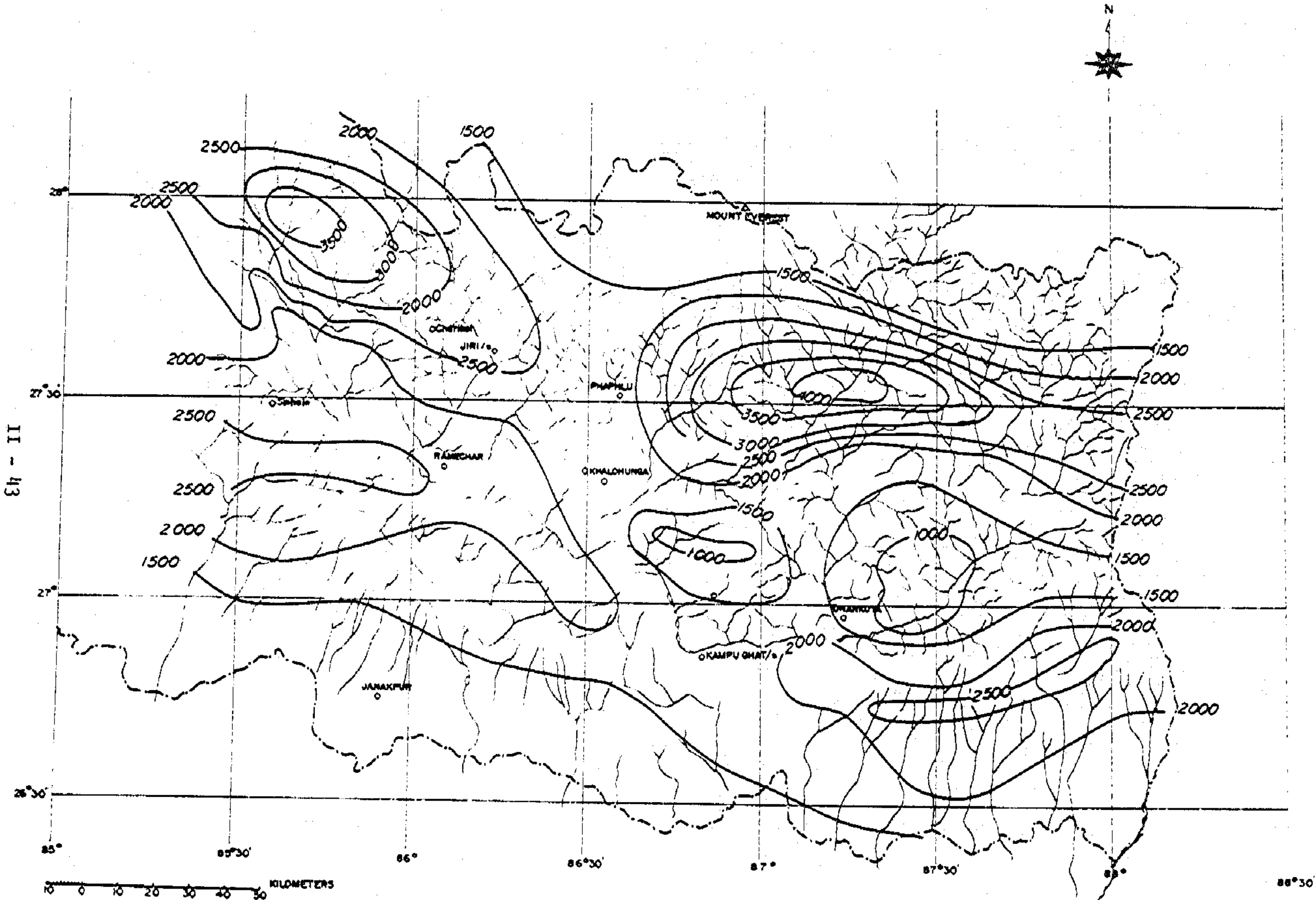
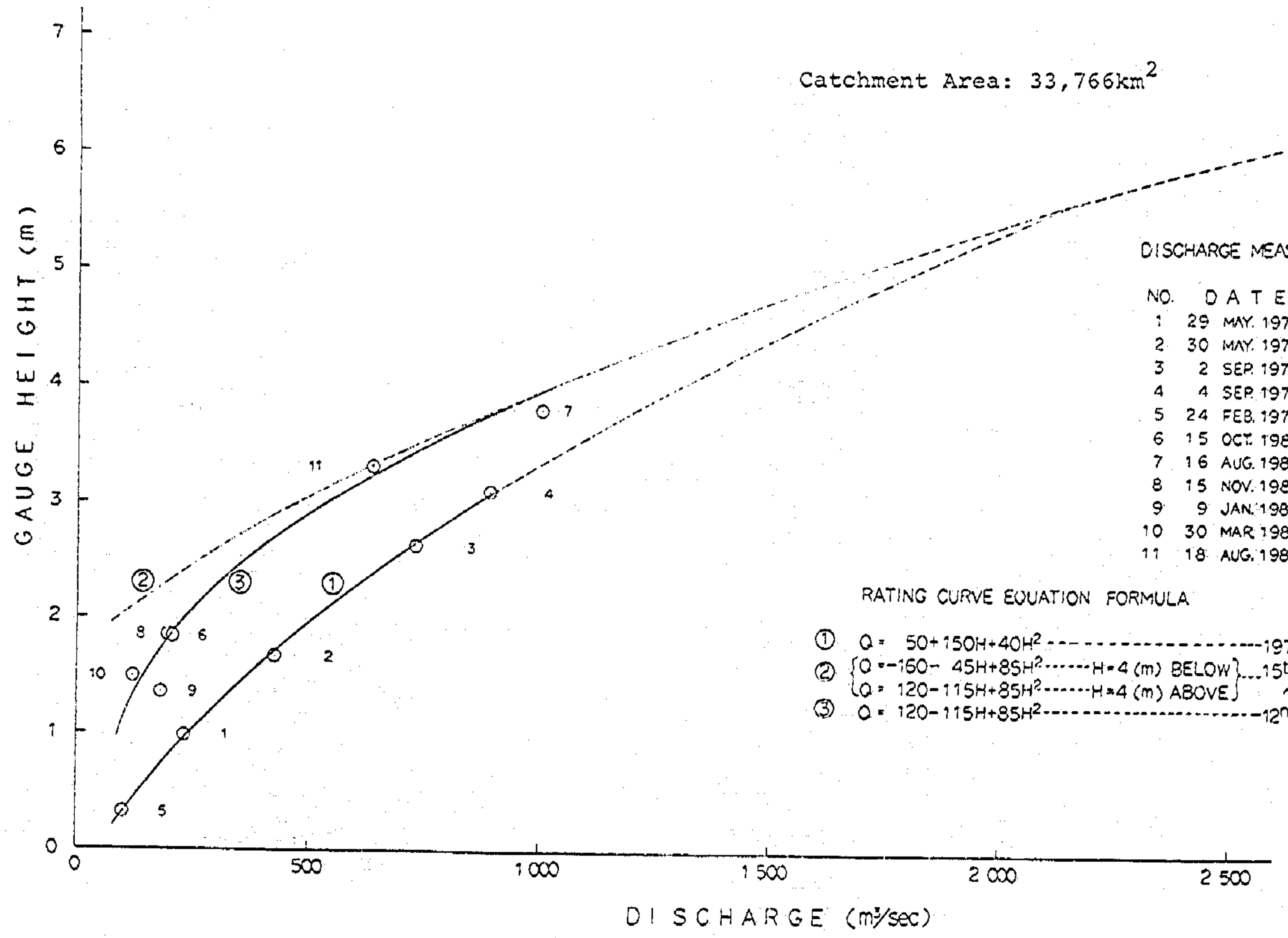


FIG. 2-4 ISOHYET MAP (1971-80)



DISCHARGE MEASUREMENT DATA

NO.	DATE	H(m)	$Q(m^3/sec)$
1	29 MAY. 1975	0.98	2.33
2	30 MAY. 1975	1.67	4.26
3	2 SEP. 1975	2.62	7.30
4	4 SEP. 1975	3.10	8.89
5	24 FEB. 1976	0.32	1.00
6	15 OCT. 1982	1.84	2.06
7	16 AUG. 1983	3.80	10.02
8	15 NOV. 1983	1.85	1.93
9	9 JAN. 1984	1.36	1.81
10	30 MAR. 1984	1.49	1.20
11	18 AUG. 1984	3.31	6.36

RATING CURVE EQUATION FORMULA

① $Q = 50+150H+40H^2$ ---------- 1975 ~ 14th August 1980

② $Q = -160-45H+85H^2$ ------ H = 4 (m) BELOW } 15th August 1980 ~ 11st August 1981
   $Q = 120-115H+85H^2$ ------ H = 4 (m) ABOVE }

③ $Q = 120-115H+85H^2$ ---------- 12nd August 1981 ~ After

FIG. 2-5 **RATING CURVE: ARUN RIVER AT TURKI GHAT GAUGING STATION**

FIG. 2-6 GAUGING STATIONS IN THE STUDY AREA

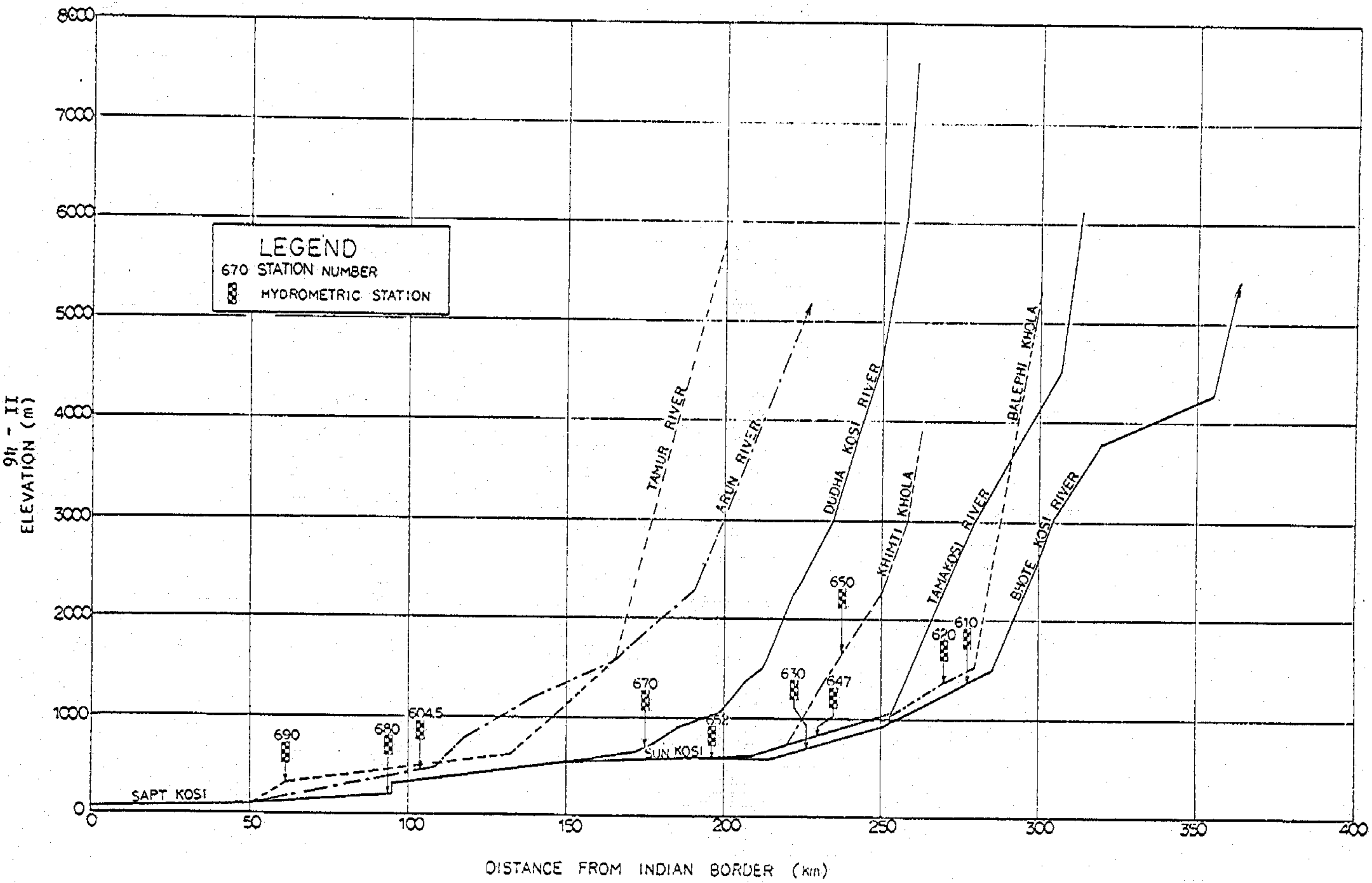
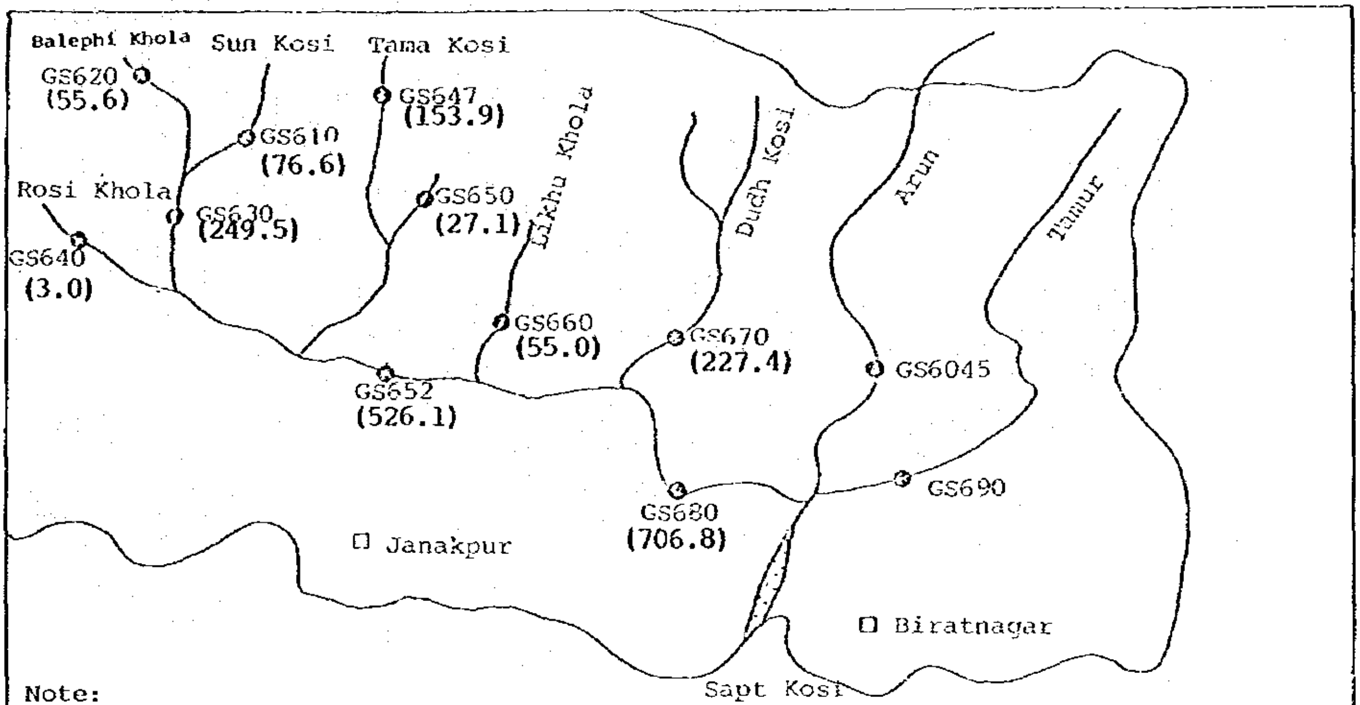


FIG. 2-7 LOCATION OF THE GAUGING STATIONS AND RIVER SLOPE OF KOSI RIVER SYSTEM



Note:
GS : Gauging Station
Figures in parentheses signifies annual average discharge at each gauging station.

FIG. 2-8 (1 of 3) **DISCHARGE BALANCE AMONG GAUGING STATIONS IN THE SUN KOSI RIVER (1971-75 ANNUAL AVERAGE)**

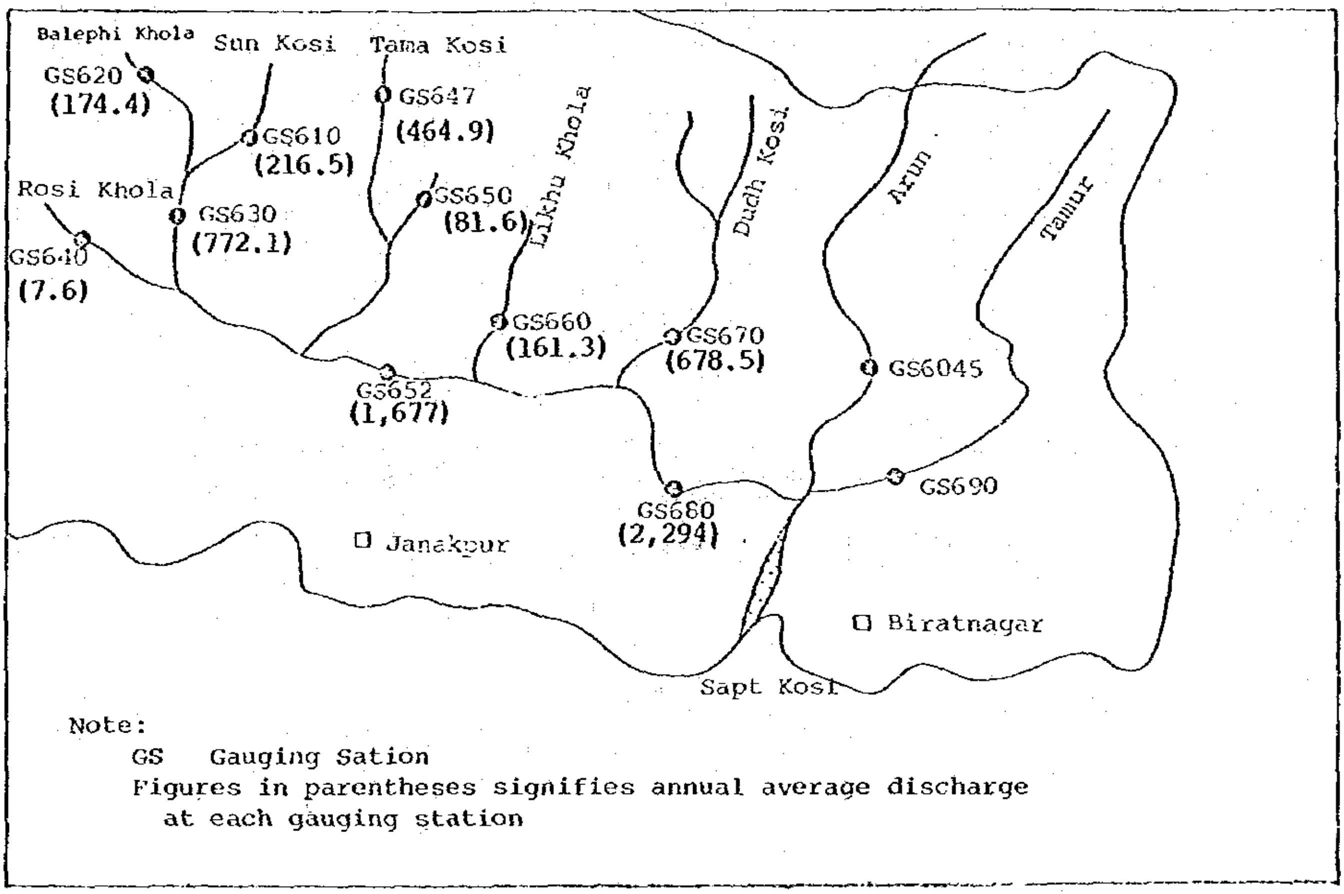


FIG. 2-8 (2 of 3) DISCHARGE BALANCE AMONG GAUGING STATIONS IN THE SUN KOSI RIVER (1971-75 AUGUST)

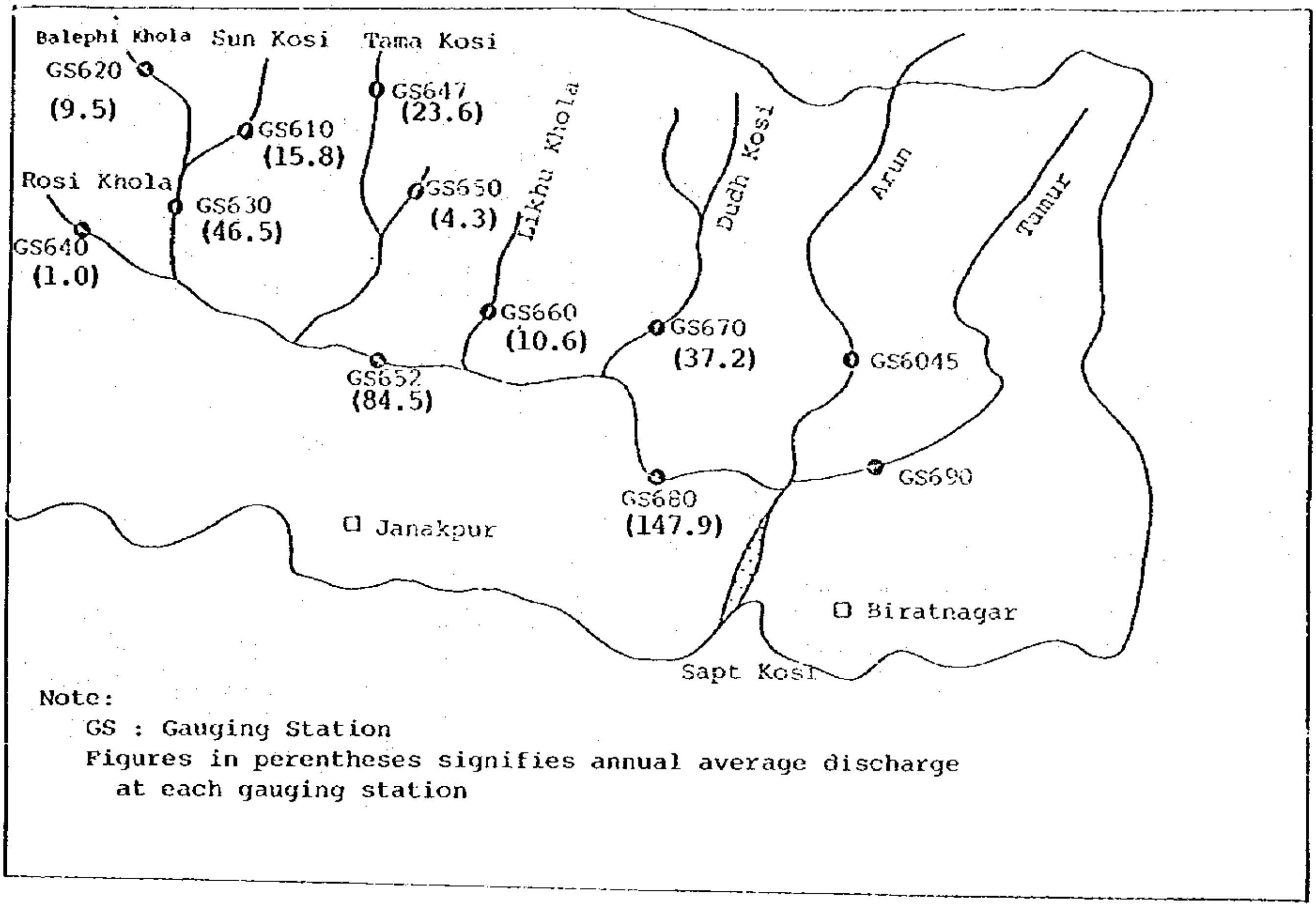


FIG. 2-8 (3 of 3) DISCHARGE BALANCE AMONG GAUGING STATIONS IN THE SUN KOSI RIVER (1971-75 MARCH)

