3.4.3 Hydraulic Simulation of DND

1) Drainage Network

The area is low-lying and flat and the drainage system is like a braided one. The drainage network is composed of drainage channels, retarding ponds and pump stations which are proposed for the storm water drainage improvement. The drainage channels the sub-catchments and the drainage network for hydraulic simulation are shown in Fig.3.12.

2) Boundary Conditions

Rainfall run-off of the sub-catchment areas were calculated by the Rational formula using the design hyetograph. The design hyetographs are created for each sub-catchment by each time of concentration as same as the design hyetograph.

Water level of the Lakhya River is LWL for gravity flow condition and HWL for pump operating condition.

	LWL(m)	HWL(m)	Pump capacity(m3/s)
KN - 2	3.00	5.75	14.5
KN - 4	3.00	5.65	50.2

3) Result of Simulation

The results of simulation shows that the peak water levels without retarding ponds are higher than the design banks, but with retarding ponds lower than the design banks (Fig.3.13).

It can be said that the simple design method using the rational formula, uniform flow calculation and mass curve calculation is adequate for designing drainage facilities such as drainage channels, pump stations and retarding areas.

TABLE 3.1 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 3.2 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) NARAYANGANJ	BWDB BIWTA	180	Lakhya	Latitude : 23 deg. 38.1 min. N 90 deg. 38.8 min. E	26. 06. 1946	Manual	1947 - 1990	-	-
12) 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	-	-
13) 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	-	-
14) 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 3.3 ANNUAL MAXIMUM DAILY RAINFALL

(unit : mm)

NO.	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		119									
3	1950		183									
4	1951	-	149									
5	1952		133									
6	1953	90	-									
7	1954	147	-									
8	1955	115	85									
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		168	137			115	
15	1962	116	87	81	107	248	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	96
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	161		78
38	1985	92		92	83	107	164	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 3.4 ANNUAL MAXIMUM TWO-DAY RAINFALL

	STATION	DHAKA	NARAYANGANJ	DHAKA	JOYDEBPUR	SAVAR	NARSINDI	BANCHARAMPUR	DAUDKANDI	MUNSHIGANJ	NARAYANGANJ	(unit : mm) 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		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	279	131	110	181	184		108	167	
17	1964	206	266	195	254	196	244	-		-	-	
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
25	1973	177	204	224	221	133	255	213		203	136	213
27	1974	-	-	183	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	164	234	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 3.5 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.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		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	616	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	330	-
30	1977	175	308	198	189	192	284	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	236	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 3.6 ANNUAL MAXIMUM MONTHLY RAINFALL

(unit : mm)

NO.	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		-	-	418
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	449
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	670
28	1975	559	627	625	634	647	490	608		876	655	399
29	1976	627	542	649	487	547	722	602		736	647	-
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	-	676	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	526	288		256
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 3.7 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 3.8 ANNUAL MAXIMUM WATER LEVEL

COMPARISON OF ANNUAL MAXIMUM WATER LEVEL RIVISED BY CHECH SURVEY

(UNIT :PWD in m)

NO.	STATION	PUBAIL	DEMRA	NAYARHAT	MILL BARAK	HARIHARPARA	SAVAR	KALATIA	KALAGACHIA	RAKABI BAZAR	DEMRA	NARAYANGANJ	MEGHNA FERRY GHAT	TONGI	MIRPUR
		BWDB	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.180	STA. NO.275.5	STA. NO.299	STA. NO. 302
	RIVER	BALU	BALU	BANGSHI	BURIGANGA	BURIGANGA	DHALESWARI	DHALESWARI	DHALESWARI	DHALESWARI	LAKHYA	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	1947-1990	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					5.09			
4	1948	5.82			6.26	-	7.20					5.36			
5	1949	-			5.96	5.94	7.23					5.33			
6	1950	5.43			5.72	-	7.04					5.27			
7	1951	-			-	-	7.35					5.27			
8	1952	5.41			5.45	-	7.10				5.58	5.33			
9	1953	-			5.66	5.24	7.06				5.58	5.27			6.27
10	1954	6.65			7.02	6.22	8.17				6.52	6.04			7.64
11	1955	-			7.05	6.40	8.26				6.77	6.16			7.66
12	1956	6.19			5.64	4.82	6.83				5.73	5.24			6.03
13	1957	5.92			5.32	5.06	7.20				5.52	5.58			6.20
14	1958	6.54			6.41	-	-				5.97	5.46			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		-	-	-				-	5.94		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	5.90	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	5.58	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	5.76	-	6.72	-
28	1972	5.64	5.40	6.97	5.26	5.01	6.66	6.07		5.00	5.44	5.12	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	5.52	5.44	6.36	6.36
30	1974	6.95	6.58	8.44	6.57	6.34	7.80	7.12		6.07	6.60	6.23	6.19	7.10	7.09
31	1975	5.73	5.60	-	5.39	5.23	-	-		5.18	5.60	5.36	5.29	-	-
32	1976	5.64	5.47	6.44	5.13	4.98	6.31	5.98		-	5.53	5.17	5.32	-	-
33	1977	6.03	5.92	7.15	5.60	5.39	6.88	6.34	5.34	5.39	5.81	5.52	5.59	6.03	5.99
34	1978	-	-	6.48	5.22	5.05	6.29	5.83	5.03	-	5.43	5.22	-	5.56	5.51
35	1979	-	5.59	6.46	5.25	5.08	-	-	-	-	5.49	5.00	-	5.60	5.54
36	1980	6.66	6.23	8.58	6.39	-	-	7.21	-	5.61	-	6.03	-	6.99	7.20
37	1981	-	5.74	6.74	5.42	-	-	-	-	-	5.65	-	5.40	-	5.79
38	1982	-	6.00	6.34	-	-	-	-	-	-	5.35	5.20	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	5.54	5.56	6.40	6.03
40	1984	6.35	6.33	8.12	6.00	5.72	7.58	7.11	5.91	5.74	6.04	5.77	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	5.33	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	5.03	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	6.09	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	-	6.63	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	5.23	-	5.38	5.42
46	1990	-	-	-	-	-	-	-	-	-	-	5.23	-	-	-
	AVERAGE	6.16	5.96	7.52	5.88	5.54	7.28	6.70	5.37	5.55	5.81	5.52	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 3.9 PROBABLE FLOOD WATER LEVEL

(Unit : PWD in m)

WATER LEVEL STATION	RETURN PERIOD (YEAR)												1988 Flood	1987 Flood	1974 Flood
	2	3	5	10	20	30	50	100	200	300	400	500			
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) Narayanganj (BWDB Sta.180)	5.56	5.71	5.88	6.10	6.30	6.42	6.57	6.77	6.97	7.09	7.17	7.23	6.63	6.09	6.23
12) 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
13) 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 1987 JICA STUDY are reflected.

