1)	Demra (Sta. 7.5)	:	X' = X + 0.007 (PWD in m)
2)	Mill Barak (Sta. 42)	:	X' = X - 0.037 (- do -)
3)	Tongi (Sta. 299)	:	X' = X + 0.122 (- do -)
4)	Mirpur (Sta. 302)	:	X' = X + 0.042 (- do -)

Where, X : observed data of BWDB
X' : revised data to be calculated

6.2 Correlation among Water Level Gauging Stations

In order to estimate an accurate water level for a large return period like 100 years, it is necessary to use the data with long duration including 1988 Floods.

Gauging stations satisfying the above conditions are listed as follows;

1)	Mill Barak (Sta. 42)	:	37 years data
2)	Savar (Sta. 69)	:	33 years data
3)	Demra (Sta. 7.5)	:	35 years data by combining Demra (Sta. 7.5) and Demra (Sta. 179) using their correlation.

Correlations of the water level of the other water level gauging stations with the water level of above three stations are shown in Fig. D.16.

6.3 Probable Flood Water Level

Probable flood water levels of Mill Barak, Savar and Demra (Sta. 7.5) are calculated by Gumble-Chow's Method. The results are shown in Fig. D.17.

Using Fig. D.17 for Mill Barak, Savar and Demra (Sta. 7.5) and the correlation of the other stations with these three stations as mentioned in section 6.2, probable flood water levels of water level gauging stations relating the study area are calculated as shown in Table D.10.

According to this table, return periods of 1987 Floods and 1988 Floods at Demra (Sta. 7.5), Mill Barak (Sta. 42) and Savar (Sta. 69) can be estimated as follows;

RETURN PERIOD OF 1987 AND 1988 FLOODS

Station	1987 Floods	1988 Floods
Demra (Sta. 7.5)	8 years	50 years
Mill Barak (Sta. 42)	10 years	70 years
Savar (Sta. 69)	15 years	200 years

The return periods of 1988 Floods at Demra (Sta. 7.5) and Mill Barak (Sta. 42) are same as that reported, about 50 - 100 year frequency.

The return period of 1988 Floods at Savar (Sta. 69) is much higher than the reported figure of 50 - 100 year. Kalatia (Sta. 70) is also determined to be of high frequency as 300 year (refer to Table D.10). However, the return period at Nayarhat (Sta. 14.5) is determined to be only slightly higher than the reported value of 50-100 years.

As the 1988 Floods of the study area came from the direction of the Brahmaputra-Jamuna River (refer to Fig. D.5), the return period of 1988 Floods of the north-western part of the study area including Savar (Sta. 69), Kalatia (Sta. 70) and Nayarhat (Sta. 14.5) seems to be higher than other portions of the study area.

However, as the duration of the available water level data of Savar (Sta. 69) is 33 years only, the probable water levels with very high frequency like 200, 300, 400 and 500 year return period seem to be rather unreliable with respect to their accuracy.

Based on the above considerations, the return period of the 1988 Floods in the north-western part of the study area can be said more of than 100 year but less than 300 year.

7. Hydraulic Simulation Model

7.1 Mike 11 Software and SWSMP

1) Mike 11 Software

Mike 11 is a software of hydrological and hydraulic simulation for rivers. It consists of Rainfall Runoff Model, Channels Flow Model, etc.

Furthermore the software can be operated with introducing river structures such as embankment, weir, pump station etc. and it can be run by a 16-bit or 32-bit microcomputers under MS-DOS or UNIX operating system. Fig. D.18 shows the process of modelling by Mike 11.

2) Surface Water Simulation Modeling Programme (SWSMP)

Government of Bangladesh has conducted the surface Water Simulation Modeling Programme (SWSMP) since 1986 in due recognition to the fact that effective control and utilization of water resources in Bangladesh is vital to economic and social development of the country.

The objective of SWSMP is :

(1) To develop a surface water simulation model for the whole country called as "General Model" (ref. to Fig. D.19), and

(2) To develop fully operational model for the regions in the country called as "Regional Models" such as South East Region Model, South West Region Model, and North West Region Model.

They are under development, but the development of General Model and South East Region Model are in the final stage. Furthermore, Flood Forecasting Model aiming Dhaka Metropolitan area and North Central Regional Model aiming North Central Region including Dhaka Metropolitan area are under development.

The software that is being developed by SWSMP is Mike 11 as mentioned before.

7.2 Formulation of Simulation Model

7.2.1 Objective of Hydraulic Simulation

In order to formulate a flood mitigation plan for the study area, it is necessary to know the difference of water levels between that of without flood protection plan and that of with flood protection plan.

Hence, the objective of hydraulic simulation of the study area is itemized as follows:

(1) To simulate the flood water level of without flood protection plan

(2) To simulate the flood water level of with flood protection plan

In this study, the design high water level of flood protection plan is determined as either higher water level of 1988 Floods or 100-year floods (refer to Supporting Report G: Flood Mitigation).

As the 1988 Floods is the recorded maximum flood and have the same order of return period as the design return period required in flood mitigation plan, the hydraulic simulation is conducted for 1988 Floods.

7.2.2 Basic Concept of Model Formulation

Fig. D.20 shows the basic concept of hydraulic simulation model for the study area. In setting up the model, following items are considered.

1) River Network

All the main rivers in the study area are included in the river network of the simulation model. They are listed as follows;

a) Dhaleswari River
b) Bansi River
c) Buriganga River
d) Turag River
e) Lakhya River
f) Balu River
g) Tongi Khal
h) Karnatali River

2) Flood Water Level

Flood water level in the study area is supposed to be determined by the discharge flowing through the rivers in the study area.

The water flows of the Meghna and Padma Rivers are assumed not to influence the flood water level in the study area.

Flood water level along the rivers in the study area is simulated by one-dimensional unsteady flow calculation of Mike 11*).

Source:

* Danish Hydraulic Institute; Mike 11 - Scientific Documentation
  - diffusive wave approach

3) Rainfall Runoff

Rainfall runoff in the study area is supposed to enter the river network through khals and act as a lateral inflow to the rivers in the study area.

This rainfall runoff is calculated by using recorded daily rainfall data of Dhaka (B.M.D.). The calculation is conducted using rational formula.

4) Boundary Condition

Boundary condition of the model is given by the daily discharge corresponding to the daily maximum water level from the outside of the study area through the Bansi, Turag, Balu, Lakhya and Kaliganga Rivers and daily maximum water level at Kalagachia (Sta. 71).

In the study area, Nayarhat (Sta. 14.5) and Demra (Sta. 179) have their rating curves given by BWDB. Other boundary discharge points do not have their rating curves of BWDB.

In the simulation, boundary discharges are calculated by using BWDB's rating curves for Nayarhat (Sta. 14.5) and Demra (Sta. 179). Other boundary discharges are estimated by trial and error method while conducting calibration of the simulation.

Furthermore, boundary discharge of the Kaliganga River is treated as a lateral inflow into the Dhaleswari River.

5) Calibration

Calibration of the simulation is conducted for the flood water level at all the water level gauging stations in the study area.

7.3 Simulation of 1988 Floods

In this section, simulation of 1988 Floods without flood protection plan is described.

Simulation of 1988 Floods with flood protection plan is conducted by inputting the information of flood protection works like embankment, dredging into this simulation model. The results of simulation with flood protection plan is described in Supporting Report G: Flood Mitigation.

7.3.1 Input Data

1) River Network

Fig. D.21 shows the river network of the simulation model.

(1) River length

River lengths of the simulation model are as follows:

a)	Dhaleswari River	:	60.20 km
b)	Bansi River	:	9.00 km
c)	Buriganga River	:	17.50 km
d)	Turag River	:	37.50 km
e)	Lakhya River	:	23.90 km
f)	Balu River	:	28.70 km
g)	Tongi Khal	:	16.00 km
h)	Karnatali River	:	11.90 km

(2) Main Stream Zone and dead water zone

During 1988 Floods, the study area was supposed to be divided into three zones. They are flood free area, main stream zone and dead water zone.

Main stream zone is supposed to be the zone with fast velocity of current along the rivers. Dead water zone is supposed to be the zone with slow velocity of current around the rivers.

Utilizing the colored satellite image of SPOT IMAGE taken between February and March, 1989, it was able to distinguish approximately the main stream zone from the dead water zone by their difference in colors. For example, as for the Dhaleswari River, the color along the river was white and the color around the river was bright red. As for the Turag River,

the color along the river was dark red and the color around the river was bright red.

Furthermore, as the SPOT IMAGE was taken during the pre-monsoon season of 1989, the traces of 1988 Floods was considered to be expressed in this SPOT IMAGE.

Based on the above two conditions and the flood free area of 1988 Floods and interview of flood flow of 1988 Floods with people, the main stream zone and dead water zone were determined as shown in Fig. D.21.

The main stream zone is input into the simulation model. The dead water zone is not input into the model. Water level along the main stream zone is calculated in the model.

River cross sections along the main stream zone are input into the model by using the surveyed river cross section of BWDB and JICA Team shown in Fig. D.3. In these river cross sections, flood plain as well as river channel are included.

2) Rainfall Runoff

Fig. D.22 shows the sub-catchment and the locations of lateral inflow into the rivers due to the rainfall runoff.

Rational formula is used for the rainfall runoff calculation. In this formula, runoff coefficient is set at 0.4 and effective rainfall ratio is determined by using Fig. D.13.

Fig. D.23 shows the daily rainfall of Dhaka (B.M.D.) during 1988 Floods used in the rainfall runoff calculation and the results of subsequent calculation.

3) Manning's Roughness Coefficient

In the General Model of SWSMP mentioned in section 7.1, Manning's roughness coefficients of the Dhaleswari River and the Lakhya River were set as follows*);

a)	Dhaleswari	:	River channel	=	0.025
			Flood plain	=	0.100

b) Lakhya River : River channel = 0.025
Flood plain = 0.100

Source:

*) Danish Hydraulic Institute; Surface Water Simulation Modelling Programme, Final Report, Master Plan Organization, 1988

In this study, the Manning's roughness coefficient of flood plain is also set at 0.100.

However, the Manning's roughness coefficient of river channel is studied by using the rating curve of BWDB at Nayanhat (Sta. 14.5), Demra (Sta. 179) and Mirpur (Sta. 302). Non-uniform calculation was performed in this comparison study.

Fig. D.24 shows the comparison of Manning's roughness coefficient of river channel. From this figure, the Manning's roughness coefficient of 0.030 is considered to be more appropriate than 0.025 for these three stations.

As a result Manning roughness coefficients of the rivers in the study area are set as follows;

	River	Manning's Roughness Coefficient	
		River Channel	Flood Plain
a)	Dhaleswari River	0.025	0.100
b)	Bansi River	0.030	0.100
c)	Buriganga River	0.030	0.100
d)	Turag River	0.030	0.100
e)	Lakhya River	0.030	0.100
f)	Balu River	0.030	0.100
g)	Tongi Khal	0.030	0.100
h)	Karnatali River	0.030	0.100

4) Boundary Condition

As described in sub-section 7.2.2 boundary condition of the model is given by the boundary discharge and the water level at Kalagachia.

(1) Boundary discharge

Boundary discharge from the Bansi and Lakhya Rivers are given by using the daily maximum water level and rating curve of BWDB at Nayanhat (Sta. 14.5) and Demra (Sta. 179) as shown in Fig. D.27 (1/3). The daily maximum water level of Demra (Sta. 179) is estimated from the daily maximum water level of Demra (Sta. 7.5) by using their correlation (refer to Fig. D.16).

Boundary discharges from the Turag, Balu and Kaliganga Rivers are estimated by trial and error method while conducting calibration of the simulation. They are shown in Fig. D.27 (1/3).

(2) Boundary water level

Boundary water level at Kalagachia is given by the recorded maximum water level as shown in Fig. D.25 (1/2).

7.3.2 Results of Calibration

Fig. D.25 shows the comparison of simulated daily maximum water levels and observed water levels during 1988 Floods for all the water level gauging stations in the study area. The differences between both water levels of about 20 cm are insignificant considering the water depth of the rivers of about 10 m.

Fig. D.26, Fig. D.27 and Fig. D.28 shows the profile of peak water level, daily maximum discharge and distribution of peak discharge of 1988 Floods simulated by the model.

Peak discharges of the rivers in the study area during 1988 Floods are estimated as follows;

a)	Dhaleswari River	:	1000-20,800 m^3/s
b)	Bansi River	:	2,700 m^3/s
c)	Buriganga River	:	2,700 m^3/s
d)	Turag River	:	700-2,700 m^3/s
e)	Lakhya River	:	2,600-3,500 m^3/s
f)	Balu River	:	100-800 m^3/s

g) Karnatali River : 1,900 m^3/s
h) Tongi Khal : 600 m^3/s

7.4 Future Recommendation

The study area is included in the North Central Region as shown in Fig. D.29. So, it may be necessary to ensure consistency between the simulation of this study and the simulation of North Central Regional Model of SWSMP mentioned in section 7.1. In this case, it is necessary to maintain the same degree of accuracy on hydrological and topographical data for the whole area of North Central Region.

However, as the simulation model of this study realizes the 1988 Floods of the study area, this model satisfies the requirement for formulating the flood mitigation plan of the study area under the existing conditions.

TABLE D.1 CLIMATE CONDITIONS IN THE STUDY AREA

MONTH	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temperature, °C												
High (EXTREME)	34.2	36.6	40.6	42.3	40.6	38.4	35.2	35.9	35.3	38.8	33.3	31.2
Low (EXTREME)	5.6	4.5	10.4	15.6	18.4	20.4	21.7	21.0	22.0	10.4	10.6	6.7
Avg.	18.8	21.5	26.1	28.7	28.9	28.7	28.7	28.7	28.7	27.4	23.6	19.8
Relative Humidity, percent	70	66	63	71	79	86	87	86	86	81	75	74
Evaporation, millimeters	104	79	81	77	78	83	87	130	118	106	75	105
Days of Rain, per month	1	2	4	8	14	19	22	22	16	9	2	1
Average Rainfall, millimeters	6.5	20.2	52.3	124	283	398.2	391.4	328.0	264.0	160.0	25.3	7.4
Wind Velocities, Knots (Knot=1,852 Km/hr)	2	2	3	5	5	4	4	4	3	2	1	1

Data : 1) Bangladesh Meteorological Department (1953 - 1985)
2) Evapolation ; H.R.Laboratory(Dhaka) No.E-10 (1978 - 1979)

Source :
JICA; Study on Storm Water Drainage System Improvement Project in Dhaka City, 1987

TABLE D.2 LIST OF RAINFALL GAUGING STATIONS AND AVAILABLE DATA

STATION NAME	AGENCY	STAION NO.	LOCATION		DATE OF ESTAB-LISHMENT	MEASUREMENT	DATA	REMARKS
1) DHAKA	B.M.D.	-	Latitude : Longitude :	23 deg. 46.0 min. N 90 deg. 23.0 min. E	1949	Manual Auto	1953 - 1990	Auto recorder(1957 - 1983)
2) NARAYANGANJ	B.M.D.	-	Latitude : Longitude :	23 deg. 37.0 min. N 90 deg. 30 .0min. E	1867	Manual	1948 - 1979	Closed in 1979
3) DHAKA	BWDB	9	Latitude : Longitude :	23 deg. 47.2 min. N 90 deg. 24.2 min. E	08. 07. 1960	Manual Auto	1957 - 1990	Incorporated into Dhaka(B.M.D.) in 1985
4) JOYDEBPUR	BWDB	17	Latitude : Longitude :	24 deg. 00.0 min. N 90 deg. 25.0 min. E	11. 03. 1961	Manual	1961 - 1990	
5) SAVAR	BWDB	31	Latitude : Longitude :	24 deg. 01.0 min. N 90 deg. 11.0 min. E	23. 11. 1961	Manual	1962 - 1990	
6) NARSINDI	BWDB	76	Latitude : Longitude :	23 deg. 57.3 min. N 90 deg. 44.5 min. E	06. 03. 1961	Manual	1961 - 1990	
7) BANCHARAMPUR	BWDB	351	Latitude : Longitude :	23 deg. 44.5 min. N 90 deg. 45.7 min. E	02. 03. 1961	Manual	1961 - 1990	
8) DAUDKANDI	BWDB	357	Latitude : Longitude :	23 deg. 32.0 min. N 90 deg. 43.0 min. E	27. 06. 1961	Manual	1983 - 1990	
9) MUNSHIGANJ	BWDB	365	Latitude : Longitude :	23 deg. 33.1 min. N 90 deg. 32.2 min. E	25. 11. 1960	Manual	1963 - 1990	
10) NARAYANGANJ	BWDB	368	Latitude : Longitude :	23 deg. 36.8 min. N 90 deg. 30.2 min. E	-	Manual	1961 - 1977	Closed in 1977
11) NAWABGANJ	BWDB	412	Latitude : Longitude :	23 deg. 39.5 min. N 90 deg. 10.0 min. E	13. 03. 1961	Manual	1965 - 1990	

TABLE D.3 LIST OF WATER LEVEL GAUGING STATIONS AND AVAILABLE DATA

STATION NAME	AGENCY	STAION NO.	RIVER	LOCATION	DATE OF ESTAB-LISHMENT	MEASUREMENT	DATA OF WATER LEVEL	DATA OF DISCHARGE	DATA OF RATING CURVE
1) PUBAIL	BWDB	7	Balu	Latitude : 23 deg. 56.5 min. N Longitude : 90 deg. 29.8 min. E	26. 6. 1945	Manual	1945 - 1990	-	-
2) DEMRA	BWDB	7.5	Balu	Latitude : 23 deg. 44.0 min. N Longitude : 90 deg. 30.0 min. E	21. 10. 1964	Manual	1962 - 1990	1979 - 1989	1979 - 1987
3) NAYARHAT	BWDB	14.5	Bansi	Latitude : 23 deg. 54.7 min. N Longitude : 90 deg. 14.0 min. E	11. 06. 1963	Manual	1964 - 1988	1979 - 1989	1977 - 1989
4) MILL BARAK	BWDB	42	Buriganga	Latitude : 23 deg. 41.9 min. N Longitude : 90 deg. 25.3 min. E	10. 10. 1906	Manual Auto	1945 - 1990	-	-
5) HARIHARPARA	BWDB	43	Buriganga	Latitude : 23 deg. 38.0 min. N Longitude : 90 deg. 28.5 min. E	04. 06. 1945	Manual	1945 - 1990	-	-
6) SAVAR	BWDB	69	Dhaleswari	Latitude : 24 deg. 01.0 min. N Longitude : 90 deg. 11.o min. E	13. 07. 1945	Manual	1945 - 1990	-	-
7) KALATIA	BWDB	70	Dhaleswari	Latitude : 23 deg. 42.9 min. N Longitude : 90 deg. 15.9 min. E	01. 10. 1958	Manual	1968 - 1990	-	-
8) KALAGACHIA	BWDB	71	Dhaleswari	Latitude : 23 deg. 34.7 min. N Longitude : 90 deg. 32.7 min. E	15. 06. 1945	Manual	1977 - 1990	-	-
9) REKABI BAZAR	BWDB	71A	Dhaleswari	Latitude : 23 deg. 34.4 min. N Longitude : 90 deg. 29.7 min. E	16. 12. 1965	Manual	1968 - 1990	-	-
10) DEMRA	BWDB	179	Lakhya	Latitude : 23 deg. 44.0 min. N Longitude : 90 deg. 31.5 min. E	18. 06. 1945	Manual	1952 - 1990	-	1977 - 1989
11) MEGHNA FERRY GHAT	BWDB	275.5	Surma-Meghna	Latitude : 23 deg. 36.2 min. N Longitude : 90 deg. 37.5 min. E	25. 09. 1965	Manual	1968 - 1990	-	-
12) TONGI	BWDB	299	Tongi Khal	Latitude : 23 deg. 52.8 min. N Longitude : 90 deg. 24.2 min. E	25. 03. 1960	Manual	1960 - 1990	-	-
13) MIRPUR	BWDB	302	Turag	Latitude : 23 deg. 47.3 min. N Longitude : 90 deg. 20.3 min. E	-	Manual	1953 - 1990	1983 - 1989	1977 - 1989

TABLE D.4 ANNUAL MAXIMUM DAILY RAINFALL

(unit : mm)

NO.	STATION	DHAKA B.M.D.	NARAYANGANJ B.M.D	DHAKA BWDB STA. NO.9	JOYDEBPUR BWDB STA. NO.17	SAVAR BWDB STA. NO.31	NARSINDI BWDB STA. NO.76	BANCHARAMPUR BWDB STA. NO.351	DAUDKANDI BWDB STA. NO.357	MUNSHIGANJ BWDB STA. NO.365	NARAYANGANJ BWDB STA. NO.368	NAWABGONJ BWDB STA. NO.412
	DATA	1953-1990	1948-1979	1957-1990	1961-1990	1962-1990	1951-1990	1951-1990	1983-1990	1963-1990	1961-1977	1965-1990
1	1948		-									
2	1949		119									
3	1950		183									
4	1951	-	149									
5	1952		133									
6	1953	90	-									
7	1954	147	-									
8	1955	115	86									
9	1956	326	149									
10	1957	73	62	72								
11	1958	137	158	113								
12	1959	125	134	120								
13	1960	141	160	112								
14	1961	185	202	154	140		169	137			116	
15	1962	116	87	81	107	246	110	-			-	
16	1963	189	197	207	127	87	146	171		73	163	
17	1964	114	231	144	161	165	136	-		-	-	
18	1965	177	-	222	173	179	122	118		112	109	127
19	1966	257	216	283	137	122	186	164		83	216	179
20	1967	125	137	98	140	142	126	146		109	118	95
21	1968	145	135	137	177	163	101	97		144	135	180
22	1969	86	252	76	69	93	157	244		109	91	72
23	1970	152	81	113	112	82	192	90		137	81	108
24	1971	251	106	196	126	88	202	135		127	-	128
25	1972	231	167	165	77	114	116	64		102	-	224
26	1973	168	170	216	206	133	144	182		127	115	129
27	1974	-	-	107	165	136	181	108		127	166	109
28	1975	143	132	158	165	235	122	179		127	132	105
29	1976	163	105	158	107	162	186	121		136	147	-
30	1977	100	193	149	104	126	123	90		141	-	53
31	1978	128	-	134	184	165	226	181		127		99
32	1979	108	-	127	229	187	157	184		127		61
33	1980	91		91	95	-	164	55		-		79
34	1981	83		81	125	114	285	136		82		86
35	1982	146		146	129	165	106	65		239		-
36	1983	128		133	193	146	199	188	125	174		179
37	1984	150		151	112	184	181	161	107	151		78
38	1985	92		92	83	107	184	61	94	113		81
39	1986	176		176	167	109	147	212	104	206		-
40	1987	138		138	153	99	120	174	155	69		79
41	1988	135		135	155	-	122	189	119	108		-
42	1989	118		118	129	102	89	73	125	84		69
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	146	150	139	140	140	154	138	118	126	132	111

TABLE D.5 ANNUAL MAXIMUM TWO DAY RAINFALL

(unit : mm)

NO.	STATION	DHAKA B.M.D.	NARAYANGANJ B.M.D	DHAKA BWDB STA. NO.9	JOYDEBPUR BWDB STA. NO.17	SAVAR BWDB STA. NO.31	NARSINDI BWDB STA. NO.76	BANCHARAMPUR BWDB STA. NO.351	DAUDKANDI BWDB STA. NO.357	MUNSHIGANJ BWDB STA. NO.365	NARAYANGANJ BWDB STA. NO.368	NAWABGONJ BWDB STA. NO.412
	DATA	1953-1990	1948-1979	1957-1990	1961-1990	1962-1990	1961-1990	1961-1990	1983-1990	1953-1990	1961-1977	1965-1990
1	1948		-									
2	1949		143									
3	1950		233									
4	1951		165									
5	1952		172									
6	1953	127	-									
7	1954	255	-									
8	1955	120	124									
9	1956	346	178									
10	1957	98	97	102								
11	1958	140	166	176								
12	1959	179	171	178								
13	1960	223	238	151								
14	1961	185	202	189	152		205	207			177	
15	1962	141	130	123	156	297	133	-			-	
16	1963	257	307	278	131	110	181	184		108	167	
17	1964	206	266	195	254	196	244	1		-	-	
18	1965	181	-	225	221	184	225	118		154	133	129
19	1966	270	302	339	229	167	211	251		100	302	202
20	1967	147	207	141	231	161	189	232		150	207	96
21	1968	240	263	235	210	197	168	172		259	263	183
22	1969	104	255	122	107	117	196	258		182	165	92
23	1970	262	132	185	147	118	232	134		164	133	172
24	1971	328	188	272	162	139	319	135		229	-	166
25	1972	251	183	215	117	145	191	98		178	-	292
26	1973	177	204	224	221	133	255	213		203	136	213
27	1974	-	-	189	182	136	237	147		229	170	154
28	1975	212	246	257	264	371	227	353		198	246	112
29	1976	263	194	275	199	250	310	168		224	218	-
30	1977	133	228	155	115	150	148	109		208	-	93
31	1978	191	-	185	267	199	230	186		168		160
32	1979	166	-	168	330	268	191	212		218		79
33	1980	125		125	132	-	203	86		-		109
34	1981	148		148	201	160	288	170		123		122
35	1982	167		167	181	208	182	96		301		-
36	1983	194		199	290	249	362	321	242	248		189
37	1984	200		201	160	261	247	234	180	219		105
38	1985	132		105	142	159	217	95	151	117		142
39	1986	321		321	271	184	294	270	196	277		-
40	1987	172		172	230	168	193	209	201	107		119
41	1988	175		175	283	-	200	301	138	155		-
42	1989	151		151	160	155	112	119	127	145		107
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	194	200	192	198	187	218	188	176	187	193	145