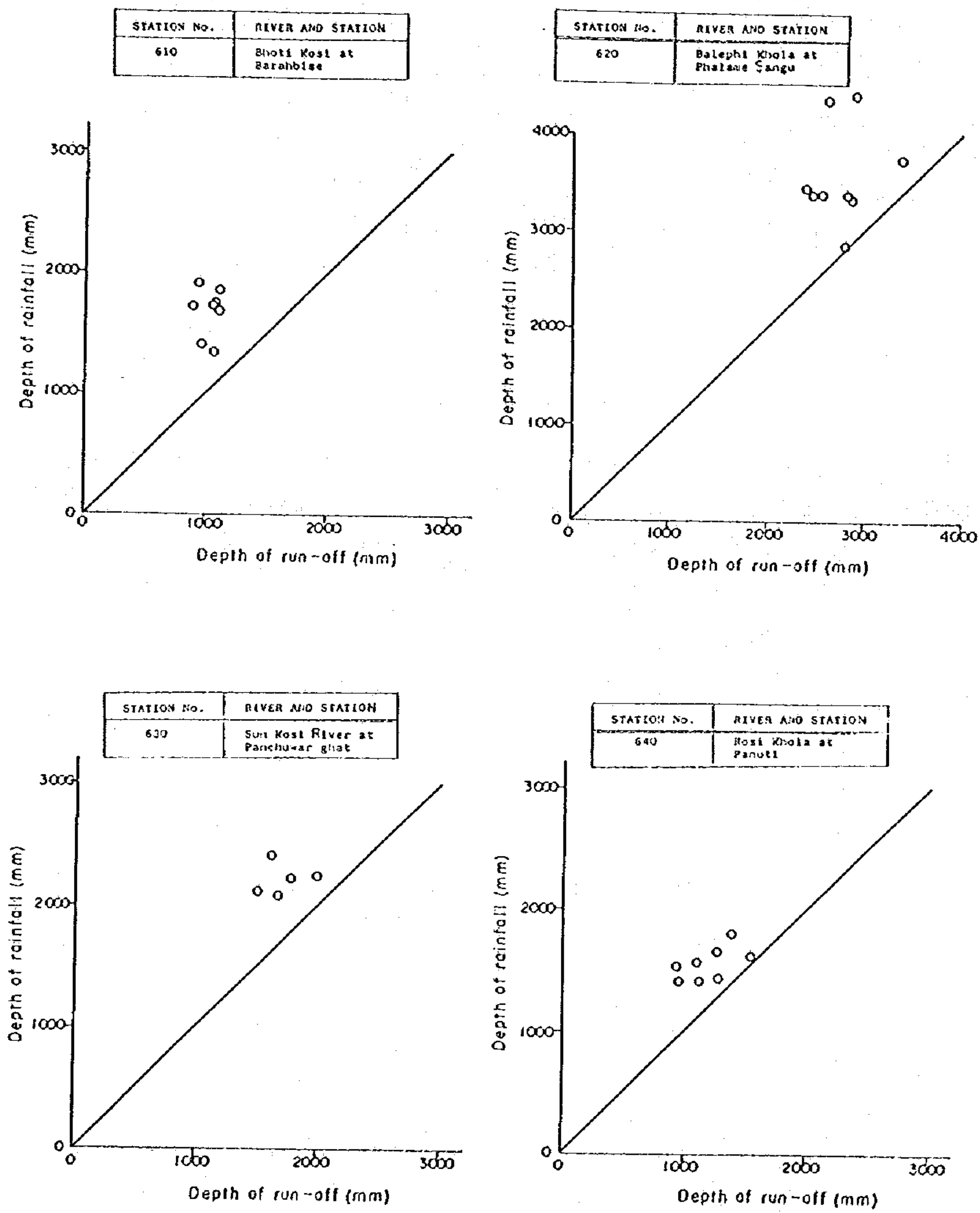


FIG. 2-9 (1 of 3) RUNOFF COEFFICIENT

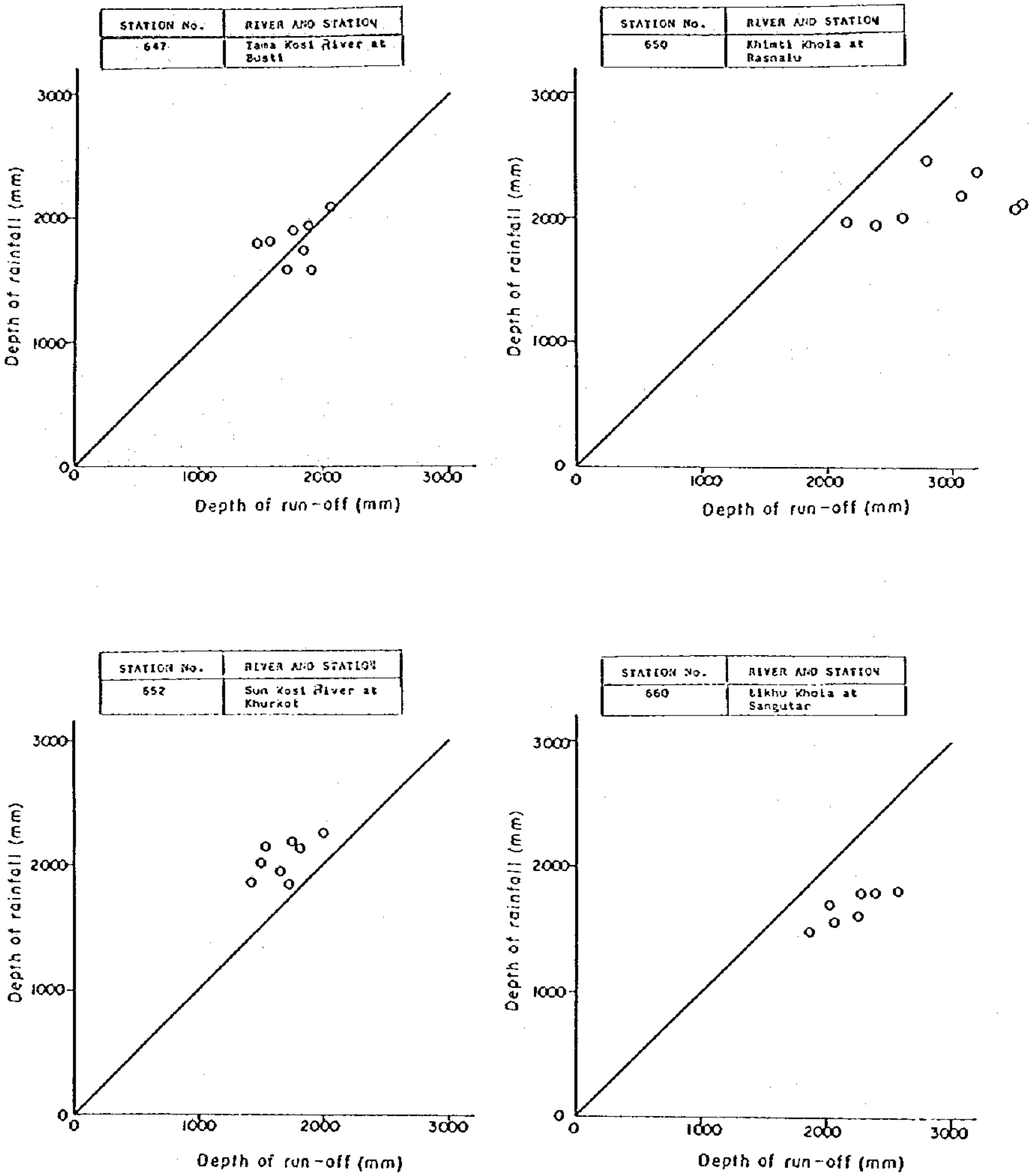


FIG. 2-9 RUNOFF COEFFICIENT
(2 of 3)

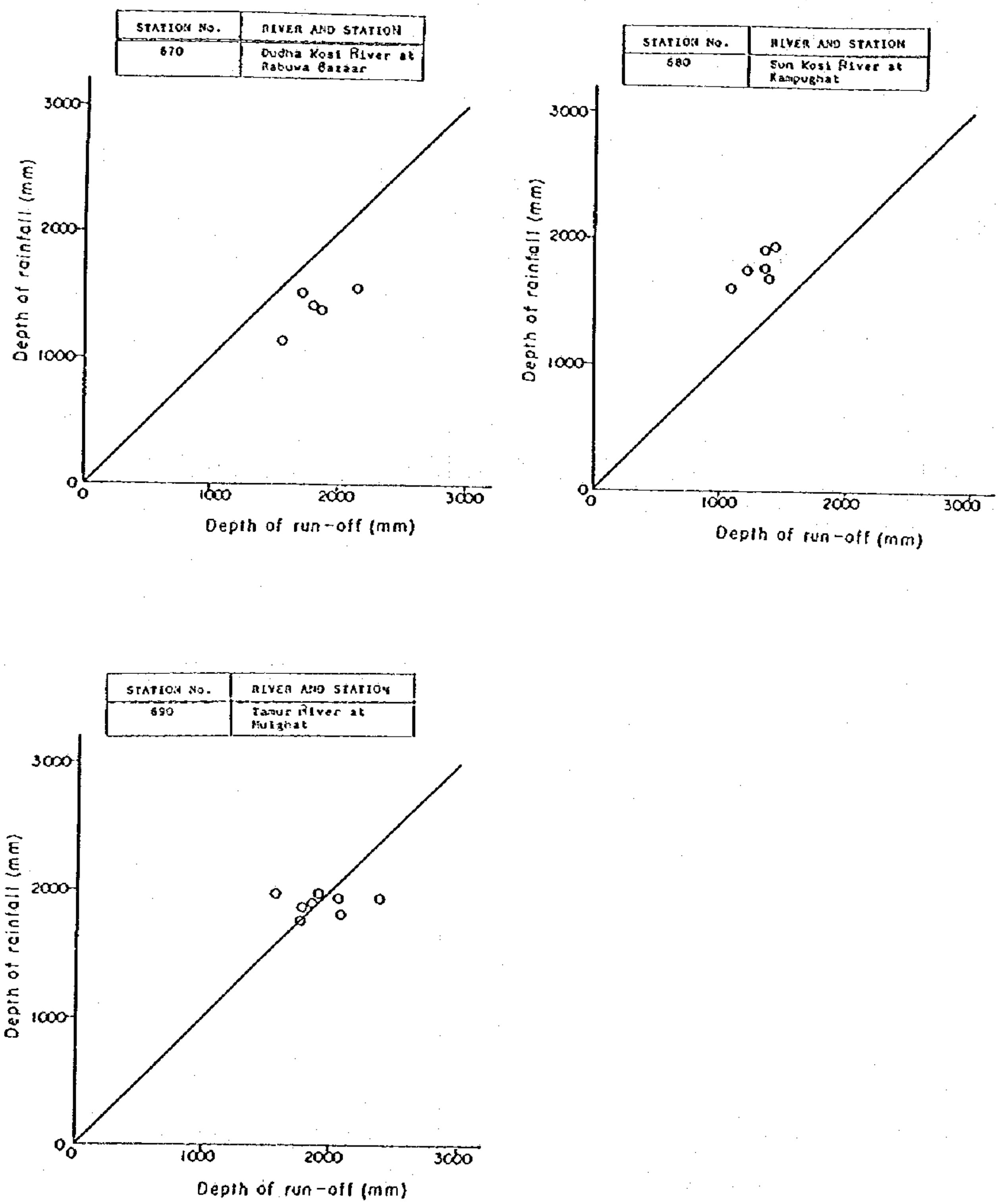


FIG. 2-9 RUNOFF COEFFICIENT
(3 of 3)

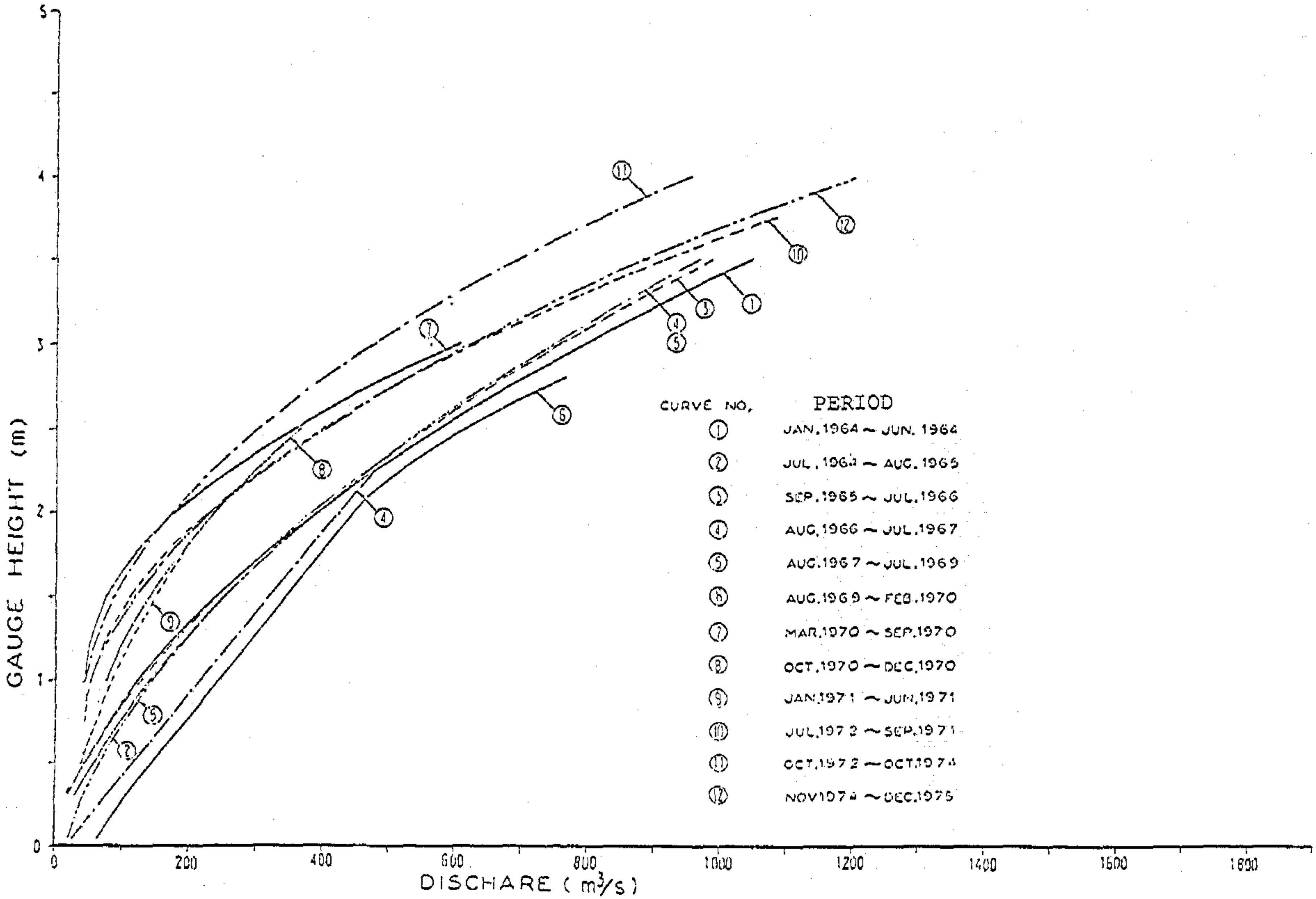


FIG. 2-10 **RATING CURVE: DUDH KOSI RIVER AT RABUWA BAZAR GAUGING STATION**

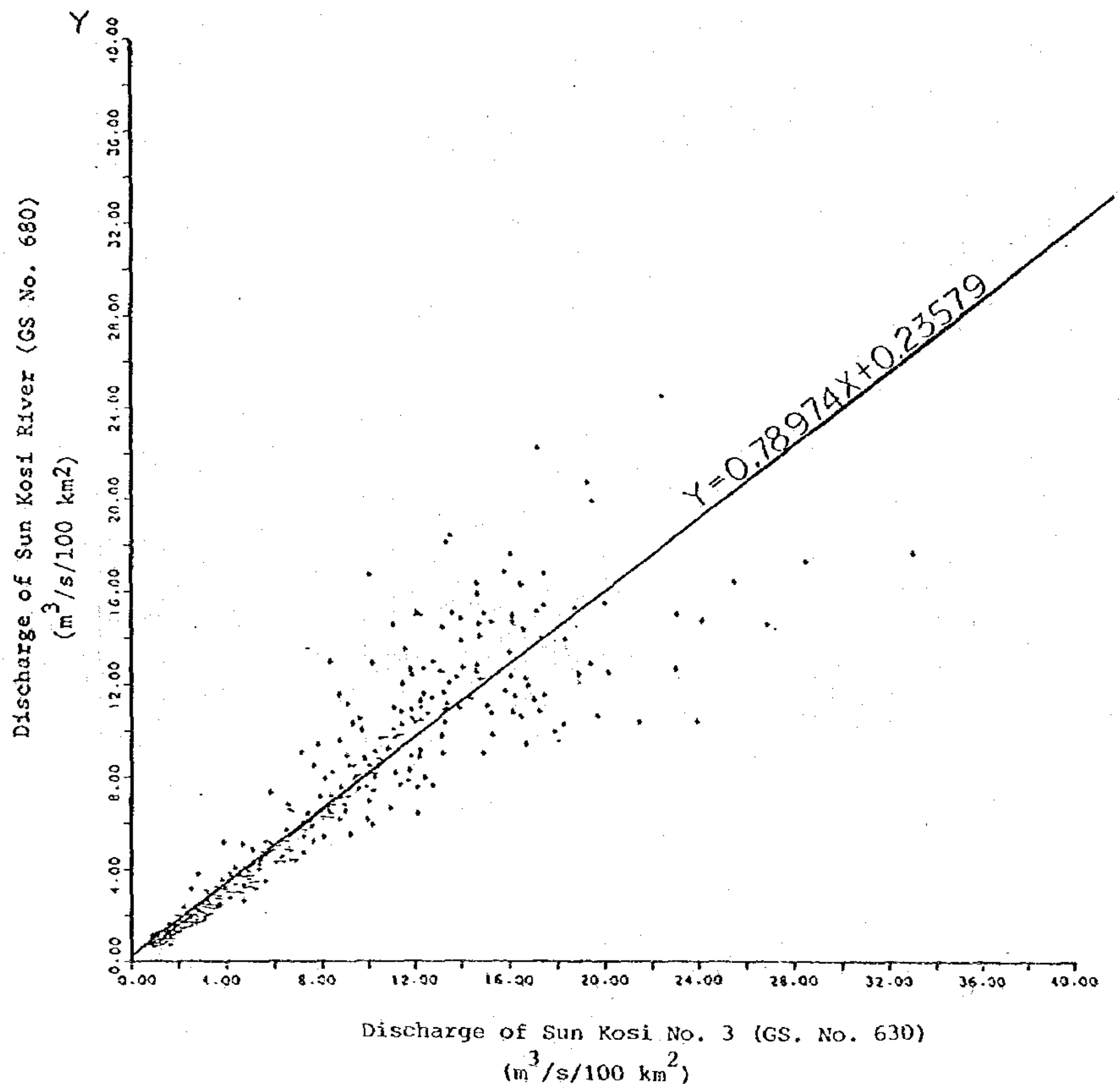


FIG. 2-11 CORRELATION OF DISCHARGE AT GAUGING STATION NO. 680 and 630
(1 of 4)