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

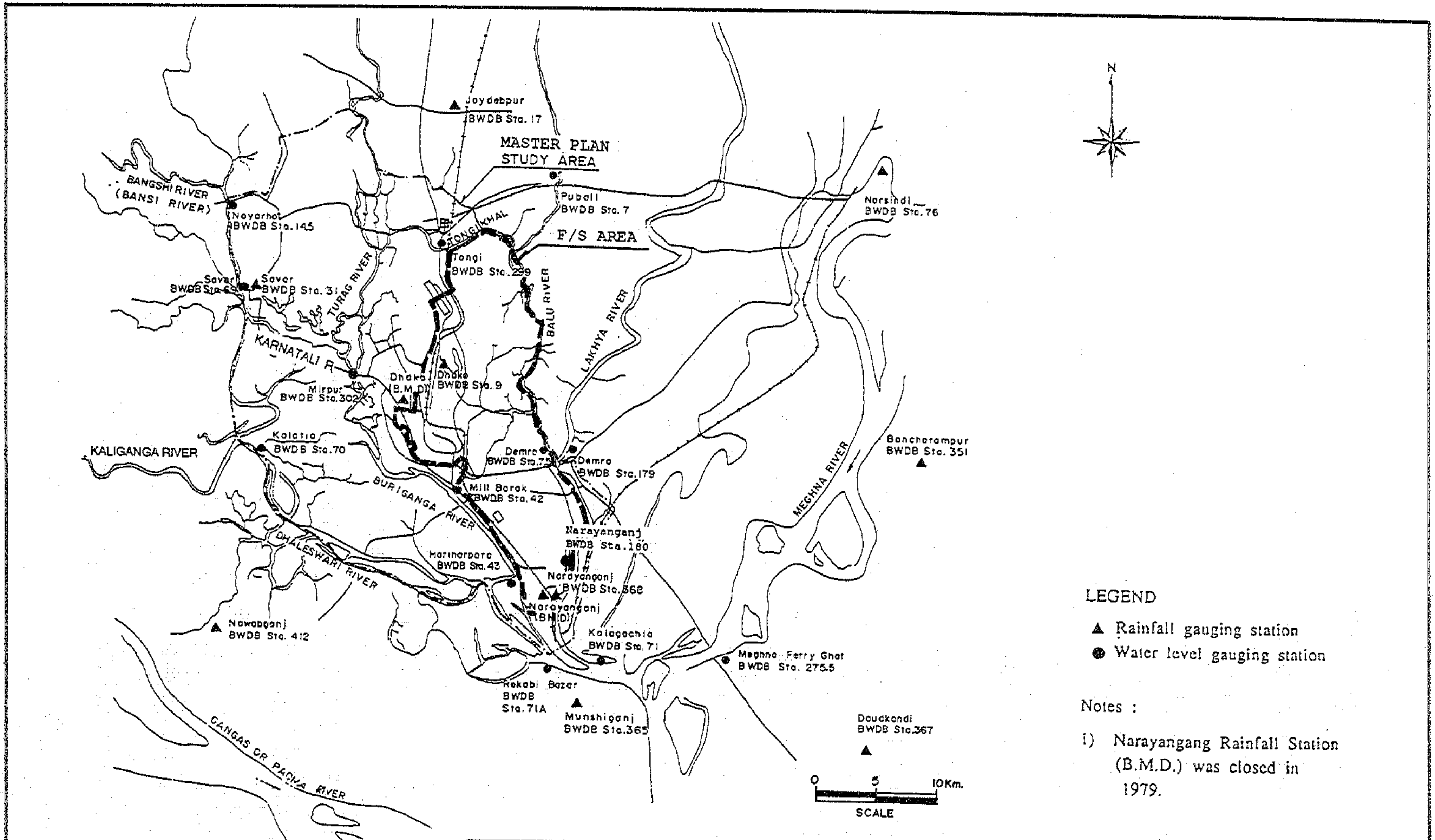


FIG. 3.1 RIVER SYSTEM AND GAUGING STATIONS IN AND AROUND THE STUDY AREA

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

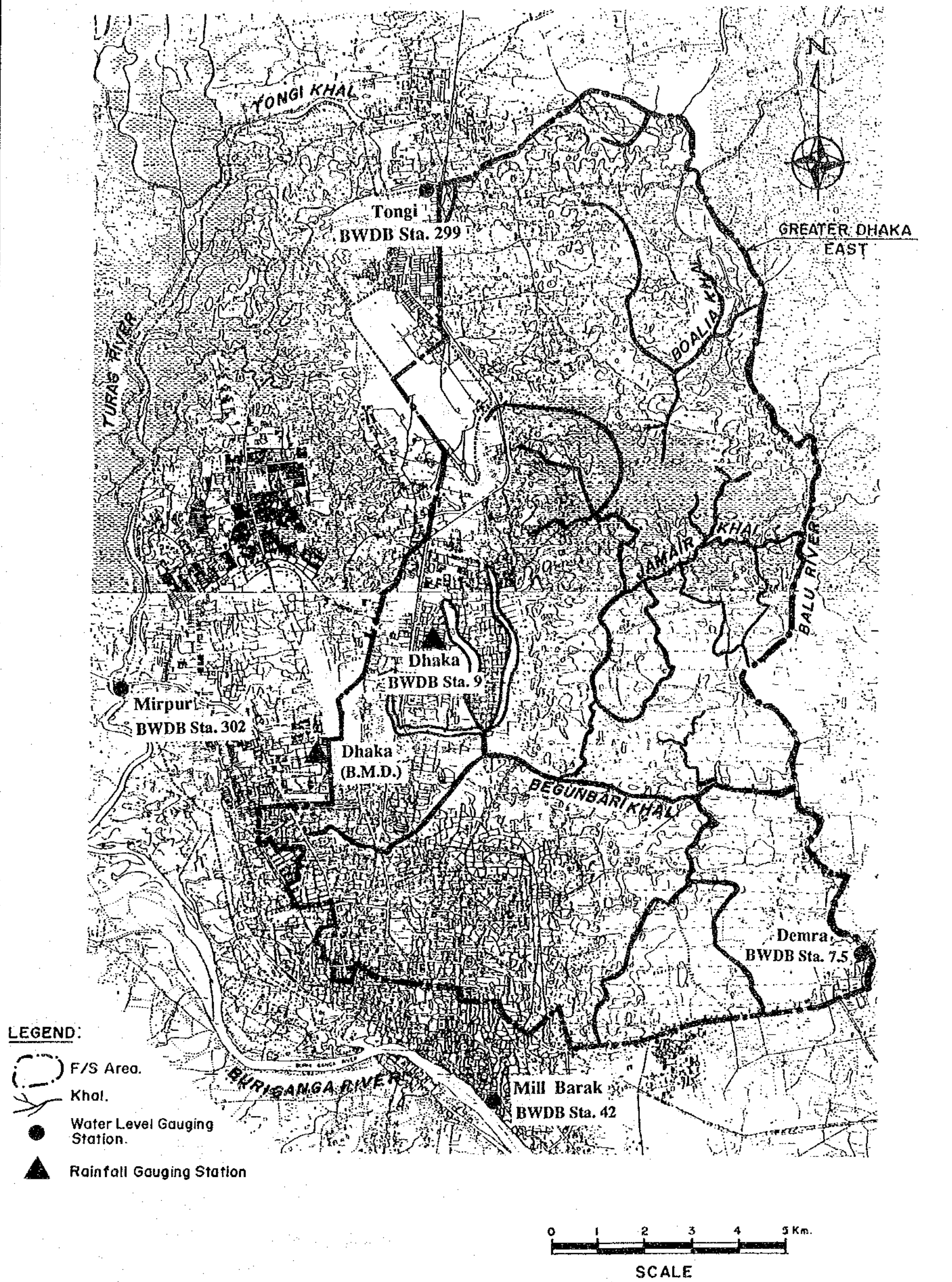


FIG. 3.2 (1) KHAL SYSTEM OF GREATER DHAKA EAST