TABLE D.6 ANNUAL MAXIMUM FIVE DAY RAINFALL

(unit : mm)

	STATION	DHAKA	NARAYANGANJ	DHAKA	JOYDEBPUR	SAVAR	NARSINDI	BANCHARAMPUR	DAUDKANDI	MUNSHIGANJ	NARAYANGANJ	NAWABGONJ
		B.M.D.	B.M.D	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
				STA. NO.8	STA. NO.17	STA. NO.31	STA. NO.76	STA. NO.351	STA. NO.357	STA. NO.365	STA. NO.368	ST/. NO.412
	DATA	1953-1990	1948-1979	1957-1990	1961-1990	1962-1990	1961-1990	1961-1990	1983-1990	1963-1990	1961-1977	1965-1990
NO.	YEAR											
1	1948		-									
2	1949		224									
3	1950		295									
4	1951		198									
5	1952		183									
6	1953	150	-									
7	1954	323	-									
8	1955	181	182									
9	1956	430	259									
10	1957	184	191	175								
11	1958	170	166	200								
12	1959	309	298	297								
13	1960	331	257	188								
14	1961	317	264	226	283		264	299			264	
15	1962	164	160	164	223	297	204	-			-	
16	1963	327	350	325	144	188	234	338		188	197	
17	1964	241	299	231	295	238	315	-		-	-	
18	1965	219	-	239	307	277	272	192		241	203	147
19	1966	288	343	360	279	190	347	389		212	327	244
20	1967	250	292	223	326	170	329	317		223	292	179
21	1968	379	343	325	263	289	314	345		377	387	301
22	1969	199	297	200	192	173	361	313		227	240	126
23	1970	303	163	248	254	157	347	229		269	142	204
24	1971	355	331	296	300	273	816	180		381	-	236
25	1972	314	215	263	163	202	283	205		394	-	377
26	1973	205	252	271	269	154	420	344		381	168	225
27	1974	-	-	236	209	174	285	211		508	220	202
28	1975	401	429	445	475	507	331	576		315	428	230
29	1976	436	318	447	368	358	410	305		288	380	-
30	1977	175	308	198	189	192	264	123		273	-	160
31	1978	216	-	244	288	283	324	311		338		231
32	1979	234	-	180	500	446	239	222		396		142
33	1980	259		259	215	-	307	140		-		188
34	1981	168		168	309	185	349	278		174		175
35	1982	193		193	209	254	361	105		338		-
36	1983	250		255	363	286	450	419	407	284		249
37	1984	296		296	315	377	491	452	330	319		146
38	1985	169		169	302	262	329	130	193	147		170
39	1986	401		401	331	255	361	355	235	402		-
40	1987	234		234	406	203	272	390	290	168		151
41	1988	301		301	413	-	369	399	243	191		-
42	1989	152		152	178	208	195	129	128	207		175
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	265	265	255	289	254	333	285	261	290	271	203

TABLE D.7 ANNUAL MAXIMUM MONTHLY RAINFALL

(unit : mm)

	STATION	DHAKA	NARAYANGANJ	DHAKA	JOYDEBPUR	SAVAR	NARSINDI	BANCHARAMPUR	DAUDKANDI	MUNSHIGANJ	NARAYANGANJ	NAWABGONJ
		B.M.D.	B.M.D	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
				STA. NO.9	STA. NO.17	STA. NO.31	STA. NO.76	STA. NO.351	STA. NO.357	STA. NO.365	STA. NO.368	STA. NO.412
	DATA	1953-1990	1948-1979	1957-1990	1961-1990	1962-1990	1961-1990	1961-1990	1983-1990	1963-1990	1961-1977	1965-1990
NO.	YEAR											
1	1948		-									
2	1949		414									
3	1950		711									
4	1951		484									
5	1952		438									
6	1953	392	552									
7	1954	810	-									
8	1955	502	340									
9	1956	690	387									
10	1957	487	415	349								
11	1958	267	374	280								
12	1959	568	605	544								
13	1960	655	533	489								
14	1961	856	489	495	-		-	537			-	
15	1962	395	298	430	393	-	477	486			-	
16	1963	621	418	678	355	-	573	711		-	-	
17	1964	629	451	673	512	554	912	-		-	-	
18	1965	480	-	442	592	575	705	484		-	-	416
19	1966	496	479	607	490	391	581	671		414	501	439
20	1967	504	525	476	550	395	563	504		431	509	304
21	1968	590	502	449	565	537	588	451		565	501	471
22	1969	540	428	494	498	628	754	489		459	434	448
23	1970	496	285	414	439	403	601	355		396	304	365
24	1971	550	644	485	629	595	911	384		930	-	471
25	1972	380	356	469	274	357	589	295		808	-	491
26	1973	621	521	618	536	444	875	524		953	-	462
27	1974	-	634	604	593	485	1048	604		1514	623	570
28	1975	559	627	625	634	647	490	608		876	655	399
29	1976	627	542	649	487	547	722	602		736	847	-
30	1977	381	539	593	385	392	504	290		526	-	422
31	1978	529	-	583	788	542	898	716		500		285
32	1979	525	-	437	685	707	635	299		632		196
33	1980	414		411	411	-	678	362		-		422
34	1981	411		320	485	-	672	446		334		392
35	1982	514		514	494	489	568	288		501		-
36	1983	408		434	639	401	705	552	-	611		344
37	1984	891		707	559	591	1065	773	963	567		378
38	1985	399		399	530	352	504	235	528	288		258
39	1986	687		687	498	477	590	558	422	596		-
40	1987	526		526	744	532	636	520	460	429		-
41	1988	580		579	716	-	692	1069	374	418		-
42	1989	347		347	484	-	332	211	362	329		-
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	537	481	509	534	502	674	501	518	600	522	402

TABLE D.8 PROBABLE STORM RAINFALL

(Unit : mm)

DURATION	RAIN STATION	RETURN PERIOD (YEAR)					
		2	5	10	20	50	100
1 day	Dhaka (B.M.D.)	137	184	215	244	283	311
	Savar (BWDB Sta.31)	133	171	196	220	251	274
	Joydebpur (BWDB Sta. 17)	133	167	190	211	239	260
	Narayanganj (B.M.D.)	142	184	212	239	273	299
2 day	Dhaka (B.M.D.)	184	239	276	311	357	391
	Savar (BWDB Sta.31)	177	231	267	301	346	379
	Joydebpur (BWDB Sta. 17)	189	240	275	308	350	382
	Narayanganj (B.M.D.)	191	239	270	301	340	369
5 day	Dhaka (B.M.D.)	251	324	372	418	478	523
	Savar (BWDB Sta.31)	240	316	367	416	479	527
	Joydebpur (BWDB Sta. 17)	274	351	402	451	514	561
	Narayanganj (B.M.D.)	253	314	355	394	444	482
1 month	Dhaka (B.M.D.)	514	636	716	793	892	967
	Savar (BWDB Sta.31)	486	573	630	686	757	811
	Joydebpur (BWDB Sta. 17)	515	619	687	753	838	901
	Narayanganj (B.M.D.)	437	558	620	679	757	814

TABLE D.9 ANNUAL MAXIMUM WATER LEVEL

(UNIT :PWD in m)

	STATION	PUBAIL	DEMRA	NAYARHAT	MILL BARAK	HARIHARPARA	SAVAR	KALATIA	KALAGACHIA	RAKABI BAZAR	DEMRA	MEGHNA FERRY GHAT	TONGI	MIRPUR
		BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
		STA. NO.7	STA. NO.7.5	STA. NO.14.5	STA. NO.42	STA.NO.43	STA. NO. 69	STA. NO.70	STA. NO. 71	STA. NO. 71A	STA. NO. 179	STA. NO.275.5	STA. NO.299	STA. NO. 302
	RIVER	BALU	BALU	BANGSHI	BURIGANGA	BURIGANGA	DHALESWARI	DHALESWARI	DHALESWARI	DHALESWARI	LAKHYA	SURMA-MEGHNA	TONGI KHAL	TURAG
	DATA	1945-1990	1962-1990	1964-1990	1945-1990	1945-1990	1945-1990	1968-1990	1977-1990	1968-1990	1952-1990	1968-1990	1960-1990	1953-1990
NO.	YEAR													
1	1945	-			6.00	-	7.41							
2	1946	-			5.96	5.28	6.84							
3	1947	5.53			5.60	-	6.98							
4	1948	5.82			6.26	-	7.20							
5	1949	-			5.96	5.94	7.23							
6	1950	5.43			5.72	-	7.04							
7	1951	-			-	-	7.35							
8	1952	5.41			5.45	-	7.10				5.58			
9	1953	-			5.66	5.24	7.06				5.58			6.27
10	1954	6.65			7.02	6.22	8.17				6.52			7.84
11	1955	-			7.05	6.40	8.26				6.77			7.86
12	1956	6.19			5.64	4.82	6.83				5.73			6.03
13	1957	5.92			5.32	5.06	7.20				5.52			6.20
14	1958	6.54			6.41	-	-				5.97			7.17
15	1959	6.08			5.74	5.33	7.12				-			6.52
16	1960	6.17			6.06	5.53	7.57				-		6.40	6.62
17	1961	-			5.48	-	7.30				-		-	5.98
18	1962	6.92	6.29		-	-	-				-		7.27	7.57
19	1963	-	5.92		-	-	-				-		6.55	6.75
20	1964	-	6.40	8.16	-	-	-				-		7.00	7.17
21	1965	-	5.81	7.62	-	-	-				5.83		6.54	6.56
22	1966	-	6.24	8.00	-	-	-				6.30		6.78	6.98
23	1967	-	5.43	7.07	-	-	-				5.46		5.87	-
24	1968	-	6.08	8.03	6.30	5.85	7.69	6.84		5.75	6.09	5.68	6.70	6.76
25	1969	6.19	5.85	7.55	5.89	5.63	7.08	6.46		5.47	5.87	5.63	6.34	6.37
26	1970	6.74	6.24	8.69	6.47	6.04	7.99	7.10		5.85	-	5.87	7.11	7.17
27	1971	6.42	6.03	-	6.19	5.85	7.36	6.81		-	6.08	-	6.72	-
28	1972	5.64	5.40	6.97	5.26	5.01	6.66	6.07		5.00	5.44	5.11	5.81	5.74
29	1973	6.25	5.88	7.70	5.84	5.55	7.21	6.55		5.46	5.88	5.44	6.36	6.36
30	1974	6.95	6.56	8.44	6.57	6.34	7.80	7.12		6.07	6.60	6.19	7.10	7.09
31	1975	5.73	5.60	-	5.39	5.23	-	-		5.18	5.60	5.29	-	-
32	1976	5.64	5.47	6.44	5.13	4.98	6.31	5.98		-	5.53	5.32	-	-
33	1977	6.03	5.92	7.15	5.60	5.39	6.88	6.34	5.34	5.39	5.81	5.59	6.03	5.99
34	1978	-	-	6.48	5.22	5.05	6.29	5.83	5.03	-	5.43	-	5.56	5.51
35	1979	-	5.59	6.46	5.25	5.08	-	-	-	-	5.49	-	5.60	5.54
36	1980	6.66	6.23	8.58	6.39	-	-	7.21	-	5.61	-	-	6.99	7.20
37	1981	-	5.74	6.74	5.42	-	-	-	-	-	5.65	5.40	-	5.79
38	1982	-	6.00	8.34	-	-	-	-	-	-	5.35	5.19	6.02	5.41
39	1983	6.05	5.90	7.23	5.73	5.43	6.96	6.38	5.44	5.49	5.81	5.56	6.40	6.03
40	1984	6.35	6.03	8.12	6.00	5.72	7.58	7.11	5.91	5.74	6.04	5.73	7.10	6.63
41	1985	5.83	5.70	7.04	5.37	5.12	6.70	6.18	5.06	5.28	5.57	5.44	5.75	5.79
42	1986	5.70	5.25	6.77	4.96	4.82	6.69	6.20	4.65	4.97	5.14	5.03	5.50	5.43
43	1987	6.90	6.46	8.74	6.60	6.23	8.30	7.53	5.92	6.02	6.38	5.99	7.02	7.30
44	1988	7.29	7.10	9.90	7.54	7.17	9.68	8.91	5.97	6.43	-	6.55	7.96	8.39
45	1989	5.47	5.44	6.21	5.06	4.78	6.34	5.92	5.04	5.10	5.34	-	5.28	5.42
46	1990	-	-	-	-	-	-	-	-	-	-	-	-	-
	AVERAGE	6.16	5.96	7.52	5.88	5.54	7.28	6.70	5.37	5.55	5.81	5.59	6.46	6.52

Notes : 1) The above water levels of Mill Barak, Mirpur, Tongi and Demra(Sta. 7.5) are revised by the results of check survey conducted in 1987 JICA STUDY .

2) The equations for the revision are as follows ;

Mill Barak	Y=X - 0.037	where X : raw data
Mirpur	Y=X + 0.042	Y : revised data
Tongi	Y=X + 0.122	
Demra(7.5)	Y=X + 0.007	

TABLE D.10 PROBABLE FLOOD WATER LEVEL

(Unit : PWD in m)

WATER LEVEL STATION	RETURN PERIOD (YEAR)												1988	1987	1974
	2	3	5	10	20	30	50	100	200	300	400	500	Flood	Flood	Flood
1) Pubail (BWDB Sta. 7)	6.15	6.34	6.55	6.83	7.09	7.24	7.43	7.67	7.93	8.08	8.17	8.26	7.29	6.90	6.95
2) Demra (BWDB Sta. 7.5)	5.89	6.07	6.27	6.53	6.77	6.91	7.09	7.32	7.56	7.70	7.79	7.87	7.10	6.46	6.58
3) Nayarhat (BWDB Sta. 14.5)	7.49	7.80	8.14	8.56	8.98	9.21	9.51	9.91	10.31	10.54	10.71	10.84	9.90	8.74	8.44
4) Mill Barak (BWDB Sta. 42)	5.78 (5.82)	6.03 (6.04)	6.30 (6.29)	6.65 (6.59)	6.98 (6.89)	7.17 (7.09)	7.40 (7.27)	7.72 (7.56)	8.04	8.23	8.36	8.46	7.54	6.60	6.57
5) Hariharpara (BWDB Sta. 43)	5.45	5.66	5.89	6.19	6.47	6.63	6.82	7.10	7.37	7.53	7.64	7.72	7.17	6.23	6.34
6) Savar (BWDB Sta. 69)	7.17	7.45	7.76	8.14	8.52	8.73	9.00	9.36	9.72	9.93	10.08	10.20	9.68	8.30	7.80
7) Kalatia (BWDB Sta. 70)	6.58	6.83	7.09	7.42	7.75	7.94	8.17	8.48	8.79	8.98	9.11	9.21	8.91	7.53	7.12
8) Kalagachia (BWDB Sta. 71)	5.33	5.46	5.61	5.81	5.99	6.09	6.23	6.40	6.58	6.69	6.75	6.81	5.97	5.92	-
9) Rakabi Bazar (BWDB Sta. 71A)	5.46	5.61	5.78	6.00	6.20	6.31	6.46	6.65	6.85	6.97	7.05	7.11	6.43	6.02	6.07
10) Demra (BWDB Sta. 179)	5.82	5.99	6.18	6.42	6.65	6.78	6.95	7.17	7.40	7.53	7.61	7.69	-	6.38	6.60
11) Tongi (BWDB Sta. 299)	6.28 (6.46)	6.54 (6.70)	6.82 (6.97)	7.18 (7.33)	7.53 (7.67)	7.72 (7.86)	7.96 (8.11)	8.30 (8.43)	8.63	8.83	8.96	9.07	7.96	7.02	7.10
12) Mirpur (BWDB Sta. 302)	6.30 (6.42)	6.59 (6.64)	6.90 (6.91)	7.30 (7.25)	7.68 (7.58)	7.90 (7.76)	8.17 (8.00)	8.53 (8.31)	8.90	9.12	9.27	9.39	8.39	7.30	7.09

Notes : 1) The results of the check survey for the water level gauging stations of Mill Barak, Mirpur, Tongi and Demra(Sta. 7.5) conducted by JICA STUDY are reflected.

2) Probable flood water levels of Mill Barak, Demra(Sta. 7.5) and Savar are caluculated by Gumbel-Chow's method.

3) Probable flood water levels of other stations except above three stations of Mill Barak, Demra(Sta. 7.5) and Savar are caluculated using the correlation with these three stations (refer to Fig. D.16).

4) Water levels in the parentheses are probable water levels of 1987 JICA STUDY.

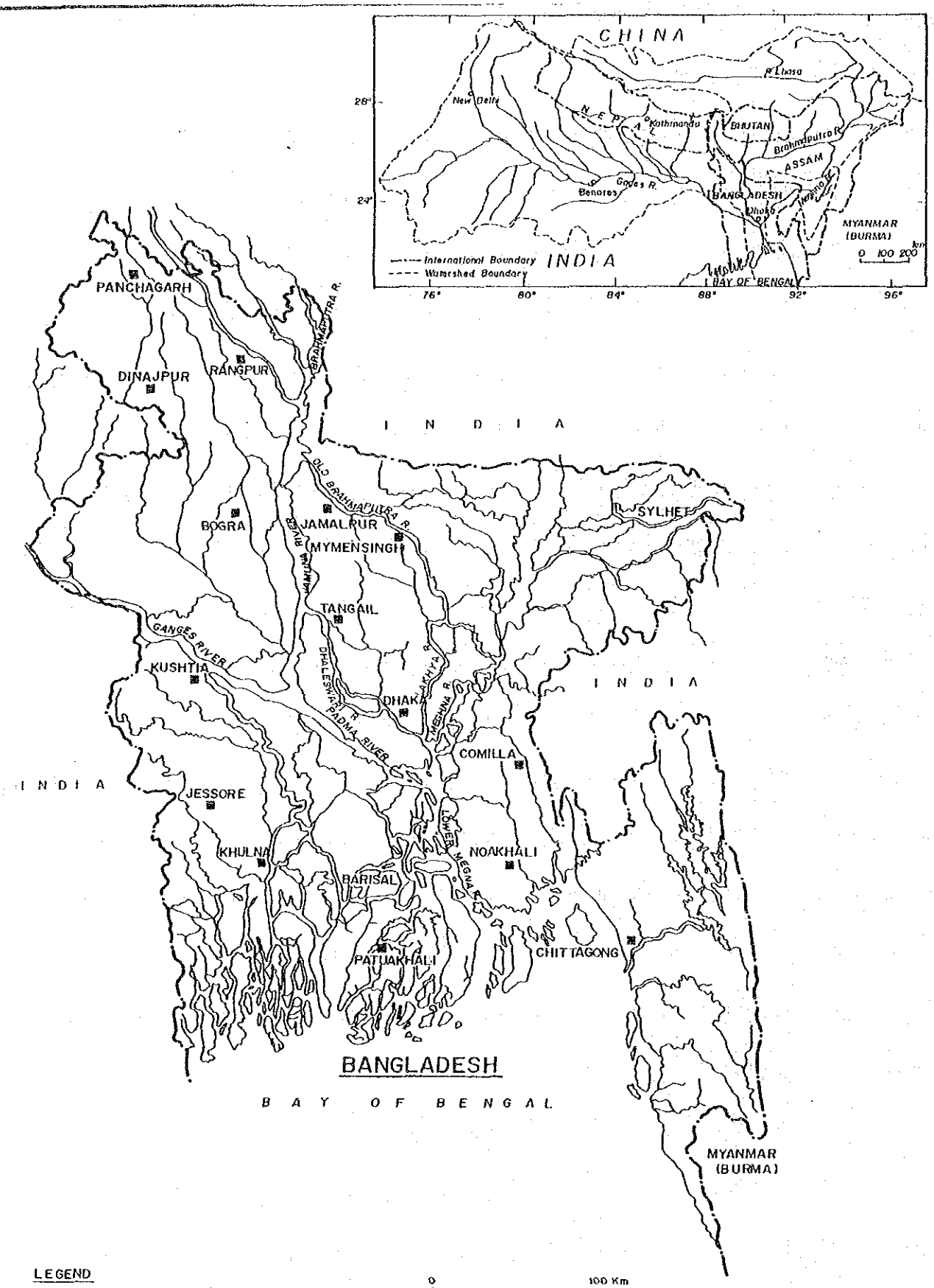


FIG. D.1 RIVER SYSTEM IN BANGLADESH

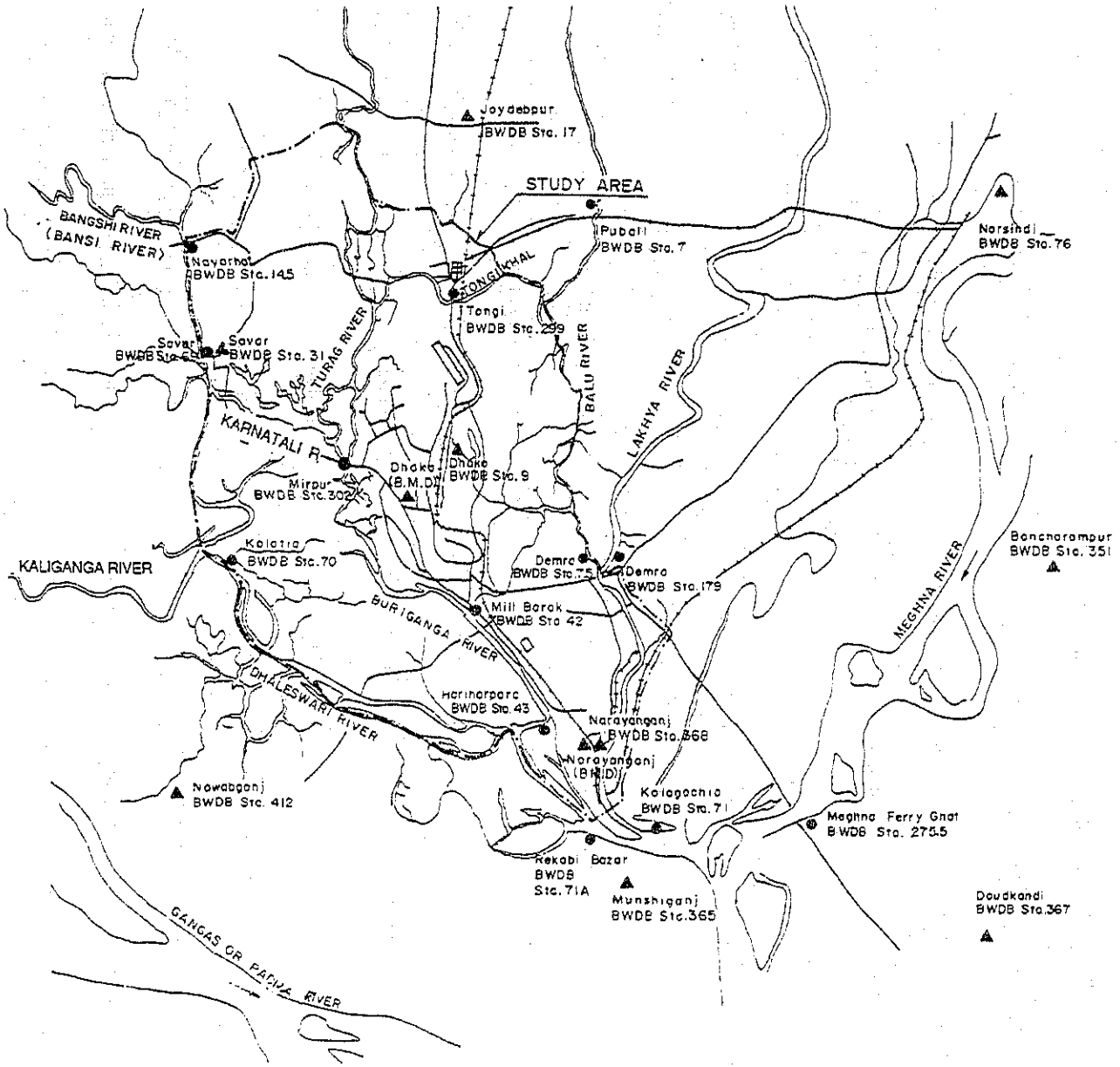
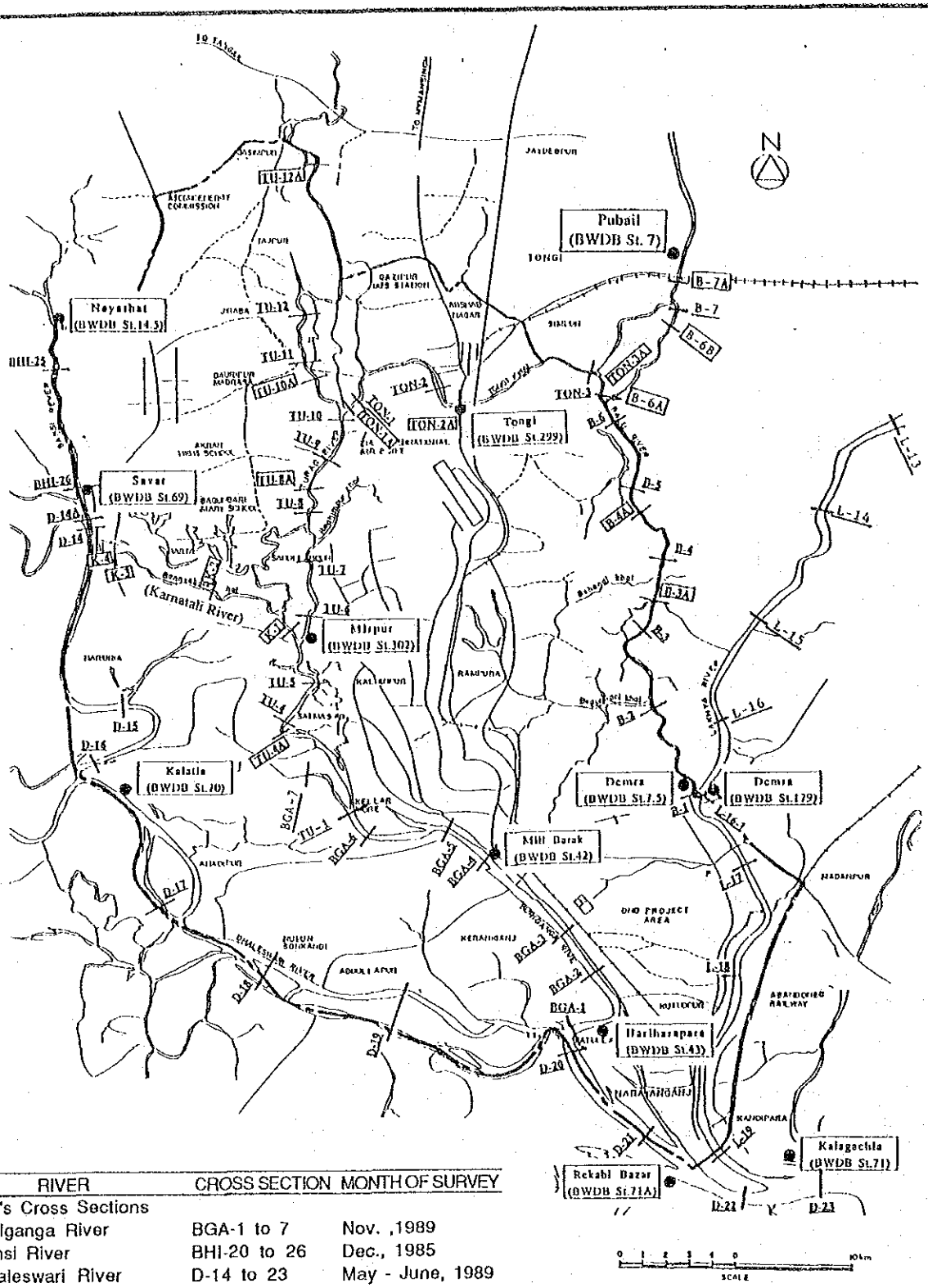