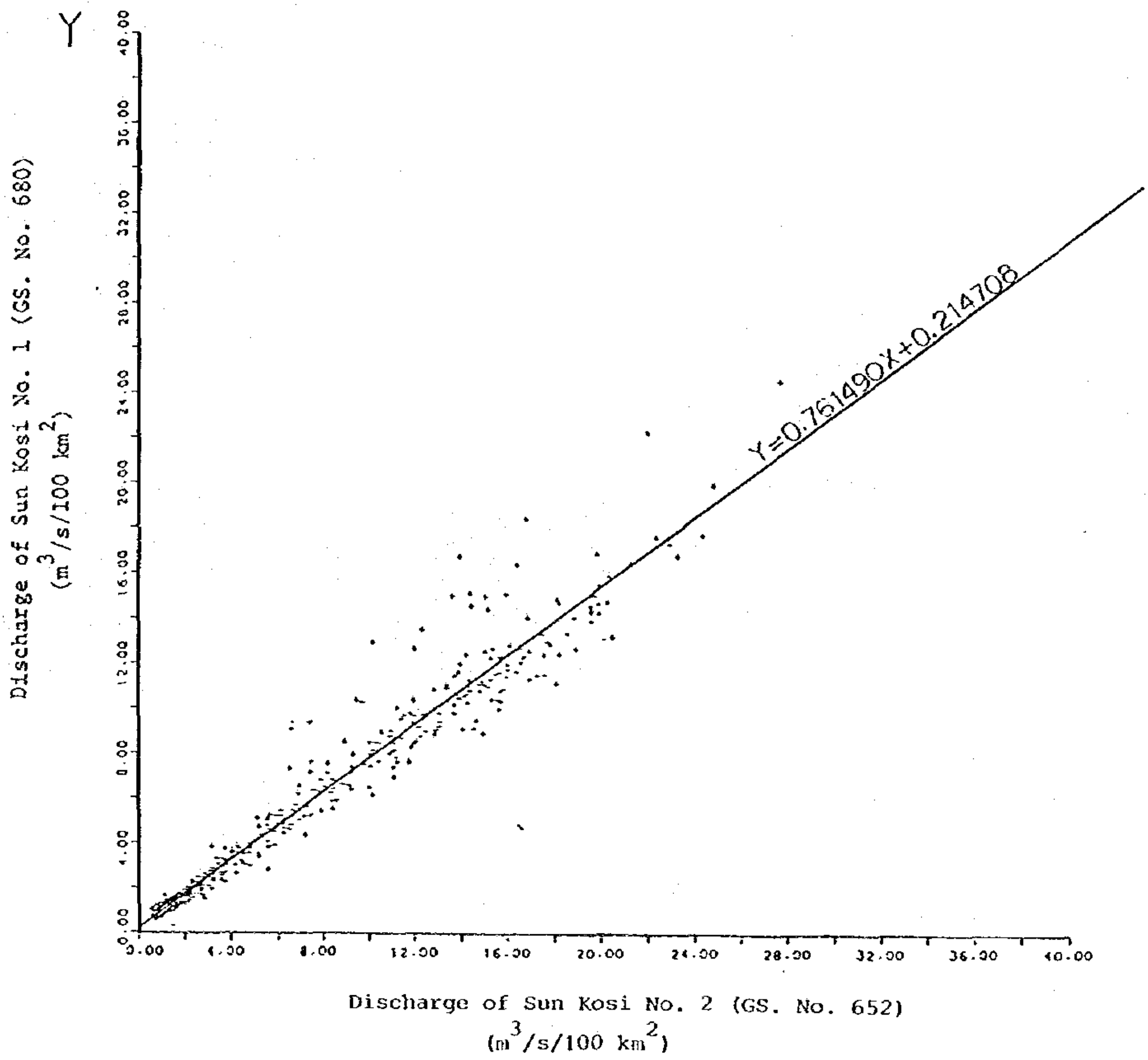


FIG. 2-11 (2 of 4) **CORRELATION OF DISCHARGE AT GAUGING STATION NO. 680 and 652**

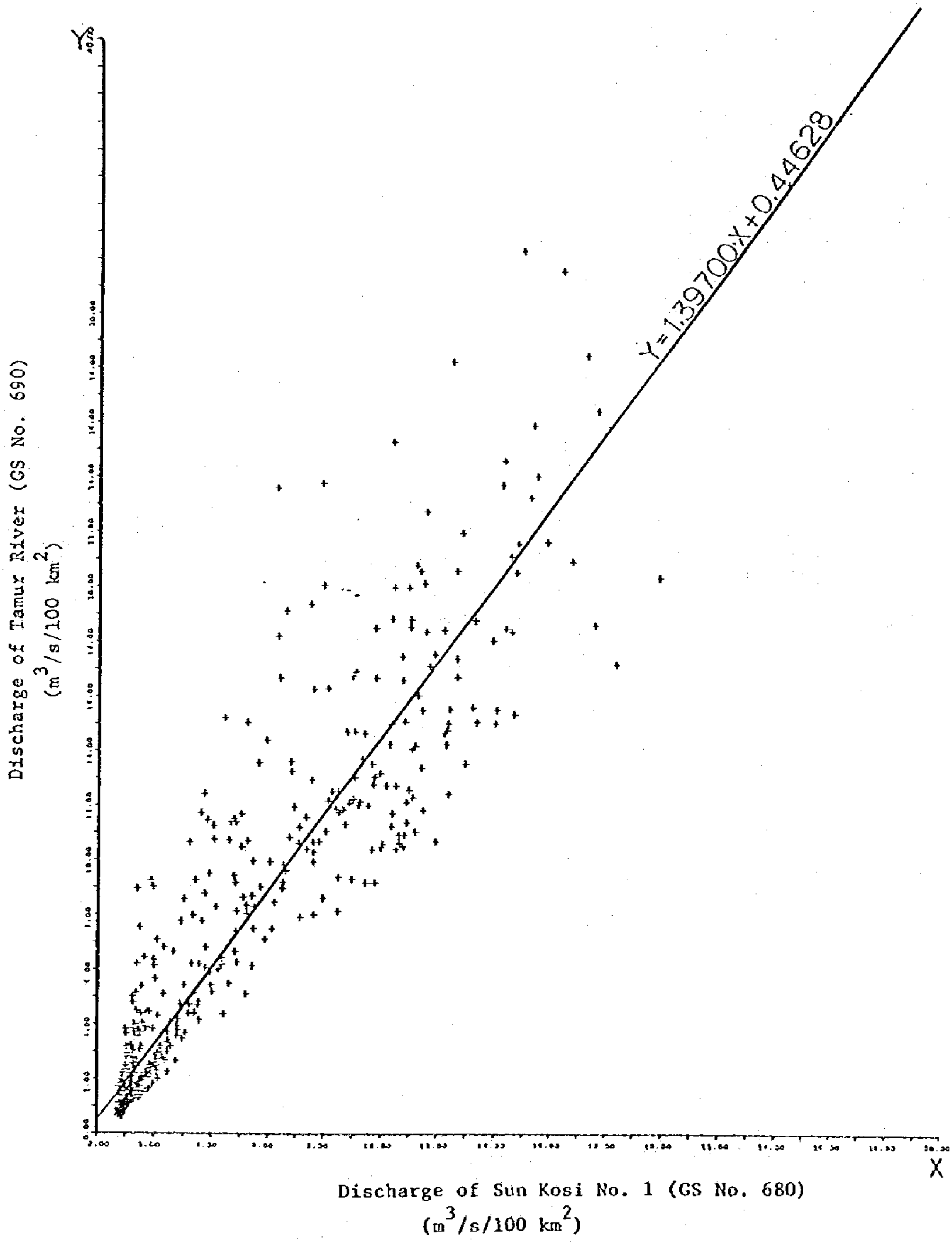


FIG. 2-11 (3 of 4) CORRELATION OF DISCHARGE AT GAUGING STATION NO. 680 and 690

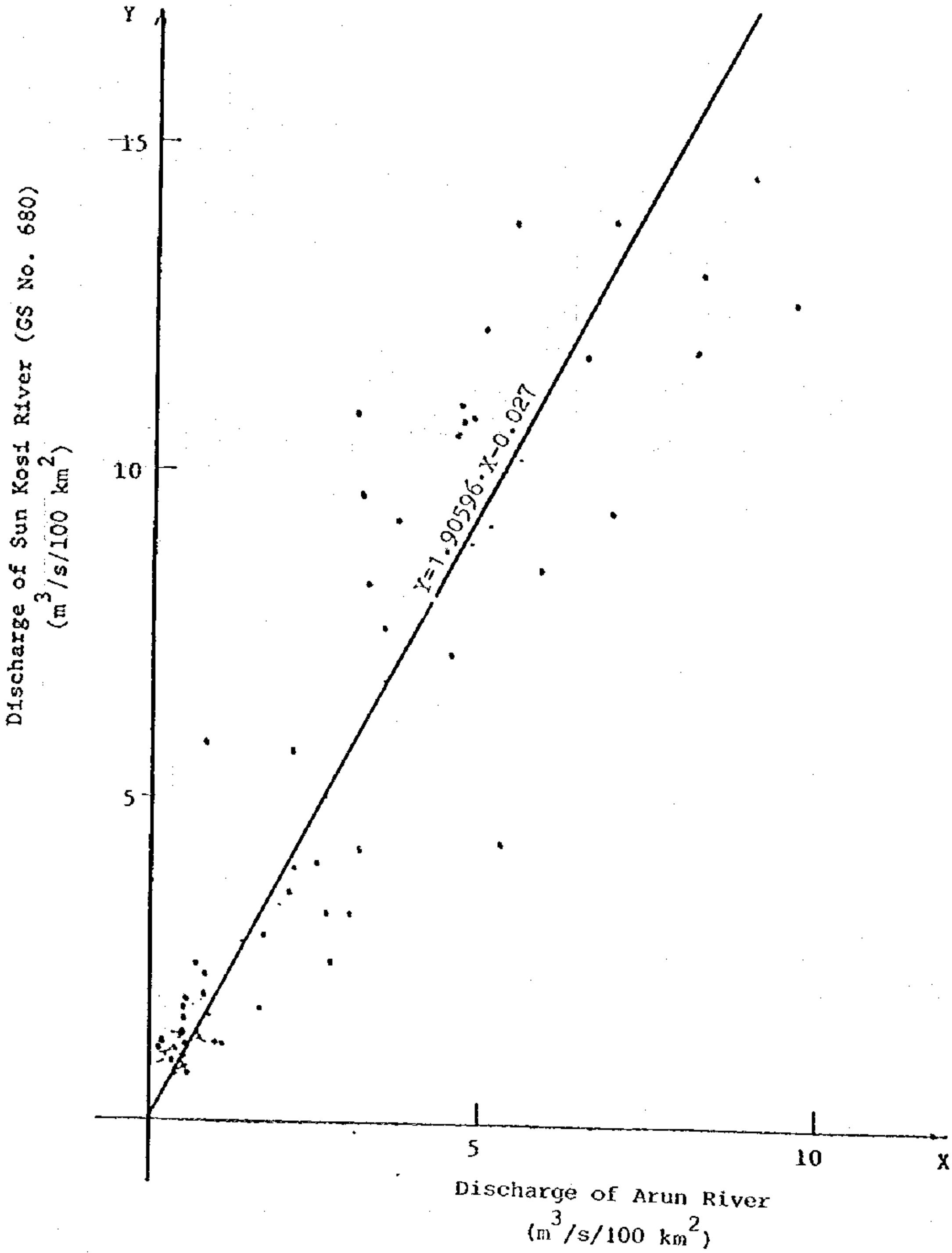
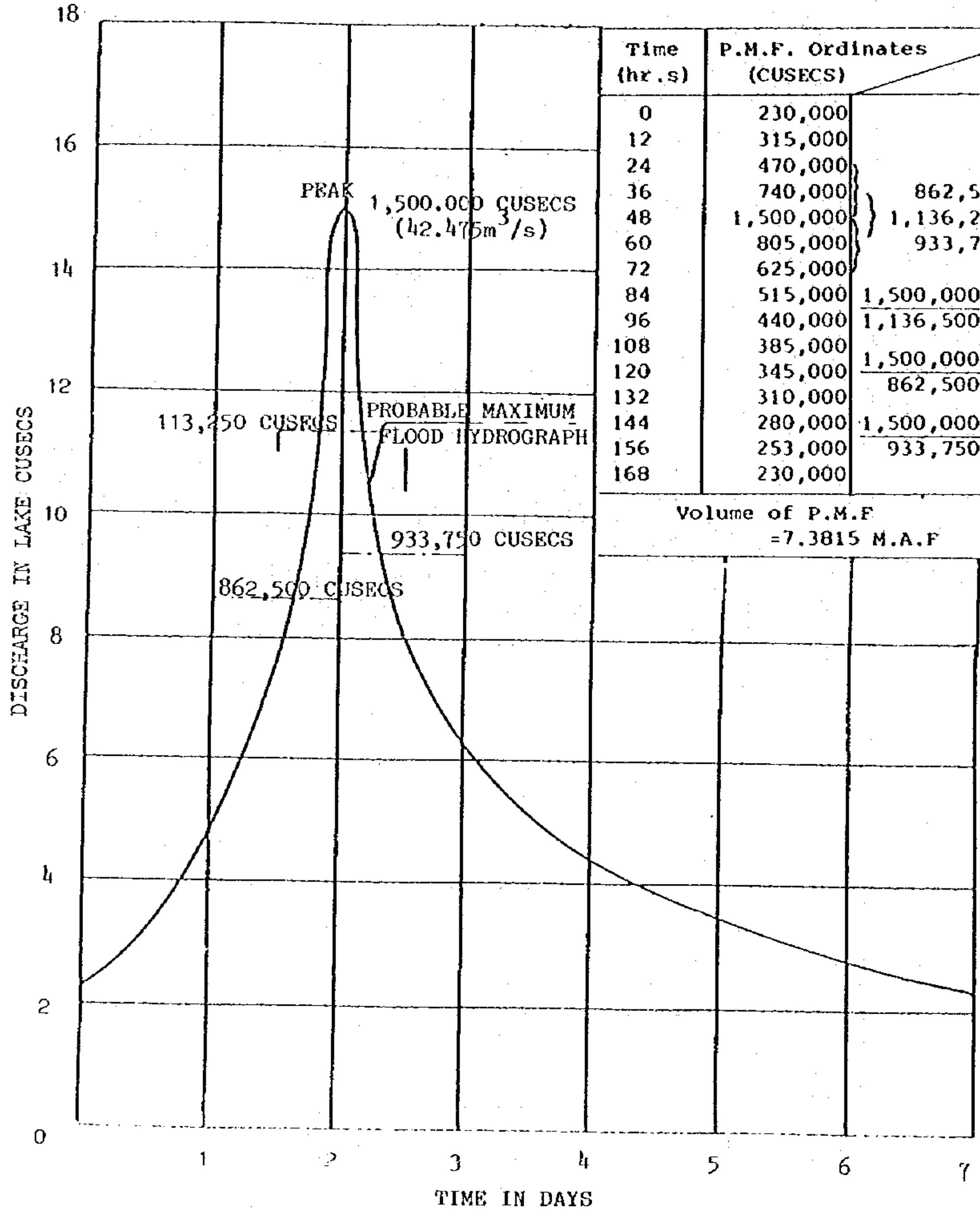


FIG. 2-11 CORRELATION OF DISCHARGE ON THE SUN KOSI AND ARUN RIVERS
(4 of 4)



Time (hr.s)	P.M.F. Ordinates (CUSECS)	
0	230,000	
12	315,000	
24	470,000	
36	740,000	862,500
48	1,500,000	1,136,250
60	805,000	933,750
72	625,000	
84	515,000	$\frac{1,500,000}{1,136,500} = 1.32$
96	440,000	
108	385,000	
120	345,000	$\frac{1,500,000}{862,500} = 1.74$
132	310,000	
144	280,000	$\frac{1,500,000}{933,750} = 1.61$
156	253,000	
168	230,000	
Volume of P.M.F =7.3815 M.A.F		

Note: The data was obtained from the Feasibility Report prepared by India in 1981.

FIG. 2-12 PROBABLE MAXIMUM FLOOD HYDROGRAPH

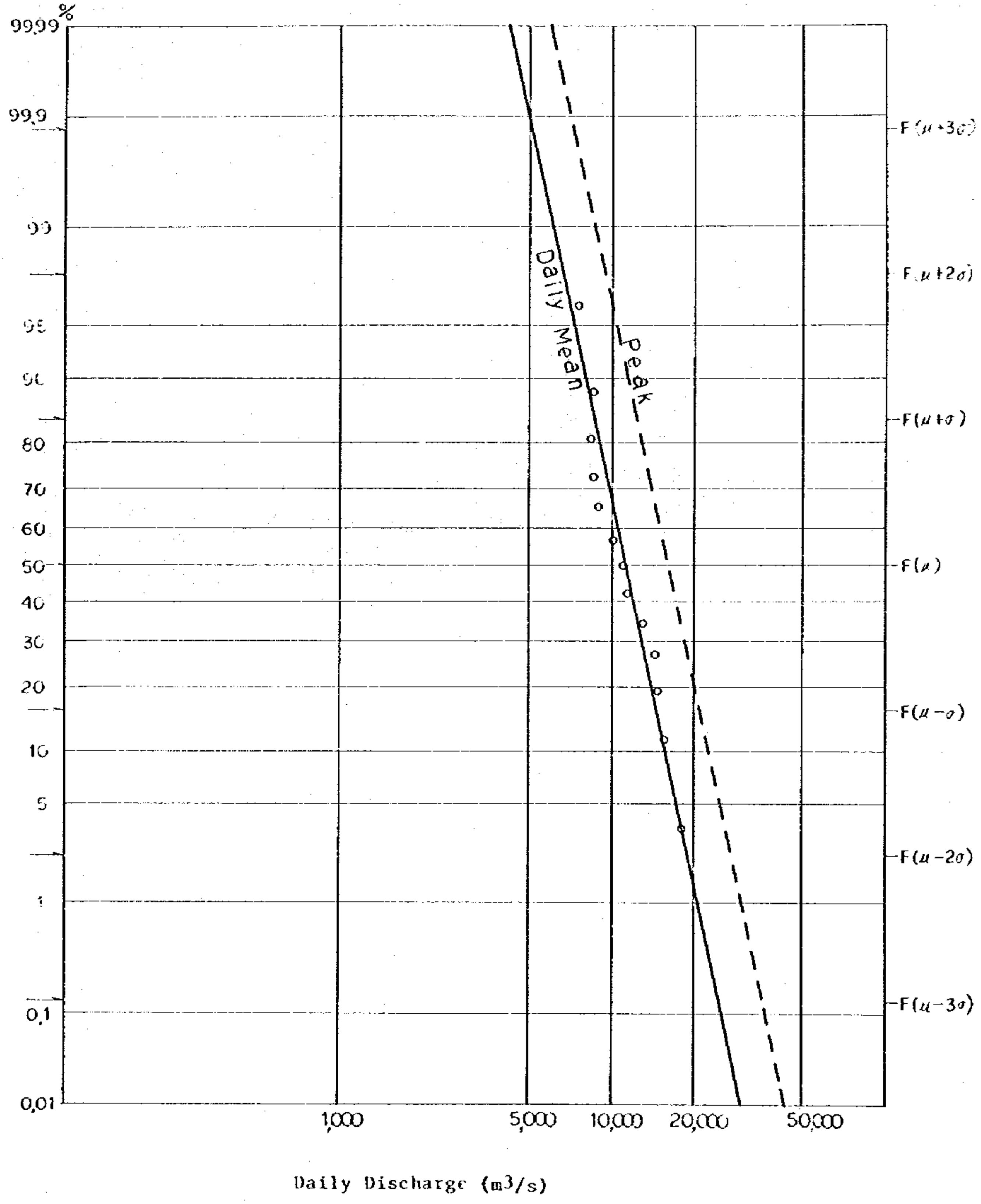


FIG. 2-13 PROBABILITY CURVE (SAPT KOSI RIVER)
(1 of 4)

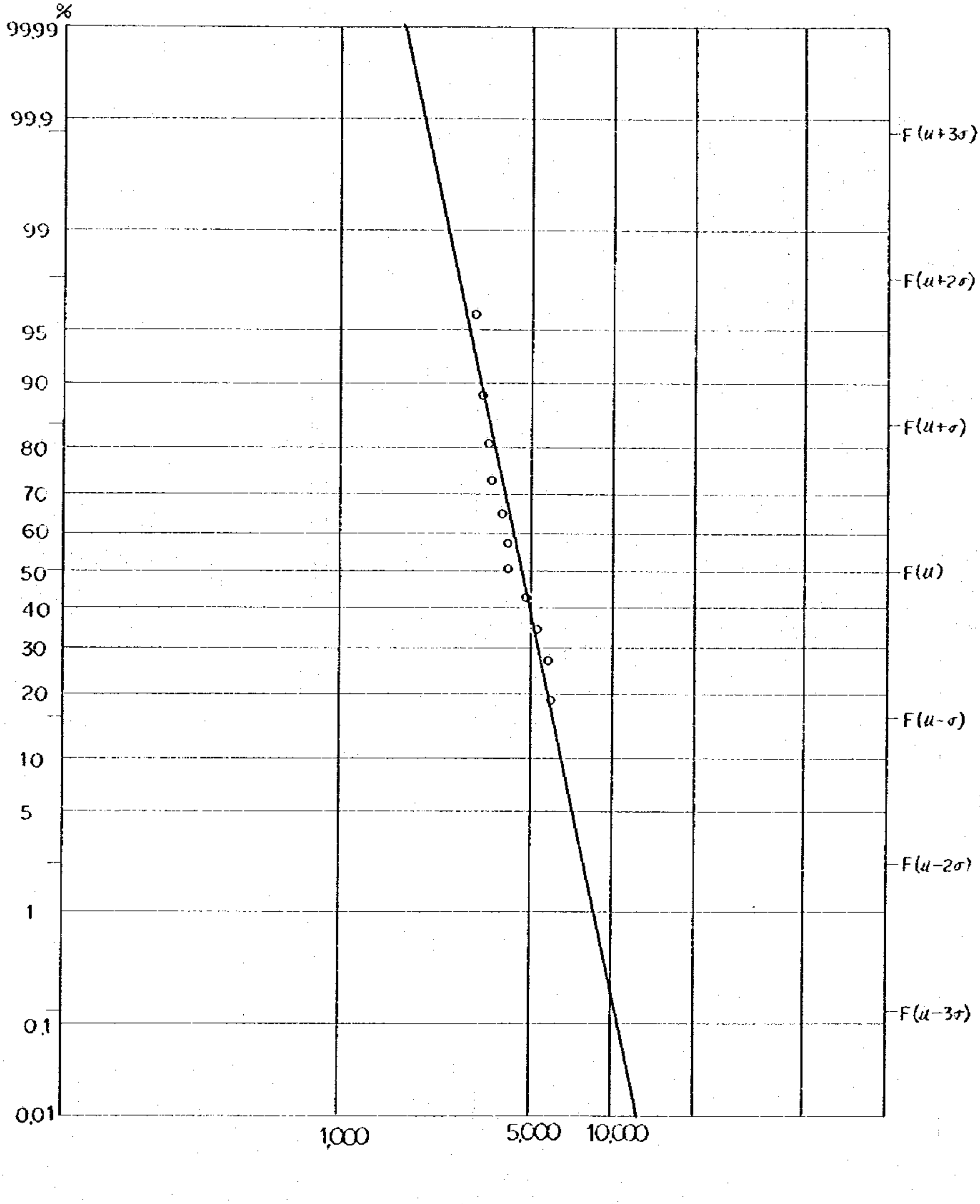


FIG. 2-13 PROBABILITY CURVE (SUN KOSI RIVER)
(2 of 4)