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

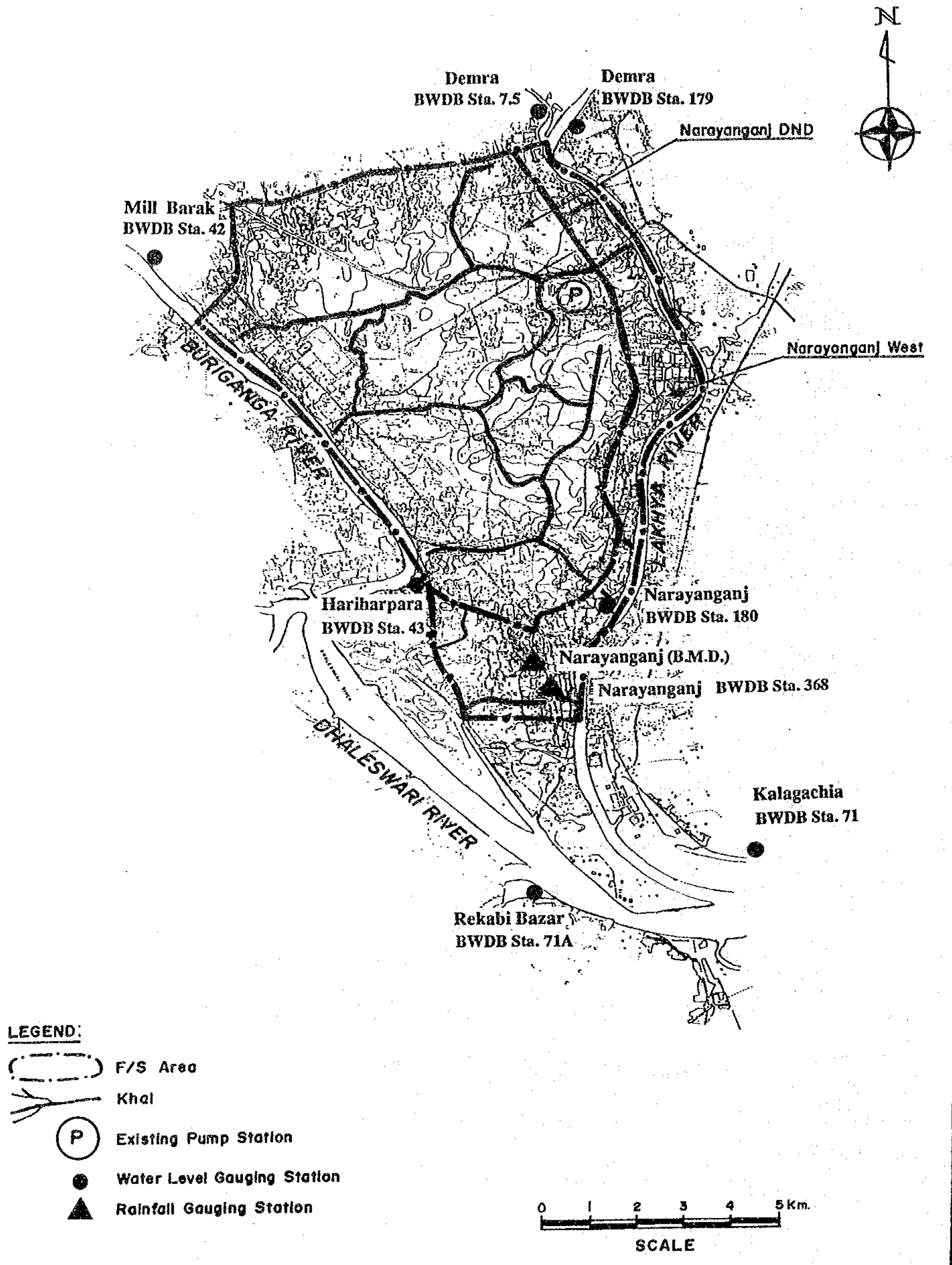
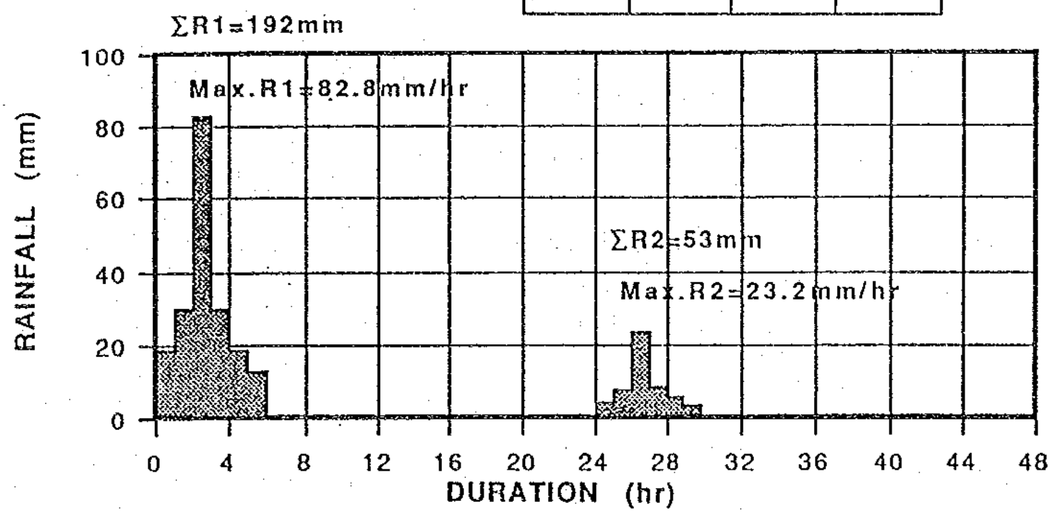


FIG. 3.2 (2) KHAL SYSTEM OF DND AND NARAYANGANJ WEST

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

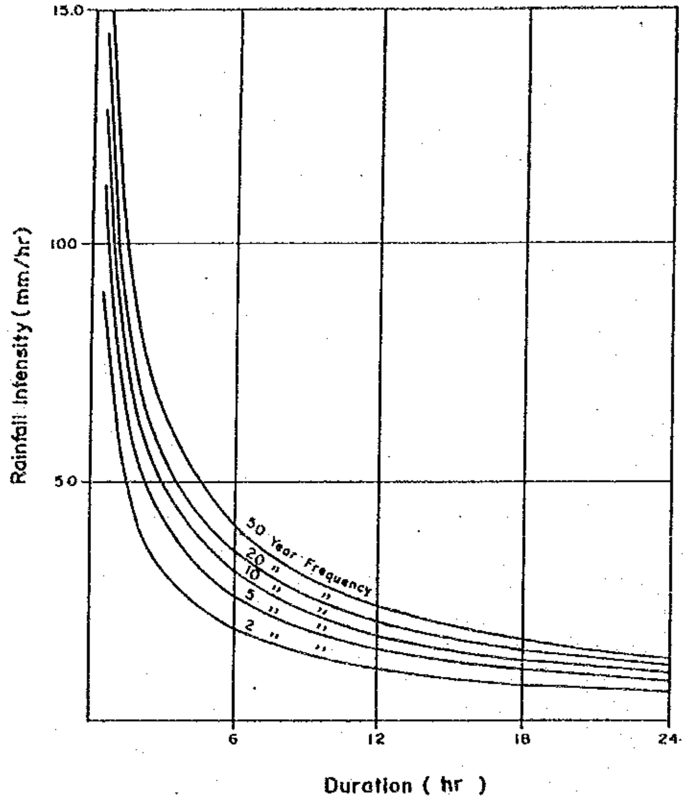


Source :