FIG. D.2 RIVER SYSTEM AND GAUGING STATIONS IN AND AROUND THE STUDY AREA

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROLOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA



RIVER	CROSS SECTION	MONTH OF SURVEY
1 BWDB's Cross Sections		
1) Burlganga River	BGA-1 to 7	Nov. ,1989
2) Bansi River	BHI-20 to 26	Dec., 1985
3) Dhaleswari River	D-14 to 23	May - June, 1989
4) Lakhya River	L-1 to 19	Jan., 1990
5) Balu River	B-1 to 7	Mar., 1990
6) Turag River	TUR-1 to 9	Feb. - Mar., 1990
7) Tongi Khal	TON-1 to 3	Feb., 1990
2 JICA TEAM's Cross Sections		
1) Balu River	B-3A to 7A	Feb. - Mar., 1991
2) Turag River	TU-4A to 12A	Feb. - Mar., 1991
3) Tongi Khal	TON-1A to 3A	Feb. - Mar., 1991
4) Karnatali River	K-1 to 4	Feb. - Mar., 1991

LEGEND :

BGA-3 Cross Section of BWDB

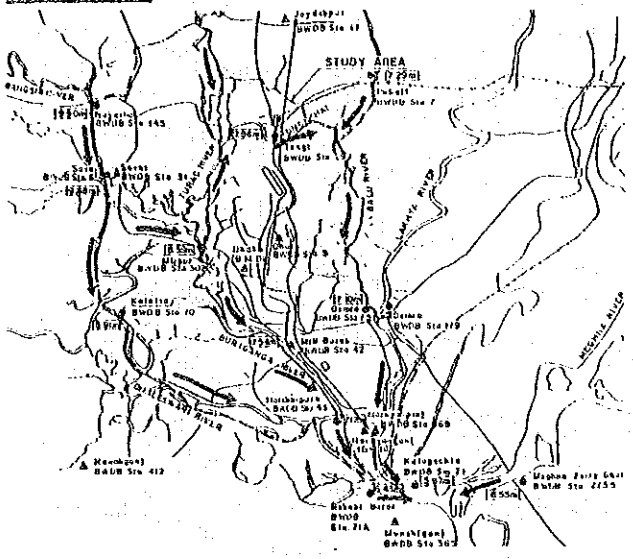
TU-4A Cross Section of JICA TEAM

● Water Level Gauging Station

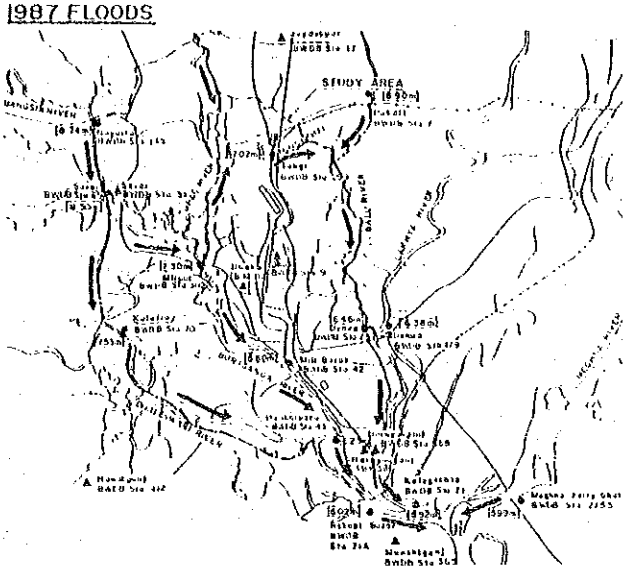
FIG. D.3 AVAILABLE RIVER CROSS SECTION DATA