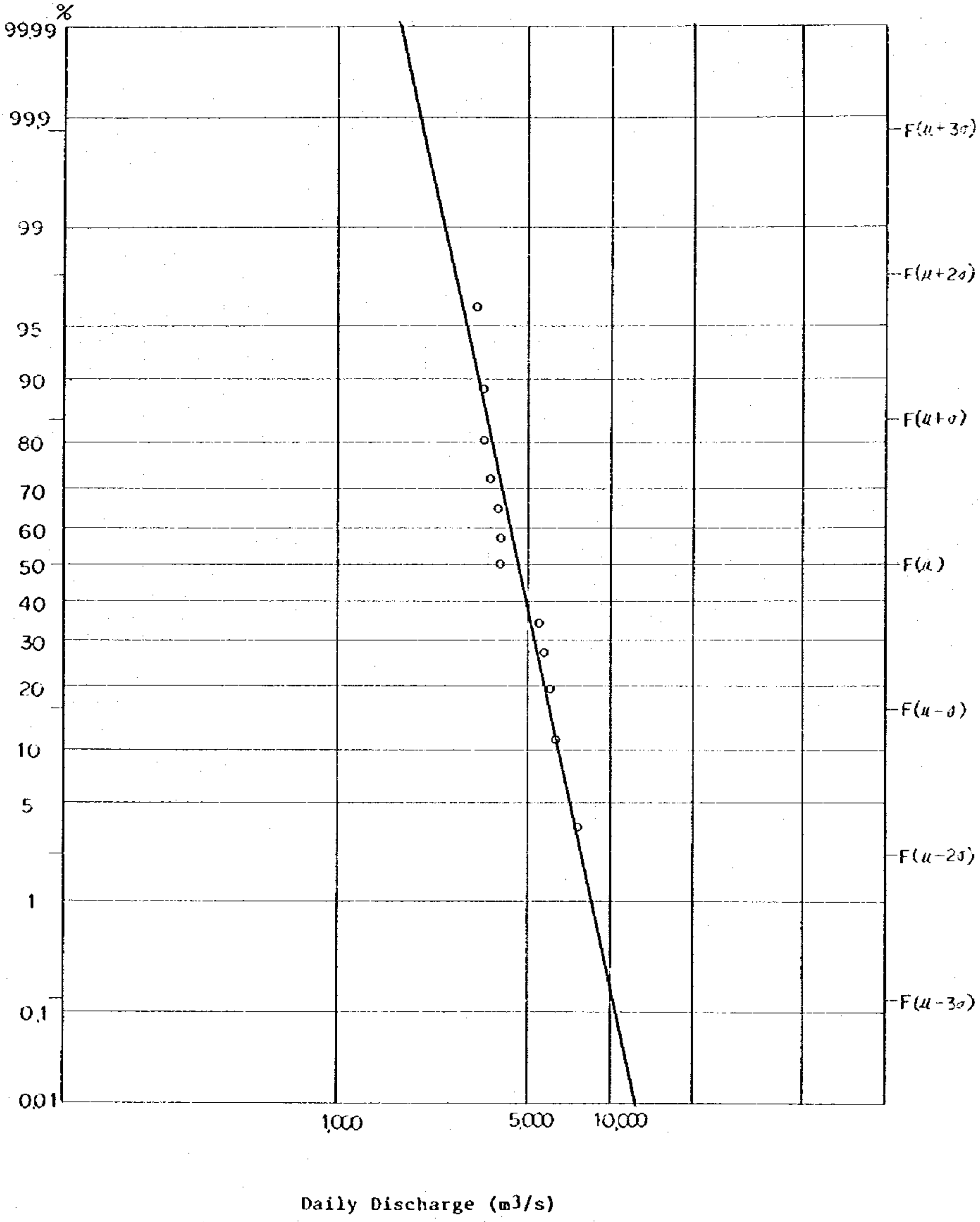
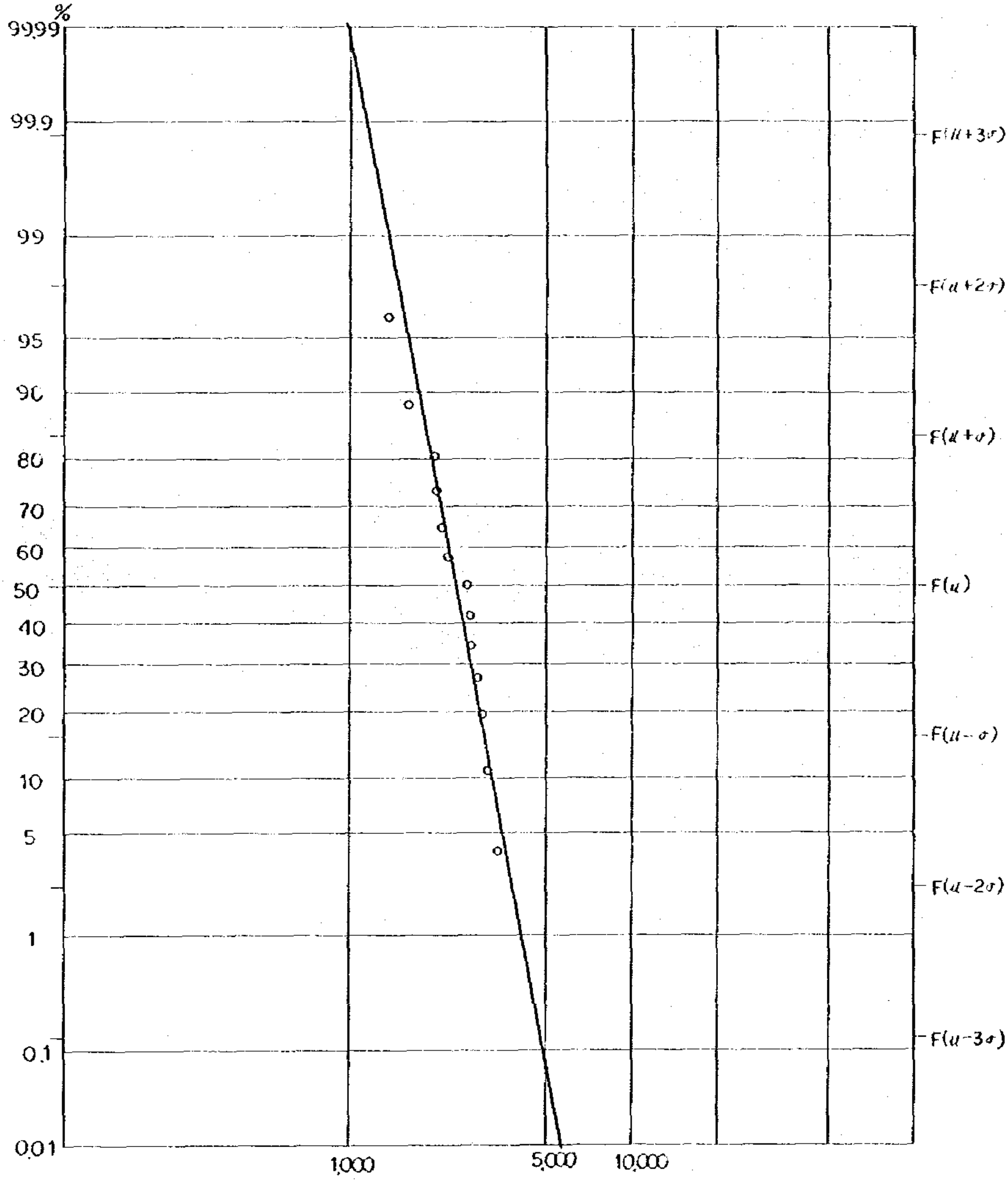


FIG. 2-13 PROBABILITY CURVE (ARUN RIVER)
(3 of 4)



Daily Discharge (m^3/s)

FIG. 2-13 PROBABILITY CURVE (TAMUR RIVER)
(4 of 4)

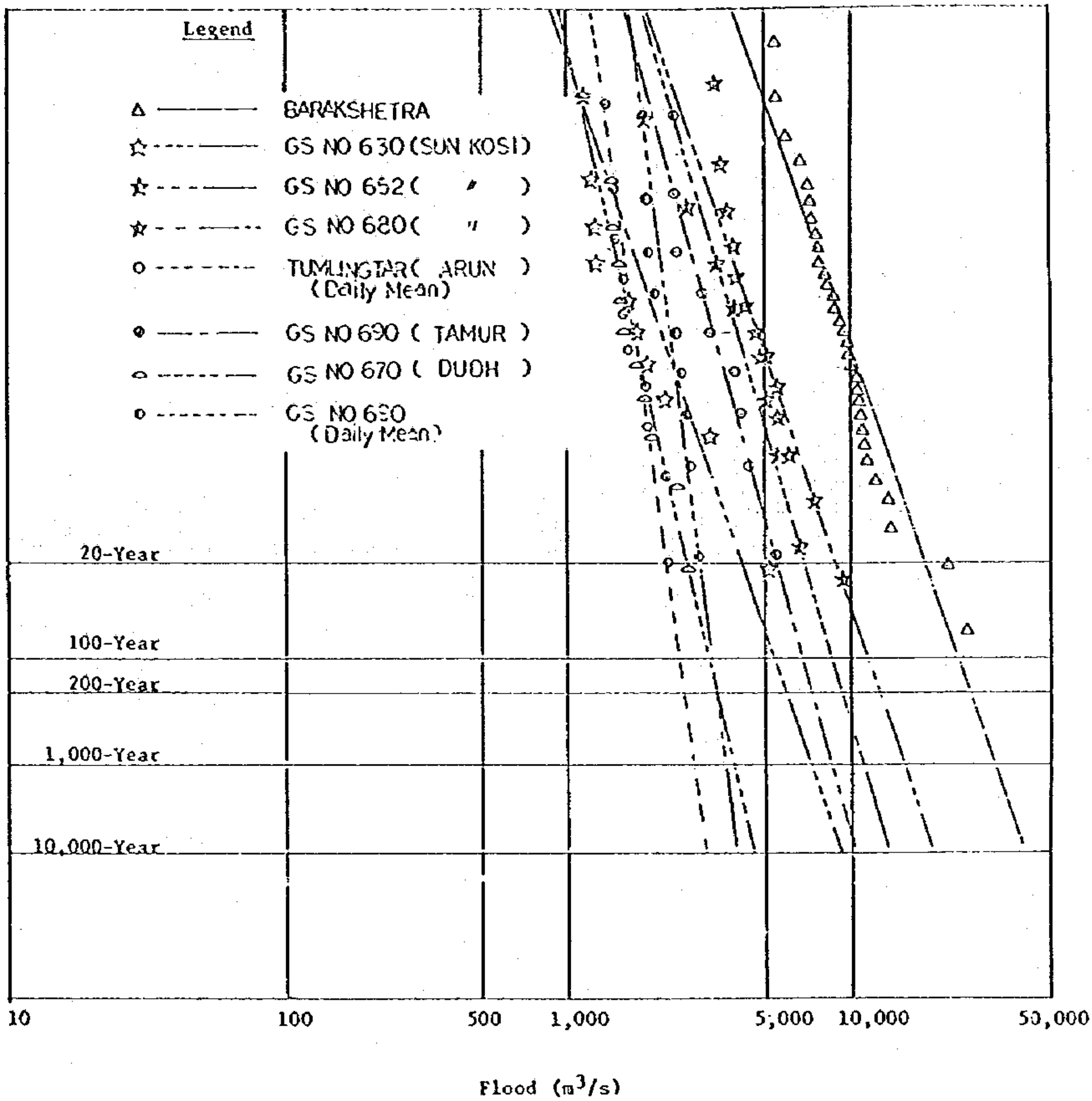


FIG. 2-14 FLOOD PROBABILITY CURVE

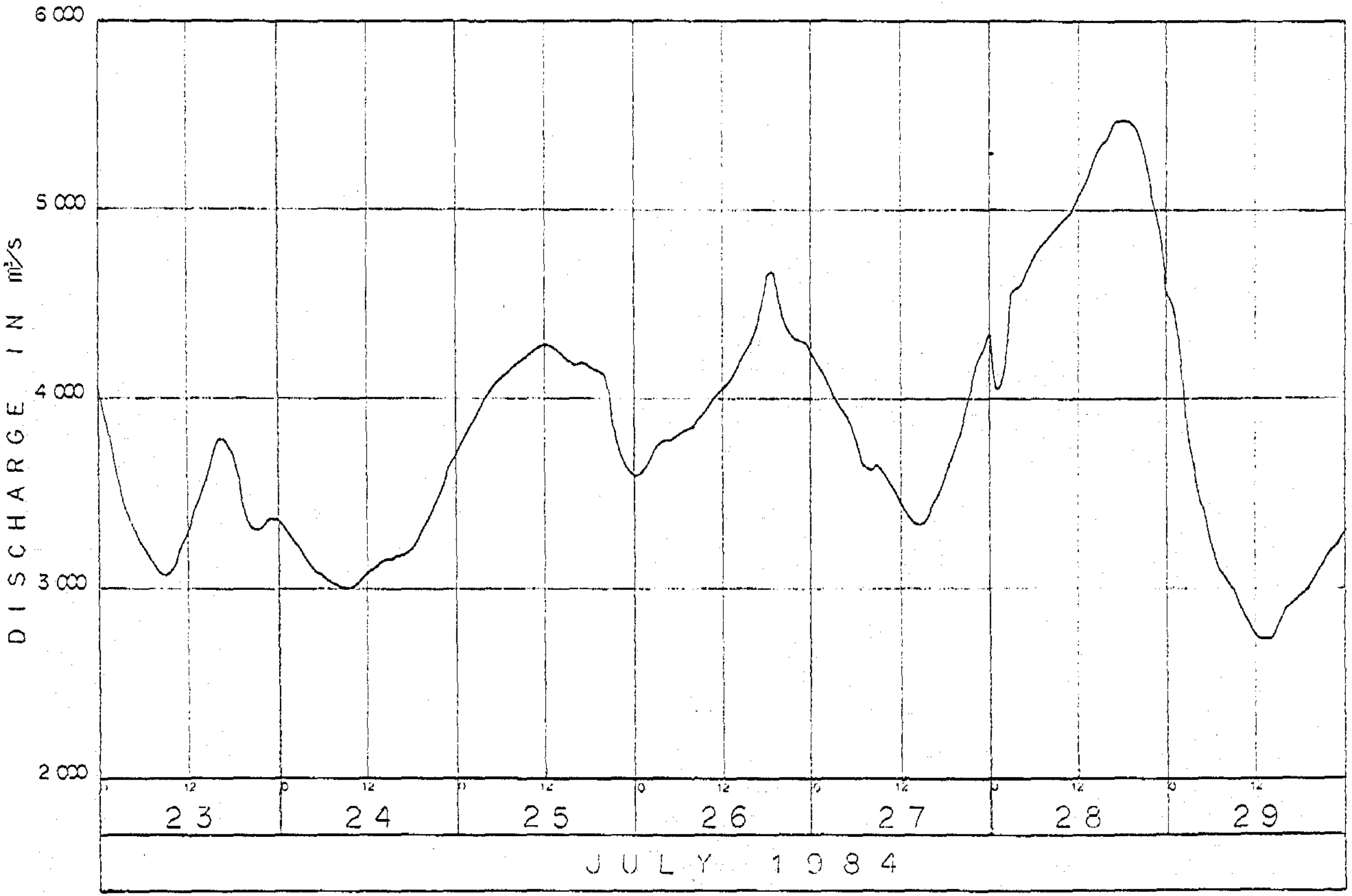


FIG. 2-15 HYDROGRAPH OF HOURLY DISCHARGE: SUN KOSI TIVER AT KAMPU GHAT (JULY 23-24,1984)

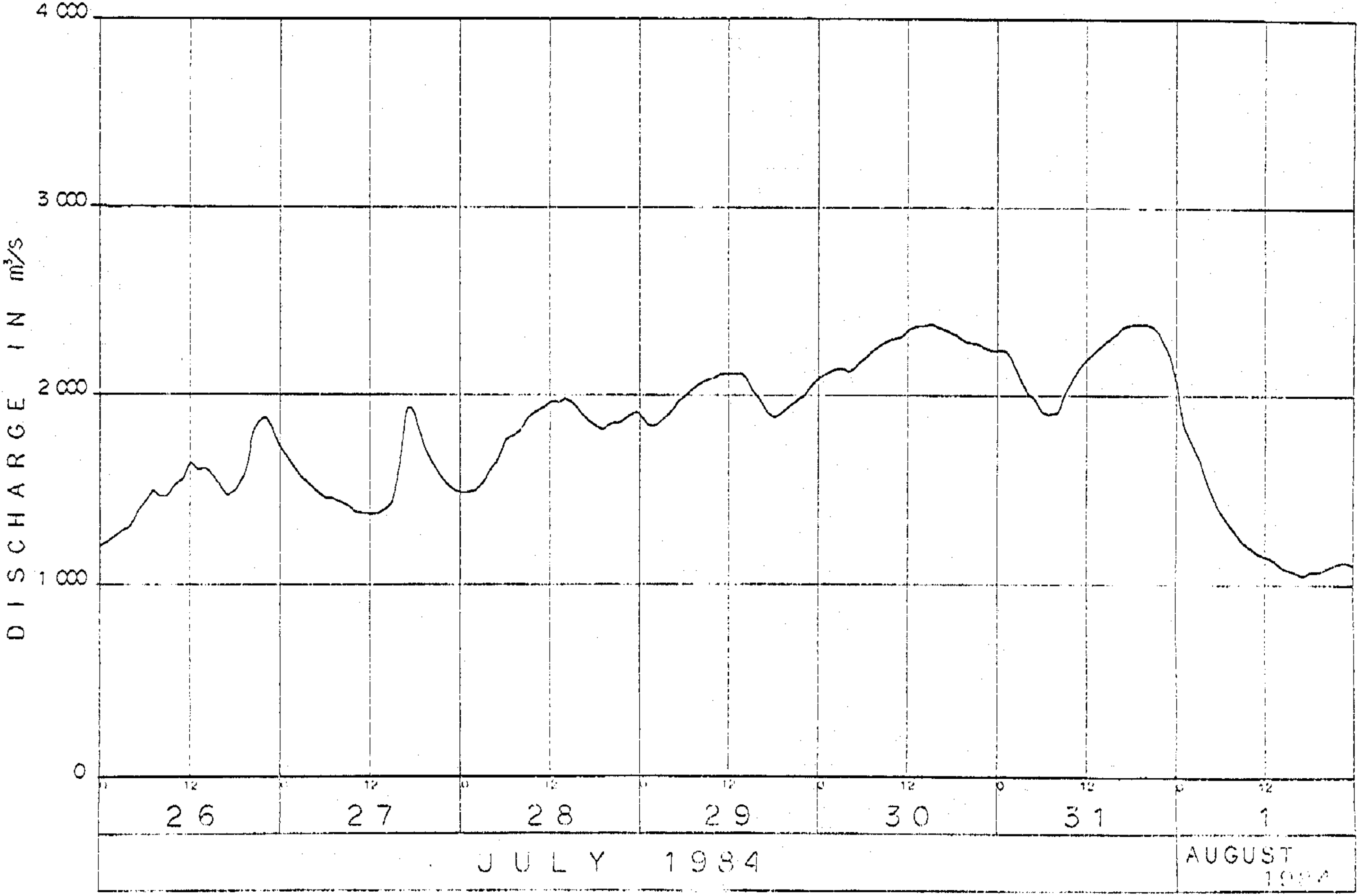


FIG. 2-16 HYDROGRAPH OF HOURLY DISCHARGE: ARUN RIVER AT RURIK GHAT (JULY 26-AUG. 1,1984)

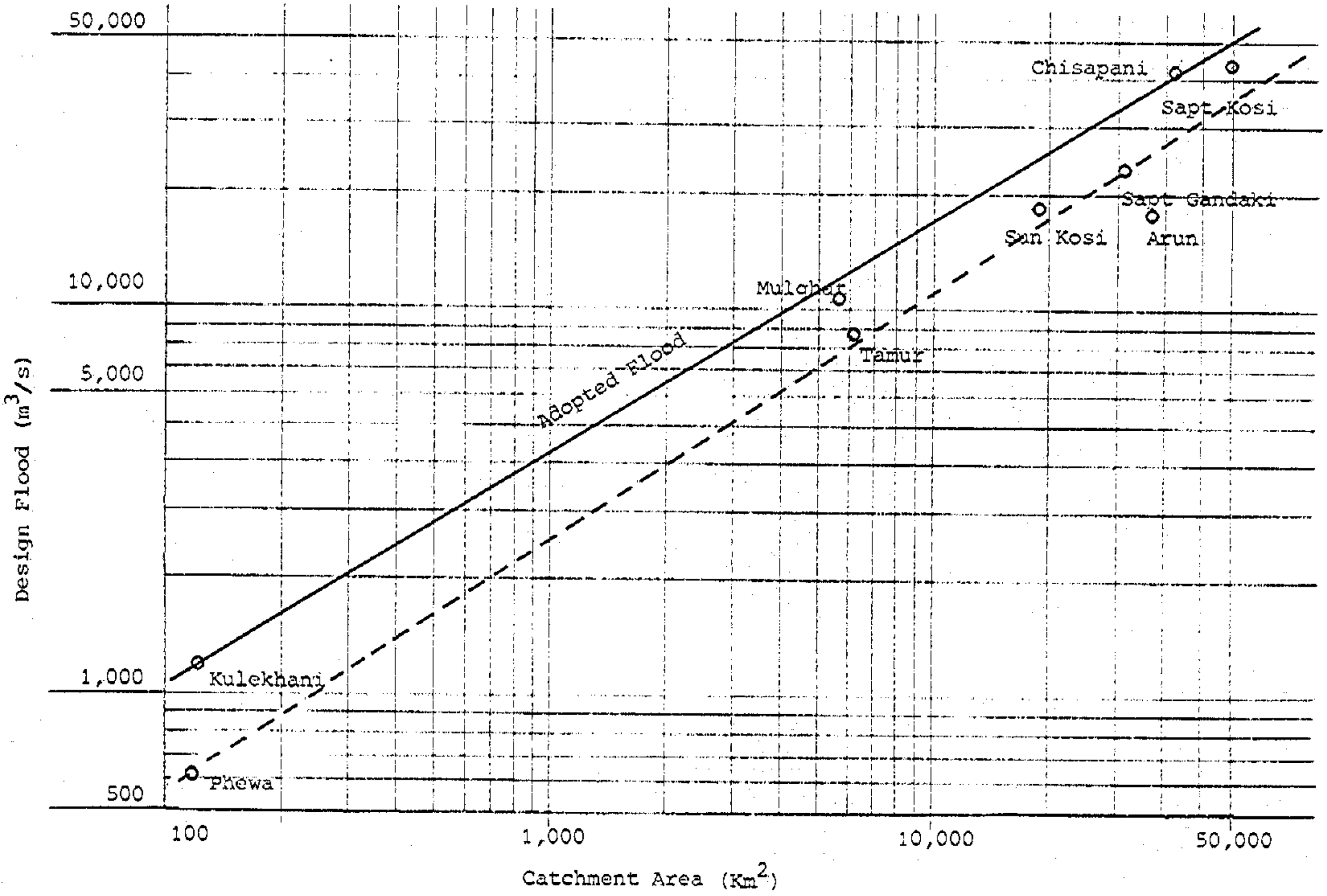


FIG. 2-17 **RELATIONSHIP BETWEEN CATCHMENT AREA AND DESIGN FLOOD DISCHARGE**

APPENDIX III

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GEOLOGY

1. TOPOGRAPHY AND GENERAL GEOLOGY

1.1 Topography

1.1.1 General

The Study area is located in the eastern part of Nepal between longitudes 85°20'-88°15'E, and latitudes 26°10'-28°07'N. The area can be broadly divided into two topographic regions; the Kosi Basin and the Terai Zone. The Kosi Basin encompasses both the Himalaya and Mahabarat mountain ranges with a wide range in elevation from 8,000m in the Himalayas along the Nepal - China border to 100m where the Kosi River flows into the Terai Zone.