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

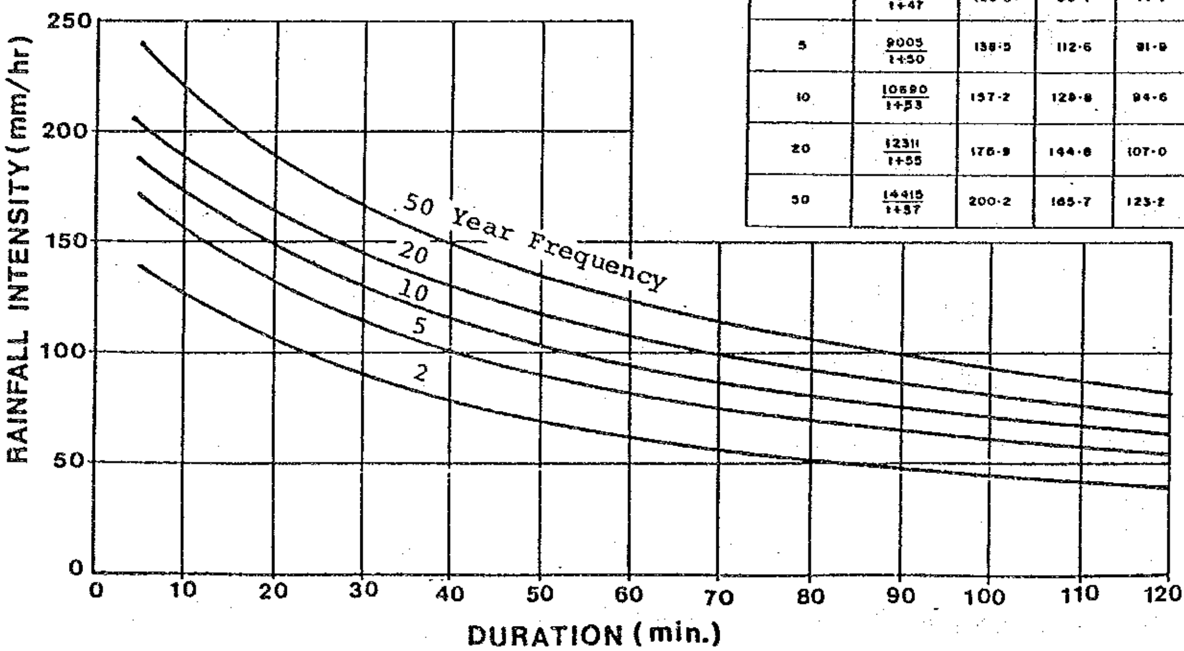
FIG. 3.3 PROPOSED DESIGN HYETOGRAPH FOR PUMP DRAINAGE PLAN

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



RAINFALL INTENSITY-DURATION FORMULA

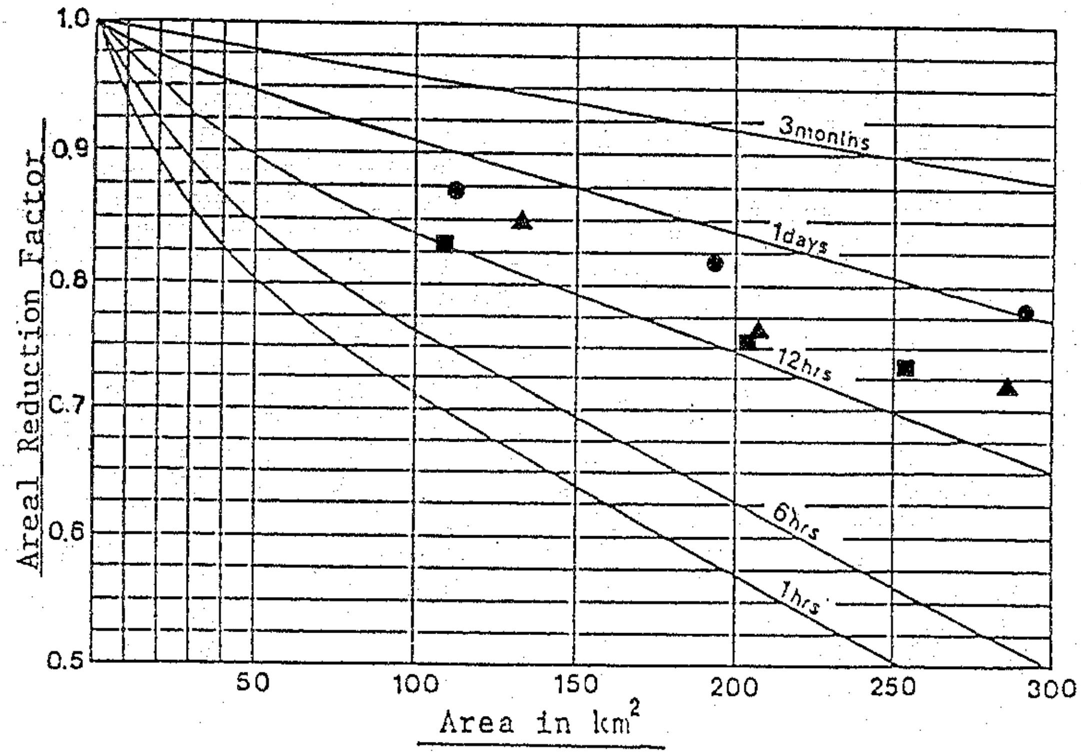
RETURN PERIOD	EQUATION	RAINFALL INTENSITY			
		15	30	60	120
2	$\frac{6689}{t+44}$	113·4	90·4	64·3	40·8
3	$\frac{7674}{t+47}$	123·8	99·7	71·7	46·0
5	$\frac{9005}{t+50}$	138·5	112·6	81·9	53·0
10	$\frac{10690}{t+53}$	157·2	128·8	94·6	61·8
20	$\frac{12311}{t+55}$	176·9	144·8	107·0	70·3
50	$\frac{14415}{t+57}$	200·2	165·7	123·2	81·4



Source :

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

FIG. 3.4 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. 3.5	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