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

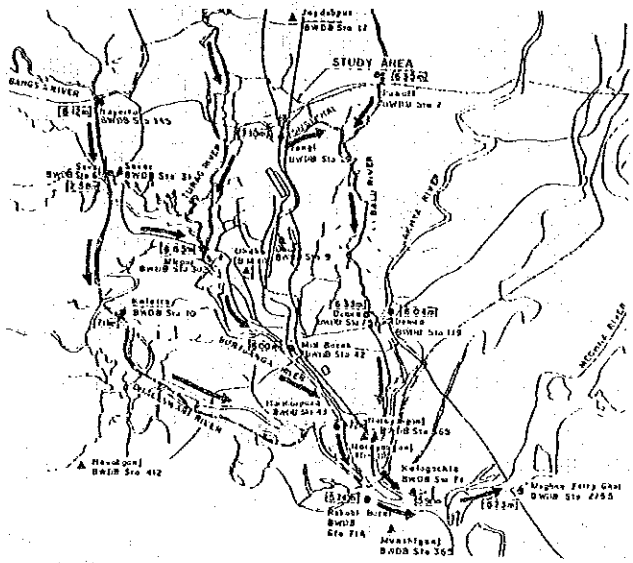
1988 FLOODS



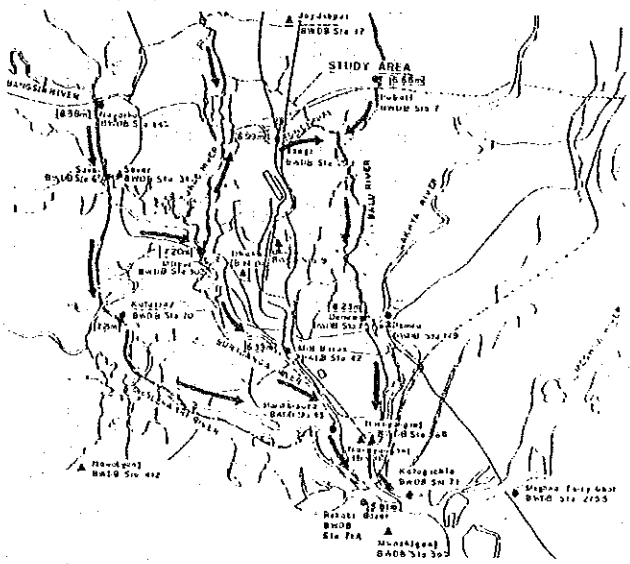
1987 FLOODS



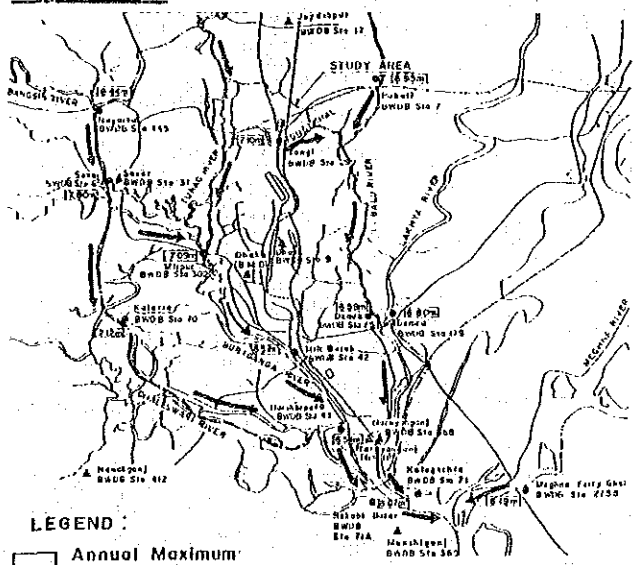
1984 FLOODS



1980 FLOODS



1974 FLOODS



1970 FLOODS

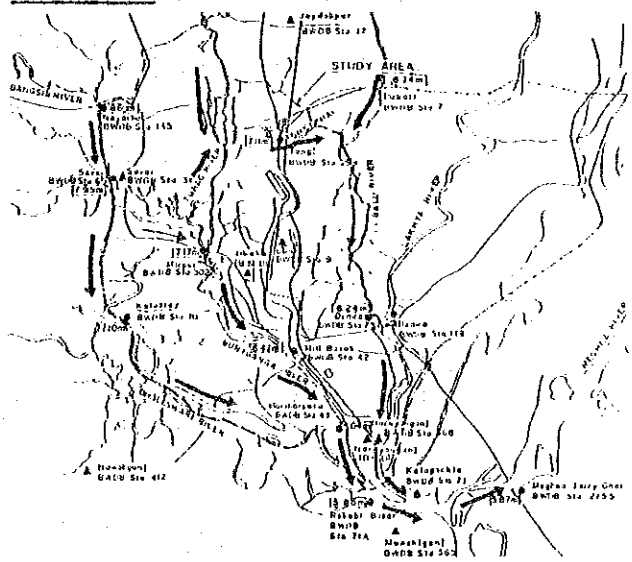


FIG. D.4 ESTIMATED FLOW DIRECTION OF MAJOR FLOODS

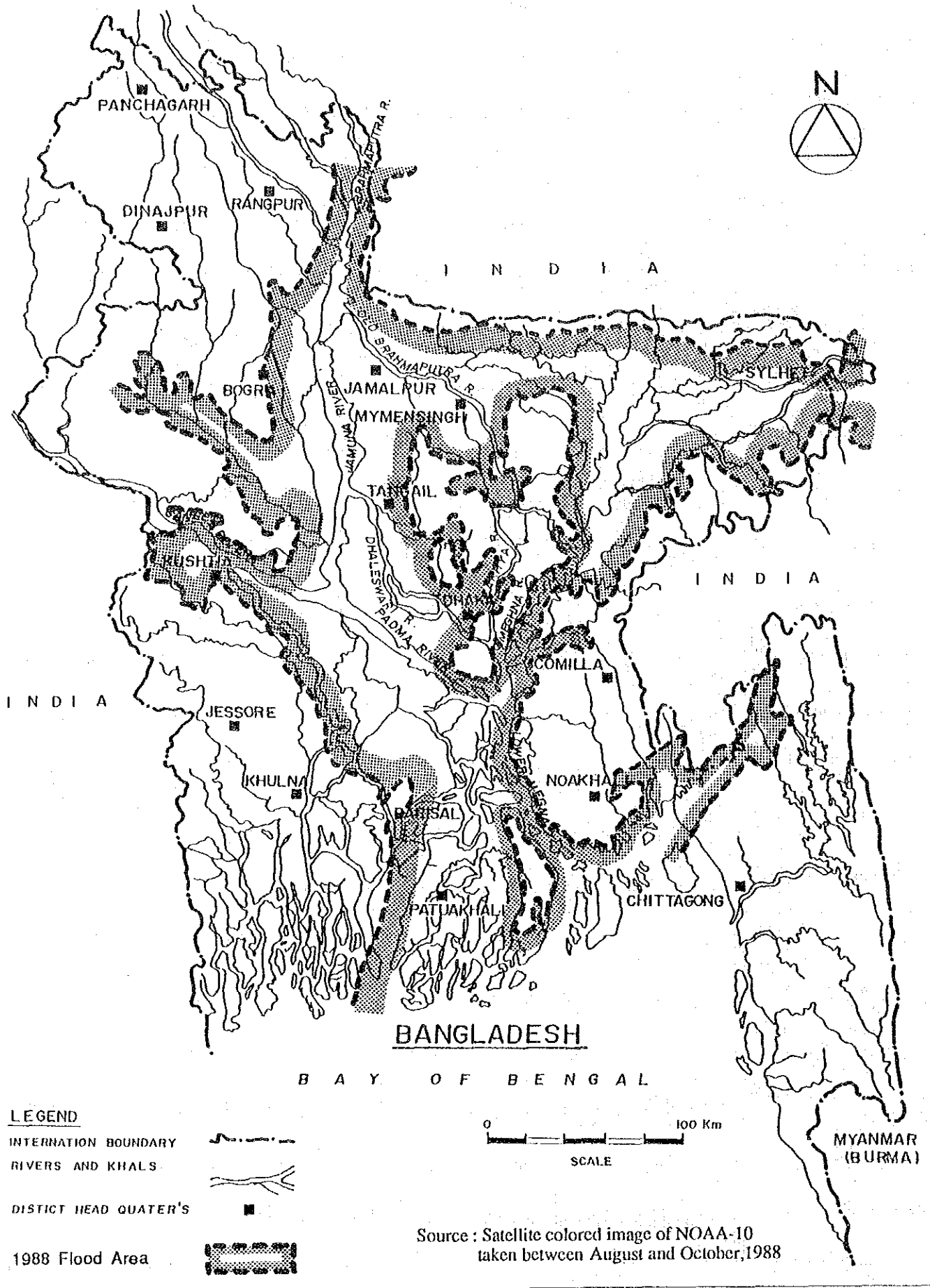


FIG. D.5 | 1988 FLOODS IN BANGLADESH

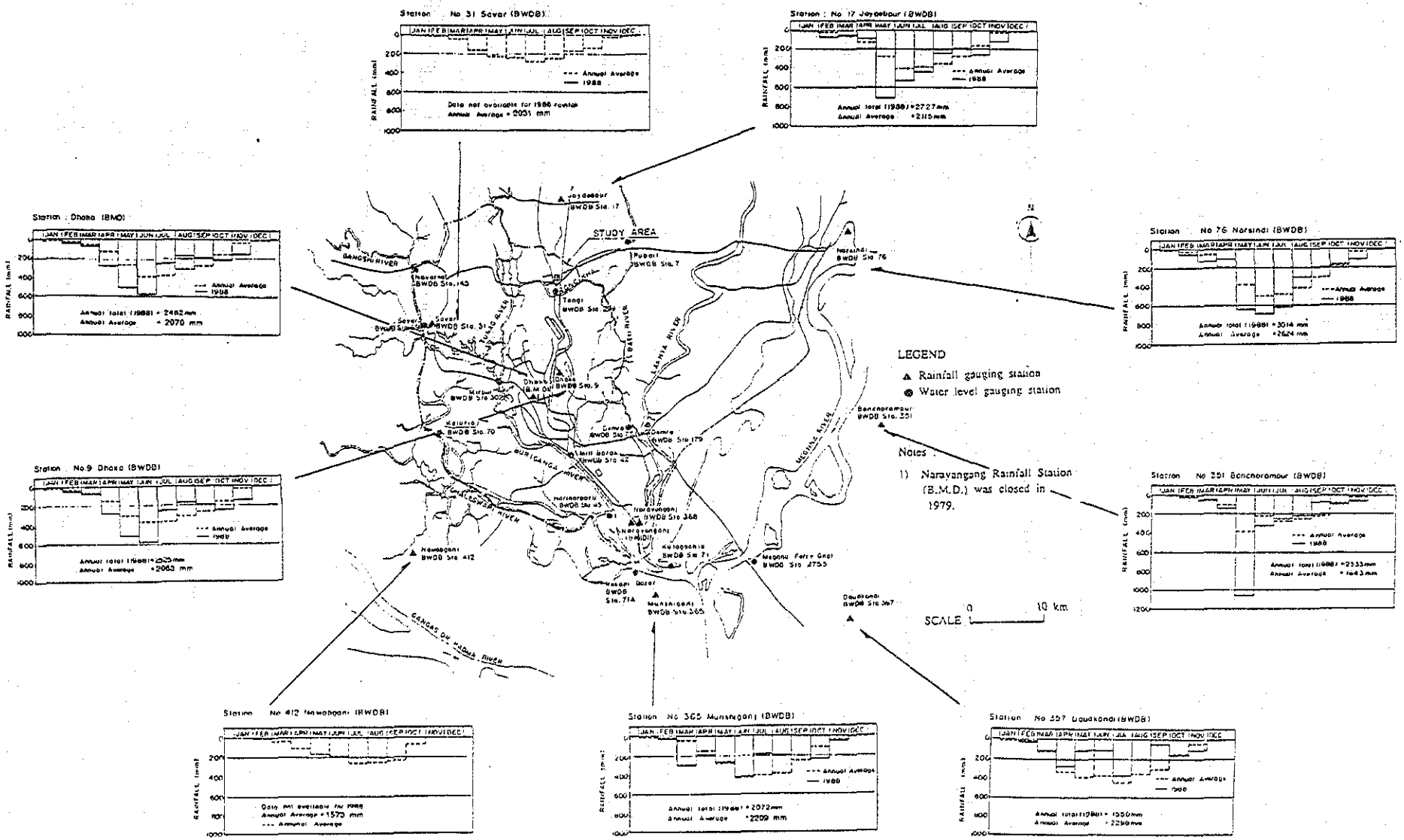


FIG. D.6 MONTHLY RAINFALL-1988 AND ANNUAL AVERAGE

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA

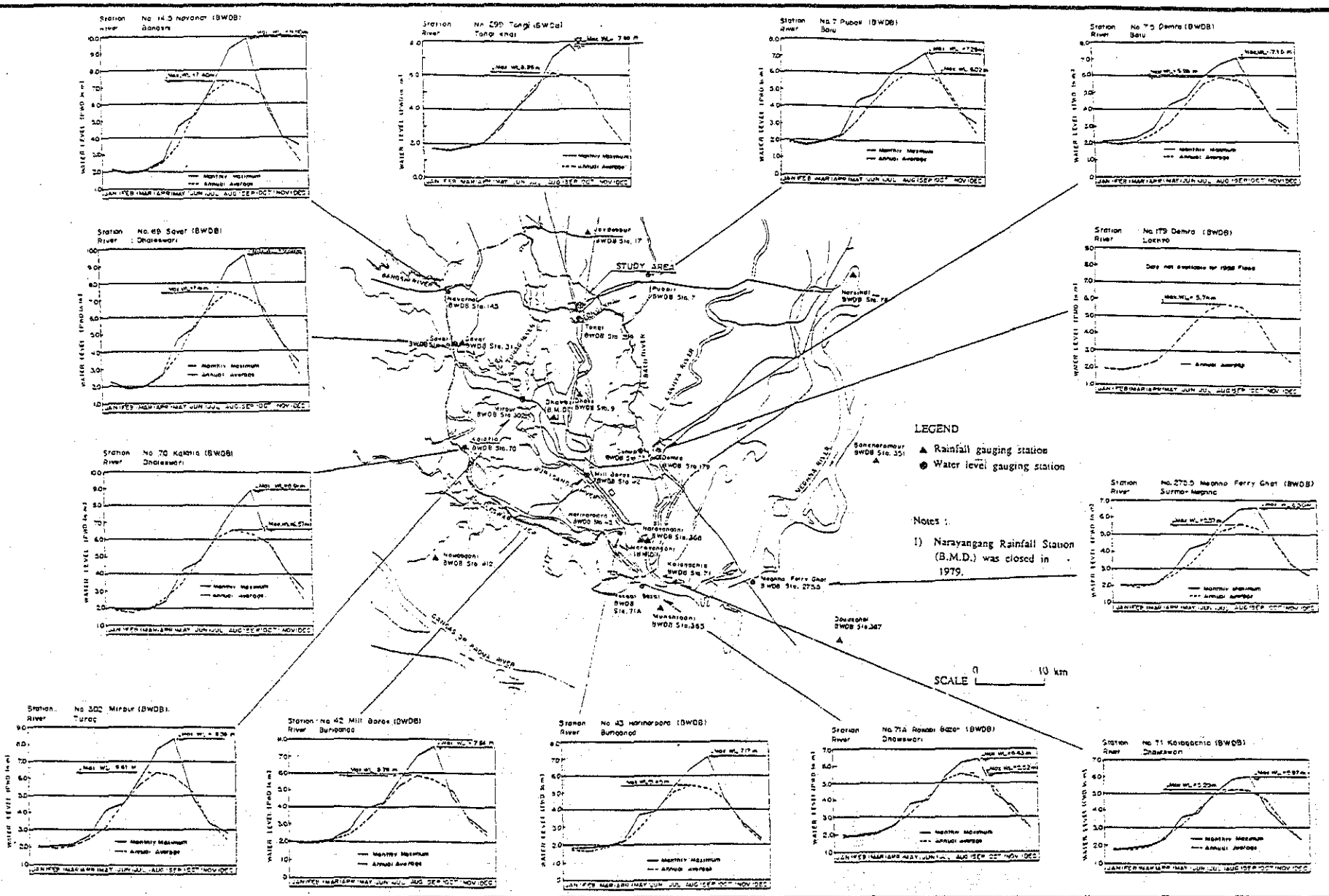


FIG. D.7 MONTHLY MAXIMUM WATER LEVEL-1988 AND ANNUAL AVERAGE

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

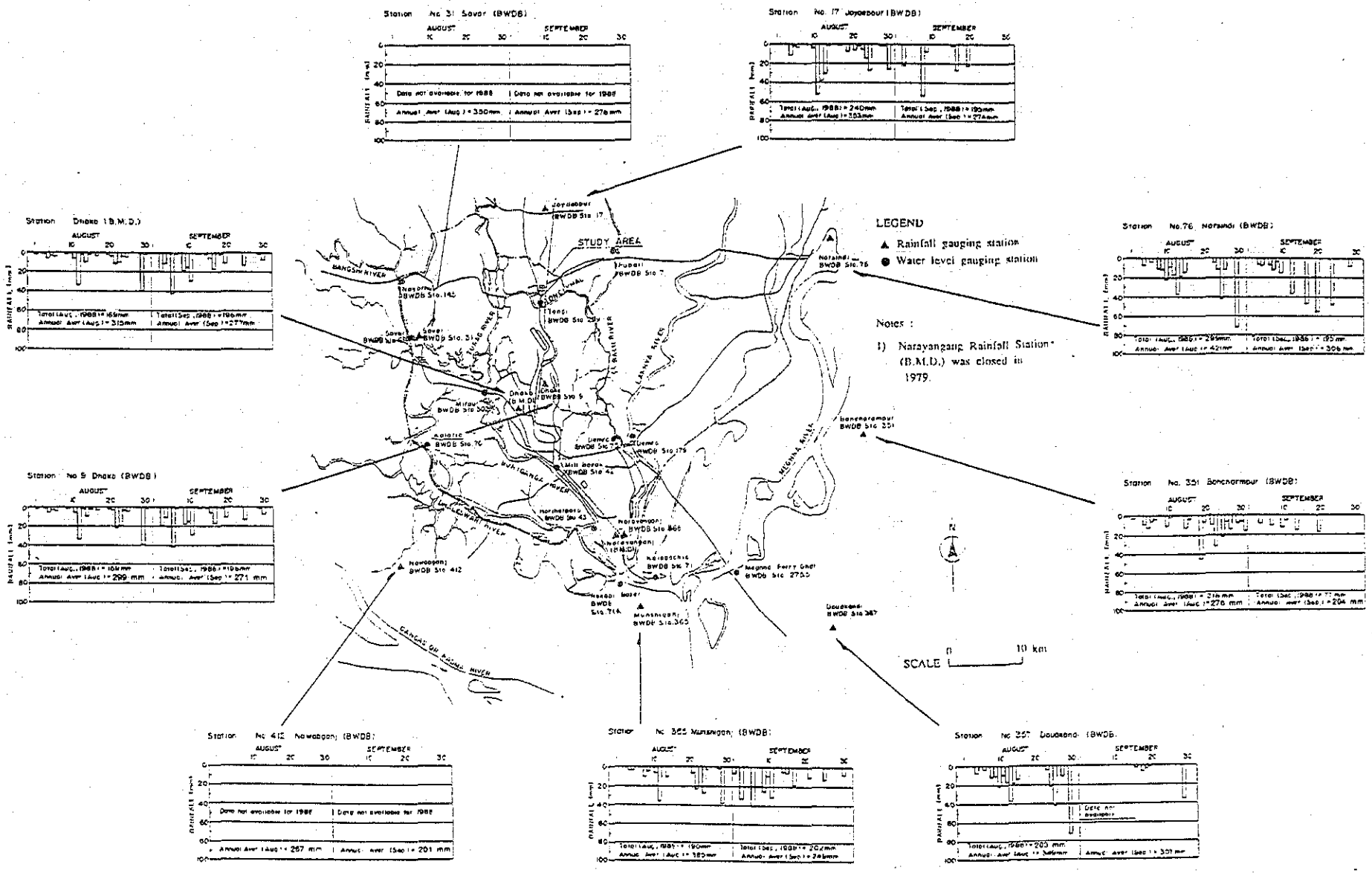


FIG. D.8 DAILY RAINFALL DURING 1988 FLOODS

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA

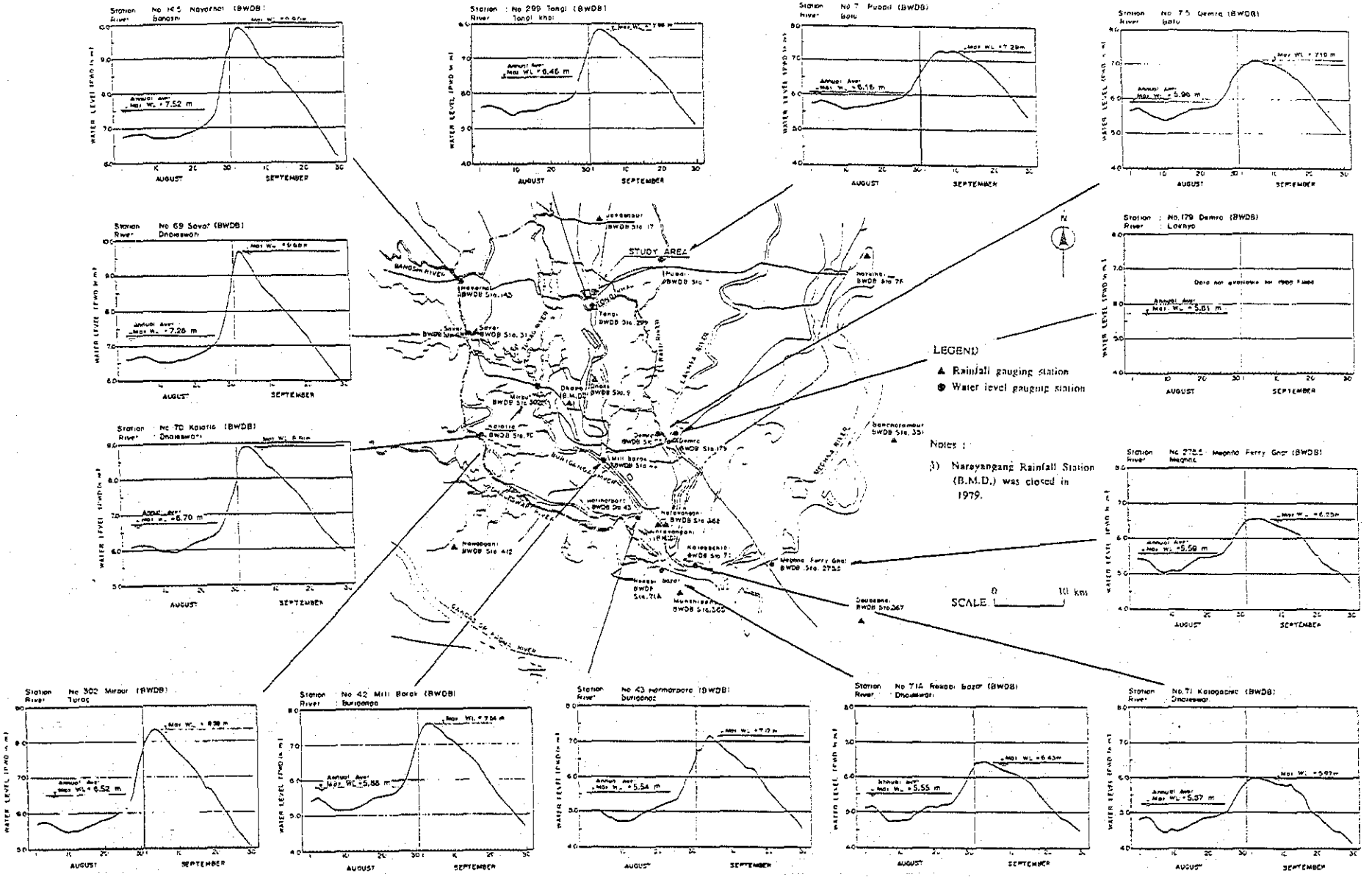
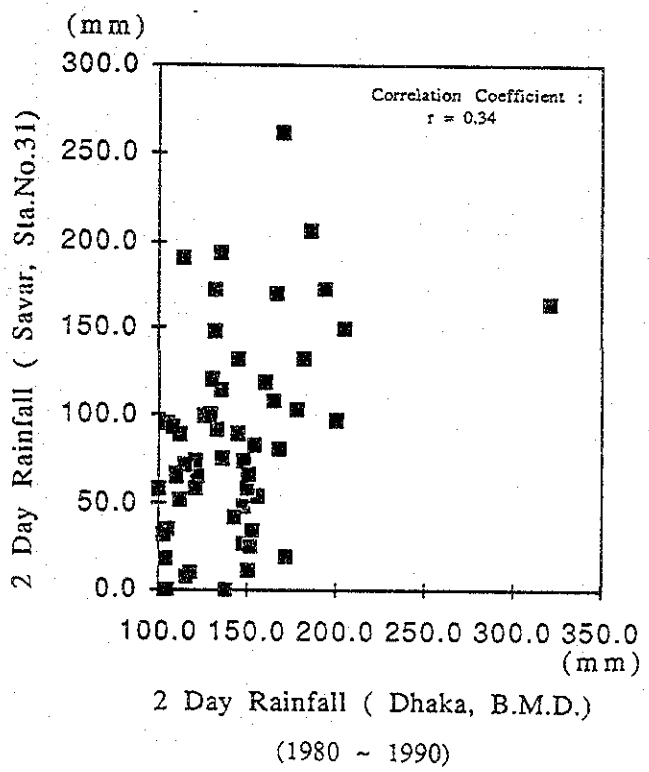
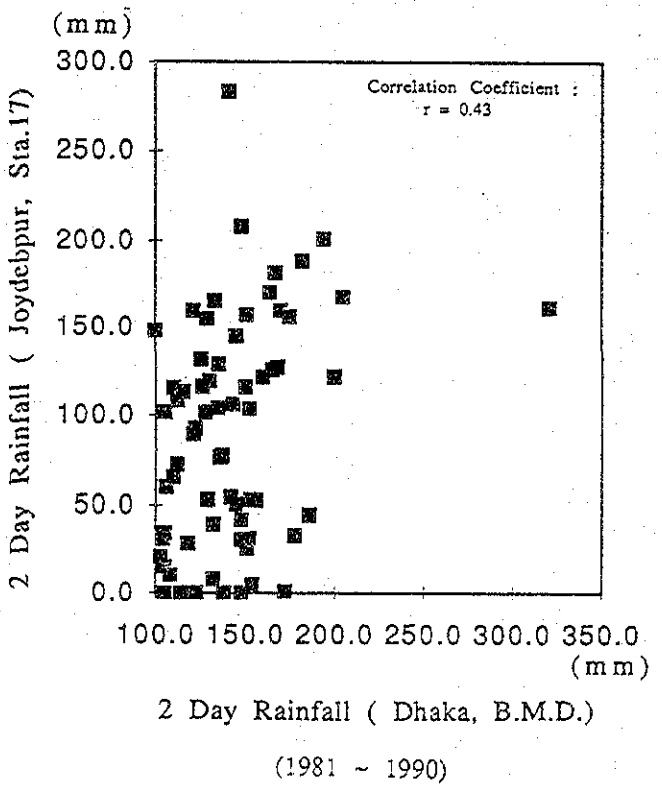


FIG. D.9 DAILY MAXIMUM WATER LEVEL DURING 1988 FLOODS

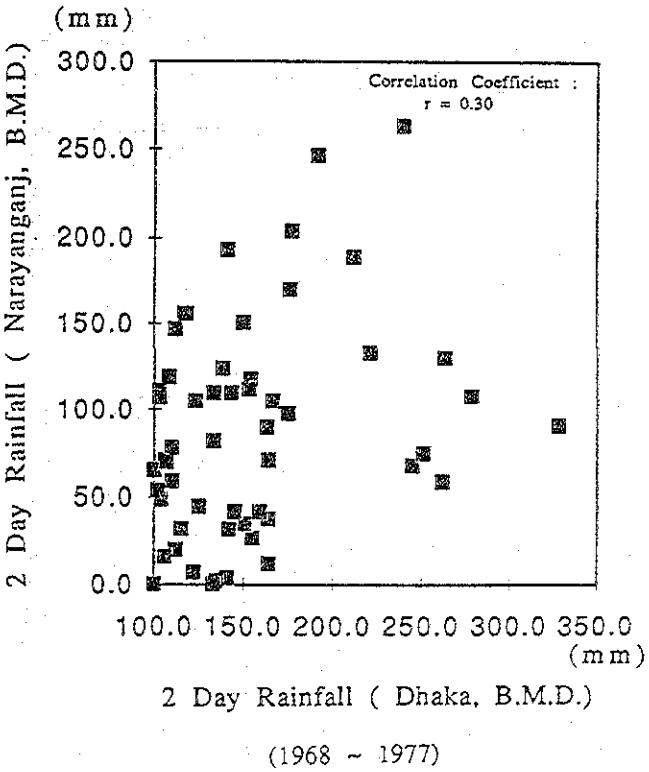
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH



(1980 ~ 1990)



(1981 ~ 1990)



(1968 ~ 1977)

FIG. D.10 CORRELATION AMONG RAINFALL GAUGING STATIONS

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

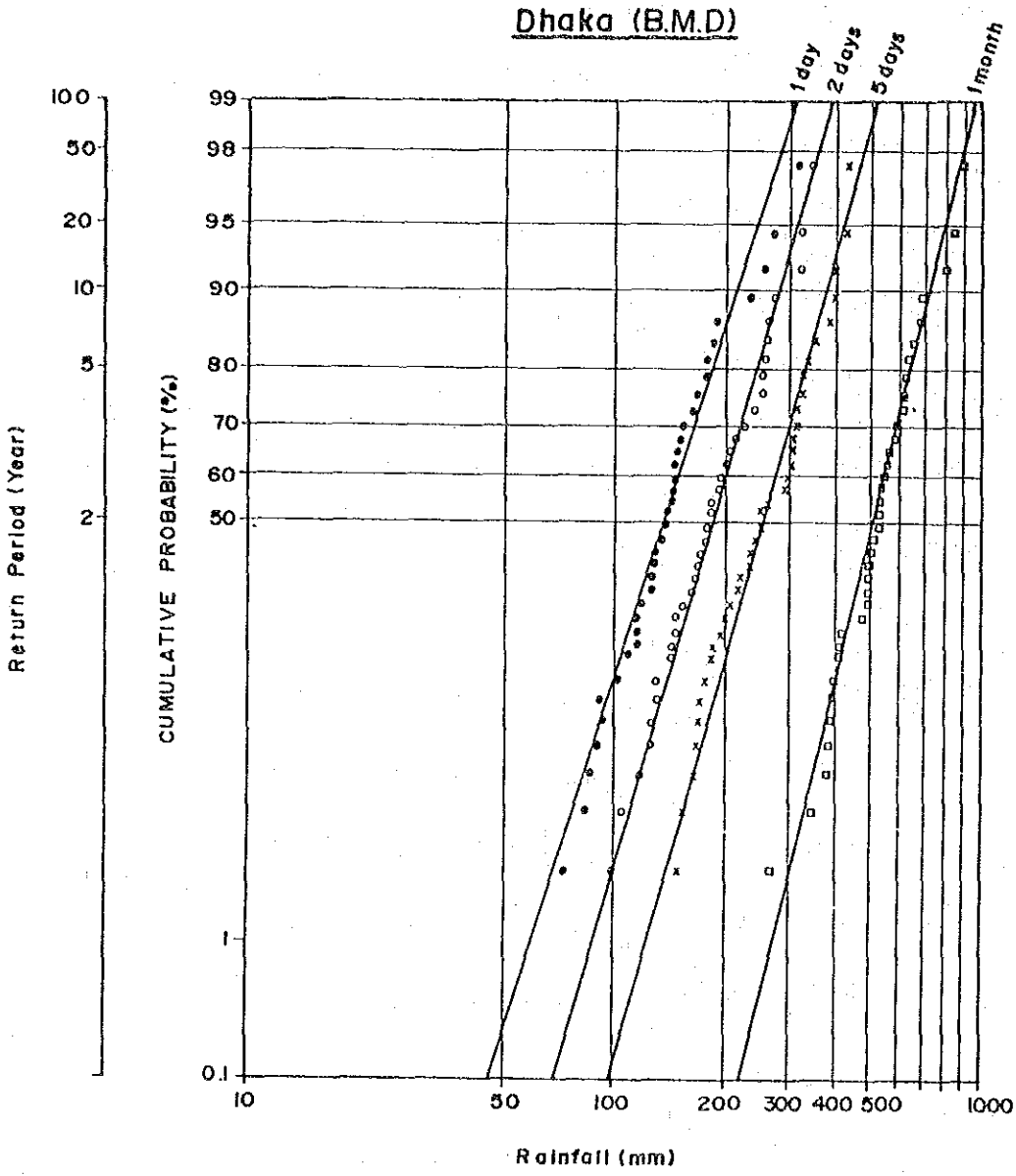


FIG. D.11 PROBABLE STORM RAINFALL

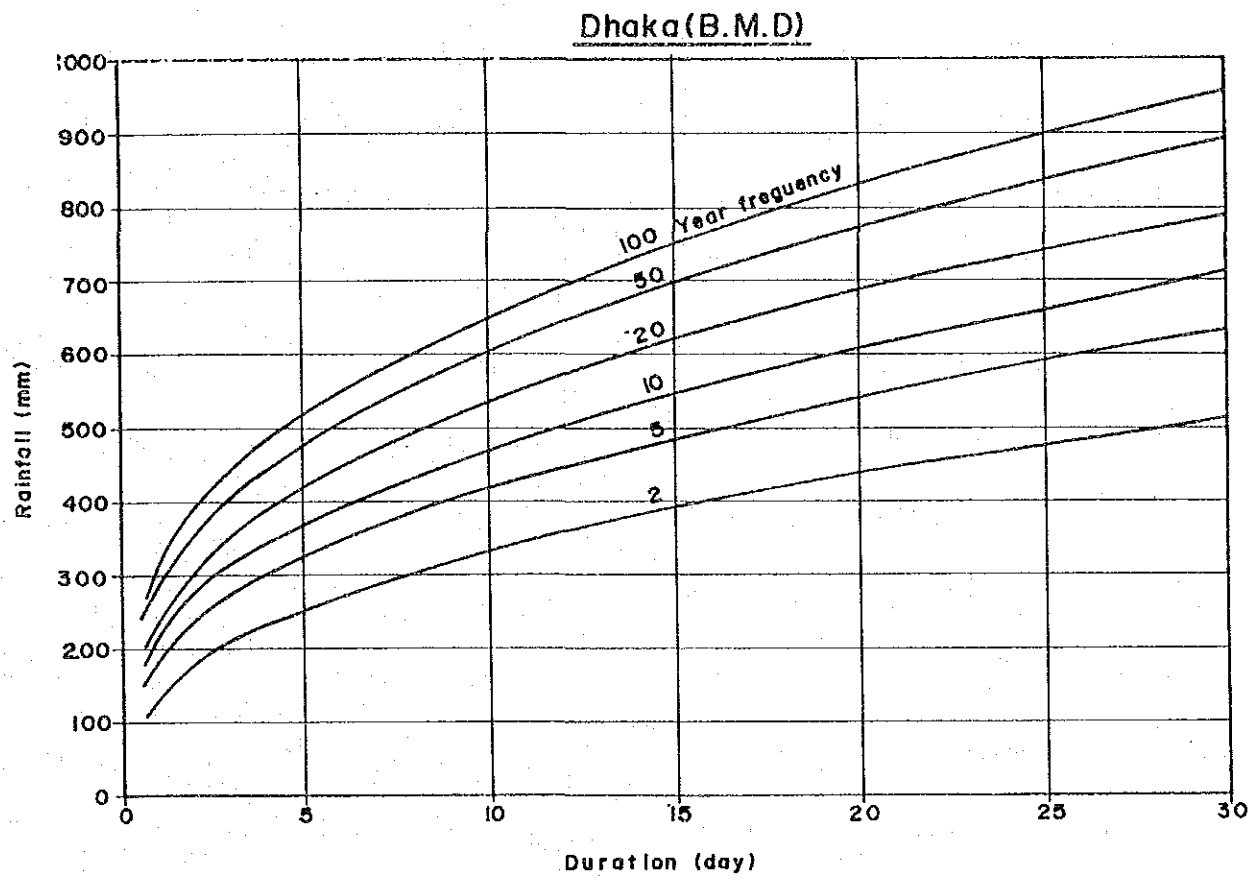
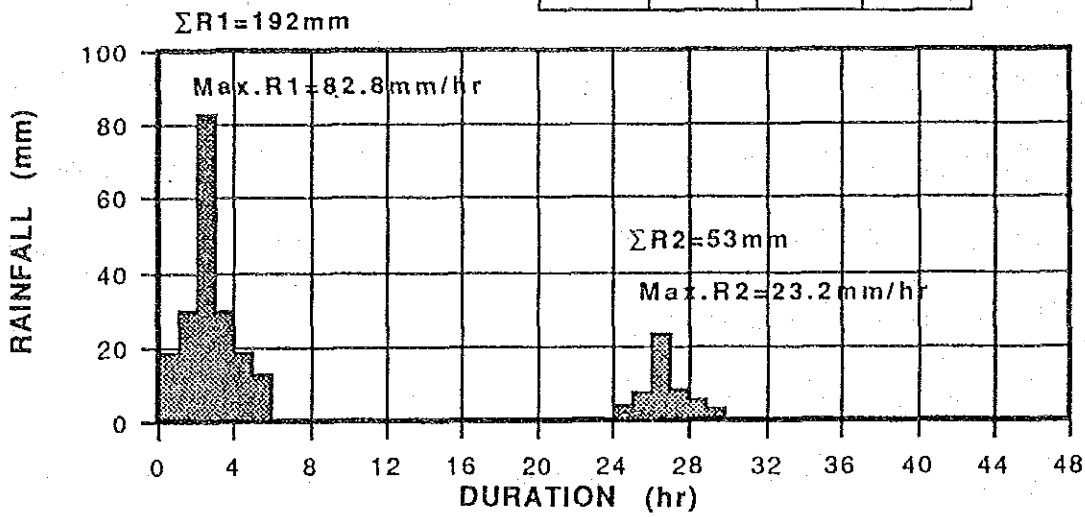


FIG. D.12 CONSECUTIVE RAINFALL-DURATION CURVE

HOURLY DISTRIBUTION

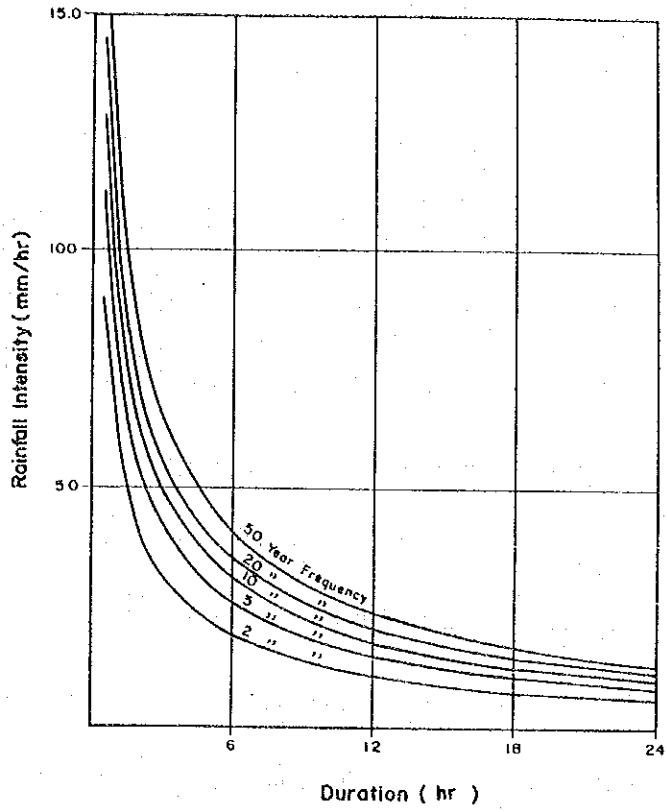
hr	%	R1	R2
1	9	17.4	4.8
2	15	28.3	8.0
3	44	82.8	23.2
4	16	30.6	8.5
5	9	18.0	5.0
6	7	14.9	3.5
TOTAL	100	192.0	53.0



Source :

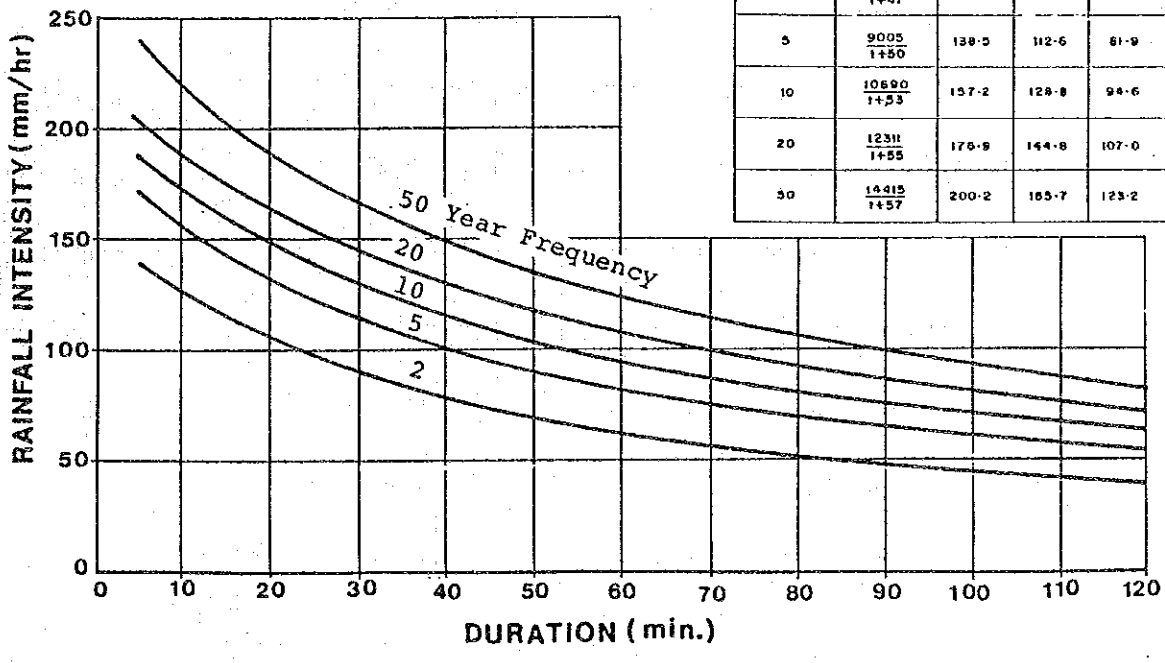
JICA; Study on Storm Water Drainage System Improvement Project in Dhaka City, 1987