The Kosi Basin in the Study area extends 230km from east to west and 120km from south to north, and is traversed by the Sun Kosi, Arun and Tamur rivers, as well as by numerous medium and small scale affluents. Although the catchment area of the Basin at the Nepal - India border is said to be 61,000km^2, the upper reaches of the Sun Kosi and its tributary, the Tama Kosi, as well as the Arun River, are located in Chinese territory within the Tibetan plateau, and catchment area within Tibetan territory is 26,450km^2 or 45% of the total.

The Terai Zone is located on the southern edge of the Kosi Basin, extending 30-40km north - south from the foothills of the Siwalik mountain range at the southernmost point of the Himalayas to the Nepal - India border, and 240km east - west over the flat alluvial plain.

Topography of the Study area, as with that of Nepal in general, may divided into the following parallel geographic regions.

- The Mountain Zone
- The Hill Zone
- The Terai Zone

A schematic topographical profile of eastern Nepal is presented on the following page.

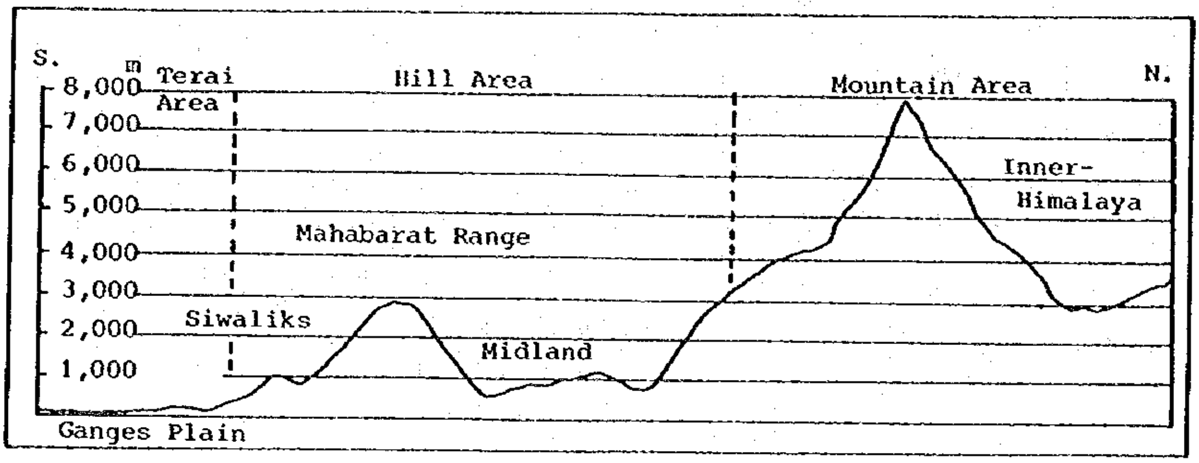


FIG. 3-1 SCHEMATIC TOPOGRAPHICAL PROFILE OF EASTERN NEPAL

1.1.2 The Mountain Zone

The Mountain Zone is situated at elevations over 3,000m and extends 30-40km southwards from the Himalaya mountain range along the Nepal-China border. The area is composed of steep mountains and deep gorges, with almost no farmland and a very low population density. Mountains over 5,000m in elevation are covered year-round with snow and ice for an area of about 5,700km^2.

1.1.3 The Hill Zone

The Hill Zone includes the southern slopes of the Himalaya mountains and the Mahabarat mountain range, ranging in elevation from 300-3,000m. Although there are numerous steep mountains in the 3,000m class, there is also a large percentage of relatively gently sloping topography. As the climate consists of subtropical to temperate, population density is comparatively high. This zone includes cultivated area with terraced fields up to elevations of nearly 2,500m.

The major problem in the area is rapid deforestation from the expansion of cultivated land which accompanies population increase, and the use of trees by local residents for both fuel and fodder. Moreover, in proportion to the high population density, transportation networks remain underdeveloped, and footpaths are the main type of transportation routes in the mountain areas.

1.1.4 The Terai Zone

Numerous rivers flow through the Terai Zone from the Mahabarat and Siwalik range, sedimentation from which formed the alluvial plain. Elevation of the said plain ranges from 60-300m with a north - south slope of 1/300-1/500. The Terai Zone is located at the northernmost part the Ganges Plain and until 10 years ago was covered by forest. Beginning in 1958, however, the area was opened in an effort to both eradicate malaria and develop new farmland. At present, the Terai Zone comprises the bread-basket of Nepal, and forested area in the same has been reduced to a small percentage of the whole.

The area has a tropical monsoon type climate and, although rainfall is comparatively low, the climate is divided into rainy and dry seasons. The majority of rainfall is concentrated in the former causing flooding of medium and small rivers. Repeated flooding is in turn causing erosion of the surrounding farmland.

In the upper reaches of medium-scale rivers such as the Bagmati, Kamla, Trijuga and Kankai rivers which flow through the Terai Zone, a basin has been formed ranging in elevation from 200-500m. This area is referred to as the Inner Terai, and agriculture is well-developed within the same.

1.2 General Geology

1.2.1 Stratigraphy

A geological map of eastern Nepal is presented in FIG. 3-2. The general stratigraphy of the area can be divided into 6 major geo'stratigraphic groups presented in TABLE 3-1.

TABLE 3-1 GEOLOGICAL GROUPS OF EASTERN NEPAL

Possible Period	Group	Lithology
1. Cenozoic	Recent	Unconsolidated sediments, gravels and sand, (alluvium)
	Siwalik	shale, sandstone, conglomerate
		Main Boundary Fault
2. Mesozoic - Paleozoic	Tethys	Shale and limestone
3. Paleozoic - Precambrian	Kathmandu	Mainly clastic and carbonate rock
	Midland	Mainly clastic and carbonate rock
		Main Central Thrust
4. Precambrain	Himal	Gneiss and schist (highly metamorphic rock)
	Igneous Rock	Granite and paragranite

The geology of eastern Nepal consists of stratum of various rock types such as low-high grade metamorphic rock, marine and non-marine deposits, silica rich-mafic rich igneous rocks.

1.2.2 Pattern of Distribution

The geology of the Study area can be roughly defined as follows:

(1) Main Central Thrust (MCT)

The Main Central Thrust (MCT) runs east-west between the Mountain and Hill zones, marking the border line between the northern Himal Group and central Midland Group.

(2) Main Boundary Fault (MBF)

The Main Boundary Fault (MBF) runs east-west through the center of the Hill Zone along the border line between the southern Siwalik Group and the central Midland and Kathmandu groups.

(3) MCT and MBF

As the MCT and MBF are major geological structural lines, the geological conditions within their vicinity are complex and various problems may be anticipated with regards to construction of engineering structures near the same.

(4) Himal Group

The Himal Group is the oldest stratum and is composed of highly metamorphic rocks. This group forms the great Himalaya chain as well as the steep mountainous topography of the upstream Kosi River. This group is mainly composed of gneiss and schist.

(5) Midland Group

The Midland Group, which is widely distributed in the central portion of the Kosi River, is mainly formed of carbonate rock, a type of clastic rock. The said group is easily weathered and the topography of areas where the same is distributed has comparatively gentle slope. Accordingly, agriculture and terraced cultivation is well developed in the Hill Zone. Landslide and slope collapse are also common in areas within this group.

(6) Kathmandu Group

The Kathmandu Group is distributed from the Kathmandu Valley to the Mahabarat range on the south side of the Sun Kosi River and, like the Midland Group, is composed of carbonate rock. Although the Kathmandu Group was formed about the same period as the Midland Group, the former is renowned for its abundance of diverse invertebrate animal fossils. From these fossils, it is assumed that the geological period of the Group correlates to the Late Precambrian period.

Granite intrusions occur frequently in the Mahabarat range where the Kathmandu Group is distributed, and such intrusions are accompanied by schist and easily weathered fragile rocks.

(7) Siwilak Group

This Group is found in the southernmost part of the Himalaya mountains. The same was formed in the Neogene Tertiary Period after the final stage of the Main Himalayan Orogency, and is composed of sedimentary river deposits carried from the Himalaya range. Accordingly, lateral changes in the rock faces are pronounced.

In addition, numerous folded axes and faults running in an east-west trend create a complex geological structure. Main rocks include shale, mudstone, sandstone and conglomerates, and generally these stratum are soft and weak with lower consolidation than old stratum.

(8) Tethys Group

Other than the above mentioned Himal, Midland, Kathmandu and Siwalik groups, there is also the Tethys Group. This Group is distributed only at elevations above 7,000m on Mt. Everest and is thus not widely distributed in eastern Nepal. Main rocks comprising the same are marine agrillaceous - carobonate sediments.

(9) Recent Group

This Group consists of alluvial deposits which form the Nepalese Terai Plain and the Indian Ganges Plain and is comprised of unconsolidated sediments such as gravels, sand and clay.

1.2.3 Orogenic Movement and Geological Structure

Paleontological content required for correlation is particularly lacking in the older strata such as the Midland and Himalaya Groups, as the same have been subjected to complex tectonic movement. The geotectonic lines which determined the geological structure of the area consist of 2 major thrusting faults; the Main Central Thrust and the Main Boundary Fault. These faults extend in an E-W trend across Nepal, acting as the major division between formation groups.

Neotectonics in the Himalayas are presently unclear, and there are numerous areas of debate concerning geological structure. However, the theory that the orogenic process began after the Teriary Period is becoming more generally accepted as evidenced by the recent Plate Tectonic Theory.

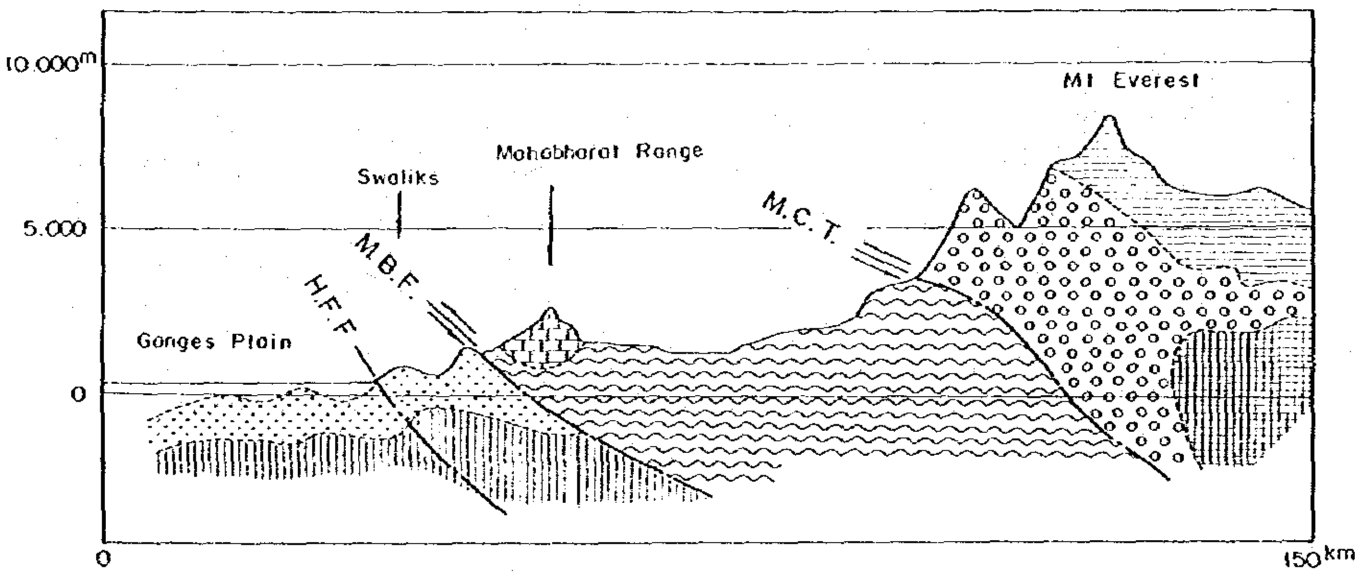
The sequence of orogenic movement is believed to be as follows:

a) Upheaval of older sedimentary rocks and the central axis portion during the Oligocene Period

b) Greatest orogenic movement in the Middle Miocene Period, and particularly upheaval of the Siwalik Zone

c) Main upheaval of the Siwalik formation occuring after the Pliocene Period with orogenic movement continuing to the present day

The source of this orogenic movement is south-north trend horizontal compressive stress which arises from collision between the Indian and Eurasian plate. It is generally accepted today that this stress which occurs in the depths of the Eurasian Plate provides the structural power of orogenic movement. Radiometric dating of intrusive granitic rock which is closely related to the final stage of orogenic movement indicates a young age of 15 million years. This clearly shows that orogeny in the Himalaya range is comparatively young and upheaval is presently continuing. The map area of the same is thus a plate to plate collision zone. A schematic geological profile is presented in FIG. 3-3.



1	Recent Group	7	Indian basement
2	Siwalik Group	8	Tibetan basement
3	Tethys Group	M.C.T	Main Central Thrust
4	Kathmandu Group	M.B.F	Main Bundary Fault
5	Midland Group	H.F.F	Himalayan Frout Fault
6	Himal Group		

FIG. 3-3 **SCHEMATIC GEOLOGICAL PROFILE**

The mountainous region is in the process of large scale orogeny,and sediment produced from the same is carried by the rivers to the lower reaches. Sediment volume in each river is large due to several factors: steep terrain; young orogenic movement; rainfall of over 2,000mm during rainy season (June to October); weathering of bedrock due to high humidity and heavy rainfall; steep river gradient; poor vegetation on the steep mountain slopes; soil composed of easily eroded unconsolidated sediments; and lack of river treatment and soil erosion control schemes in both the mountains and lowlands.

The combination of the above factors results in widespread landslides, slope failure, etc., which further increase the amount of sediment in the rivers.

1.2.4 Geological Conditions at Proposed Priority Sites

Conditions required for dam foundation can be summarized as follows:

a) sufficient reliable support strength and shearing strength; and

b) resistance to permeation

As the Study area was formed from the Mesozoic to Precambrian periods, the same has the following geological characteristics which require special consideration in dam planning.

a) Deep weathering occurs in the granite rock area (including gneiss).

b) Water leakage from underground caves is prevalent in the carcareous sediment zone.

c) Due to the arrangement of original minerals in a uniform direction, foliation occurs in the schist while exfoliation along the foliation plain is pronounced and resistance to vertical stress on the said plain is high. Resistance to horizontal stress however, is extremely low. In particular, gneissosity of mica schist is high and anisotropy is very pronounced.

d) Proliferance of faults and large fragmented portions in the metamorphic zone exist. As this zone often follows along the tectonic line, there is much directionality in the arrangement of faults and folding.

e) Although not as pronounced as in schist, gneiss also has stratified arrangement of minerals and a strong anisotropic trend. Moreover, arrangements include variations from silica rich type strata to strata with numerous stripes of color mineral. Those portions of gneiss with accumulations of biotite are formed of easily weathered soft strata.

The majority of proposed dam sites are located in the Hill Zone Midland Group. The three sites on the Arun River however, are located on Himal gneiss on the northern side of the Main Central Thrust.

All priority sites are marked on the geological map in FIG. 3-2. Location of sites either on the two thrust lines or on the carcareous sediment zone was avoided owing to difficulty in dam construction.

The following points should be considered in geological evaluation of each site.

a) Midland Group rocks are folding and have a complex geological structure. Sun Kosi No.2 site, for example, has slipfaced layers on a folding axial plain and numerous cracks which should be carefully noted in planning.

b) Excluding Sun Kosi No.3, the main formation rock of the Midland Group Zone site is schist formed by metamorphism of clastic rock with some phyllitic slate interbedded.

c) Tamur No.3 site is an example of sites where foundation rock is mainly formed by phyllitic rock.

d) As schist is form by phyllitic rock, it is easily broken lamellately, and permeability and rock strength of the same is considered inferior.

e) Tama Kosi No.3 is composed of paragneiss. The paragneiss, like gneiss and schist, is highly anisotropic rock, which is one cause of weathering.

In addition to the above, detailed investigation for each site is required in the next survey. At this point, however, the proposed sites do not appear to have demerits for dam planning.

1.2.5 Diversion Project

The Sun Kosi Diversion Scheme which is the key irrigation project in the Terai Area, consists of a 17km diversion tunnel to divert water from the Sun Kosi River to the Kamla River. The tunnel route passes through the Mahabharat Range and the Siwalik Hills which are represented by Neogene formation and the Midland Group and Kathmandu Group formed during the Paleozoic and Precambrian periods. The main Boundary Fault divides the above two Group formations.

The said Fault was caused by the upheaval of the Mahabharat Range and a wide shear zone exists in the area of the same. Accordingly, in selection of the tunnel route the following points should be considered.

a) Construction near the major fault will require extensive engineering treatment; and,

b) Faults and shear zones are extremely disadvantageous for foundation in tunnel formation, and the amount of over-break and timbering required will be greatly increased.

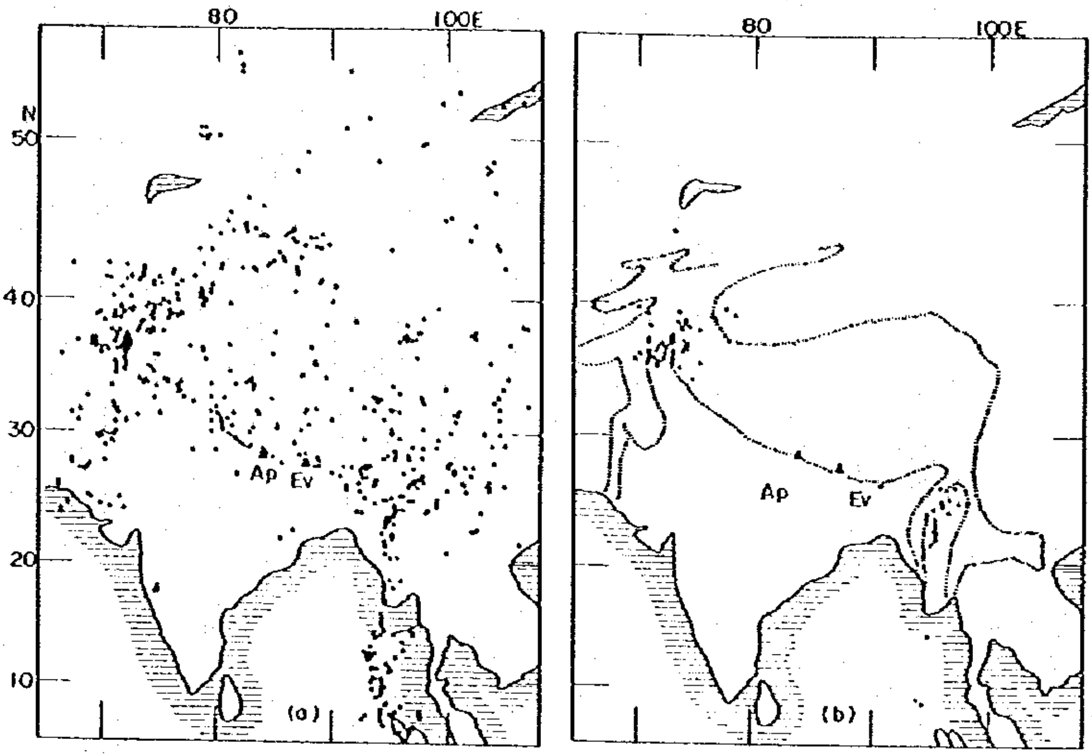
However, as the Sun Kosi diversion route is located on the MBF compression zone where the width of the faulting shear zone is judged to be only about 10m, the same should not present any major hindrance to plan implementation.

In the Trijuga Diversion Scheme, due to distribution of the main structure of the MBF and the large shear zone on the Sun Kosi River left bank (north side), faulting structure is expected to have little influence on the intake and tunnel route. However, the diversion route from the Tamur River, which is the alternative diversion scheme for the Sapt Kosi East area, crosses several faults including the MBF and accordingly, careful planning is required.

1.3 Earthquakes and Crustal Movement

1.3.1 Characteristic Distribution of Epicenter in and around the Himalayas

The Himalaya region is an active earthquake zone. FIG. 3-4 presented on the following page shows the results of the data collected by ESSA (Coastland Surveying Department, USA) from 1961-67 on epicienter distribution in the said region alone.



▲ Ap: Mt Annapurna, Ev: Mt Everest

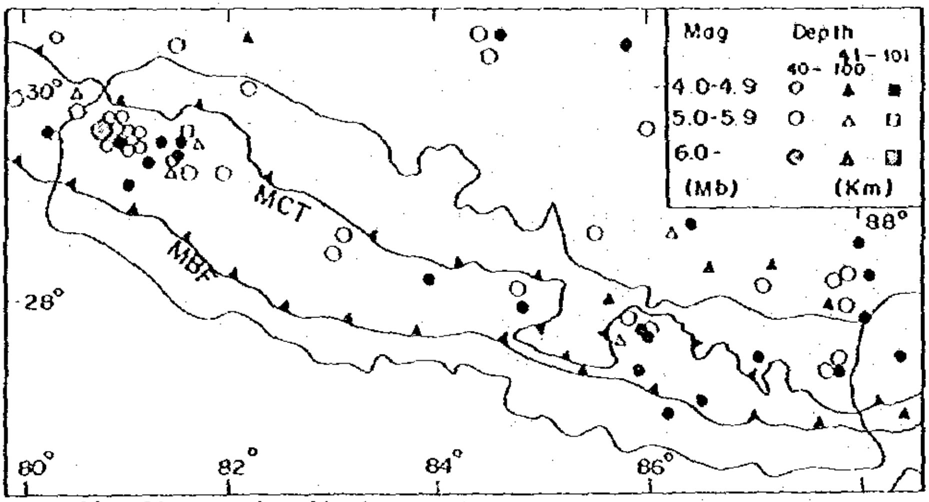
FIG. 3-4 **EPICENTER DISTRIBUTION OF SHALLOW (a) AND DEEP EARTHQUAKES (b) IN AND AROUND THE HIMALAYAS**
Ap: Mt. Annapurna, Ev: Mt. Everest

The above epicenter figure differs significantly in comparison with the general world trend. Firstly, despite the fact that no trench exists on either flank of the Himalaya range, deep earthquakes are concentrated around the same. Secondly, distribution of shallow earthquakes is clearly bounded on the southern edge by the Himalaya range while the northern boundary, on the other hand, is widely dispersed and unclear.