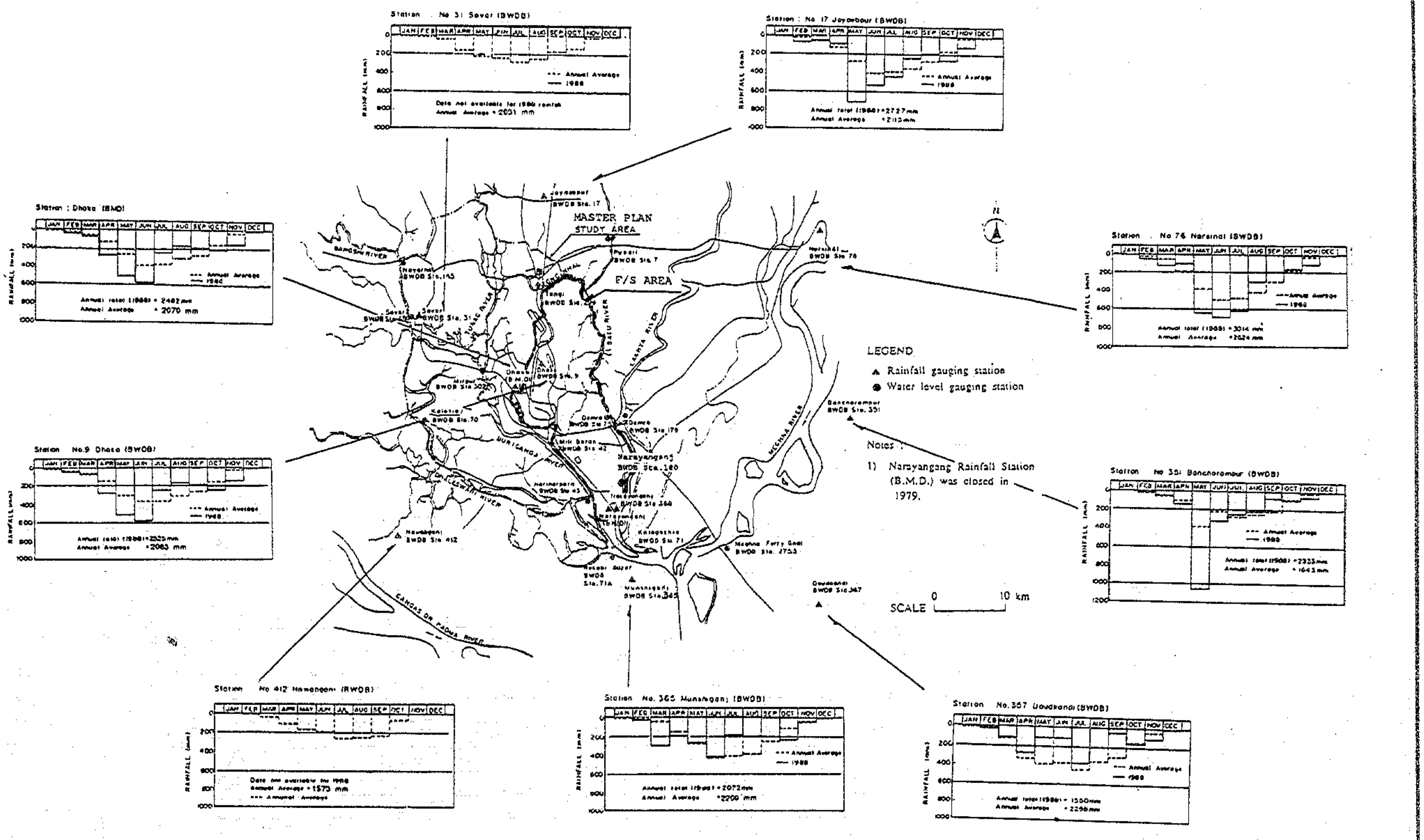


FIG. 3.6 MONTHLY RAINFALL-1988 AND ANNUAL AVERAGE

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

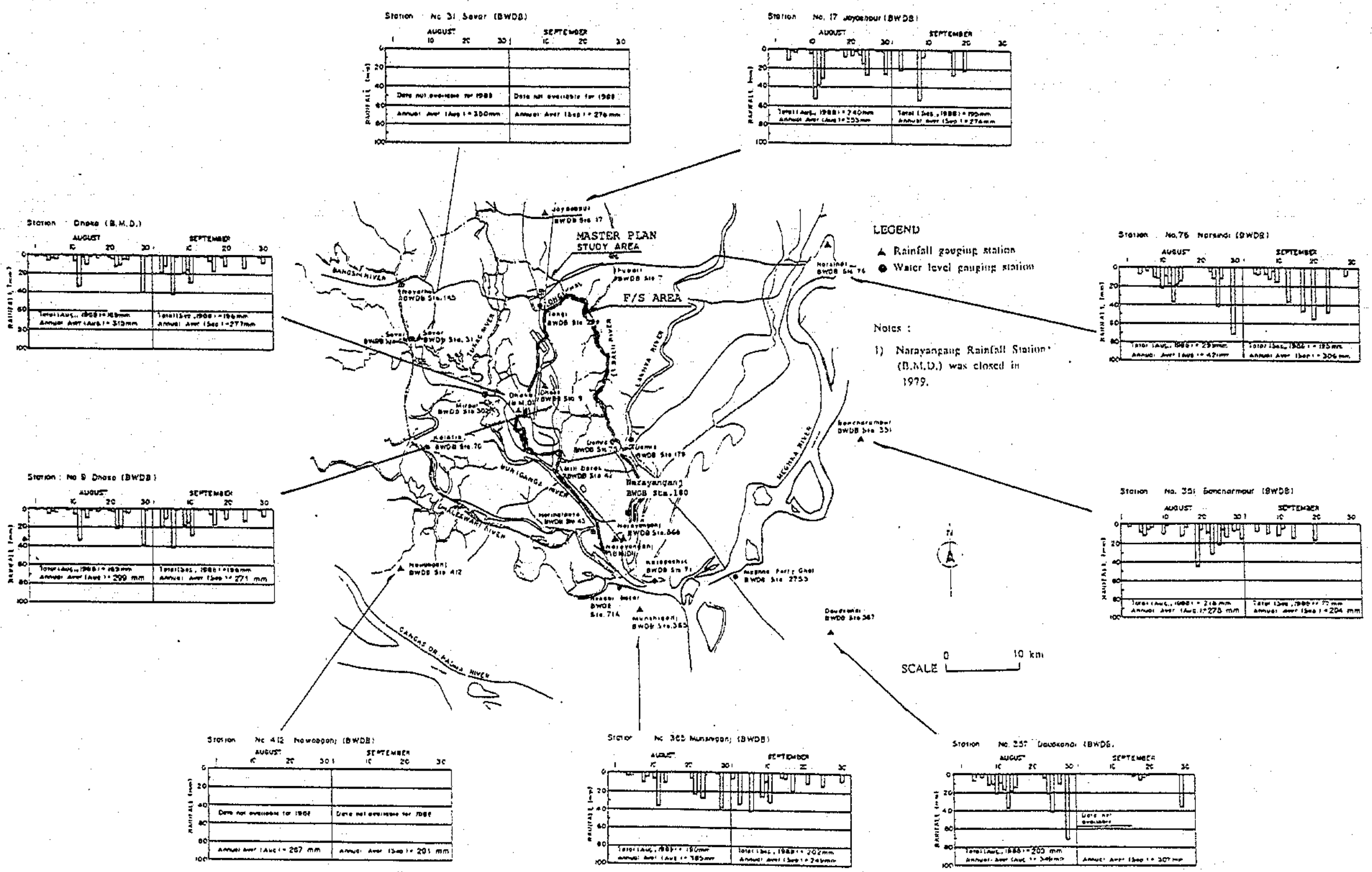


FIG. 3.7 DAILY RAINFALL DURING 1988 FLOODS