FIG. D.13 PROPOSED DESIGN HYETOGRAPH FOR PUMP DRAINAGE PLAN



RAINFALL INTENSITY-DURATION FORMULA

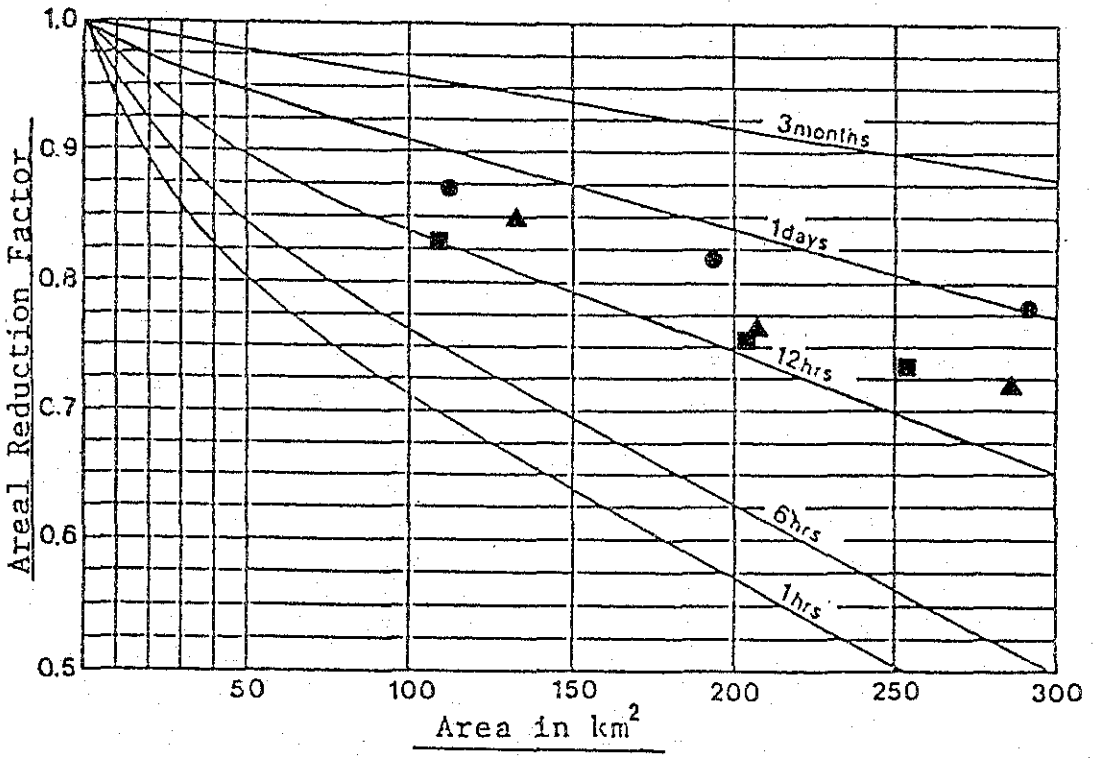
RETURN PERIOD	EQUATION	RAINFALL INTENSITY			
		15	30	60	120
2	$\frac{6889}{t+49}$	113·4	90·4	64·3	40·8
5	$\frac{7674}{t+47}$	125·8	99·7	71·7	45·0
5	$\frac{9005}{t+50}$	138·5	112·6	81·9	53·0
10	$\frac{10690}{t+53}$	157·2	128·8	94·6	61·8
20	$\frac{12311}{t+55}$	175·9	144·8	107·0	70·3
50	$\frac{14415}{t+57}$	200·2	165·7	123·2	81·4



Source :

JICA; Study on Storm Water Drainage System Improvement Project in Dhaka City, 1987

FIG. D.14 RAINFALL INTENSITY AND DURATION RELATIONSHIP



Legend

Areal Reduction Ratio
of 1 Day Rainfall (Dhaka, B.M.D)

● : 1970. 7.13

■ : 1972. 5.25

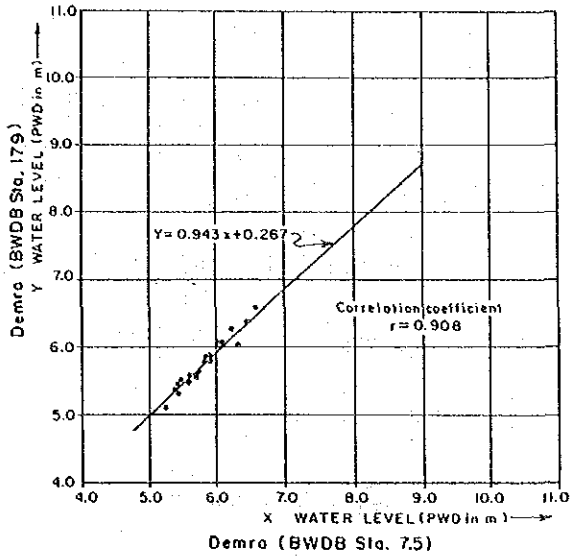
▲ : 1975. 8. 8

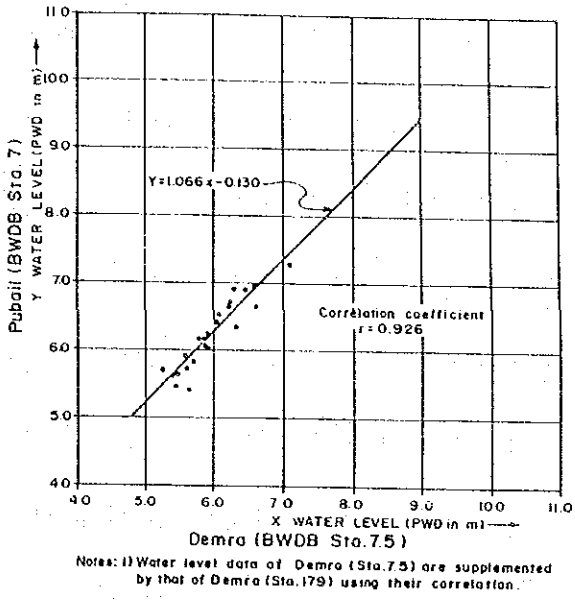
Source :

NEDECO ; master Plan for Drainage and Flood Control of Jakarta, 1973

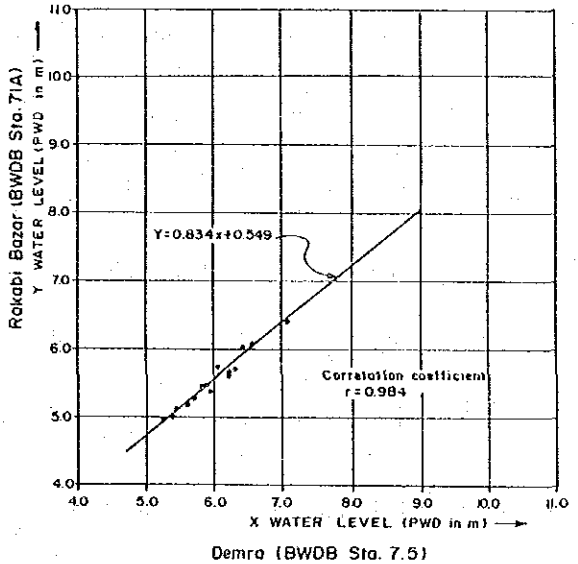
FIG. D.15	AREAL REDUCTION CURVES FOR POINT RAINFALL

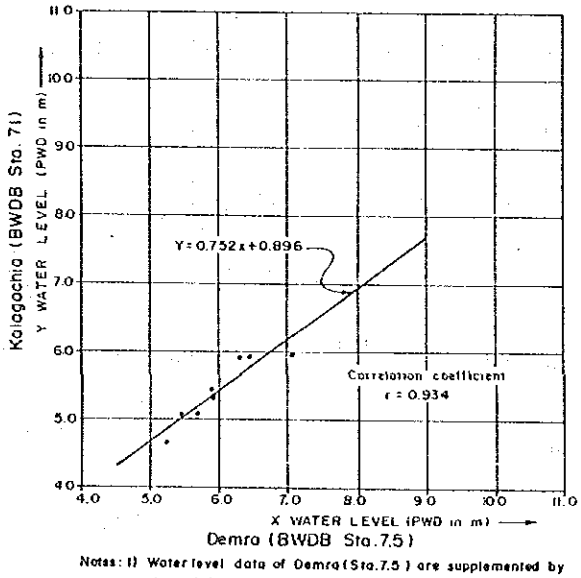
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH





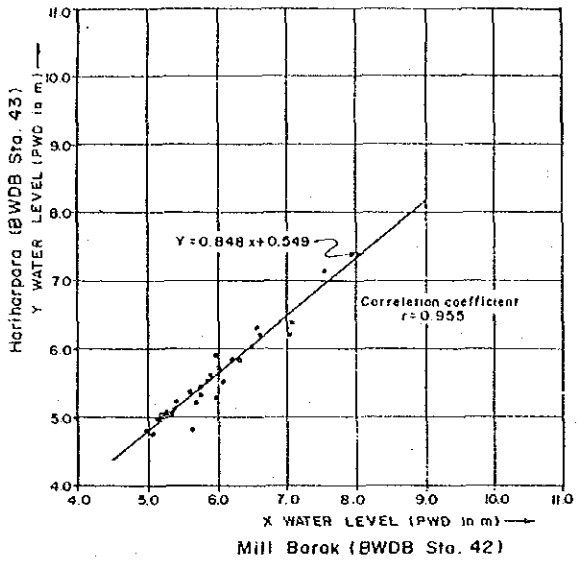
Notes: 1) Water level data of Demra (Sta. 7.5) are supplemented by that of Demra (Sta. 179) using their correlation.

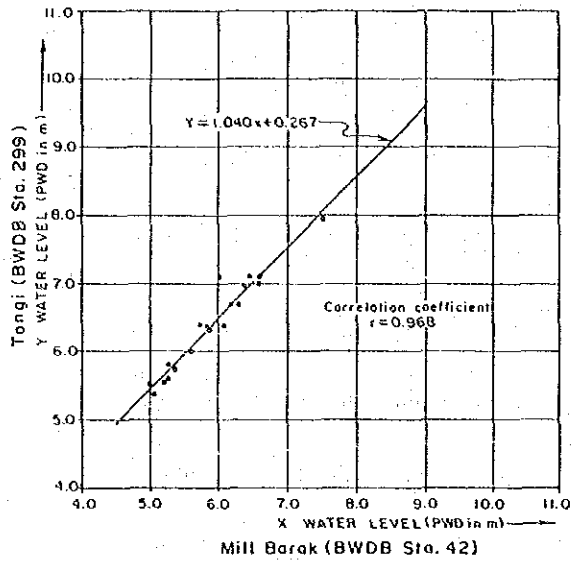




Notes: 1) Water level data of Demra (Sta. 7.5) are supplemented by that of Demra (Sta. 179) using their correlation.

FIG. D.16 CORRELATION AMONG WATER LEVEL GAUGING STATIONS (1/3)





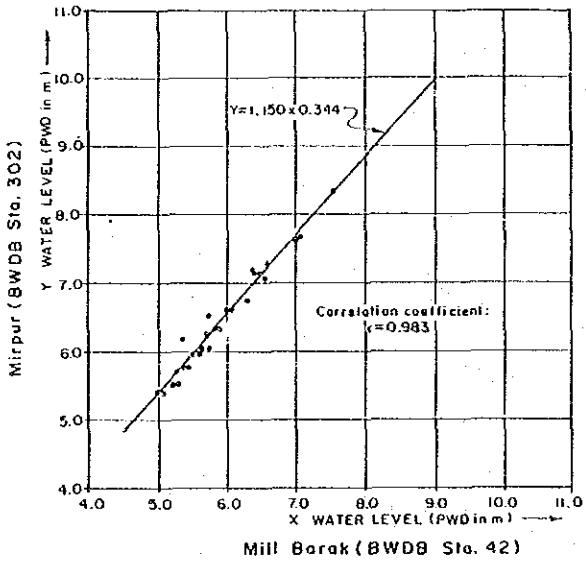
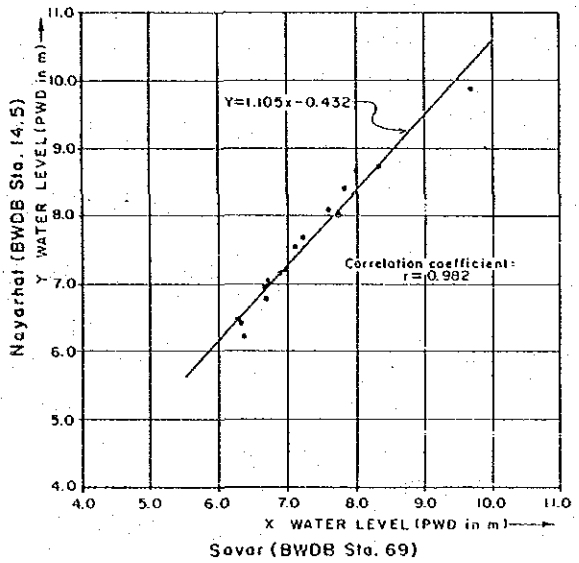


FIG. D.16	CORRELATION AMONG WATER LEVEL GAUGING STATIONS (2/3)



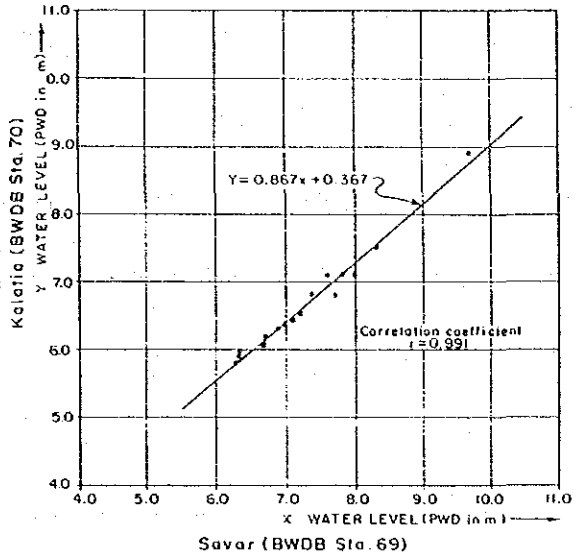
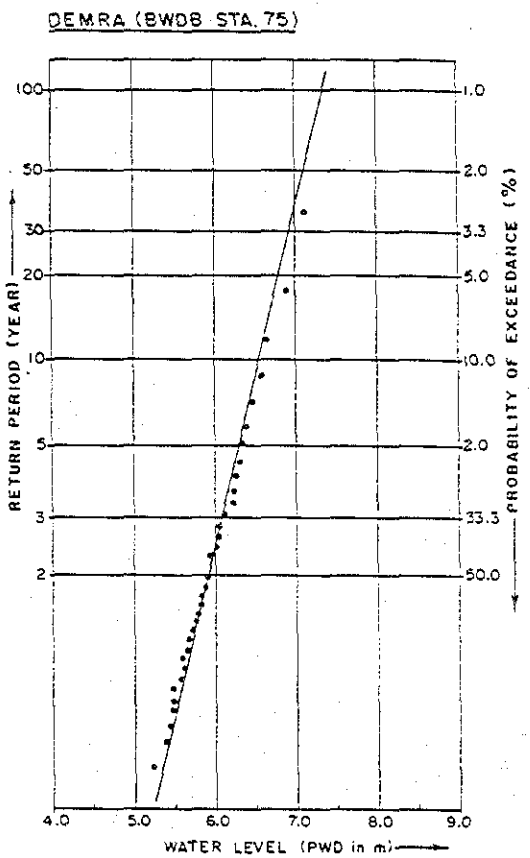
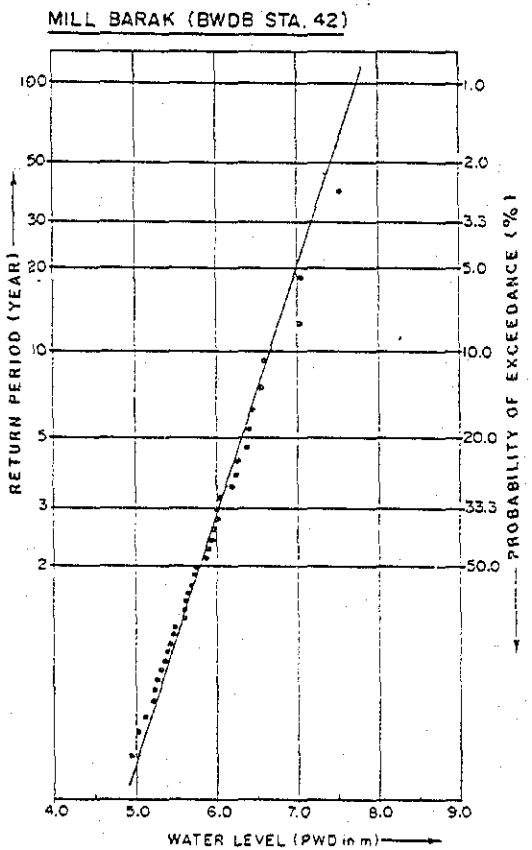
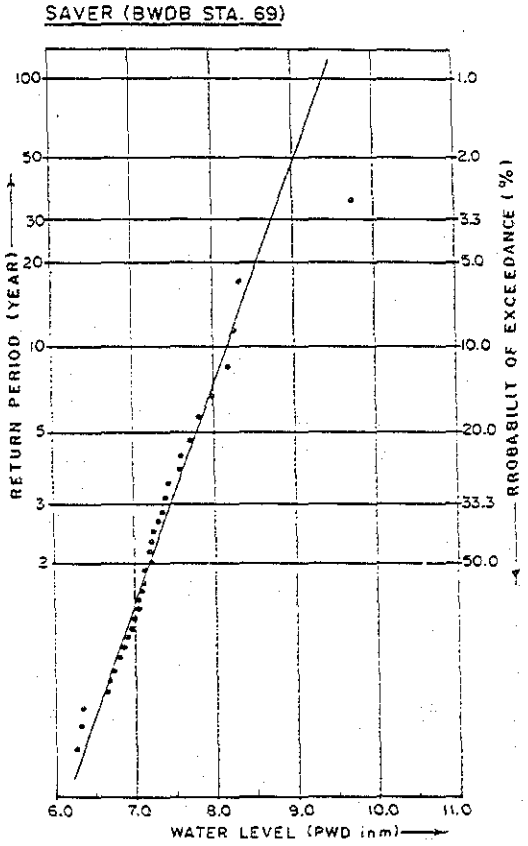


FIG. D.16 CORRELATION AMONG WATER LEVEL GAUGING STATIONS (3/3)



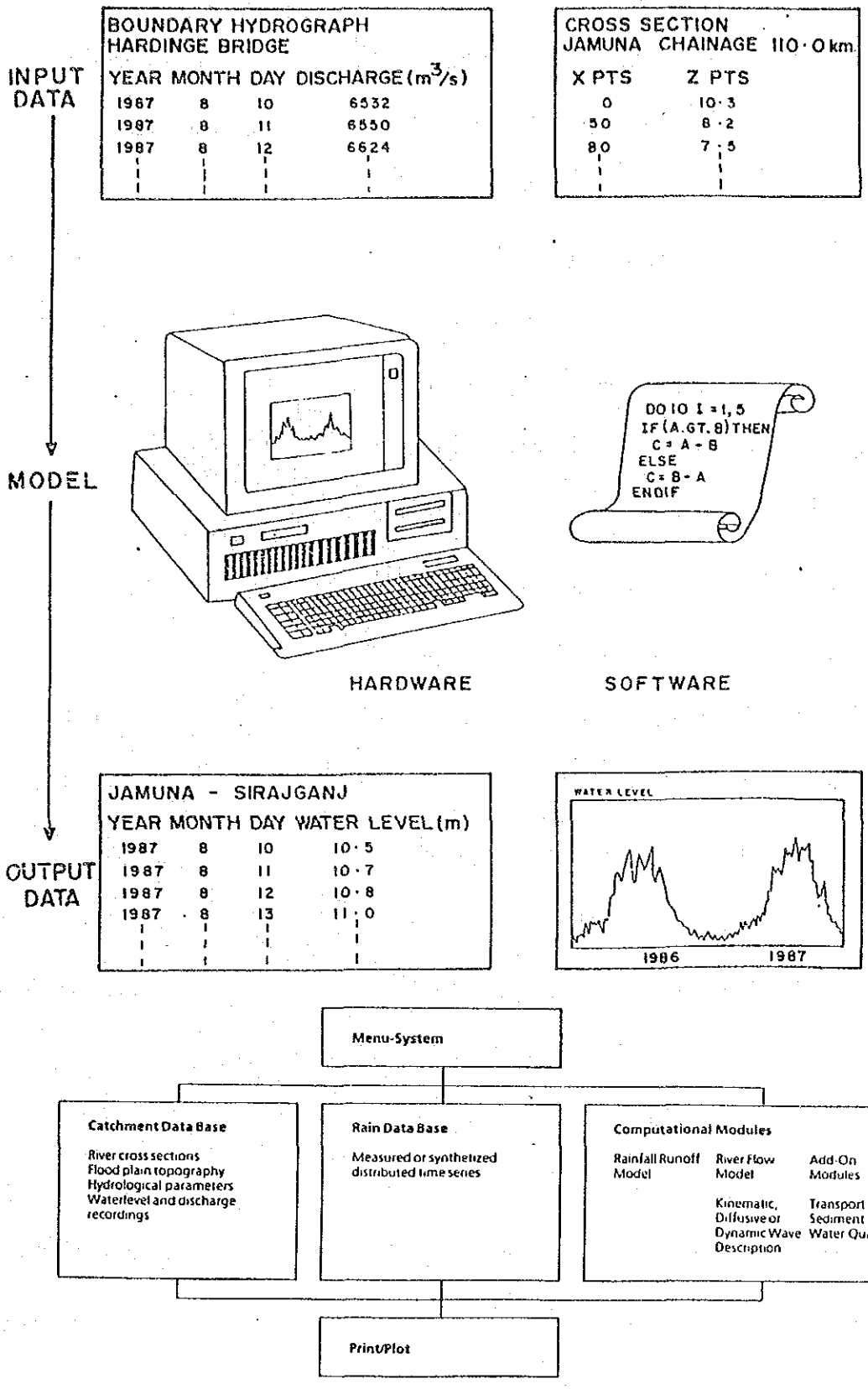




D - 50

FIG. D.17	PROBABLE FLOOD WATER LEVEL

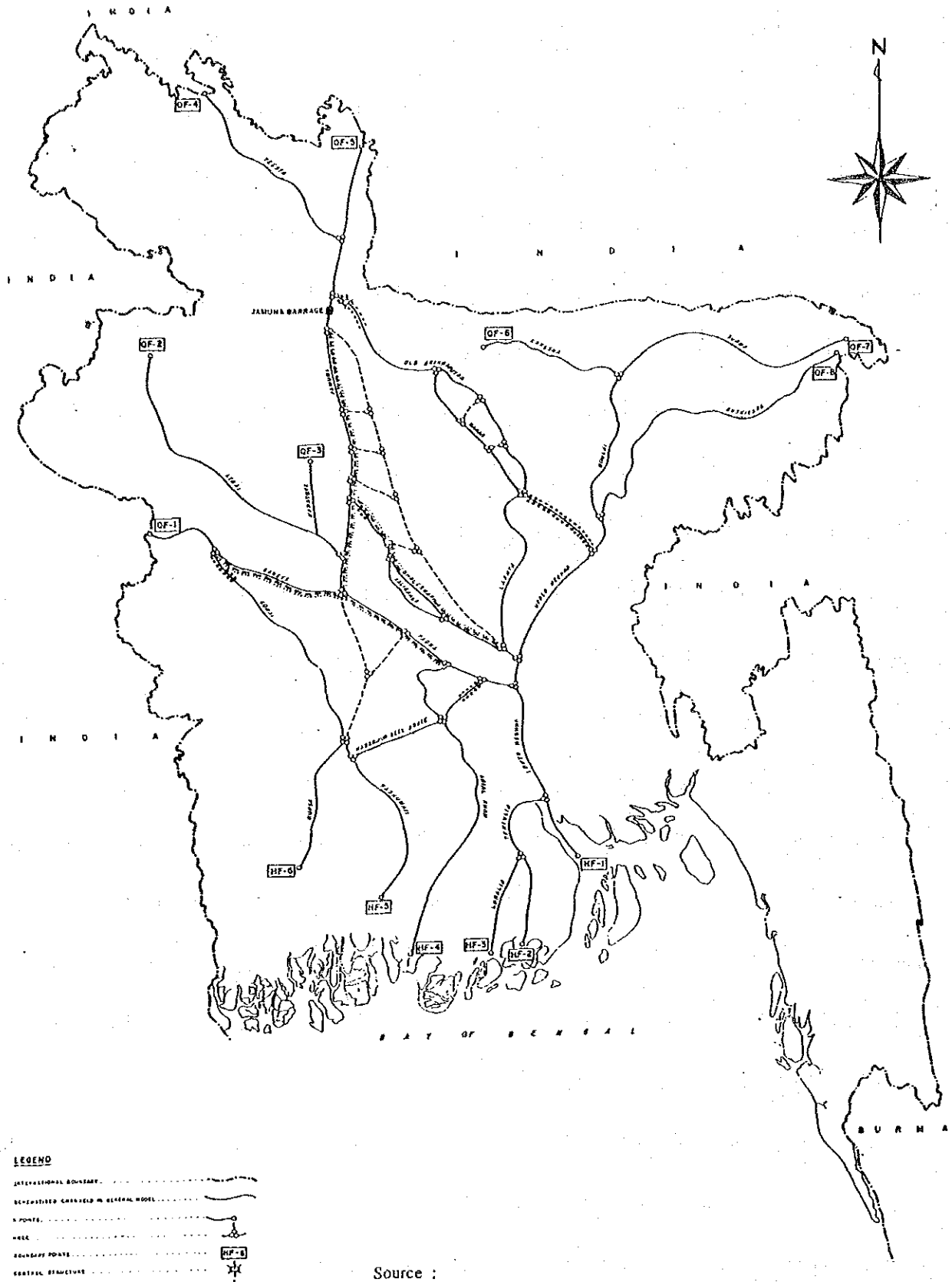
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH



Source :

Danish Hydralic Institute; Surface Water Simulation Modelling Programme,Final Report,Master Plan Organization,1988

FIG. D.18 Diagram of Hydrological Modelling Process by Mike 11

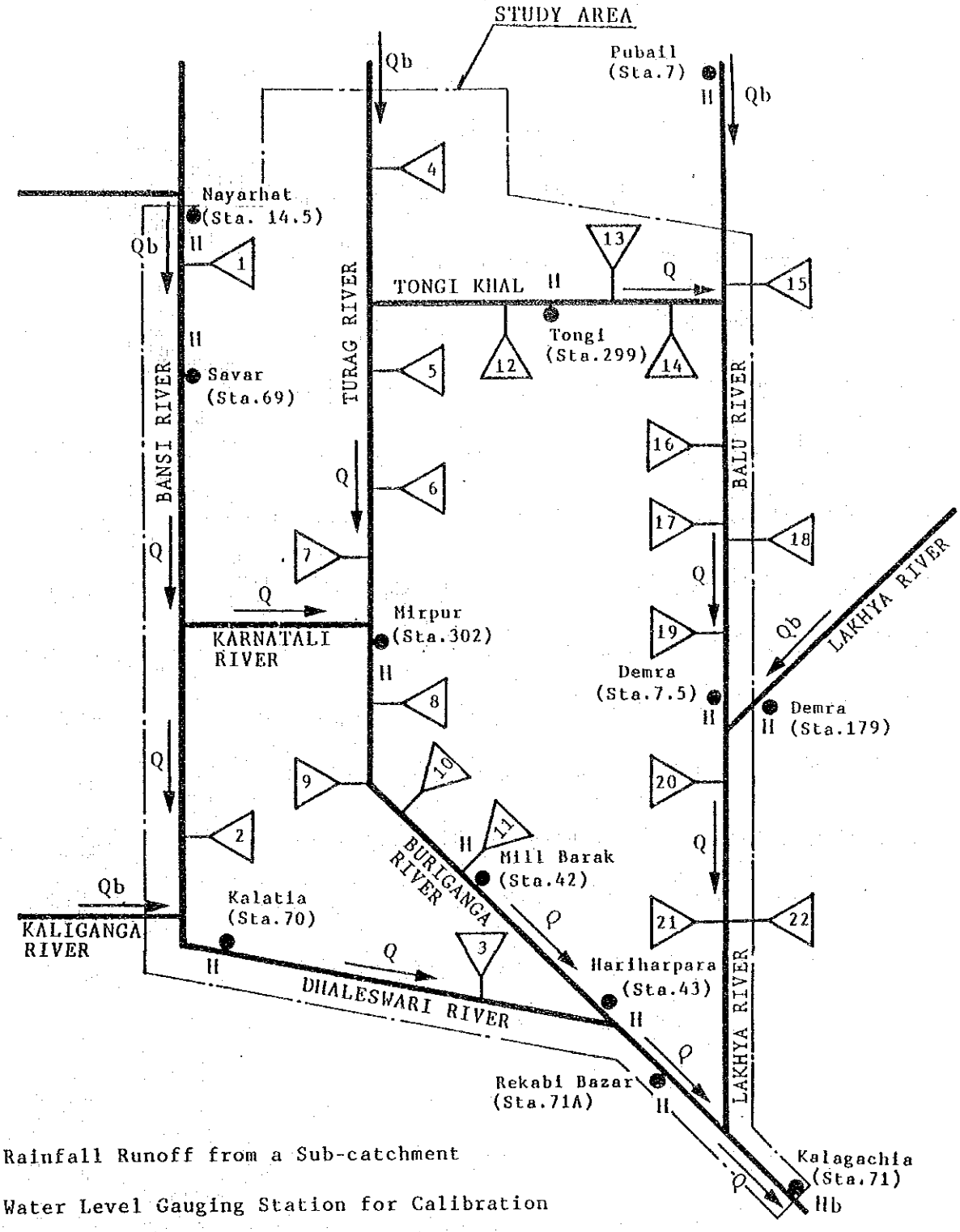


Source :

1) Danish Hydralic Institute; Surface Water Simulation Modelling Programme,Final Report,Master Plan Organization,1988

2) Danish Hydraulic Institute; A Short Description, Mike 11, 1988

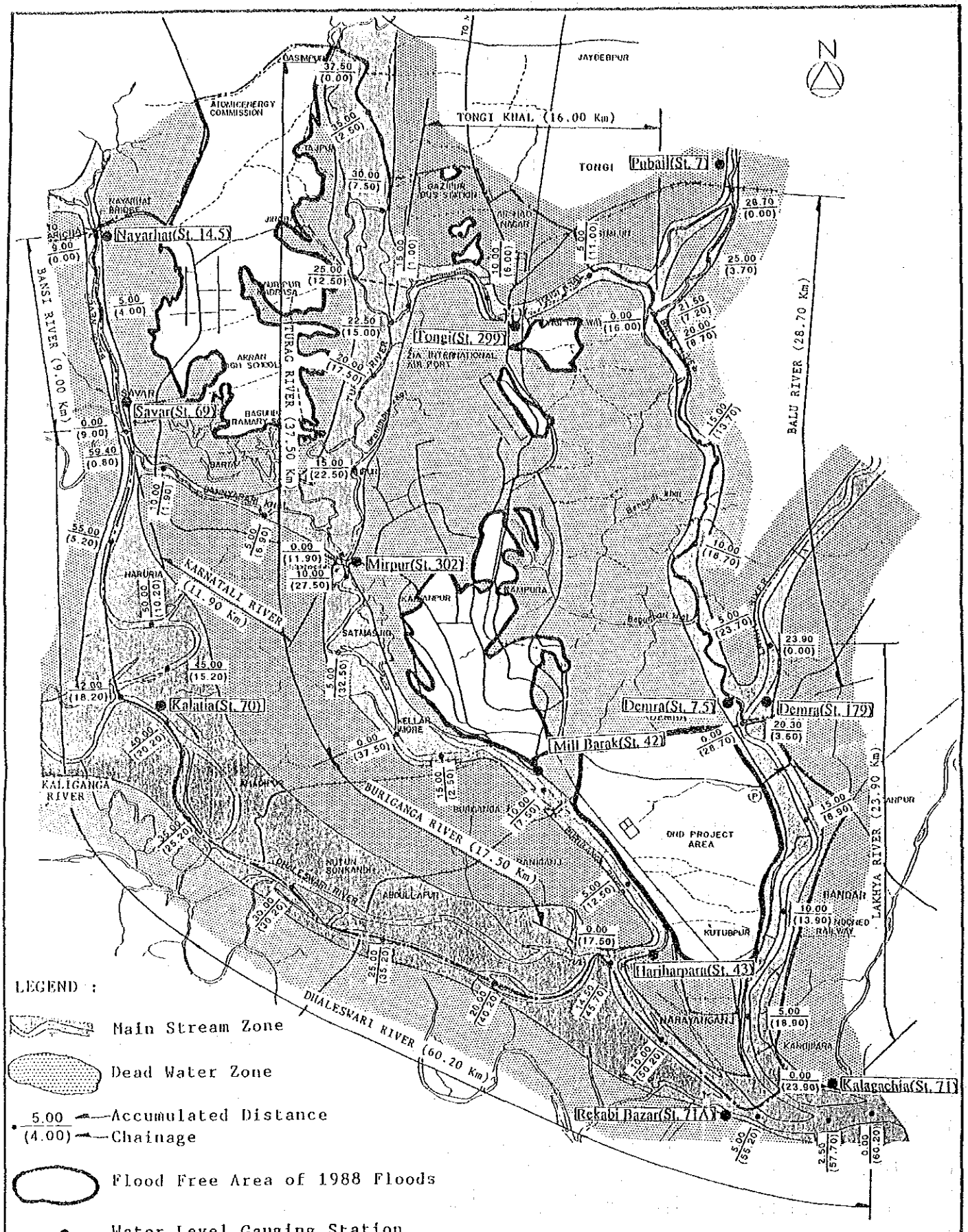
FIG. D.19 General Model developed by SWMC



LEGEND :

- Rainfall Runoff from a Sub-catchment
- ● Water Level Gauging Station for Calibration
- Qb Boundary Discharge to be inputed
- Hb Boundary Water Level to be inputed
- H Water Level to be simulated
- Q Discharge to be simulated

FIG. D.20 PROPOSED SIMULATION MODEL

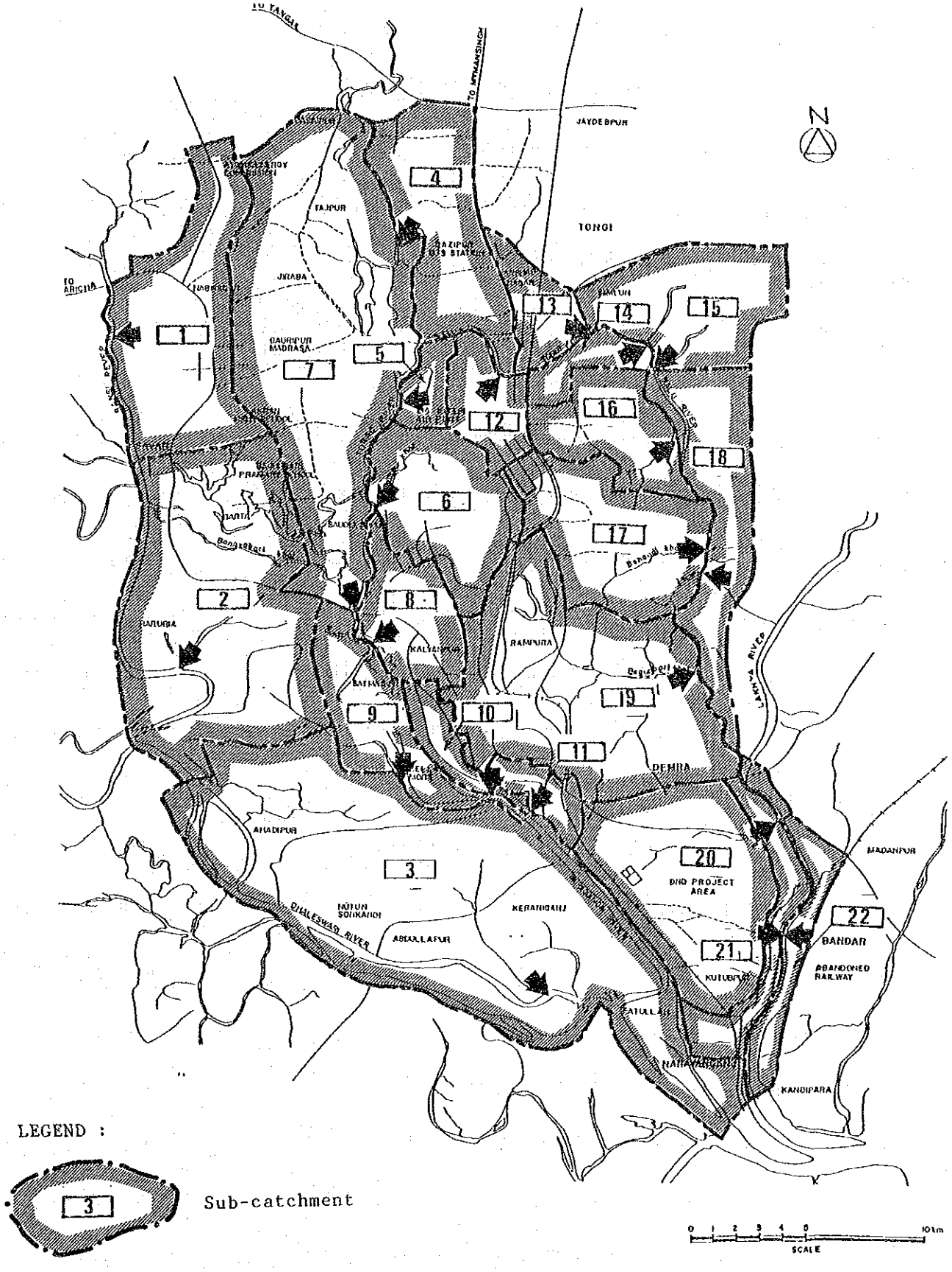


Note : Main Stream Zone and Dead Water Zone are estimated by using the satellite colored image (SPOT IMAGE :taken between Feb. - Mar., 1989).

FIG. D.21 RIVER NETWORK OF THE SIMULATION MODEL

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA



LEGEND :

3 Sub-catchment

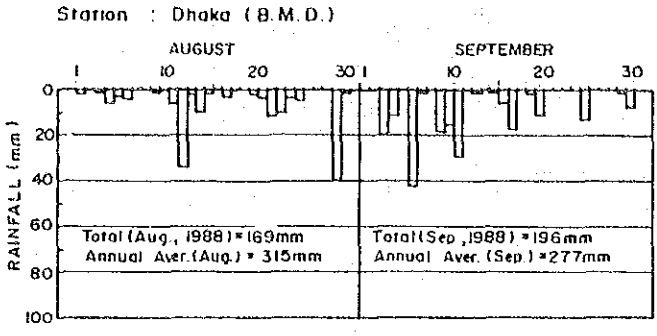
Location of Rainfall Runoff into the River

FIG. D.22 SUB-CATCHMENT OF THE SIMULATION MODEL

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA

RAINFALL (AUG. - SEP., 1988)



RUNOFF (AUG. - SEP., 1988)

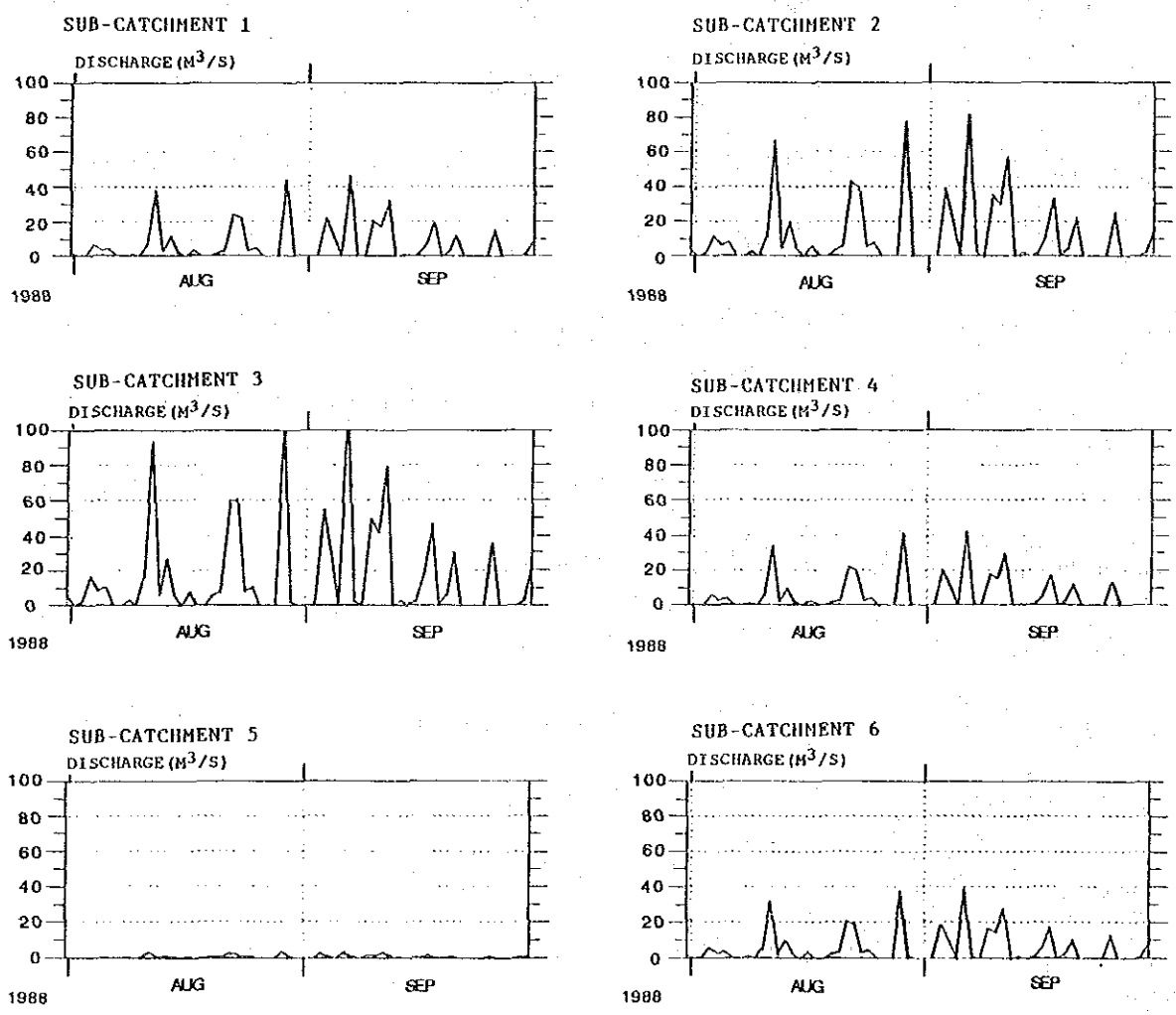
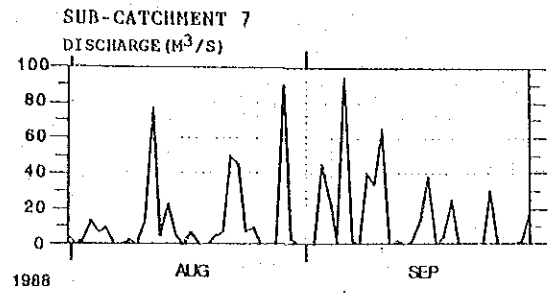
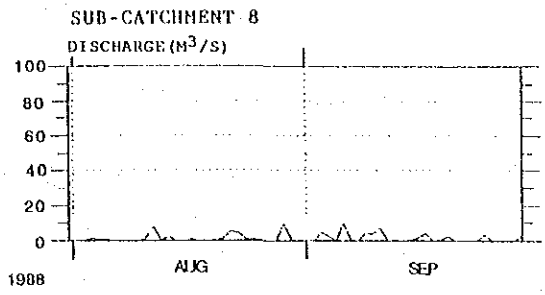
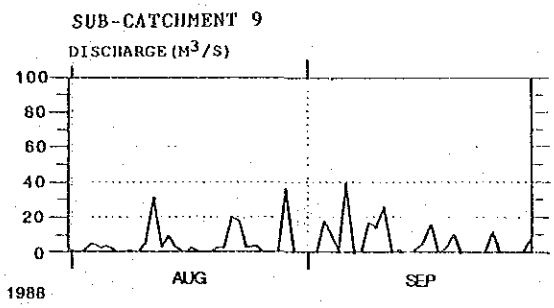
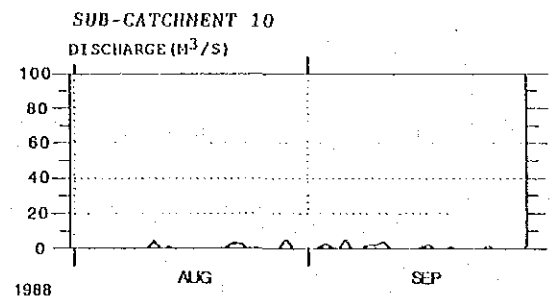


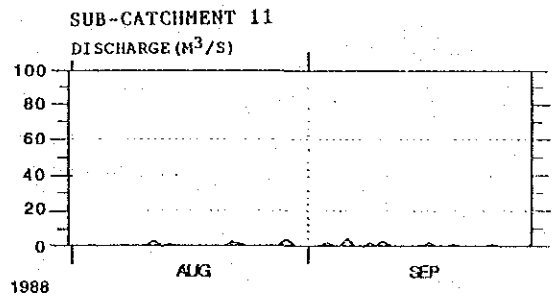
FIG. D.23 RAINFALL RUNOFF OF THE SUB-CATCHMENT(1/3)

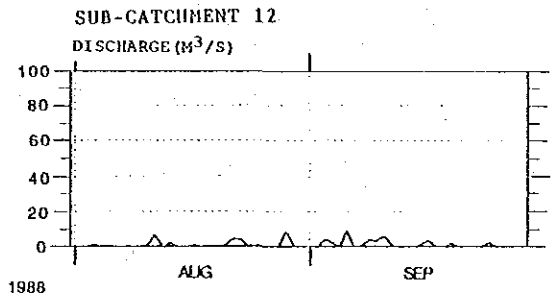


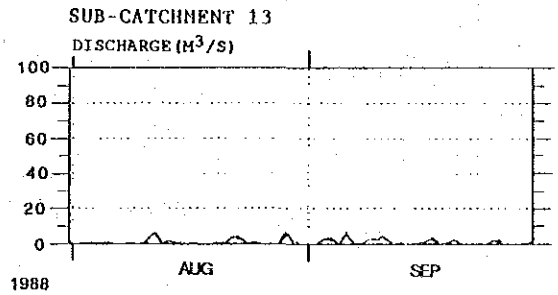


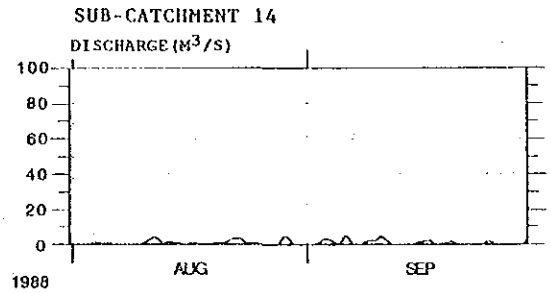


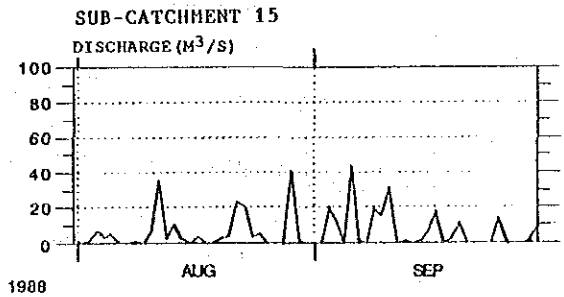












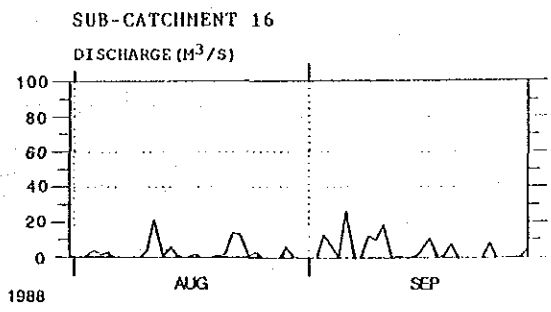


FIG. D.23 RAINFALL RUNOFF OF THE SUB-CATCHMENT(2/3)