1.3.2 Earthquakes of Nepal

Although Nepal has suffered numerous damages due to earthquakes in the past, seismic observation was only begun recently. FIG. 3-5 shows earthquakes occuring in Nepal and its vicinity from 1964-77 based on observations of the International Seismological Center.

From this figure, it is evident that numerous earthquakes are concentrated in western Nepal, including the earthquake of 1966. The epicenter distribution of central and eastern Nepal is concentrated between the MCT and MBF and along the northern side of the MCT. In comparison, less earthquake activity occurs in the western region and earthquakes on the southern side of the MBF are extremely rare. Depth of most observed earthquakes is within 40km, exhibiting shallow earthquake characteristics.



Mb: Magnitude of body wave (1964~1977)

FIG. 3-5 **SEISMICITY IN/AROUND NEPAL**
Mb: Magnitude of Body Wave (1964-77)

FIG. 3-6 presents epicenter distribution in central and eastern Nepal for earthquakes with magnitudes greater than 2 observed from April 1980 to November 1981. During this period, the pattern of epicentral distribution for earthquakes observed with magnitudes under 4 was the same as that for magnitudes 4-6 as shown in FIG. 3-6. Moreover, close observation reveals that comparatively high magnitude earthquakes occur along the MTC. In the Kathmandu Valley, on the other hand, no earthquakes were observed during this period. Along the Indian border in southern Nepal, earthquakes of magnitudes greater than 5 were not observed. It is therefore assumed that a seismicity gap occurs in the said area.

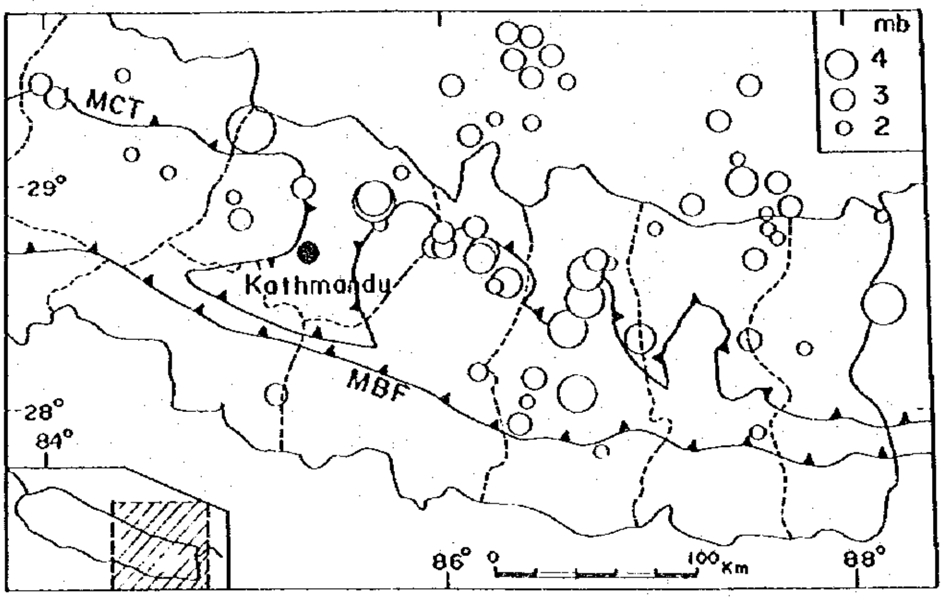


FIG. 3-6 EPICENTER DISTRIBUTION IN MIDDLE/EASTERN NEPAL

(1) Historical Earthquakes

It is a well-known fact that earthquakes occur at the same spot in a series of intervals. The lengh of interval, however, differs according to location. Existing records of seismic waves in Nepal cover only a 100-year period. However, based on detailed analysis of historical records of serious earthquake damage, earthquake intervals and future earthquake intensity can be estimated to some degree.

TABLE 3-2 presents historical earthquakes in the Kathmandu Valley.

TABLE 3-2 HISTORICAL EARTHQUAKES IN THE KATHMANDU VALLEY

Year	Description
1242	Severe earthquake in which many houses collapsed
1255	Severe earthquake; collapse of many temples and houses killing 20 - 30% of the population including King Abhayamalla
1255-58	King Jayedeva's reign troubled by a violent earthquake, famine and epidemics
1344	Death of King Jayarimalla in Deopatan the day after a violent earthquake

cont'

1387	Severe earthquake during the reign of Jayasthitimalla
1408	Tremendous earthquake; temple at Machindranath and all other buildings destroyed; innumerable human beings perished
1681	Nepal Valley rocked by severe earth tremor; number of houses damaged uncountable; followed two days later by a less violent shock
1767	21 earthquake shocks in twenty-four hours
1808	Violent earthquake destroying many houses; great temples, such as Pashupati and Taleju escaped injury but in Bhadgaon, numerous lives were lost
1823-24	17 earthquake shocks in 24 hours
1833	Earthquake shock towards evening followed by another at midnight; fourth shock so violent many buildings and temples collapsed in Kathmandu, Patan, Bhadgaon and villages. Similar to catastrophe of 1408.

This table is based on a document recording past events written in the Newar Dynasty which ruled the Kathmandu Valley. Eleven historical earthquakes occuring from 1242 to the 19th century are recorded in the same.

TABLE 3-3 presents major earthquakes occuring in the 20th century. Five earthquakes of magnitudes greater than 6 were recorded and seismological data from the same is available for future study.

TABLE 3-3 **MAJOR EARTHQUAKES IN THE 20TH CENTURY**

Date	Epicenter	Magnitude 1/	Location and Damages
1916	30.00 N	7.5	Far Western Nepal
8.28	81.00 E		Extent of damage unclear
1934	26.5 N	8.4	Nepal - India Border
	86.5 E	(Ms)	Deaths: 8,519 (Nepal), 7,253 (India)
1.15	27.55 N	8.3	Houses Destroyed: 80,893 (Nepal)
	87.09 E	(Ms)	

cont'

1936 5.27	28.5 N 83.5 E	7.0	Western Nepal (Dhaulagiri) Damages unclear
1966 6.27	29.6 N 80.8 E	6.0 (Mb)	Far Western Nepal Deaths: 42, Houses Destroyed: 3,969
1980 7.29	29.6 N 81.1 E	6.1 (Ms)	Far Western Nepal Deaths: 178, Houses Destroyed: 13,258

1/: Richter's local magnitude
Ms: Magnitude of surface wave
Mb: Magnitude of body wave

Past earthquakes in Nepal are considered to be more numerous than those recorded in the table. To estimate the number of previous earthquakes, more data on historical earthquakes must be collected. From this data and future earthquake observation, theoretical understanding of the earthquake mechanism in Nepal can be improved.

General trends of earthquakes in central and eastern Nepal may be summarized as follows:

a) The crust directly below the Himalaya mountains is approximately 80km thick which is extremely thick in comparison with the 30-60km thickness found in other continental crusts.

b) Earthquakes occur mainly to the north of the MBF boundary.

c) Less seismic activity occurs in central-eastern Nepal than in western Nepal.

d) The earthquake mechanism has an angle of about 45° and earthquakes on the south side are caused by reversal faulting movement below the Himalayan range.

e) According to plate tectonics, the Himalaya range is subjected to strong south-north trend compressive stress, similar to Hindukush and Burma on the two edges of the India plate, by collision of the Indian subcontinent and Urasian continent.

f) Compressive stress caused by movement of the Indian subcontinent to the south works against the front face of the Eurasian continent to the north in the form of large scale folding and sporadic shallow earthquakes while at the same time absorbing stress.

g) Almost no deep earthquakes with hypocentric depths greater than 100km occur.

h) Earthquakes which occur in central and eastern Nepal are considered to be shallow earthquakes occurring in the inner inland crust. Even for magnitudes over 6, the greatest damage is caused not by seismic movement itself but by resultant secondary effects such as landslides and debris flow.

i) As the above type of earthquake is known to occur in Nepal, external stress due to earthquakes must be considered in design of the Kosi River Plan as well. Evaluation of earthquakes is required for earthquake proof design based on location, frequency and actual results of previous earthquakes. The following are methods for earthquake proof design.

Seismic intensity method: static analysis

Previous earthquakes are statistically measured, maximum acceleration of the proposed construction site is determined and acceleration selected according to priority of the structure is used in planning. This method is based on expectation analysis. The majority of concrete gravity dams are designed according to seismic intensity.

Simulation method of seismicity: dynamic analysis

Fill dams tend to become larger in scale each year. As the seismic coefficient method alone is insufficient for large fill dams, the same should be used in combination with the dynamic analysis method. In this case, seismic wave-form input is required.

According to Dr. Kanai's proposal, for example, microtremors at the proposed site and records of strong seismic waves at sites with similar microtremor characteristics may be used as seismic waveform input.

2. *GEOLOGICAL INVESTIGATION AT DAM SITES*

2.1 Existing Geological Survey Reports

During the geological survey of eastern Nepal all available data on the Kosi Basin was collected and initially reviewed before actual site investigation (TABLE 3-18).

2.2 Initial Survey

2.2.1 Stage Survey

The survey was conducted in 3 stages; A, B, and C. In stage B, seismic survey and drilling were undertaken as part of field investigation. An outline of each stage is given below.

(1) Stage A: 18 June - 30 August, 1983

Collected existing topographical and geological maps and other data, selected the hydropower plan dam site on the map, and made a draft survey plan for the subsequent stage.

(2) Stage B: 16 November 1983 - 15 February 1984

Conducted geological and topographical field survey of the hydropower dam site proposed in Part A with dam-hydropower engineering experts. Helicopters were used for all survey trips as there were no access roads passable by car.

(3) Stage C: 17 July - 14 August 1984

Stage C included supplementary field surveys for investigations carried out in Part B, and field reconnaissance of the Main Boundary Fault which is particularly related to the diversion route for the irrigation project.

2.2.2 Field Investigation

Seismic survey and boring were conducted for the sites in the table below. These sites are among those selected as high priority dam sites in stages A through C. Contents of the survey are presented in TABLE 3-4.

TABLE 3-4 CONTENT OF INVESTIGATION

Site	Drilling Works	Seismic Survey	Remarks
Sun Kosi - No.2	1984/1 - 1984/2 50m x 3 points: 150m	Line S-1 : 540 m S-2 : 400 S-3 : 400 S-4 : 350 S-5 : 345 S-6 : 95	Total 2,130 m
Sun Kosi - No.3	1984/11 - 1984/12 40m x 1 points 45m x 1 points: 85m	Line S-1 : 510 S-2 : 400 S-3 : 410 S-4 : 335 S-5 : 350 S-6 : 110	Total 2,115 m
Tama Kosi - No.3	1984/10 - 1984/11 40m x 2 points: 80m	Intake site Line S-1 : 380 S-2 : 300 S-3 : 170 S-4 : 150 S-5 : 170 Powerhouse Line S-6 : 310 S-7 : 150	(Subtotal 1,170 m) (Subtotal 460 m) Total 1,630 m
Arun No.3	1985/1 20m x 1 point 80m x 1 point : 50m		
Total	365m	19 Lines	5,875 m

Location of measuring lines for the seismic survey and the drilling survey location map for each site are shown in FIG. 3-7 to 3-9.

2.3 Results of Field Reconnaissance and Field Investigation

2.3.1 Sapt Kosi High Dam Site

(1) Stratigraphy

Stratigraphy of the Sapt Kosi High Dam Site is presented in FIG. 3-10 and summarized in the following table.

TABLE 3-5 SCHEMATIC STRATIGRAPHY IN/AROUND SAPT KOSI AREA

Possible Age	Formation	Lithology
Cenozoic	Siwalik	Shale, mudstone, sandstone, conglomerate
Lower Paleozoic	Sanguri	Shale, quartzite
Paleozoic to Precambrian	Chharling Khola Schist	Feldspathic quartz-biotite schist
	Mulghat Argillite	Shale interbedded dolomite

Source: Geology of Dharam-Dhankuta, Nepal Geological Survey

The composition of the formations listed in the above table may be outlined as inset below.

1) Paleozoic to Precambrain Period

a) Mulghat Argillite Formation: This formation is composed primarily of argillite - shale with a small amount of dolomite.

b) Chharling Khola Schist Formation: This formation consists mainly of feldspathic quartz-biotite schist with an amphibiolite sill.

2) Lower Paleozoic Period

a) Sanguri Formation: This formation is composed of shale and quartzite and adjoins the lower chharling khola schist formation along a fault.

The Sanguri formation is distributed from near the tri-confluence in an east-west line along the Tamur River to the south side. The southern boundary is formed by the 10km zone up to the MBF which follows a WNW-ESE trend along the Kokaha Khola River which converges at Barahakshetra.

3) Cenozoic Period

a) Siwalik Formation: The Siwalik formation is composed of fine to medium grained sandstone, silt stone and shale and correlates to the Middle Siwaliks.

(2) Geological Structure

Each formation shown in FIG. 3-10 has an EW trend, while the pre-tertiary formation which is bounded to the north by the MBF has a complex fold structure. Major faults in the site area are as follows:

a) Main Boundary Fault: This is a reverse fault (thrust) which separates the Tertiary Siwaliks from the pre-tertiaries. The general trend of the same is E-W with a northerly dip of the fault plane. Extension of the fault is shown in the geological map.

b) Tamur River Fault: This fault has an E-W trend and is found in the northeast portion of the mapped area.

c) Arun River Fault: The said fault has a NNE-SSW trend and runs through the center of the area.

(3) Kosi High Dam Geology

The proposed dam site is planned in the middle of the Paleozoic-Precambrian period Sanguri formation and is located between Tribeni and Barahakshetra.

Geological conditions of the dam axis are good with direct outcroppings of hard schist on both banks. Topographical conditions are also favorable with steep v-shaped slopes on both banks and site location at the narrowest river width between Tribeni and Barahakshetra. A survey adit excavated over 30 years ago is still visible and is located about 7m above the riverbed on the left bank dam axis.

Based on field survey, the dam is judged to have suitable strength as a dam foundation for a high dam.

(4) Kothar Project Site

This site, which is planned as an alternative to the high dam, is about 1.5km to the south of the MBF and is thus located in the Tertiary Period Siwalik Formation area. In the dam site vicinity, the said formation is composed predominantly of sandstone and some shale. The strength of the same is inferior to that of older strata, and, in addition, the formation includes other faults which derive from the MBF.

Accordingly, it is judged that various problems exist with regards to strength and permeability in use as a dam foundation. Thorough investigation of the same is particularly required for construction of a large-scale dam.

2.3.2 Sun Kosi No.1 Site

This site is the same as B-Dam site studied by Nippon Koei Co., Ltd. for a feasibility study[1/] in 1972. The proposed site is located in Udayapur Garhi District in the central Kosi Basin (latitude 27°39'N; longitude 86°E). The confluence of the Dudhu Kosi River is about 7km upstream from the same.

Stratigraphy of the area including the site according to A.S. Narosimhan is as shown in TABLE 3-6 while a geological map is presented in FIG. 3-11.

TABLE 3-6 SCHEMATIC STRATIGRAPHY OF SUN KOSI NO.1 AREA

Assumed Period	Formation	Lithology
Middle Miocene	Lower Siwalik	Sandstone with interbedded clays
Tertiary	Younger Granite - Complex	Granite gneiss, porphyroblastic
Cambrian	Bhimphedi	
	Upper	Biotite schist with interbedded marble and calc-silicate
	Lower	Biotite schist, coarse textured with a few interbeds of quartzite
Precambrian	Suparitar	Phyllite with interbedded slate and limestone

(1) Stratigraphy and Rock Facies

1) Suparitar formation

This formation is the bottom layer underlying the area and is distributed in the upper reaches of the southern Kokaru Khola, Maruwa Khola, Tawa Khola, etc., with a width of about 1km and a WNW-ESE trend.

The main component is phyllite interposed with calcareous slate and limestone. The formation adjoins the Lower Siwalik Formation through the MBF.

1/ Feasibility Study of Irrigation Development in the Terai Plain, (Phase-II), Nepal (Annex 1), by Nippon Koei Co., Ltd. (1972)

2) Bhimphedi formation

The Bhimphedi formation is the stratum directly above the Suparitar formation. The southern portion of the same is mainly composed of comparatively coarse grained biotite-schist with some quartzite while the northern portion consists of biotite schist with marble or calc-silicate.

3) Younger granitic complex intrusion

This rock complex intrudes into the above mentioned Bhimphedi Formation and consists of 2 rock masses; one which extends along the Sun Kosi-Tawa Khola divide (1,500m -1,800m) with an WNW-ESE trend, and one along the Sun Kosi left bank. This formation has an overall gneissose texture with tourmaline-pegmatite and aplite as well as porphyroblast 1/ caused by thermodynamic metamorphism.

4) Lower siwalik formation

This is the uppermost stratum in the area and is composed of sandstone with interbedded clay from sediments desposited during the Middle Miocene Period.

(2) Geology and Geological Structure of Proposed Dam Site

The bedrock of the proposed dam site is comprised of the upper stratum of the Bhimphedi Formation which accumulated during the Cambrian period. Biotite schist is the main component of the same.

The formation covers a broad geological area with a general WNW-ESE trend in eastern Nepal and a syncline extending in the same direction in the southern Sun Kosi River. The site is located on the north wing of the said syncline and the stratum also extends in a ENE-WSW direction dipping 30° SE. Elevation of the riverbed at the dam axis is approximately 310m and the site is located near the narrowest portion of the river valley.

1/ A term given to the pseudo-phenocrysts of rocks produced by thermo-dynamic metamorphism. The corresponding texture is called porphyroblast. Large grains or crystals commonly perfect, developed in schists resulting from deformation of rock originally containing phenocrysts.

A geological profile of the dam axis according to the 1972 Nippon Koei Co. survey is given in FIG. 3-12. Topography of the dam axis is comprised of steep slopes on the right bank and asymmetrical gentle slopes on the left bank. Width of the riverbed is about 130m and thickness of the riverbed determined by boring is 26.2m.

The majority of slopes on the left bank are covered by talus-like depris with a maximum thickness of about 20m. Results of seismic survey indicate that the upper 10-20m layer of bedrock has a seismic wave velocity of 1.5 to 1.8km/sec and comparatively frequent weathered, cracked and fissured zones. Moreover, fresh bedrock is considered to be distributed in the deeper portions.

The right bank has a slope of 50° and thickness of the weathered portion of the slope, including the shallow overburden, is estimated at about 5-8m. Faults which would have a direct influence on the dam foundation have not as yet been found. From the above factors, Nippon Koei Co. concluded that construction of a 150m high concrete gravity dam was possible at this site. Results of the present field survey also indicate that there is no major geological problem to construction of the proposed 147m dam with a HWL of 425m. However, construction of a dam larger than the above is impossible due to geological restrictions on the right bank.

2.3.3. Sun Kosi No.2 Site

The Sun Kosi No.2 (Su.2) dam site is located at latitude 27°00'N and longitude 86°10'E in the central Sun Kosi Basin. The riverbed elevation of the same is about 400m. The geology of the area has been reported by P.K. Aryal, S.N.Jha[1/] and P.N. Sharma[2/]. Stratigraphy of the same is summarized in TABLE 3-7 while a geological map is presented in FIG. 3-13.

1/ Geological map of Sindhuli Area, Topographic Sheet No.: 72-E/16, I/4

2/ Geological Map of Parts of Sindhuligarh and Ramechap Districts of Eastern Nepal, Topographic Sheet No.: 72-I/3

TABLE 3-7 STRATIGRAPHY OF SUN KOSI NO.2 SITE AREA

Possible Age	Formation	Lithology
Middle Miocene	Middle Siwalik	Grey sandstone and shale
Tertiary	Granite Intrusion	Granite and granitic gneiss
Cambrian	Bhimphedi Towakhola	Fine - coarse textured quartz-biotite-schist with marble band
Precambrian	Upper Suparitar	Crystalline limestone with calcareous phyllite
	Lower Suparitar	Flysch formation, schistose grit, phyllite, quartzite, conglomerate

(1) Stratigraphy and Rock Facies

1) Precambrian Period

a) Lower Suparitar Formation: This formation is the lowest in the area and is divided into lower flysch type[1/] sediments and upper metabasic rock. In the northeast corner of the geological map, both layers adjoin an E-W trend thrust fault.

Flysch sediments consist of gritstone (sandstone), phyllite, quartzite, conglomerate, etc., and were first termed the "Flysch Formation" by P.K. Sharma.

This formation is broadly distributed on the left bank of the Sun Kosi River.

b) Upper Suparitar Formation: This formation is almost the same as the Chandaho Khola Formation and was named by R.K. Aryal. The lower portion of the same is mainly composed of phyllite, and limestone (dolomite) while the upper portion is composed of garnetiferous phyllite and quartzite. The stratum is distributed in the northern and southern sections on either side of the WNW-ESE trend syncline axis shown in the geological map.

The southeastern area of the formation is crossed by the MBF and adjoins the Tertiary Formation (Siwalik F) which is widely distributed in the south.

1/ The widespread deposits of sandstones, marls, shales and clays, which lie on the northern and southern borders of the Alps. Although largely consisting of sandy and calcareous shales (hence the name in reference to their fissile character), the flysch also contains beds of sandstone and conglomerate.

2) Cambrian Period

a) Bhimphedi Towakhola Formation: This formation is distributed in the central portion of the area presented in the Geological Map, and comprises the main structure of the proposed dam site foundation. It consists of fine to coarse textured garnetiferous muscovite-biotite schist and a highly foliated fissile bed and is interbedded with grey to greyish white quartz vein along the foliation plane which contains pegmatites as well as occasional granitic intrusions.

The schist in the lower portion of this formation is comparatively coarse while that in the upper portion tends to be finer.

3) Tertiary Period

a) Middle Siwalik Formation; Middle Miocene Period: This formation is distributed adjacent to the MBF in the southeast. The same consists mainly of grey sandstone and shale. Medium to coarse, well-bedded, micaceous friable, grey to greyish-white sandstone occurs interbedded with grey to greyish white shale, nodular clays and thin bands of pseudo-conglomerate and clay-stone.

4) Granite and Granitic Gneiss

a) Intrusion: This intrusion mass is divided into 2 distributions; one large oval shaped rock mass south of the proposed dam site, and one rock mass in the southeastern area. The rock consists mainly of tourmaline granite partly metamorphosed to granite gneiss, and intruded by pegmatites and quartz lenses.