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

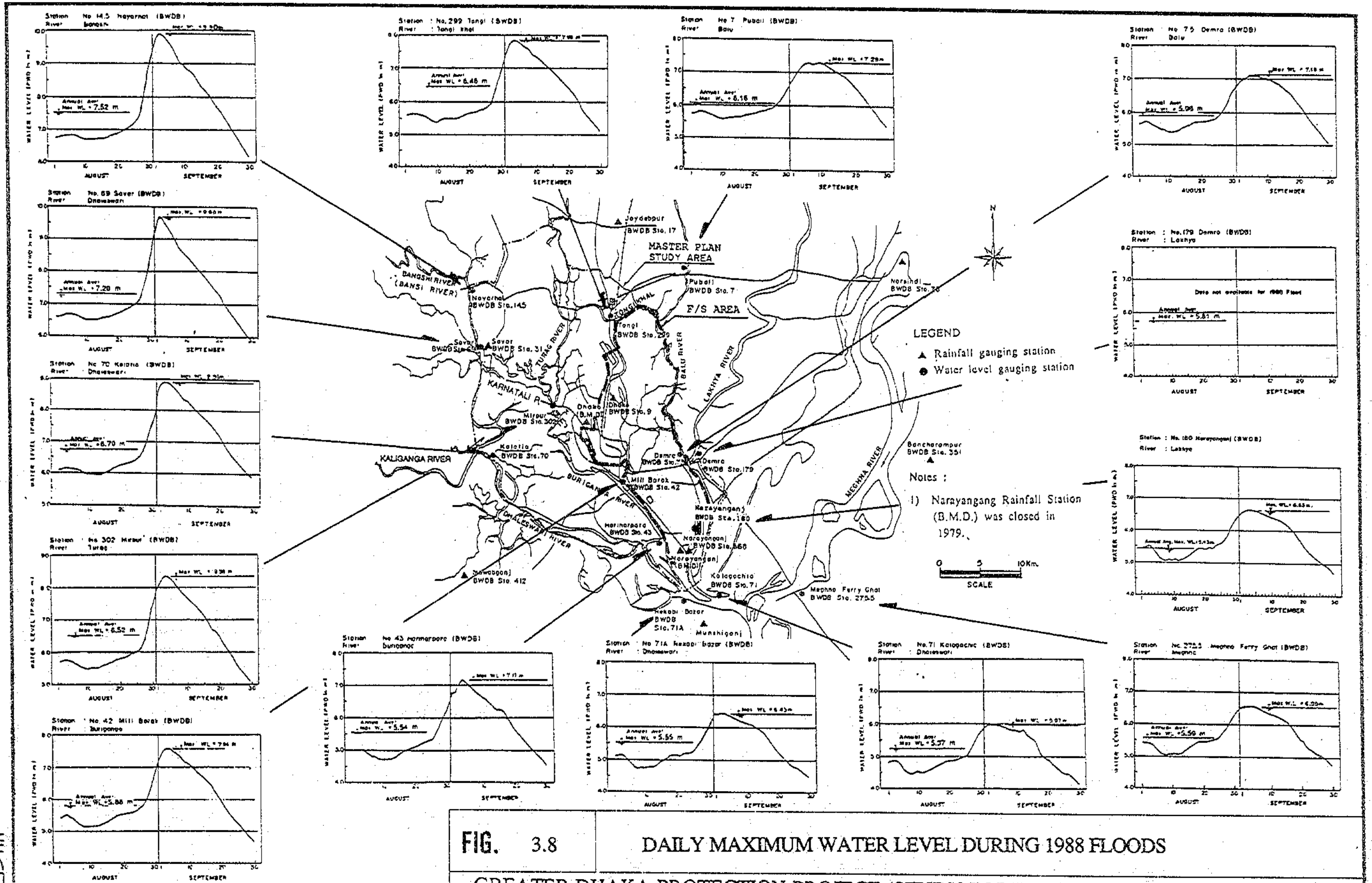
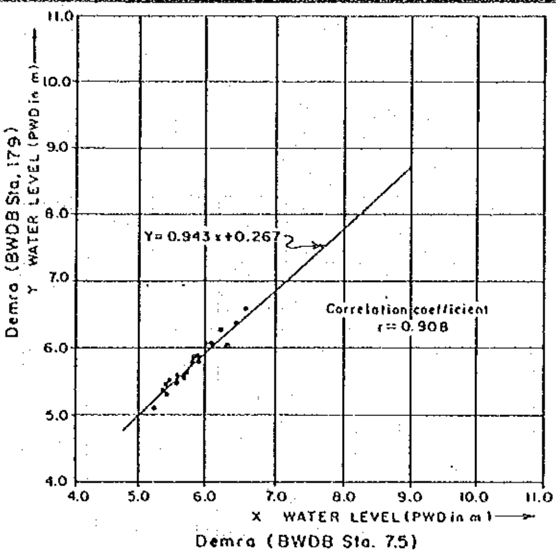
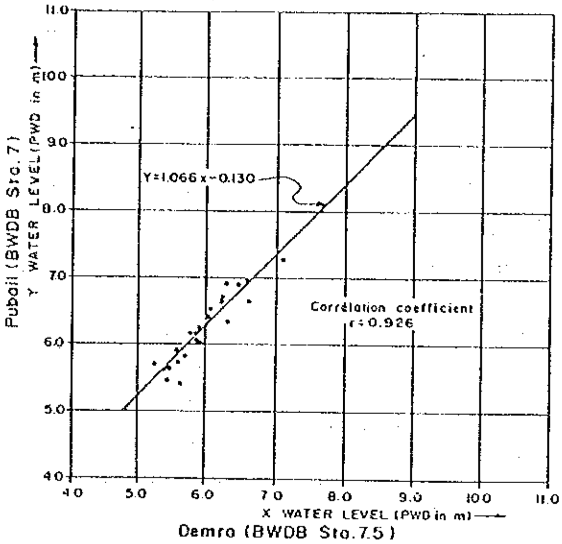


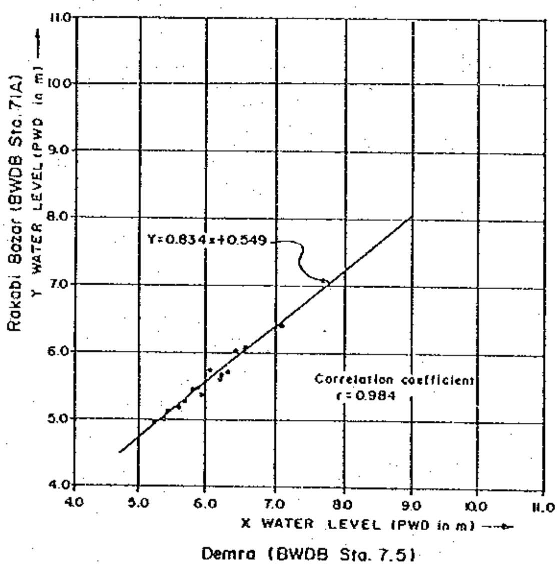
FIG. 3.8 DAILY MAXIMUM WATER LEVEL DURING 1988 FLOODS