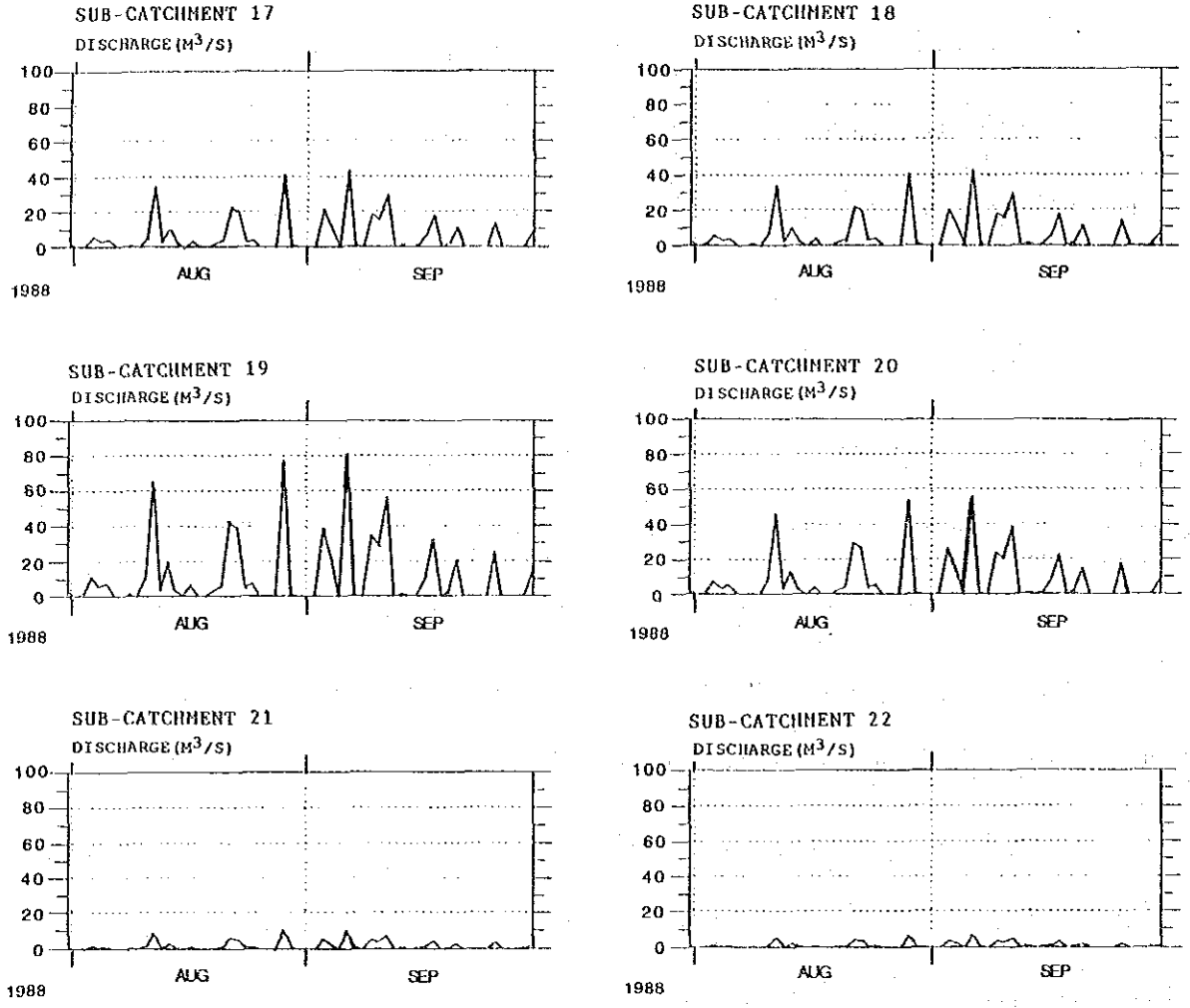
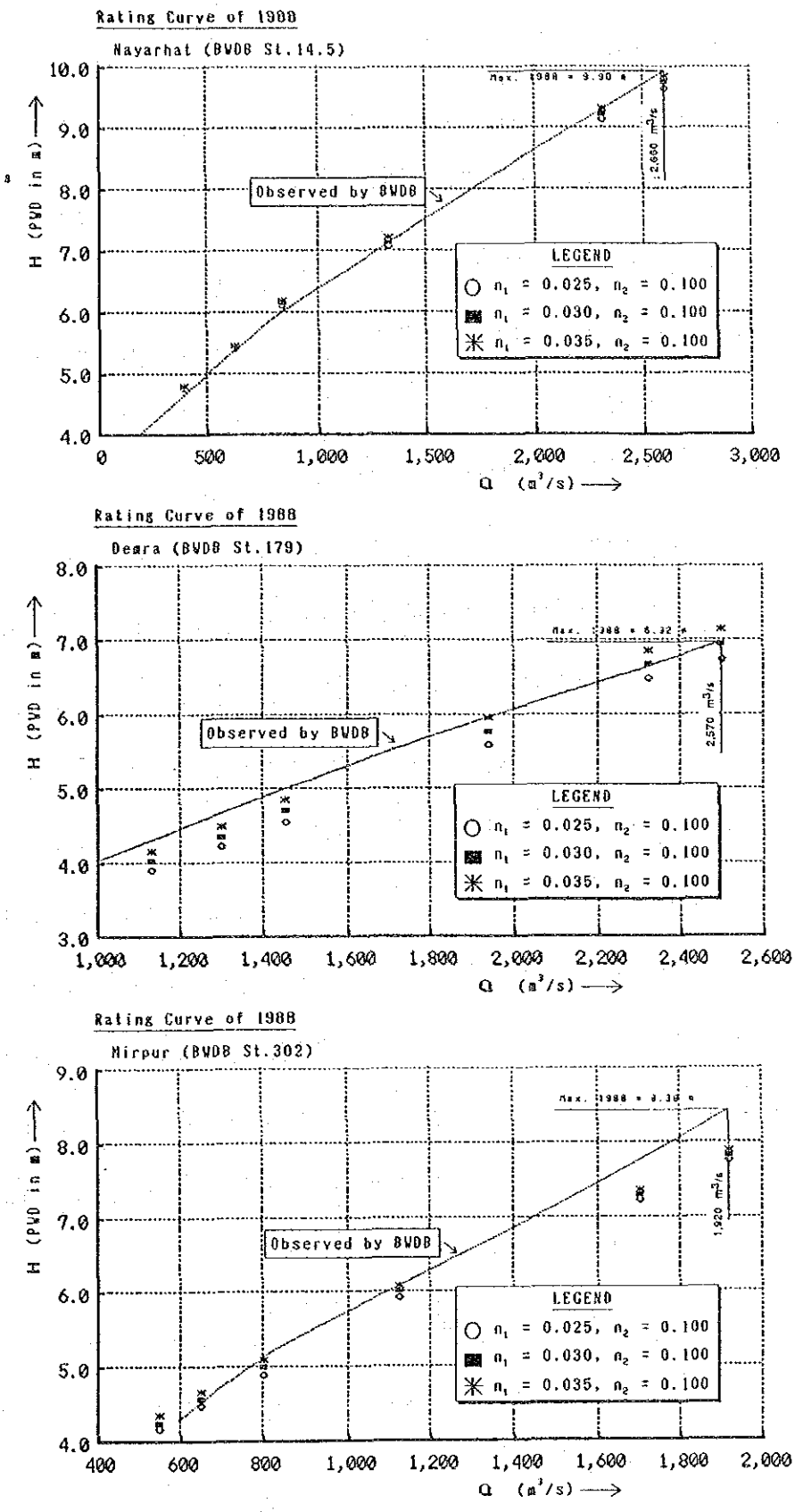


FIG. D.23 RAINFALL RUNOFF OF THE SUB-CATCHMENT(3/3)



Notes :

1) n1 is a manning's roughness coefficient of river channel.
2) n2 is a manning's roughness coefficient of flood plain.

FIG. D.24 COMPARISON OF MANNING'S ROUGHNESS COEFFICIENTS

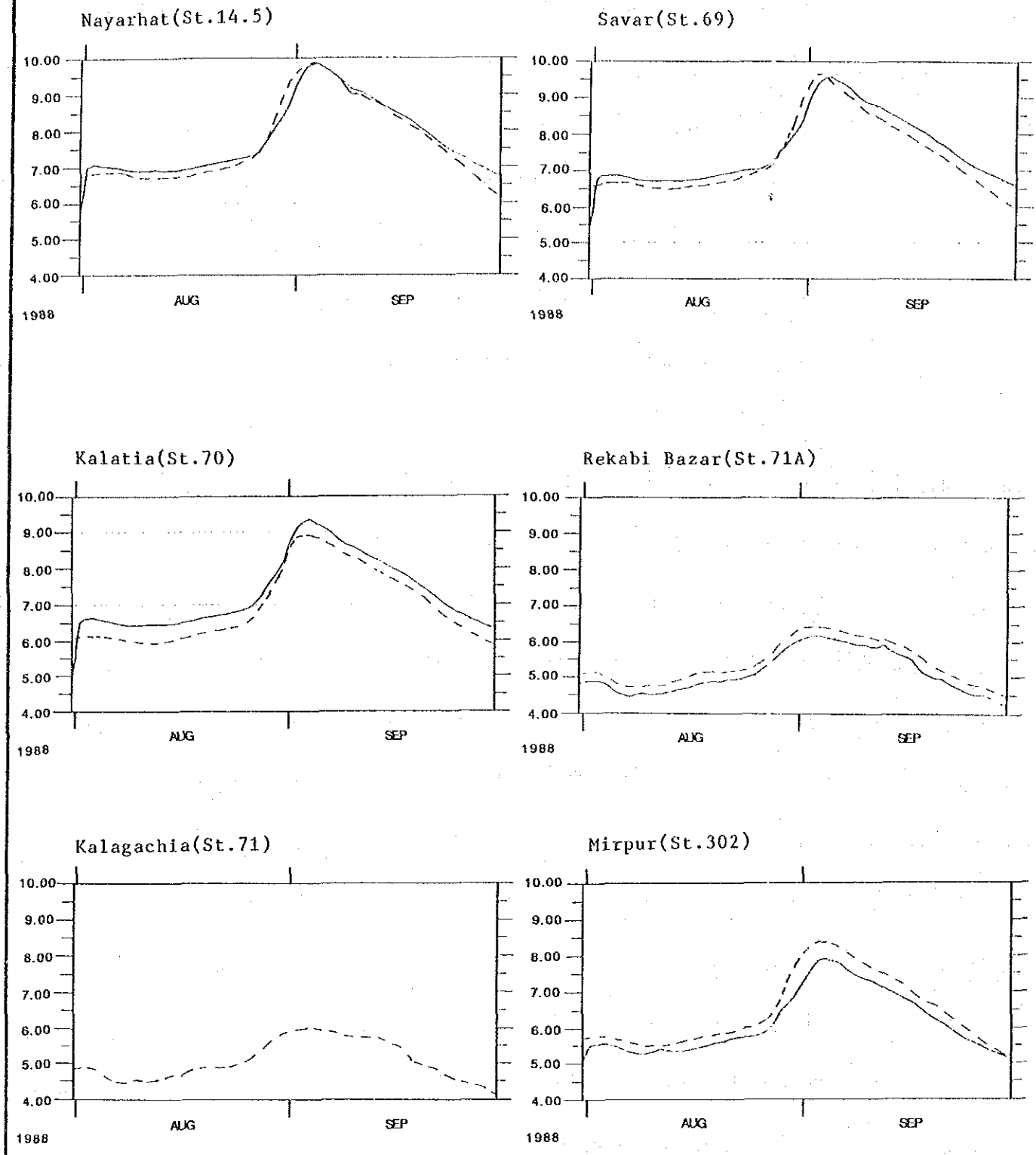


FIG. D.25 RESULTS OF CALIBRATION - DAILY MAXIMUM WATER LEVEL OF 1988 FLOODS(1/2)

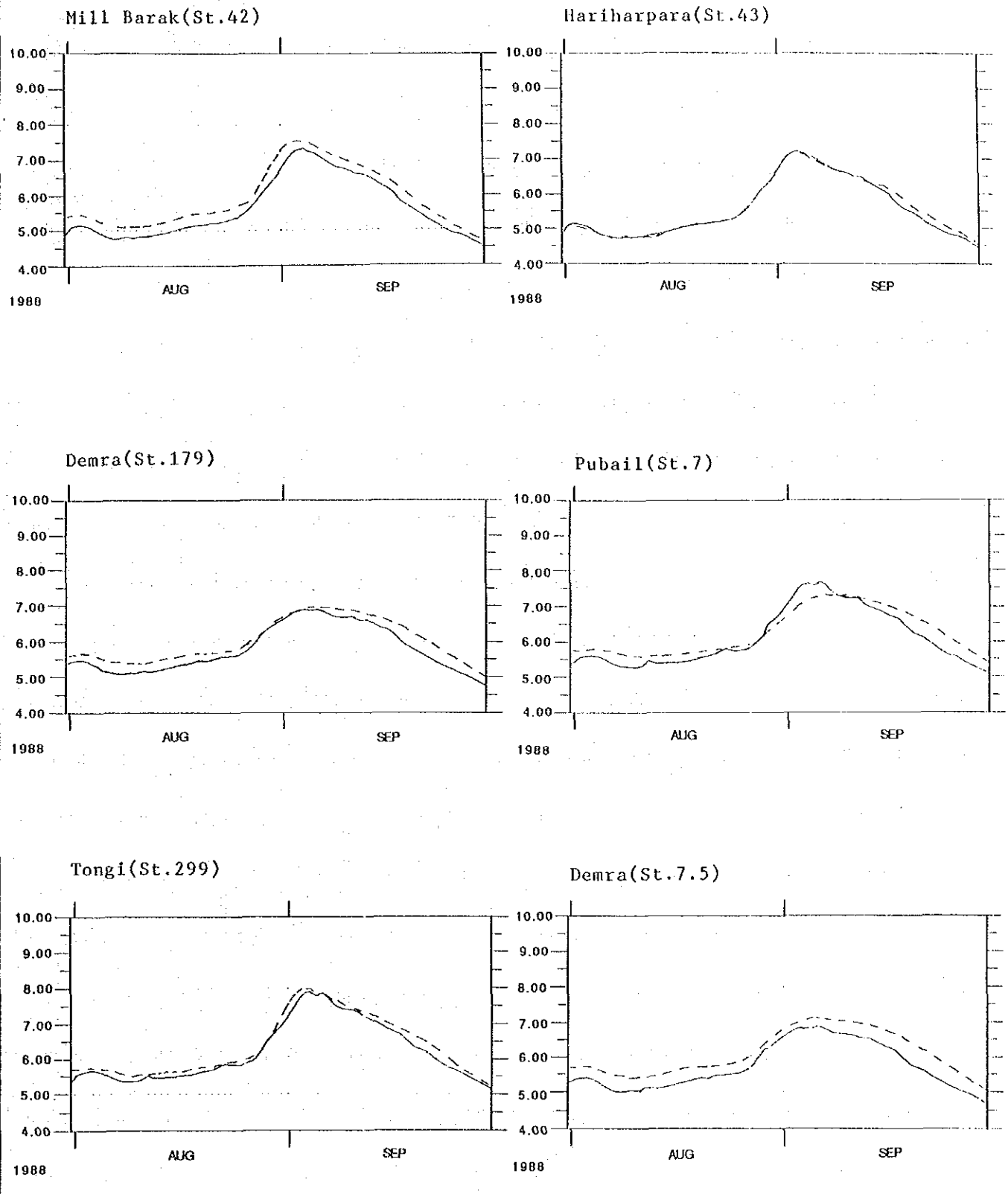
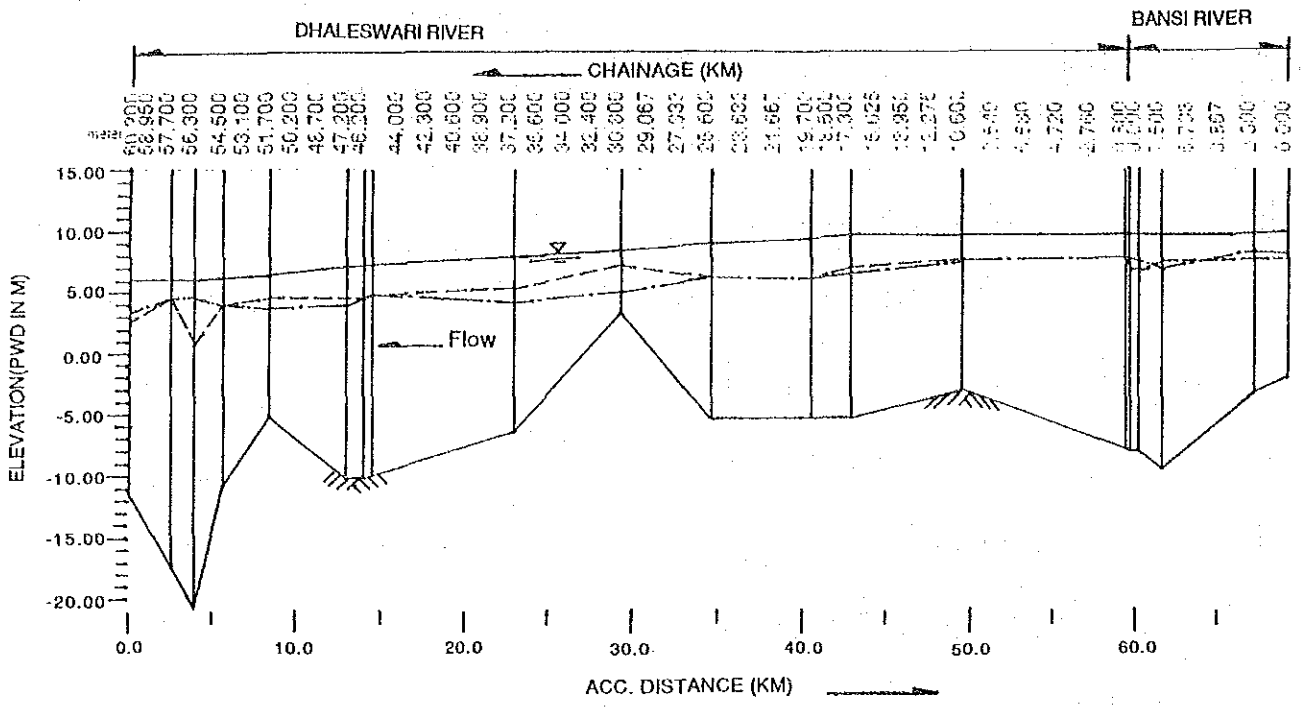
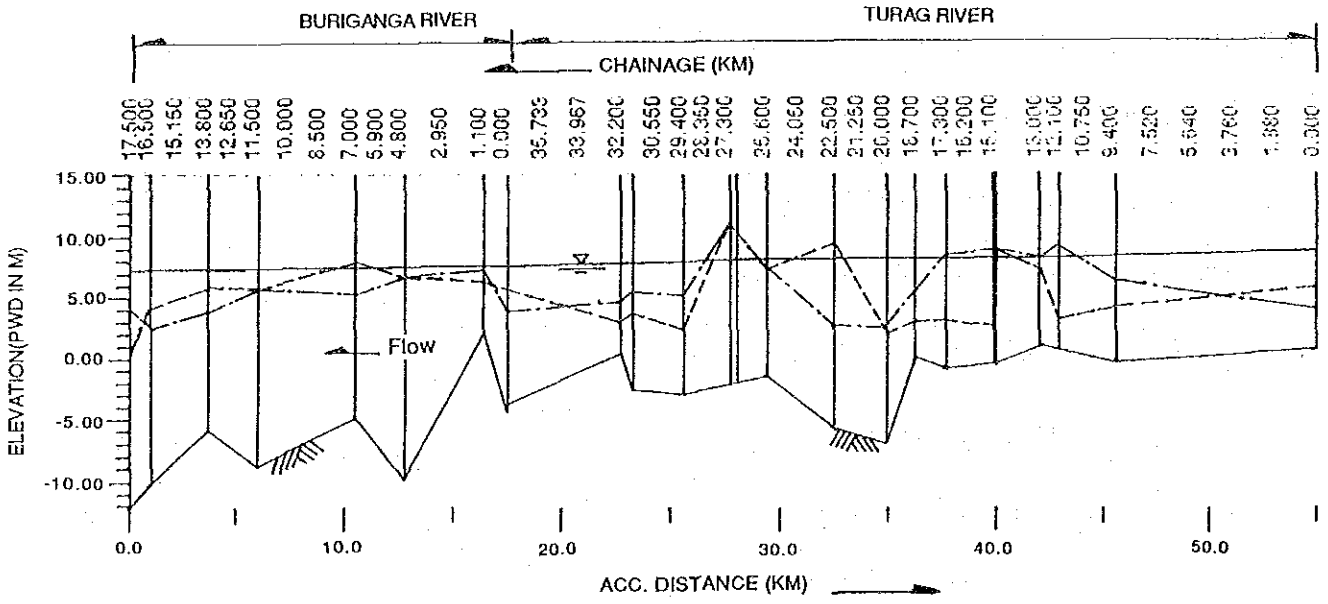


FIG. D.25 RESULTS OF CALIBRATION - DAILY MAXIMUM WATER LEVEL OF 1988 FLOODS(2/2)

1) DHALESWARI RIVER AND BANSI RIVER



2) BURIGANGA RIVER AND TURAG RIVER

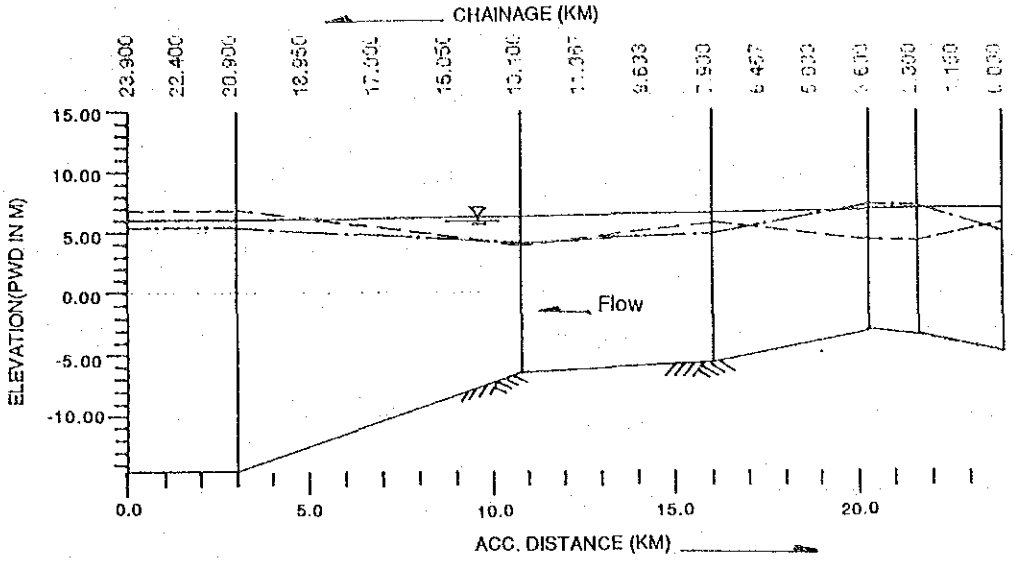


LEGEND :

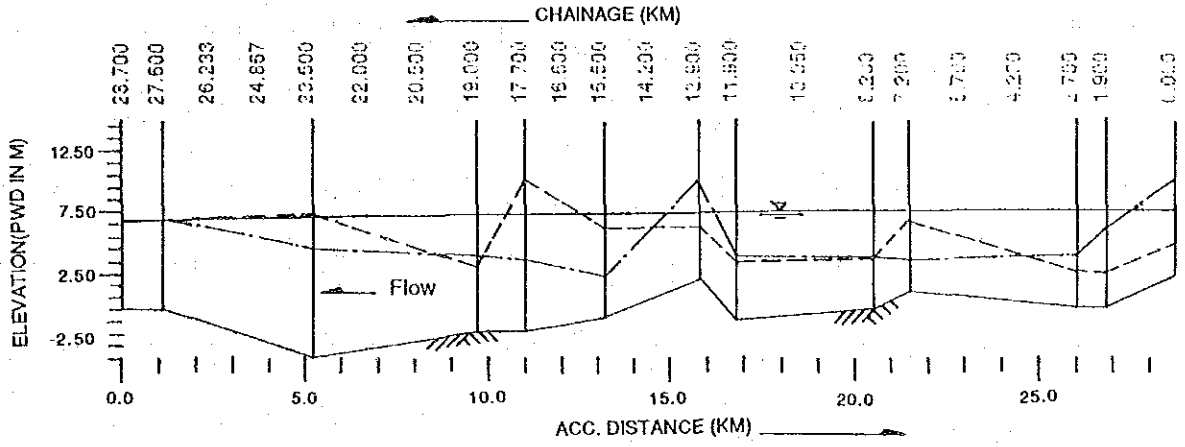
- Simulated Peak Water Level of 1988 Floods
- Lowest River Bed
- Left Bank
- Right Bank

FIG. D.26 RESULTS OF CALIBRATION - PROFILE OF PEAK WATER LEVEL OF 1988 FLOODS (1/2)