(2) Geological Structure

Geological structure of the area generally exhibits a WNW-ESE trend. A large syncline occurs on the south side of the SU.2 dam planning area and a granitic rock intrusion mass is distributed along the axis of the same. The MBF with the same trend as above runs through the south of the area and the distribution area of the Tertiary Siwalik Formation is located on the southern side of this fault.

The dam site area is located on the north wing of this syncline and consequently the stratum slopes to the south.

(3) Drilling Investigation

Drilling investigation was carried out during the dry season from January - February 1984 at three 150m extension bore holes. A drilling core logs were drawn up after analysis of the collected cores. In addition, permeation tests were concluded for the bedrock with a 5m pitch (FIG. 3-39).

(4) Seismic Exploration

Seismic exploration was conducted to survey weathering conditions of the bedrock around the site. Results of analysis were aranged in a cross-sectional analysis drawing for each exploration line, and are presented in FIG. 3-14. Velocity Layer Section by Seismic Exploration - SU.2.

Bedrock from the surface layer to the foundation rock was divided into 5 velocity layers in accordance with the seismic survey. Estimated geological conditions of the velocity layers based on the boring results etc. are as presented in the table presented on the following page.

TABLE 3-8 **ESTIMATED GEOLOGICAL CONDITIONS OF SEISMIC-VELOCITY LAYERS**

Velocity Layer	Seismic Velocity (km/sec)	Corresponding Geology
1st	0.3-0.5	Topsoil and talus
2nd	0.8-12	Talus, gravels and sand and/or upper weathered zone
3rd	1.6-2.0	Few consolideted gravels and sands and/or middle weathered zone
4th	2.6-2.9	Well consolidated gravel, and sands and/or lower weathered zone.
5th	4.6-5.0 partly 5.5	Basement rock (fresh layer)
		Low velocity layer and/or sheared zone

1) 5th layer (4.6-5.0km/sec, 5.5km/sec)

This was the highest velocity obtained in the Study area and is thought to correspond to fresh rock which does not reach as far as ground surface where it would be exposed to direct weathering.

In the middle of this layer there is a low velocity zone as well as a sheared fault zone. These areas are marked on the cross sectional analysis diagram.

2) 4th layer (2.6-2.9km/sec)

This velocity layer corresponds to portions of the 5th layer below, which have been weathered, and to well consolidated river deposits. Distributed in both banks, the rock itself is fresh; however, zone weathering has occured along cracks etc., and thus it corresponds to the lower weathered layer. In the riverbed portion, gravel and sand are well consolidated and siesmic velocity is higher.

3) 3rd layer (1.6-2.0km/sec)

This layer represents weathered 4th layer rock and consists of the consolidated river deposits in the mountain area. Although some portions of the rock in both banks are hard, cracks and fissures occur and some clay content is also predicted.

4) 2nd layer (0.8-1.2km/sec)

As the velocity layer is weathered 3rd layer, the same corresponds to the upper weathered layer and talus deposits. Velocity in the riverbed portion is 1.0-1.2km/sec equivalent to loose river deposits.

5) 1st layer (0.3-0.5km/sec)

This velocity layer corresponds to topsoil and talus deposits.

(5) Rock Test

Core boring survey was carried out and rock samples were taken for laboratory testing to determine the physical properties characteristics of rock which forms the dam foundation. Results of laboratory tests are tabulated in TABLE 3-9 while the schematic sampling map for rock tests is presented in FIG. 3-15.

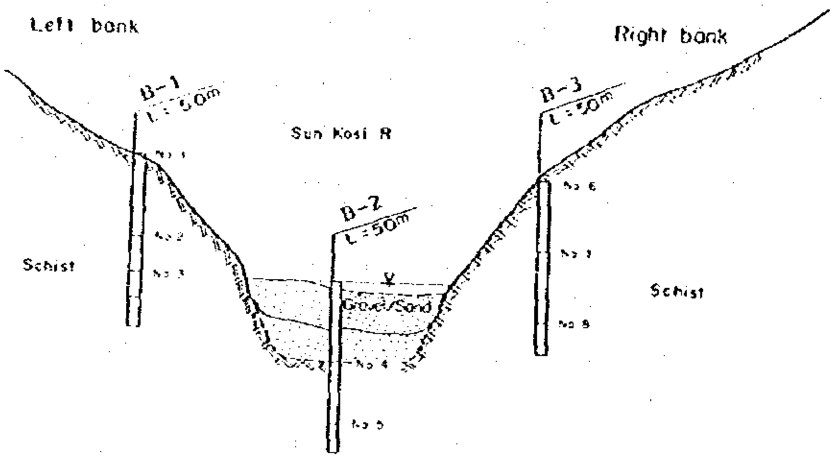


FIG. 3-15 **SCHEMATIC SAMPLING MAP FOR ROCK TESTS**
NO.1 - NO.8; SAMPLE NO.

1) Test items

Using 8 test pieces, tests were carried out to determine apparent specific gravity, water absorption coefficient, net porosity, water content, velocity of super-sonic wave, and compressive strength. In addition, calculations were made for dynamic modulus of elasticity, dynamic poisson's ratio, static modulus of elasticity and static poisson's ratio.

(6) Results of Investigation

The combined results of the above surveys is presented in FIG. 3-16, the geological cross-sectional diagram.

1) Geology

Geology in the dam axis vicinity consists mainly of comparatively highly metamorphic strata in the form of fine to coarse biotite schist from the Bhimphedi Towa Khola Formation.

The schistosity of the schist has a N60W-EW direction, dipping 30-80°S. Bare rock is visable where folding with a small pitch occurs. An obvious folding structure of phyllitic slate 5-10m in thickness is found within the schist, indicating that the geological structure of the dam axis is fairly complex.

In general, the geology of the area is comprised predominantly of fine grained mica schist with some 10cm-1m coarse type schist (Occassionally coarse schist is as large as 10m). Some sheets of phyllitic slate are found on the upstream slope of the dam axis right bank. In some cases, these sheets may have been folded.

In summary, schist with well developed schistosity is generally distributed and numerous folding structures occur. In addition, the following axial plain is formed by slipping of the fault.

2) Topography of the dam axis

The topography on both banks of the proposed dam axis is symmetrical. Width of the riverbed at the same is about 120m. During the dry season, water level is very low and the left bank riverbed is exposed while in the rainy season water level rises to 6-7m. Average slope of both banks is extremely steep at approximately 50°.

3) Drilling survey results

The thickness of the riverbed at drilling site B-2 was measured at an extremely thick 29m. Bore samples in the slope of B-1 and 3 sites, on the other hand, revealed that thickness of the talus deposit layer is very shallow at 0.3-1.8m.

From the perspective of rock classification, stable CH grade rock is found in site B-1 (left bank) at a depth of 19m20, site B-2 (riverbed) at a depth of 29m, and site B-3 (right bank) at a depth of 22m50, corresponding to the central portion of the 4th seismic velocity layer. CH grade rock has a super sonic wave velocity of Vp ≑ 4-5km/sec as indicated by the core sample tests, and a compressive strength of qu : 500-1,000kg/cm^2, which is considered suitable strength for dam foundation.

Results of permeability tests are shown in the geological cross sectional diagram. The Lugeon value for both banks shows an obvious decreasing trend in proportion to depth. The Lugeon value near the top of the left bank CH grade rock zone is 30 Lu, while in the vicinity of the hole, Lugeon is only 3 Lu. Lugeon value on the right bank from ground surface to GL-20m (the top of the CH grade zone) decreases from 174 Lu to 50 Lu, while that between GL -20 to .45m is 0 to several Lu indicating extremely low permeability. Permeability of bedrock in the riverbed ranges from 0-5 Lu to 50 Lu clearly indicating that permeability occurs along well-defined cracks.

4) Results of seismic survey

The estimated CH grade rock line is shown in FIG. 3-16. In the lower slope portion on both banks, the same is distributed from the ground surface to a depth of about 20m. In the upper slope of the left bank, the CH grade rock line shows a tendency to increase gradually in depth.

The low velocity zone in the 5th layer is delineated in the 5th layer distribution map.

5) Rock test results

Average values for physical characteristics of the bedrock are presented in TABLE 3-9, except for B-3 No.7. Compressive strength of the bedrock was valued at 700kg/cm^2 which is greater than that for CH grade rock.

(7) Geotechnical Considerations

From the reports from first stage field study no serious drawbacks to planning of a 170m dam at the proposed site have been discovered. Preliminary drilling and siesmic survey both indicate sufficient strength for high dam foundation. As for permeability, test results reveal that permeability decreases as depth increases, a very desirable trend. Thus, both topographically and geologically the site is considered extremely attractive.

1) Dam type

Rock fill type dam planning potential is negative in this zone due to insufficient quantity of suitable impervious fill materials such as topsoil and talus deposits. The concrete gravity dam has therefore been recommended as the dam type for this site.

(8) Recommendations

Thorough geological investigation is recommended in the next stage to clarify geological structure of the site particularly with regards to the more complex geological features. In addition, drilling surveys and, if necessary, adit surveys, should be carried out along with study of rock permeability and strength characteristics to determine the parameters required for designing of dam foundation structure.

2.3.4 Sun Kosi No.3 Site

(1) General

Sun Kosi No.3 (SU-3) site is located in the central Sun Kosi basin at latitude 27°32'N and longitude 85°47'E. Riverbed elevation is approximately 530m. The proposed dam site is located near Raniduh village 14.5km downstream from Dolalghat town at the junction of the Sun Kosi and Indrawati rivers. In this area, although the Sun Kosi meanders frequently, general flow trend is NNW-SSE.

Stratigraphy is presented in TABLE 3-10 and data for the same were obtained from the Exploration Development Board, "Photogeological Map, Topo Sheet No: 72-E/10,14 with additional Fill in Geology" by J.Stocklin, K.D.Bhaftarai, S.M.Tamrakar (1982) and "Geological Map of Nangre - Bhorle - Sun Kosi Area" by B.B.Nadgir and P.N.Sharma (1962). The geological map is presented in FIG. 3-17.

A thrust fault runs in a NNW-SSE trend about 5km to the west of the Sun Kosi River and in the same direction as river flow. This fault divides two major groups, forming the boundary between the western Bhimphedi group and the eastern Nawakot Group. The stratigraphic relationship between the two is unclear.

TABLE 3-10 **STRATIGRAPHY OF SUN KOSI NO.3 SITE AREA**

Possible Age	Formation Group	Description
Precambrian to Lower Cambrian	Bhimphedi	
	-Kalitar	biotite schist and quartzite
	-Ruduwa	garnetiferous biotite and chlorite schist gneissic, with Chak quartzite and granitic gneiss
Paleozoic	Upper Nawakot	
	-Robang	chloritic phyllite, some quartzitic and calo phyllite
	-Malekhu limestone	fine grained siliceous and dolomitic limestone
	-Jhiku calcareous	calc-phyllite, phyllitic limestone and dolomite
	-Benighat slate	slate phyllite with black carbonaceous slate.
Upper - Precambrian	Lower Nawakot	
	-Kuncha	phyllite, phyllitic sandstone, gritstone, conglomerate

1) Nawakot Group

Kuncha formation

This formation belongs to the lower Nawakot Group and consists of phyllite and phyllitic sandstone, gritstone and conglomerate.

The Kuncha formation is distributed in 2 areas around the Sunkosi-Indrawati confluence and the downstream side southeastern area, and forms the bedrock of the SU.3 site.

Benighat slate

Benighat slate is an important component of the Upper Nawakot Group and is composed of slaty phyllite with carbonaceous slate. From the confluence of the Jhikukhola and Sun Kosi rivers, this stratum covers the lense-shaped Jhiku calcareous bed (calc phyllite, phyllitic sandstone, and dolomite).

Malekhu limestone

Malekhu limestone is a fine grained siliceous and dolomitic limestone as reported by J. Sotocklin.

Robang formation

This is the uppermost stratum of the Nawakot Group and is composed of chloritic phyllite, some quartzite and calc-phyllite.

Bhimphedi group

This group consists of, from bottom to top, the Ruduwa Formation (garnetiferous biotite and chlorite schist: gneissic with quartzite and quartzitic gneiss) and the Kalitar Formation (biotite schist and quartzite, garnetiferous schist).

(2) Geology of the Proposed Dam Site

1) Geology and topography

Geologically, the dam site is composed of the Kuncha Formation belonging to the Nawakot Group which is thought to have been deposited during the upper Precambrian period.

The dam axis is primarily comprised of sedimentary rock in the form of sandstone with a thickness from several centimeters to 10cm interbedded with phyllitic slate 1m -10cm thick. The riverbed width at the axis is 100m. The right bank has a steep average incline of 60° extending from the riverbed to a height of 35m and a comparatively simple slope of about 40° above the same. The steep cliff on the left bank slope extends 80m above the riverbed. Topography of the left bank, however, is asymmetrical and the upper portion of the same has a comparatively gentle terraced slope (average incline about 20°). This gently sloped portion is composed of a thick layer of coarse to fine grained silty terrace sediments and talus deposits (maximum thickness: 20m). The boundary face of the bed has a small waving pitch and comparatively large undulation while at the same time, it has an E-W strike and a gentle 10-20° dip in the north.

Three fault structures of about 1m in width were identified in the dam axis vicinity including both parallel and oblique faults against the dam axis, with shear zone. The fault which is shown on the existing geological map as running directly through the dam axis with a NNW-SSE trend does not appear to disrupt the geological structure of either the right or left bank. Moreover, the thickness of a chert bed can be traced on the left bank and on the right bank as well.

Finally it was judged from field investigation that an E-W trend is more likely than the NNW-SSE trend recorded on the existing geological map. Although more detailed study is required in future surveys, the existence of the recorded fault is considered unlikely.

Topographical and geological problems which may be expected in dam construction with regards to dam access include:

- distribution of the silt layer mixed with gravels covering the bedrock on the left bank
- weathered condition of the bedrock
- lines of structural weakness such as joints which include permeable layers
- thickness of the gravel layer distributed on the wide riverbed

In order to identify these problems more clearly, a total of 2,115m seismic exploration and a drilling survey of the left bank and riverbed for 40.0m and 50.0m, respectively was carried out.

(3) Drilling Investigation

Drilling investigation was carried out from November to December 1984 at two 85m extension bore holes. Drilling core logs were drown up after analysis of the collected cores. In addition, permeation tests were concluded for the bedrock with a 5m pitch (See FIG. 3-39, Drilling Core Logs at SU-3).

(4) Seismic Exploration

Seismic exploration was undertaken to study the bedrock in the dam site vicinity. The results of analysis are presented in a travel time curve diagram for each exploration line and an analyzed profile as shown in FIG. 3-19.

Seismic survey revealed 5 velocity layers from ground surface to the bedrock layer. Estimated geological conditions which correspond to seismic velocity are presented in TABLE 3-11.

TABLE 3-11 ESTIMATED GEOLOGICAL CONDITIONS OF SEISMIC VELOCITY LAYERS (at Su. 3 site)

Velocity Layer	Seismic Velocity (km/sec)	Corresponding Geology
1st	0.3 - 0.5	Topsoil and talus
2nd	0.8 - 1.1	Talus and gravels and sands and/or upper weathered zone
3rd	1.5 - 1.8	Little consolidated gravels and sands and/or middle weathered zone
4th	2.5 - 2.6 2.7 - 2.9	Well consolidated gravels and sands and/or lower weathered zone
5th	4.2 - 4.3 4.6 - 4.8	Basement rock (fresh layer)
		Low velocity layer and/or sheared zone

1) 5th layer (4.2 - 4.3 km/sec, 4.6 - 4.8 km/sec)

This layer represents the highest velocity obtained in the survey and corresponds to fresh rock which is not exposed to weathering from the ground surface. Although a velocity of 4.2 - 4.3km/sec was obtained in the right bank mountainous area, if it is assumed that the type of rock is identical to that for 4.6 - 4.8 km/sec, the above low velocity indicates the existence of numerous cracks in some portions.

As velocities corresponding to a low velocity zone and faulting shear zones were obtained, the same were marked on the cross-sectional analysis diagram.

2) <u>4th Layer (2.5 - 2.6km/sec, 2.7 - 2.9km/sec)</u>

The layer corresponds to weathered 5th layer, representing the lower weathered stratum, and well consolidated river deposits. Although the rock on both banks is fresh, cracks are assumed to occur. Where the bedrock shows a velocity of 4.2 - 4.3km/sec, the velocity decreases to 2.5 - 2.6km/sec and the number of cracks is considered to be greater than where velocity is 2.7 - 2.9km/sec. The riverbed is considered to consist of well consolidated coarse to fine gravels.

3) <u>3rd Layer (1.5 - 1.8km/sec)</u>

This layer corresponds to weathered 4th layer and the central weathered portion and riverbed correspond to less consolidated river deposits. Although much of the rock is considered to be hard, there are some cracks and interbedded clay.

4) <u>2nd Layer (0.8 - 1.1km/sec)</u>

This layer is composed of weathered 3rd layer material and corresponds to the upper weathered portion and talus deposits. The riverbed corresponds to loose river deposits.

5) <u>1st Layer (0.3 - 0.5km/sec)</u>

This layer corresponds to topsoil and talus deposits.

(5) <u>Soil Test for Construction Materials</u>

A survey particularly with regards to impermeability was carried out to investigate construction materials which is one of the factors involved in determining dam type. In general, soil material is composed of weathered rock, weathered residual soil, talus deposits, and weathered river terrace sediments. Soil material suitable for dam construction has low natural water content, optimum impermeability and required strength and permeability coefficient.

Observation of geological distribution revealed that of the 13 priority sites only SU.3 has a sufficiently large volume of appropriate soil material. Lack of sufficient quantity at the other sites indicates that the possibility of fill dam construction at the same is very slight.

In the SU.3 proposed dam site area, the thick talus deposit layer (mixed with gravel and silt) distributed on the left bank was selected as appropriate soil material.

1) Core material sampling

A total of 9 soil samples were collected; 3 in Stage B and 6 in Stage C. Locations of the same are shown in FIG 3-20. Samples 013006 and 080501 which are not on the map were collected 1,500m downstream from the axis on the left bank at elevation 655.7m

Results of laboratory tests[1/] are tabulated in TABLE 3-12.

2) Soil test results

Aptitudes of Soil Grading Test at SU.3, FIG 3-21, and Compaction Curves, FIG 3-22. were formulated from the results of soil tests.

Grading distribution and core material

The general characteristics of fill dam core material grading distribution may be summarized as follows:

a) suitable proportion of fine to coarse grain diameter distribution;

b) inclusion of 10-15% fine grain (greater than 0.074m/m) and 5% clay (less than 0.005m/m) necessary to achieve impermeability

c) avoidance of excessively fine grade material to prevent development of high pore water pressure.

1/ Conducted at HMG Nepal Tribhuvan University, Institute of Engineering Consultancy Services

Based on the impermeable-permeable material optimum limit curve (FIG 3-23) proposed by the US Department of the Interior Bureau of Reclamation, Sample 012905 is in the fine grade impermeable material zone in which cracks may develop during construction. Other samples, however, are judged to be suitably impermeable as well as having appropriate grade distribution.

Compaction test

Maximum dry density (γ d max) and optimum moisture content (W opt) can be determined from the compaction test. Under fixed compaction conditions, soil with both γ d max and W opt has optimum cohesion and angle of internal friction. Permeability coefficient is minimum when water content is some percentage higher that W opt. Accordingly, compacted W opt soil material generally has close to maximum shear strength and impermeability. Even in consideration of engineering factors such as pore water pressure development and stability when saturated, the above soil condition is optimum for dam material. W opt d max is thus an important indicator in evaluation of core material.

Examples of soil materials used in Japan and by the US Department of the Interior Bureau of Reclamation are presented in FIG. 3-24 indicating the natural moisture content (Wn) and optimum moisture content of the same. Natural moisture content of soil materials in the western states is generally less than optimum moisture content. With the addition of water, however, optimum moisture content is easily achieved.

This is one of the main factors in the suitability of the said soil (excluding certain extremely coarse materials for use as impermeable material. Natural moisture content of Japanese soil materials, on the other hand, is frequently greater than the optimum moisture content. Due to the wet, humid climate of Japan, soil materials show a high natural moisture content trend, and accordingly, moisture regulation and drying of materials must be considered with regards to use as core material.

SU.3 soil samples are also plotted in FIG. 3-24. From this figure it can be seen that soil samples from Nepal have similar characteristics to those from the United States.

X-Ray analysis

To indentify clay minerals in the soil the 9 samples were subjected to X-ray analysis. Results of the same are shown in TABLE 3-13 presented on the following page. Large anounts of seritic clay were identified in all samples and chlorite vermiculite content was next in terms of quantity. Small amounts of montmorillonite were also included. All of the above indicate a comparatively simple clay mineral combination.

Chlorite, vermiculite, and montmorillonite are formed by weathering from colored minerals (olivine, biotite), while sericite is composed of hydro-aluminosilicate minerals derived from feldspar.

TABLE 3-13 LIST OF CLAY MINERALS BY X-RAY DIFFRACTION

Clay Minerals Sample No.	Sericite	Chlorite	Vermiculite	Montmorillonite
12905	4	3	-	-
2	4	3	2	-
6	4	2	2	2
080401	4	3	2	-
2	4	2	3	1
3	4	1	3	2
4	4	2	3	1
5	4	1	3	2
080501	4	-	3	2

Note: Numbers indicate relative ratio of x-ray peak
4: high, 3: middle, 2: little, 1: very little

Soils containing large quantities of clay minerals (such as montmarillonite) which expand with increased water content, can adversely affect dam stability when used as core material. The results of analysis however, indicate that the clay mineral content in the soil of the area is fairly small and therefore should present no problem in use as core material.

(6) Rock Test

Core boring survey was carried out and rock samples were taken for laboratory testing to determine the physical properties of the rock which forms the dam foundation. Results of laboratory tests are tabulated in TABLE 3-9 while the schematic sampling map for rock tests is presented in FIG. 3-18.

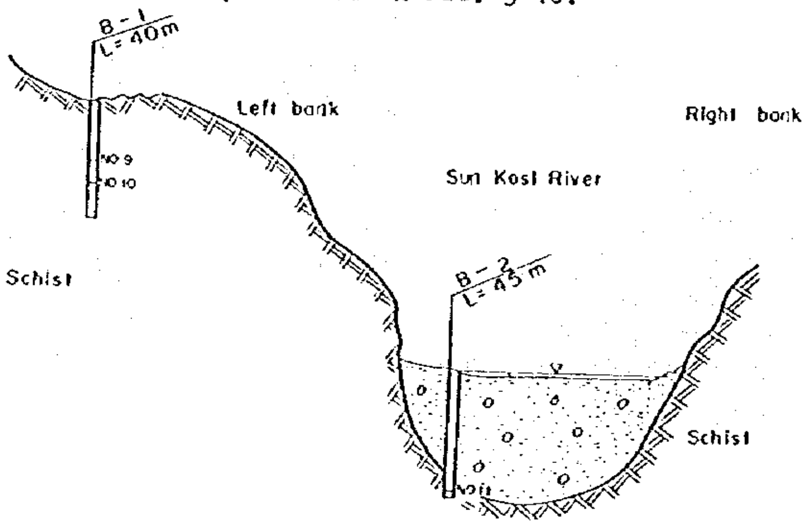


FIG. 3-18 SCHEMATIC SAMPLING MAP FOR ROCK TESTS (SU-3 site)
(No. 9 to 11: Sample No.)