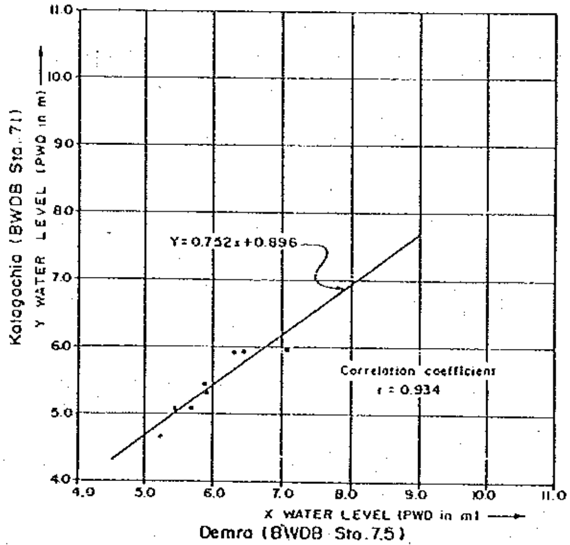
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH



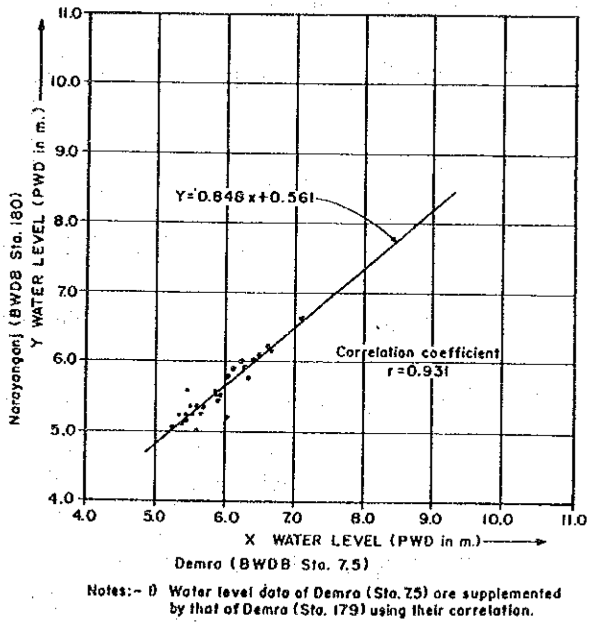


Notes: 1) Water level data of Demra (Sta. 7.5) are supplemented by that of Demra (Sta. 179) using their correlation.





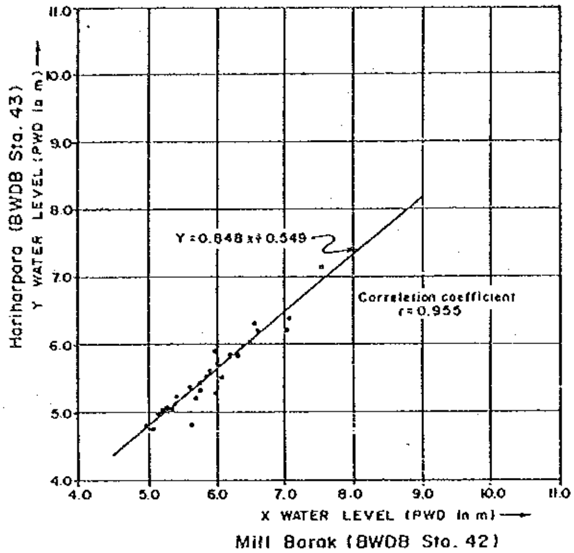
Notes: 1) Water level data of Demra (Sta. 7.5) are supplemented by that of Demra (Sta. 179) using their correlation.

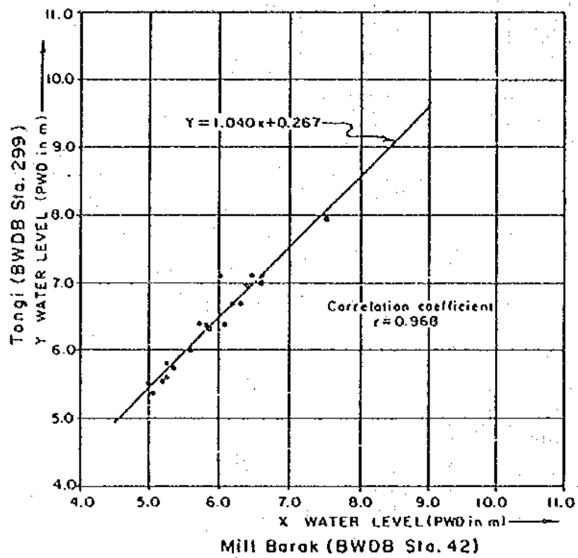


Notes:- 1) Water level data of Demra (Sta. 7.5) are supplemented by that of Demra (Sta. 179) using their correlation.

FIG. 3.9 (1)	CORRELATION AMONG WATER LEVEL GAUGING STATIONS (1/3)

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





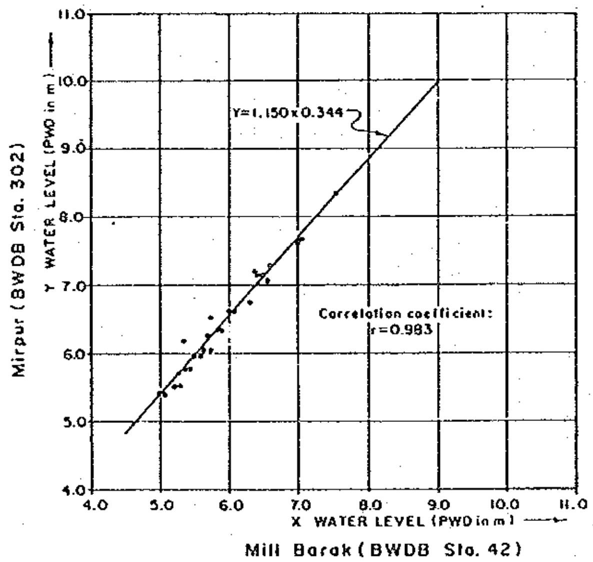
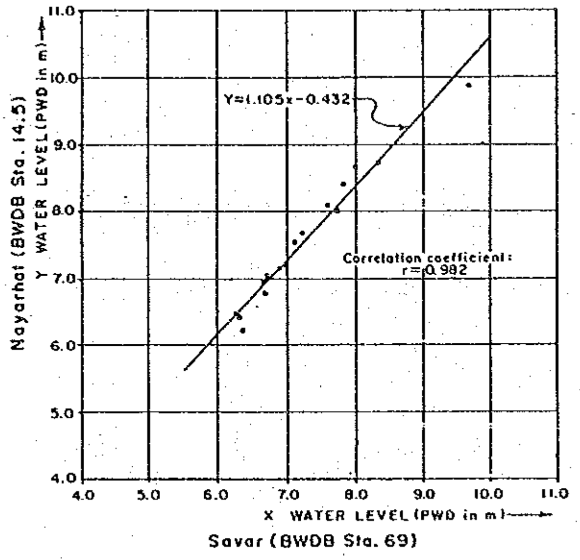