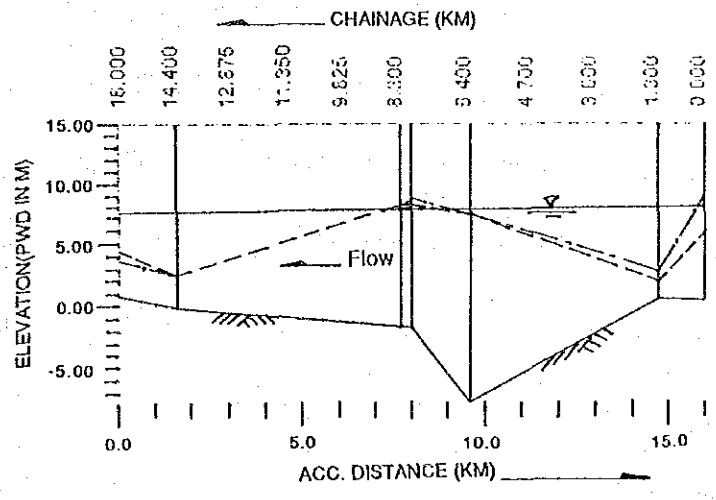
3) LAKHYA RIVER



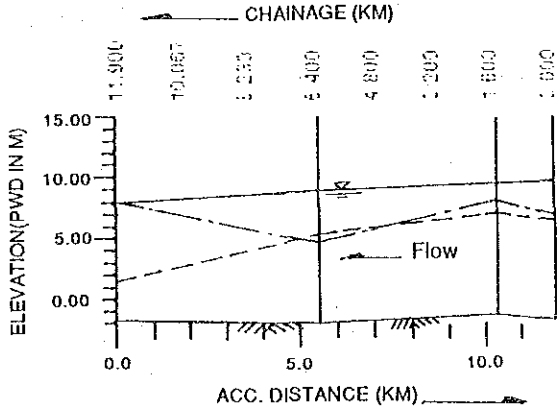
4) BALU RIVER



5) TONGI KHAL



6) KARNATALI RIVER

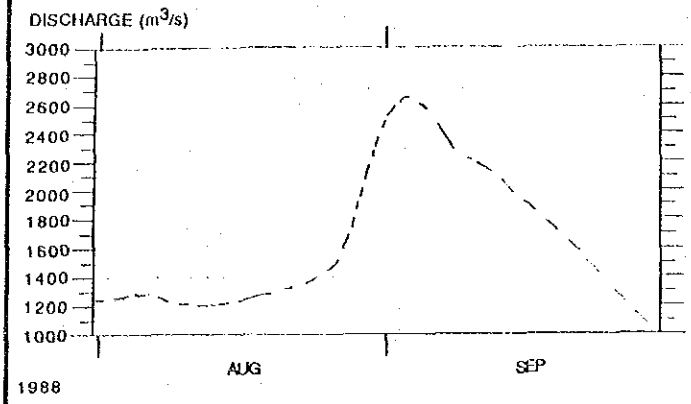


LEGEND :
- Simulated Peak Water Level of 1988 Floods
- Lowest River Bed
- Left Bank
- Right Bank

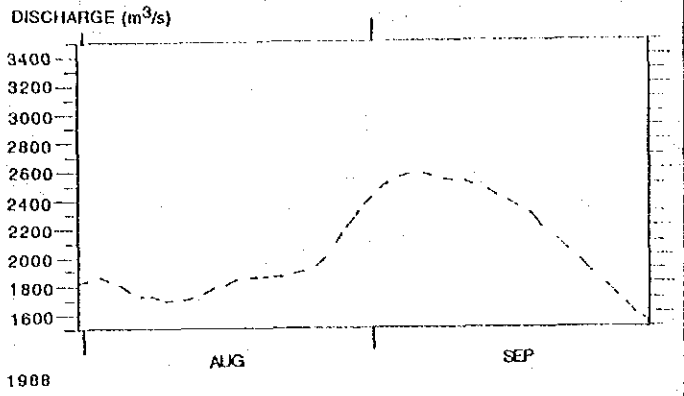
FIG. D.26 RESULTS OF CALIBRATION - PROFILE OF PEAK WATER LEVEL OF 1988 FLOODS (2/2)

1) INPUTED BOUNDARY DISCHAGE

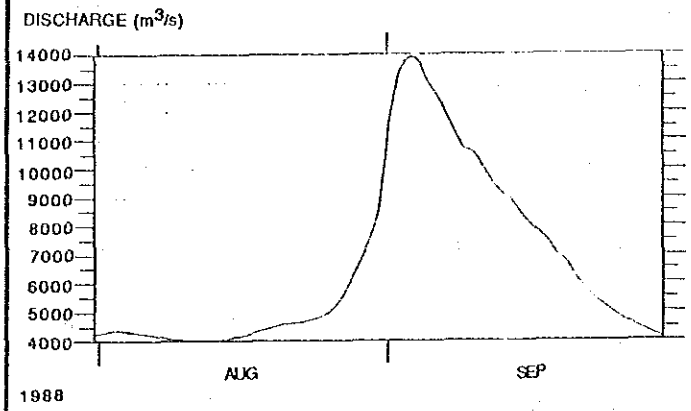
BANSI RIVER
(CHAINAGE = 1.00 KM)



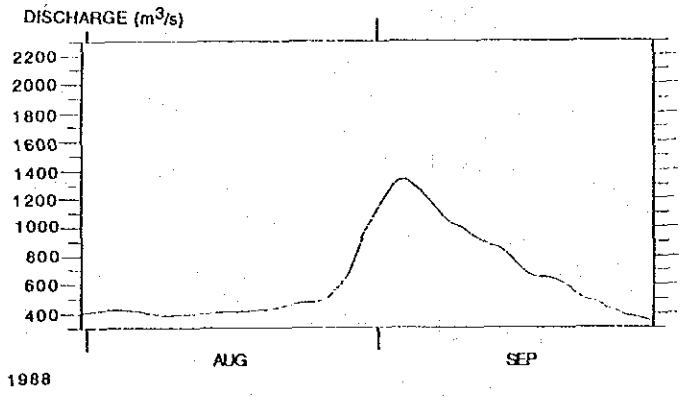
LAKHYA RIVER
(CHAINAGE = 0.58 KM)



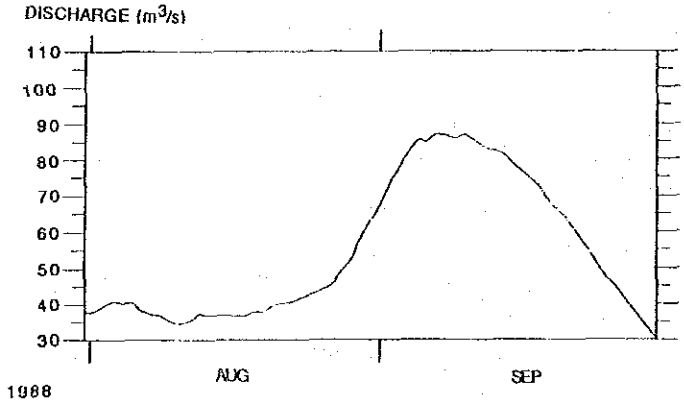
KALIGANGA RIVER



TURAG RIVER
(CHAINAGE = 0.94 KM)



BALU RIVER
(CHAINAGE = 0.95 KM)



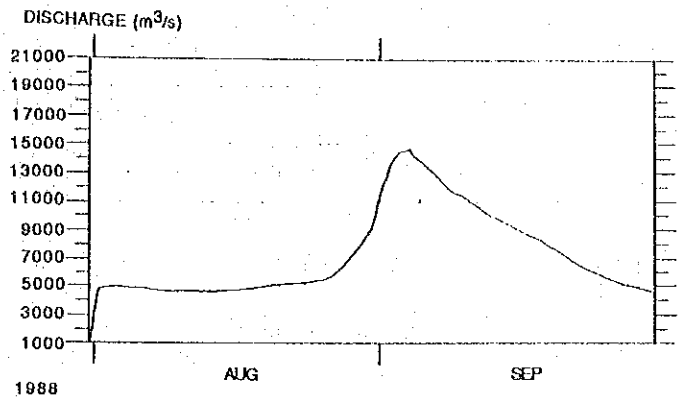
LEGEND :

- - - - - Calliculated Discharge by using BWDB's Rating Curve
——— Assumed Discharge made by trial and error method

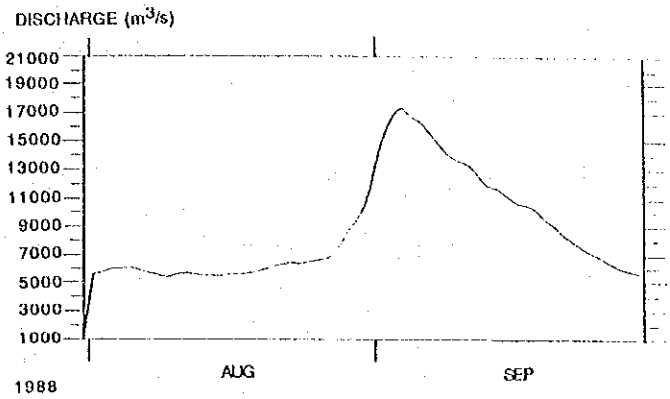
FIG. D.27 RESULTS OF CALIBRATION - DAILY MAXIMUM DISCHARGE OF 1988 FLOODS (1/3)

2) CALCULATED DISCHARGE BY MIKE 11

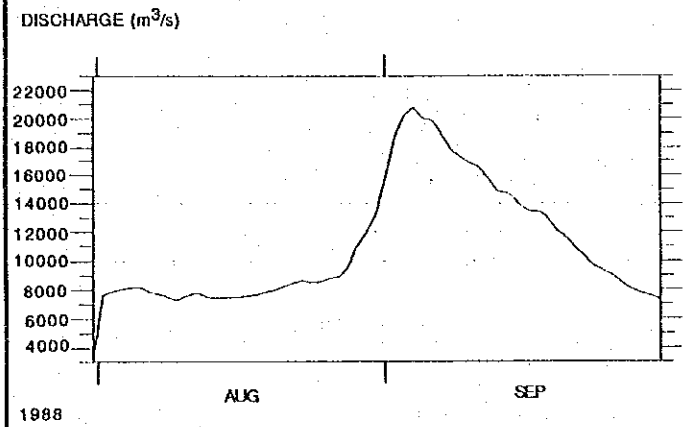
DHALESWARI RIVER
(CHAINAGE = 31.60 KM)



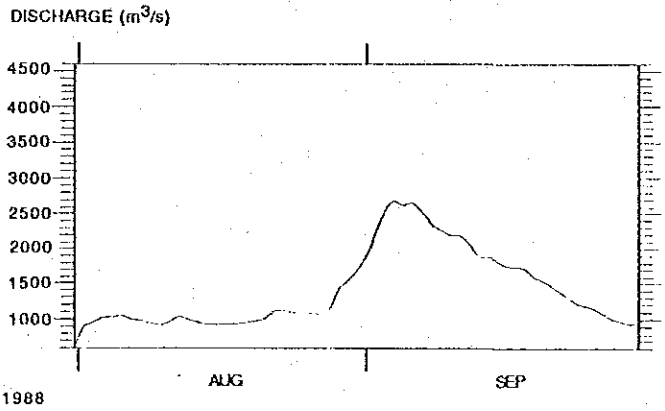
DHALESWARI RIVER
(CHAINAGE = 55.40 KM)



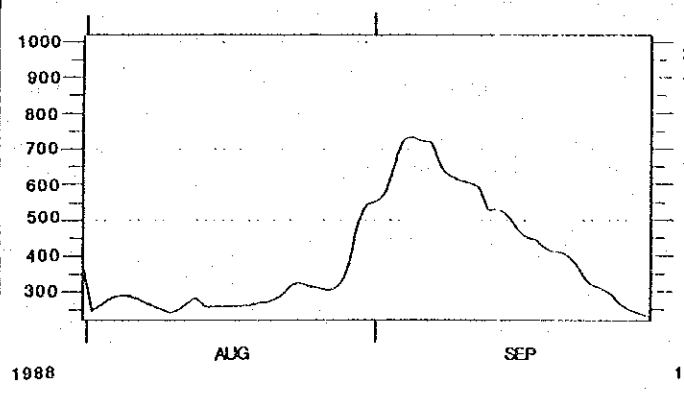
DHALESWARI RIVER
(CHAINAGE = 59.58 KM)



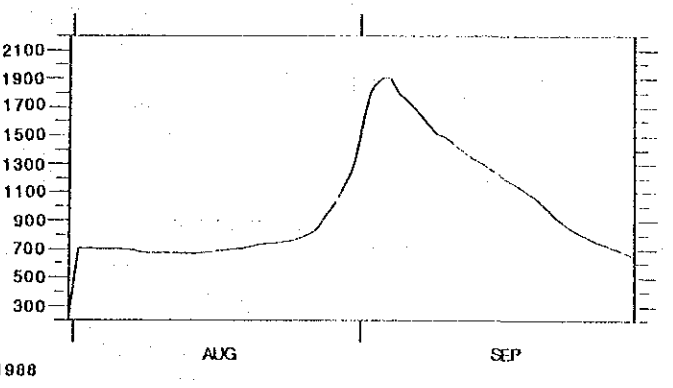
BURIGANGA RIVER
(CHAINAGE = 7.75 KM)



TURAG RIVER
(CHAINAGE = 18.00 KM)



KARNATALI RIVER
(CHAINAGE = 5.60 KM)



LEGEND :

——— Simulated Discharge by Mike11

FIG. D.27 RESULTS OF CALIBRATION - DAILY MAXIMUM DISCHARGE OF 1988 FLOODS (2/3)

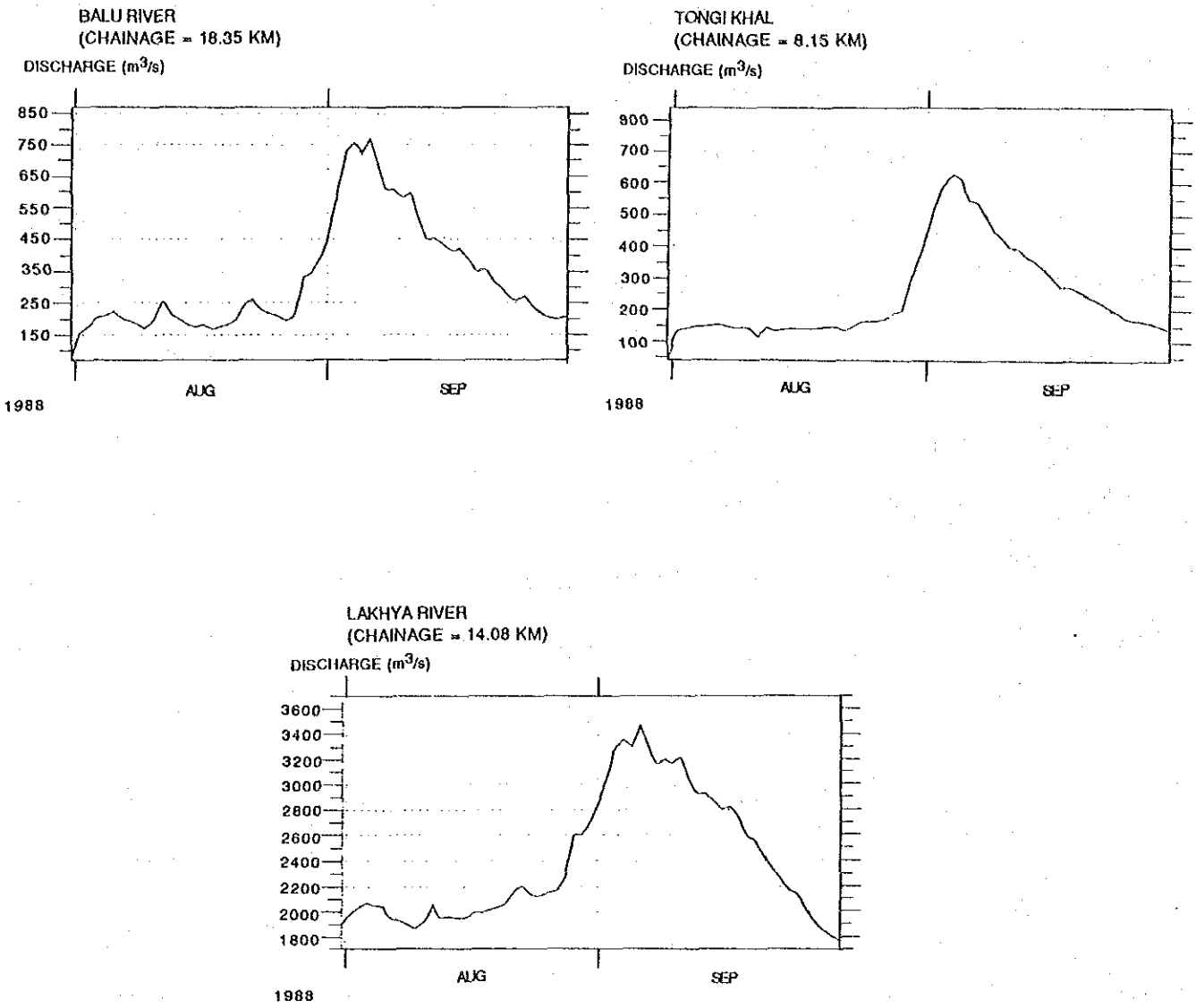
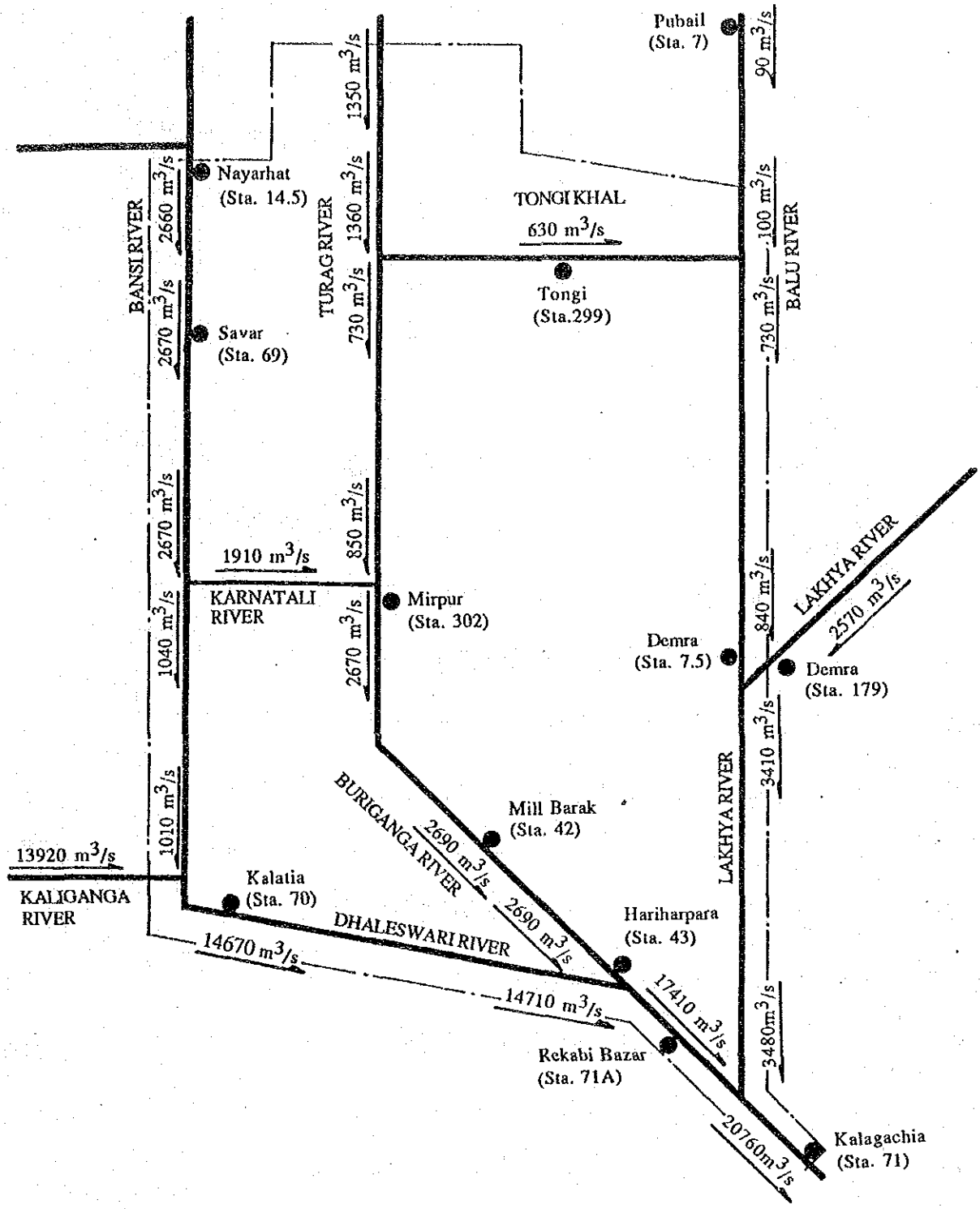


FIG. D.27 RESULTS OF CALIBRATION - DAILY MAXIMUM DISCHARGE OF 1988 FLOODS (3/3)



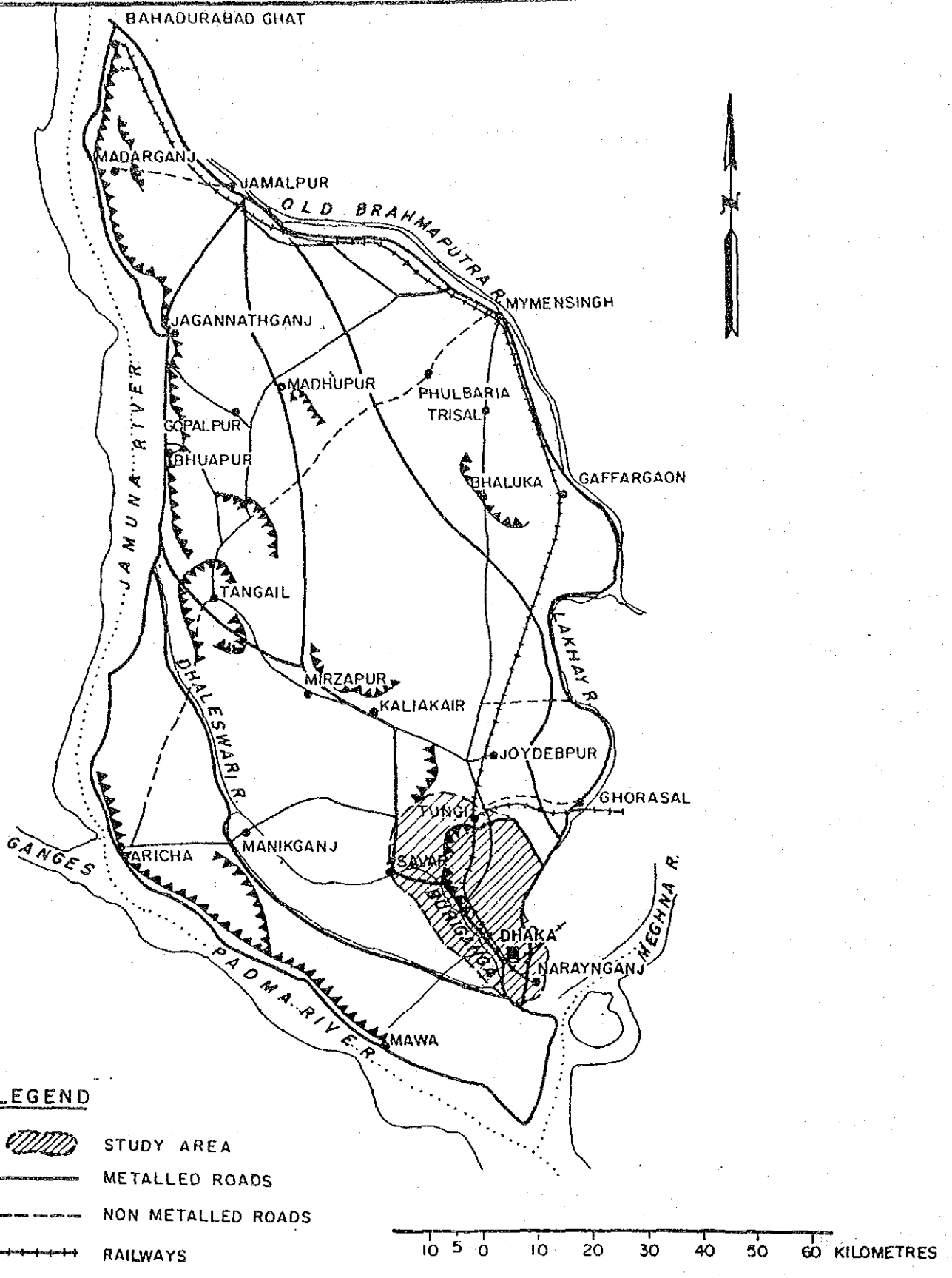
LEGEND :

● Water Level Gauging Station

FIG. D.28 RESULTS OF CALIBRATION - DISTRIBUTION OF PEAK DISCHARGE OF 1988 FLOODS

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA



Source :
France/EEC ; North Central Regional Study,
Phase I : Reconnaissance, 1990

FIG. D.29 STUDY AREA IN NORTH CENTRAL REGION

SUPPORTING REPORT E

FLOOD AND FLOOD DAMAGE

SUPPORTING REPORT E
FLOOD AND FLOOD DAMAGE

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