In addition, according to the results of drilling investigation, the thickness of the riverbed at drilling site B-2 was measured at 35.5m. At drilling site B-1 (left bank), on the other heand, the talus deposit layer is extremly thick at 10m. This thickness coincides with the 1st to 3rd seismic velocity layers.

From the perspective of rock classification, stable CH grade rock is found in site B-1 (left bank) at a dept of 25.3m, and in site B-2 (riverbed) at a depth of 36.0m, corresponding to the 5th seismic velocity layer. CH grade rock has a super sonic wave velocity of Vp = 4-5km/sec as indicated by the core sample tests and a compresive strength of qu = 430-450kg/cm^2.

Results of permeability tests are shown in the geological cross sectional diagram and drilling core logs. The Lugeon value for bote sites shows a decreasing trend in proportion to depth. The Lugeon value near the left bank CH grade rock zone is less than 10Lu, and the CH grade rock zone near the top of the riverbed is also less than 10Lu.

(7) Results of Investigation

The stratum which comprises the dam axis foundation corresponds to the Kuncha Formation which belongs to the Nawakot Group of sediments deposited in the Precambrian Period. The formation is composed of alternate layers, several tens of centimeters to several meters thick of sandstone, and phyllitic slate 10cm-1m thick. The dam axis vicinity consists predominantly of sandstone sedimentary rock.

Topography of the dam axis is asymmetrical. The average slope of the right bank is a steep 60° from the riverbed to a relative height of 35m with bare rock outcrops. Above this point, the slope becomes simpler with an incline of about 40°, and the face of the same is covered by talus deposits and debris.

The left bank rises steeply for 80m from the riverbed; however, the portion above the same has a comparatively gentle terraced slope with an average incline of about 20: The same is covered in silty talus sediments containing boulder gravel and granules, and terrace sediments, with a maximum thickness of 20m. Dip and strike of the stratum is gentle at E - W/10 - 20°N. Two faults were determined to intersect the dam axis diagonally. The scale of the same including the shear zone is about 1m.

According to the results of seismic survey, depth of the basement-fresh layer is comparatively shallow at 20-30m; however, bedrock depth of the gentler portion of the left slope is deep at 30-40m. Depth of the top layer of sand and gravel in the riverbed is unclear, but maximum depth is estimated at 40m. The talus deposits which cover the left bank upper slope are a subject for further study with respect to possible use as a core material and depth of the sound rock line (FIG. 3-25).

2.3.5 Tama Kosi No.3 Site

This site is located about 23km NNE of the junction of the Sun Kosi and Tama Kosi rivers which originate from Mt. Chhoba - Bamal (5,960m) on the Tibetan border, and Gauri - Shanker (7,146m).

The intake dam is designed as a concrete qravity type with a height of 60m. The proposed dam site is situated at latitude 27°38'N and longitude 86°07'E. A motorway is located about 2.0km downstream from the intake dam site providing excellent accessibility. The said road runs from Charikot to Jiri and branches from the national road (Chaina road), which runs from Kathmandu through Dolalghat to the border of China. The powerhouse site is planned about 7.5km downstream from the intake dam site, and the 2 sites will be connected by an intake tunnel planned on the left bank. The power generation plan is a PRR type.

In the site vicinity, the river flows from north to south and the same is joined by two comparatively large affluents from both right and left banks about 2.5km downstream from the proposed regulating pond site; namely, the Charnawati Khola from the right bank and the Khani Khola from the left bank. Valley width is narrowest at the proposed intake site with a widening trend on both upstream and downstream sides.

(1) General Geology (FIG. 3-26)

1) Lower Suparitar formation (Precambrian)

This formation is divided along the midland thrust into a gneiss and a phyllite layer. The former is pushing up the latter.

The gneiss of this formation is considered to be Sailung gneiss as defined by P.N.Sharma and is the main structural component of the area. The Sailung gneiss complex is thought to be partly a granitized equivalent of the Suparitar Flysch formation and is a composite para-and ortho-gneissic complex. Granite and granite-gneisses are associated with all the Precambrian to Paleozoic rock series of Nepal viz. the Chitlang series and the Bhimphedi and the Suparitar formations.

The main constituents of the series are a younger tourmaline-granite intrusive into the Bhimphedis and Chitalangs and an older gneiss complex comprising biotite-granite-gneiss, porphyroblastic gneiss, augen-gneiss, streaky gneiss or banded gneiss. All the variations, however, may not necessarily be present in a given area. Also, elsewhere patches of tourmaline-granite are seen (possibly) within the gneissic complex. This gneissic complex has been called the "Sailung gneiss" and is considered, in part, a granitised equivalent of the Suparitar flysch formation.

In general, the tourmaline-granite and the granite-gneisses of the gneissic complex occur as concordant linear belts or interlayered bands running parallel to the foliation of the rocks within which they occur. Accordingly, they have been mapped as one unit along with the rock intruded or associated with them in the field.

2) Upper Suparitar Formation

This formation is composed of, from bottom to top, greenish chlorite-phyllite, white quartzite, grey quartzite (fine to medium grained massive) and white magnesite. The same is distributed from the mid to upper stream of the Khani Khola.

3) Bhimphedi Formation (Cambrian)

This formation is distributed only in the southwest portion of the mapped area and is composed of garnet metamorphic biotite schist.

(2) Geological Structure

Geological structure follows an E-W trend with a syncline extending from the vicinity of the confluence point, exhibiting a structure supportive of the same. Phyllite, which is located in the lowest layer distributed to the north of the proposed dam site, is connected to the upper gneiss layer along the large-scale Midland Thrust. A NNW-SSE trend fault running from the left bank to the Khani Khola has been recorded. Decomposition of rock into soil due to in-site weathering and landslide formations are particularly pronounced in gneiss distribution areas which have comparatively high elevations.

(3) <u>Drilling Investigation</u>

Drilling investigation was carried out from October to November 1984 at two 80m extension bore holes. Drilling core logs were drawn up after analysis of the collected cores. In addition, permeation tests were concluded for the bedrock with a 5m pritch (FIG. 3-39: Drilling Core Logs at TA-3).

(4) <u>Seismic Exploration</u> (FIG. 3-27)

Geological structure of the dam site vicinity was studied by seismic surveying. Results of analysis are given in FIG. 3-27 in the form of analysed profiles for each measurement line. The survey indicated the existance of 5 velocity layers which are tabulated in TABLE 3-14 along with corresponding geology for the same. The survey was carried out in 2 locations; at the dam site and the penstock line at the powerhouse site.

The characteristics of each layer are as described below.

1) <u>5th layer (4.2-4.3km/sec, 4.5-4.6km/sec, 5.0km/sec)</u>

As this layer had the largest velocity, it is considered to correspond to fresh rock which is not exposed to direct weathering. In addition, a low velocity zone and fault shearing zones were also found. The same are marked on the cross-sectional analysis diagram.

2) <u>4th Layer (2.6 - 2.8km/sec)</u>

This layer corresponds to the lower weathered zone and consists of weathered 5th layer. Although the rock itself is considered to have hard portions, in general, cracks are numerous and weathering is advanced. The riverbed portion corresponds to well consolidated river deposits such as boulder gravel and sand.

3) 3rd Layer (1.6 - 1.8km/sec, 1.8-1.9 km/sec)

This layer corresponds to the central weathered zone as it is composed of weathered 4th layer. Hard rock in both banks is thought to be plentiful; however, cracks are developing. Riverbed velocity is 1.8 - 1.9km/sec and corresponds to little consolidated river deposits.

4) 2nd Layer (0.8 - 1.1km/sec, 1.1 - 1.2km/sec)

This layer represents the upper weathered zone and is composed of weathered 3rd layer. Velocity of the riverbed portion is 1.2 - 1.2km/sec which corresponds to loose riverbed deposits.

5) 1st Layer

This layer corresponds to topsoil and talus deposits.

(5) Rock Test

Core boring survey was carried out and rock samples were taken for laboratory testing to determine the physical properties of the rock which forms the dam foundation. Results of laboratory tests are tabulated in TABLE 3-9 while the schematice sampling map for rock tests is presented in FIG. 3-28.

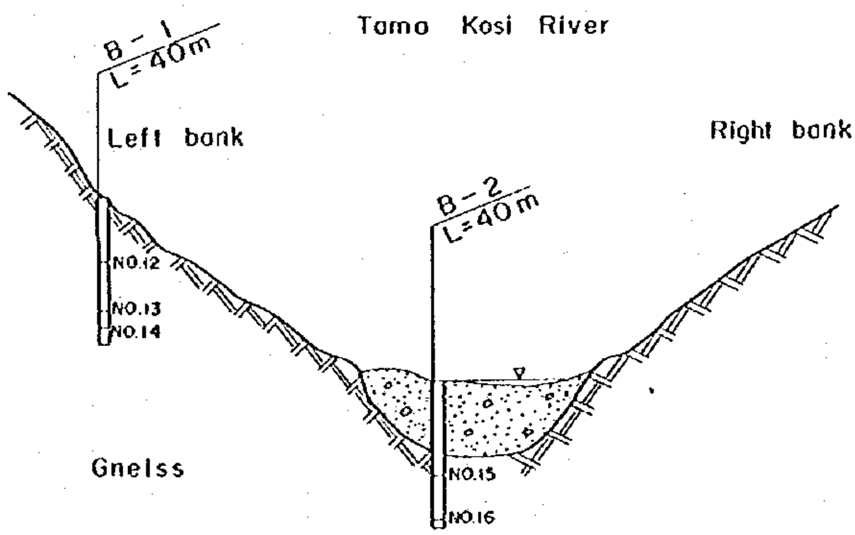


FIG. 3-28 **SCHEMATIC SAMPLING MAP FOR ROCK TESTS** (TA-3 site)
(No.12 to 16: Sample No.)

(6) Drilling Survey Results

According to the results of drilling investigation, the thickness of the riverbed at drilling site B-2 was measured at 20.4m. At drilling site B-1 (left bank), on the other hand, the talus deposit layer is extremly thick at 9m.

From the perspective of rock classification, stable CH grade rock is found in site B-1 (left bank) at a depth of 21.7m, and in site B-2 (riverbed) at a depth of 20.4m, corresponding to the middle of the 3rd seismic layer and the 5th seismic layer. CH grade rock has a super sonic wave velocity of Vp = 3.8-4.0km/sec as indicated by the core sample tests, and a compresive strength of qu = 500-600kg/cm^2.

Results of permeability tests are shown in the geological cross sectional diagram and drilling core logs. The Lugeon value for site B-1 (left) is 16-54Lu in the zone drilled in this investigation and for site B-2 (riverbed), the lugeon value exhibits a decreasing trend in proportion ot depth. The Lugeon value near the top of the bedrock at site B-2 is 58Lu, and near the low zone at a depth of 35m is less than 10Lu.

(7) Construction Considerations for Each Plan

1) Tama Kosi 3 - Regulation Pond Site (FIG. 3-29)

The proposed regulation pond site has an elevation of about 830m and valley width at the riverbed is about 55m. Slope is 32 - 35° from the riverbed to a height of about 50m and topography is symmetrical. The slope of the upper portion of the left bank, however, is gentle at 25°.

The said upper portion is covered by a talus layer mixed with debris, and gneiss is distributed in the riverbed and on the slope face from 40 - 60m above the riverbed. The slope over 60m above the riverbed is covered by comparatively thick talus deposits.

A thick layer of talus deposits is distributed from the riverbed to about 70m above the same on the right bank. Fresh gneiss rock is distributed above this height. Granite gneiss rock facies in this area are complex formations such as augenic gneiss and granitic gneiss. A zone of accumulated mica occurs in part of the same. The rock facies have a WNW-ESE trend and a gneissosity of 30^{o}-10^{o}S dip, and is composed of a lamellar rock plain. Several joints occur both in the same direction as the plain and diagonally. The reservoir dam site did not appear to have any major topographical or geological defects.

Intake tunnel

The proposed intake tunnel route of the same runs along the Tama Kosi left bank from the inlet of the reservoir dam to the proposed power generation site. A relatively large affluent, the Khani Khola, crosses the tunnel route about 2km downstream from the proposed dam site. Study of overburden and erosion conditions at this point, as well as investigation of the Khani Khola Fault shown on the existing geological map, is necessary.

Powerhouse and surge tank sites

According to the seismic survey, the surge tank site and the penstock route which runs from EL870m to the riverbed, is covered by talus deposits, excluding the central area between EL820-830m. The said deposits have an average thickness of 10m in the upper portion and a maximum of 10m at the bottom of the slope where the powerhouse is planned. Subsequent drilling survey is required to determine potential strength for the foundation of the penstock and powerhouse.

2) Tama Kosi No-2

A run-of-river type powerhouse is planned at this site. Intake will be from directly below the tailrace of the TM.3 powerhouse and water from the same will be conveyed via a tunnel about 10km long on the left bank. The powerhouse site is located upstream of the junction with the Khimte Khola. The valley at this site is wide and terracing occurs on the slopes.

Geology between the intake and the powerhouse is composed of gneiss similar to TM.3. This plan is directly related to the Tama Kosi No.3 Project and thus selection of detailed intake, tunnel route, penstock line and powerhouse will become possible with the determination of various components of the same.

3) Khimte Khola No.1 Site

The Khimte Khola River is a tributary of the Tama Kosi, branching off about 12km upstream from the junction of the Sun Kosi and Tama Kosi rivers. The intake dam of the Khimte Khola No.1 site is located 9km from the confluence with a water level intake of 1,219m, the highest of all 13 priority sites. Catchment area at the site, on the other hand, is the smallest at 360km^2. As with Tama Kosi No.2, the proposed powerhouse site is above the river terrace slope.

Geology between the intake dam and powerhouse sites consists of gneiss - granite. The tunnel route is planned along the right bank about 8.3km in length. Run of river type generation is proposed for the powerhouse and accordingly, intake dam scale and powerhouse capacity are comparatively small.

Results of preliminary survey indicate that the possibility of a large structural line crossing the tunnel foundation is small and geological inadequacies of the site are few.

2.3.6 Arun Nos 1,2,3 Sites

The Arun River originates in the Tibetan Plateau and, after entering Nepalese territory, flows southward gathering flow from numerous tributaries and finally joining the Sun Kosi at Tribeni village. The three hydropower plans are all run-of-river type, and the average river gradient between the Arun No.3 intake (EL:792.5m) and the No.1 tailrace (EL:H417.0m) is steep at 1/100. Accordingly, the topographical features of the area have high hydropower potential.

The No.3 intake site is planned about 6km south of Buidep and at the bottom of the curve where the Arun River makes a wide U-turn to the west. Water will be conveyed from this point to the powerhouse via an intake tunnel planned on the left bank. Powerhouses planned downstream from the above will have intake facilities located directly below the upstream powerhouse. As these dams form a hydropower series, all intake tunnels are planned on the left bank in accordance with river conditions.

(1) Geology at Arun Nos. 1 - 3 Sites

A schematic geological map of the Arun 1-3 site vicinities is presented in FIG. 3-30, adapted from the Geological Map of a Portion of Sankhuwa Sabha and Bhojipur District Eastern Nepal by R.N. Yadav.

The structure which determines the geology of the area is the WNW-ESE trend Ekulade Fault running through Kumalgaon. The northern side of the fault is a gneiss distribution area belonging to the Himal Group while the Arun River right bank side is quartz - biotite schist. In addition, the Arun Fault extending northwards from Kumalgaon in a N-S trend has also been reported by R.N.Yadav.

The Arun 1-3 hydropower schemes are planned in the highly metamorphic, hard gneiss distribution area.

(2) Arun 3 Intake Site

The incline of both sides of the gneiss outcropped, V-shaped valley is a steep 50°. Width of the riverbed is about 30m. Hydropower planning at this site is SRR type with intake dam and a low dam height. Geological and topographical defects are judged to be few. However, formulation of a detailed topographic map and geological survey to determine location of incidental facilities on the intake side, and the intake tunnel, penstock and powerhouse sites is necessary.

Accordinging to R.N.Yadav's geological map, the Arun Fault crosses the planned intake tunnel route. Depending on the scale of the same, construction work could be significantly affected and therefore further study is required.

(3) <u>Drilling Investigation at Penstock and Powerhouse in Arun 3</u>

Drillihng investigation was carried out during January 1985 at two bore holes. One was 20m deep at penstock site B-1, and the other was 30m deep at powerhouse site B-2.

Drilling core logs were drawn up after observation and analysis of the collected cores (See FIG. 3-31 Drilling Points in Arun 3 site and FIG. 3-39 Drilling Core Logs).

According to the results of drilling ivestigation, the thickness of the talus deposit layer was measured at 5.7m at penstock site B-1. As for rock classification, the bedrock at site B-1 is all stable B grade. At powerhouse site B-2, on the other hand, the thickness of the terrace deposit layer was measured at 17.8m and stable B grade rock at site B-2 was found at a depth of 18m.

Core boring survey was carried out and rock samples from each drilling site were taken for laboratory testing to determine the physical properties of the rock which forms the structural foundations. Results of laboratory tests are tabulated in TABLE 3-9, while the schematic sampling map for rock tests is presented in FIG. 3-32.

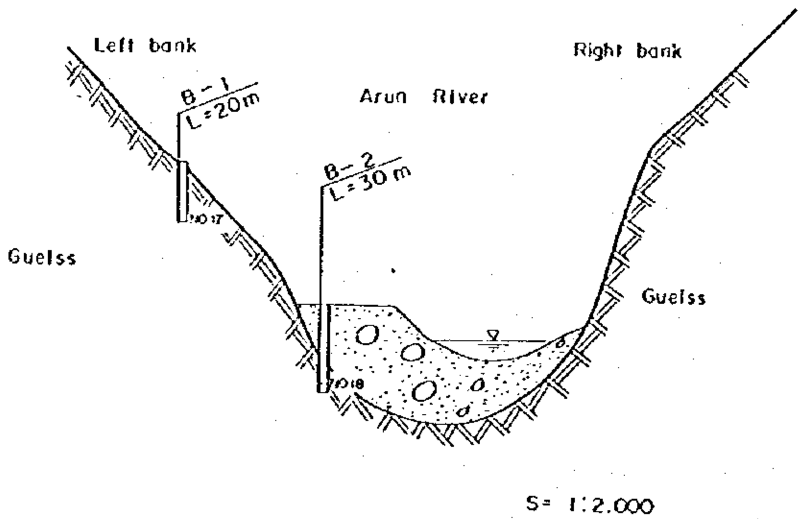


FIG. 3-32 **SCHEMATIC SAMPLING MAP FOR ROCK TEST** (AR-3 site)
(No.17 - No.18: Sample No.)

2.3.7 Tamur No.1 Site

The Tamur No.1 site is located about 35km east of the tri-confluence at Tribeni village, and about 16km east of Dhankuta, the area's center. Stratigraphy of the dam site is presented in TABLE 3-15 and a geological map is presented in FIG. 3-33.

TABLE 3-15 **STRATIGRAPHY OF TAMUR NO. 1 AREA**

Possible Age	Formation	Lithology
Cambrian	Dhankuta Schist	Quartz, Biotite, Muscovite, -Schist
Precambrian	Telio Khola	Phyllite and Quartzite

Source: Adapted from Geology of Dharan Dhankuta Map Area; J.M. Tater (1967) and Geology of a Portion of Southeastern Dhankuta and Western Ilam

The proposed dam site consists of the Telio Khola Formation and Dhankuta schist. The former is composed of alternate layers of phyllite and quartz distributed along the Tamur River with a width of 5-6km. The upper portion is covered with a broad, thick layer of Dhankuta schist which is mainly composed of quartz, biotite, and muscovite and various types of schist.

Geological structure of the site is comparatively simple. An anticline extends ENE-WSW along the Tamur River. Accordingly, stratum on the north bank dips 20-40° N while that on the south bank dips 25°-35°. In addition, data on a large fault which reportedly cuts across the formation in this area is not available.

From the above factors, the following geological considerations should be noted in engineering of the dam axis.

a) Dam foundation rock is formed of phyllite and quartzite of the Telio Khola Formation.

b) Due to the lamella of this stratum, limitations exist in the strength of phyllite regarding use for foundation rock. Moreover, defects due to weathering are also numerous.

c) Geological structure of the dam axis consists of an ENE-WSW strike and a southward 25-30° dip. Accordingly, relationship between native slope and structure (strike and dip) of strata is concordant on the right bank while the left bank is not concordant.

As the right bank is susceptible, possibility of slope sliding during excavation is high and study of the same is therefore required.

2.3.8 Dudh Kosi No.1 Site

The Dudh Kosi No.1 Site is located about 25km ENE from the confluence of the Dudh Kosi River with the Sun Kosi. A large tributary flows WNW-ESE and joins the Dudh Kosi directly upstream from the axis on the right bank. Stratigraphy of the area may be classified as in the table below.

TABLE 3-16 TENTATIVE STRATIGRAPHIC UNITS OF DUDH KOSI NO. 1 AREA

Lithology	Probable Age
Augen gneisses, feldspathic schists and granites	Tertiary
Carbonaceous phyllites, dark grey phyllites, and siliceous limestones	Eocambrian
Grey and green phyllites interbedded with quartzites, conglomerate bearing quarzite, phyllites, gritty phyllites, intrusive granites	

A geological map of the proposed dam site area is presented in FIG. 3-34. Phyllite is distributed over a major portion of the area. The phyllite stratum in western Okhaldhunga is typical and has been termed Okhaldhunga Phyllite by Toni Hargen. The same is mainly composed of grey to green phyllite with a thick conglomerate layer of quartzite and phyllite distributed in the lower portion. A granite complex with some augen gneiss and feldspathic schist occurs above the Okhaldhunga Phyllite and is thought to have formed in the Tertiary Period.

General directionality of geological structure is an E-W strike dipping north on the north side, and south on the south side of the Andheri Fault (ENE-WSW trend) which acts as a boundary. There is also the Dudh Kosi Fault which has the same trend as the Andheri Fault and is predominantly distributed along the Dudh Kosi River, displacing each layer on the south side.