FIG. 3.9 (2) CORRELATION AMONG WATER LEVEL GAUGING STATIONS (2/3)



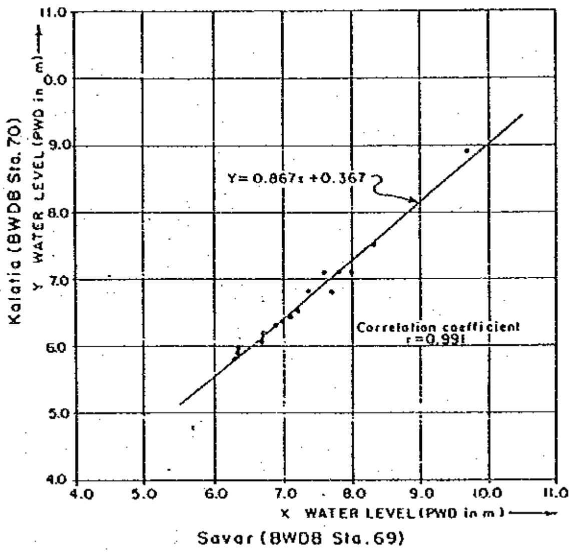
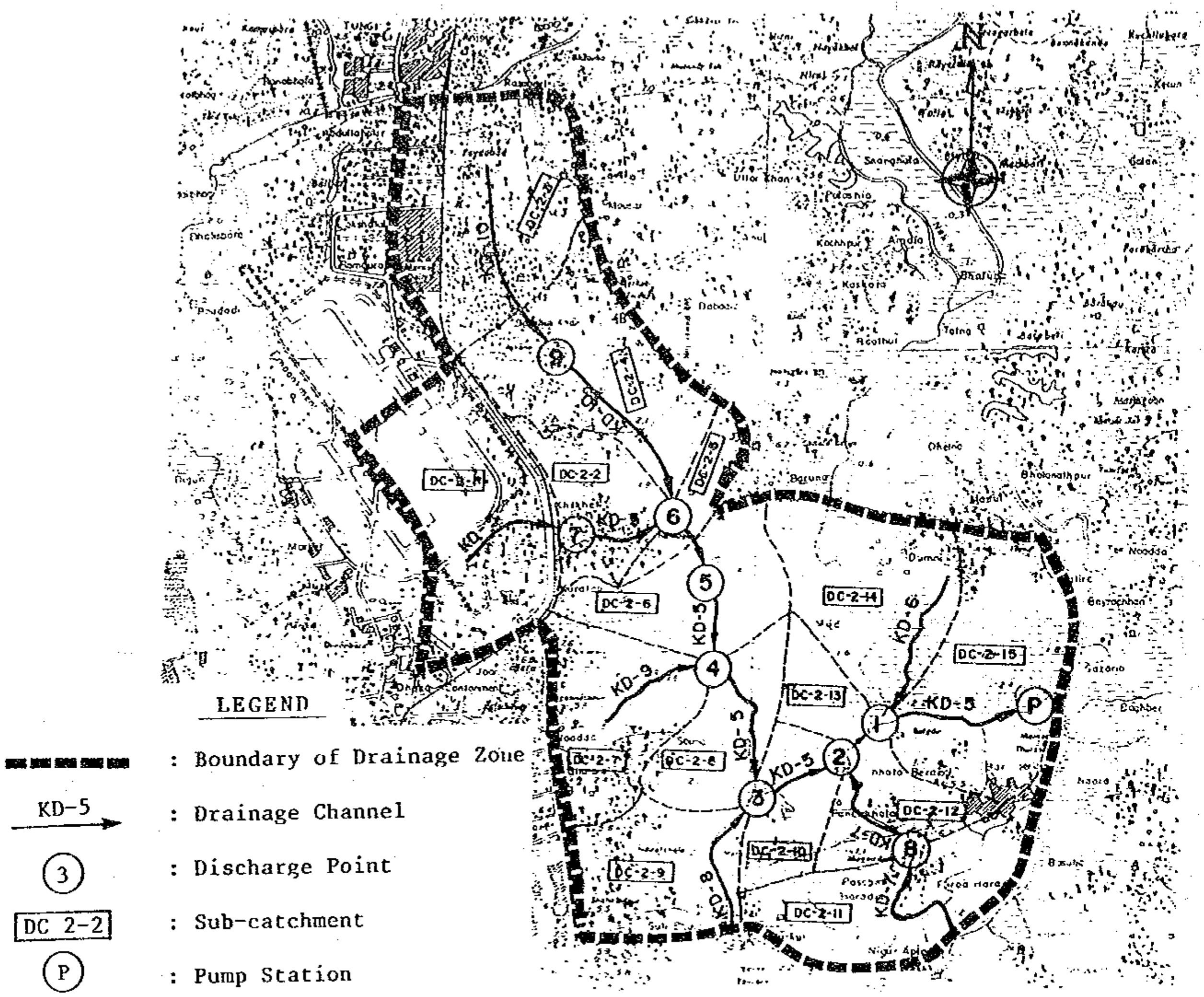
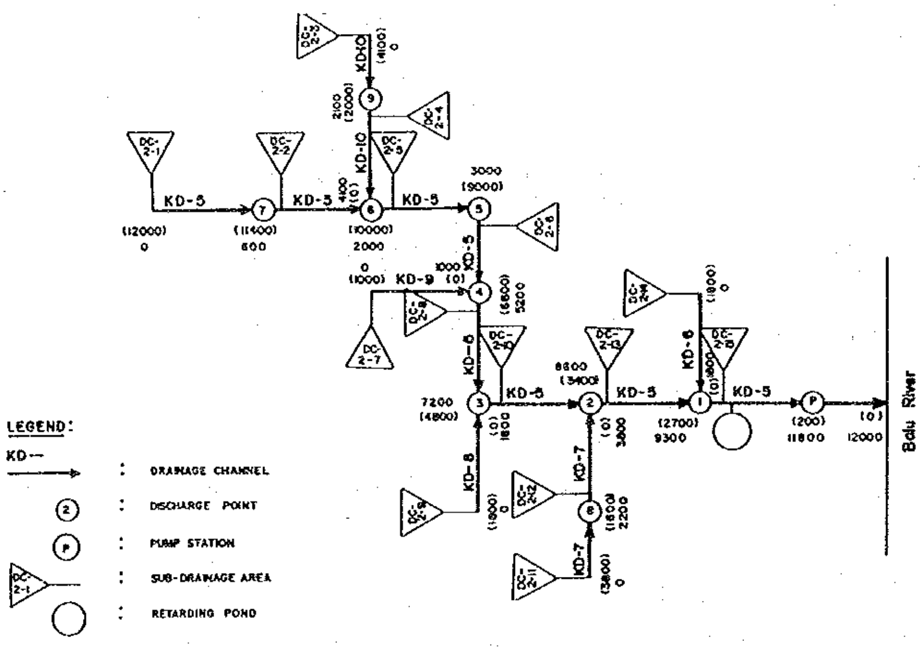


FIG. 3.9 (3) CORRELATION AMONG WATER LEVEL GAUGING STATIONS (3/3)

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

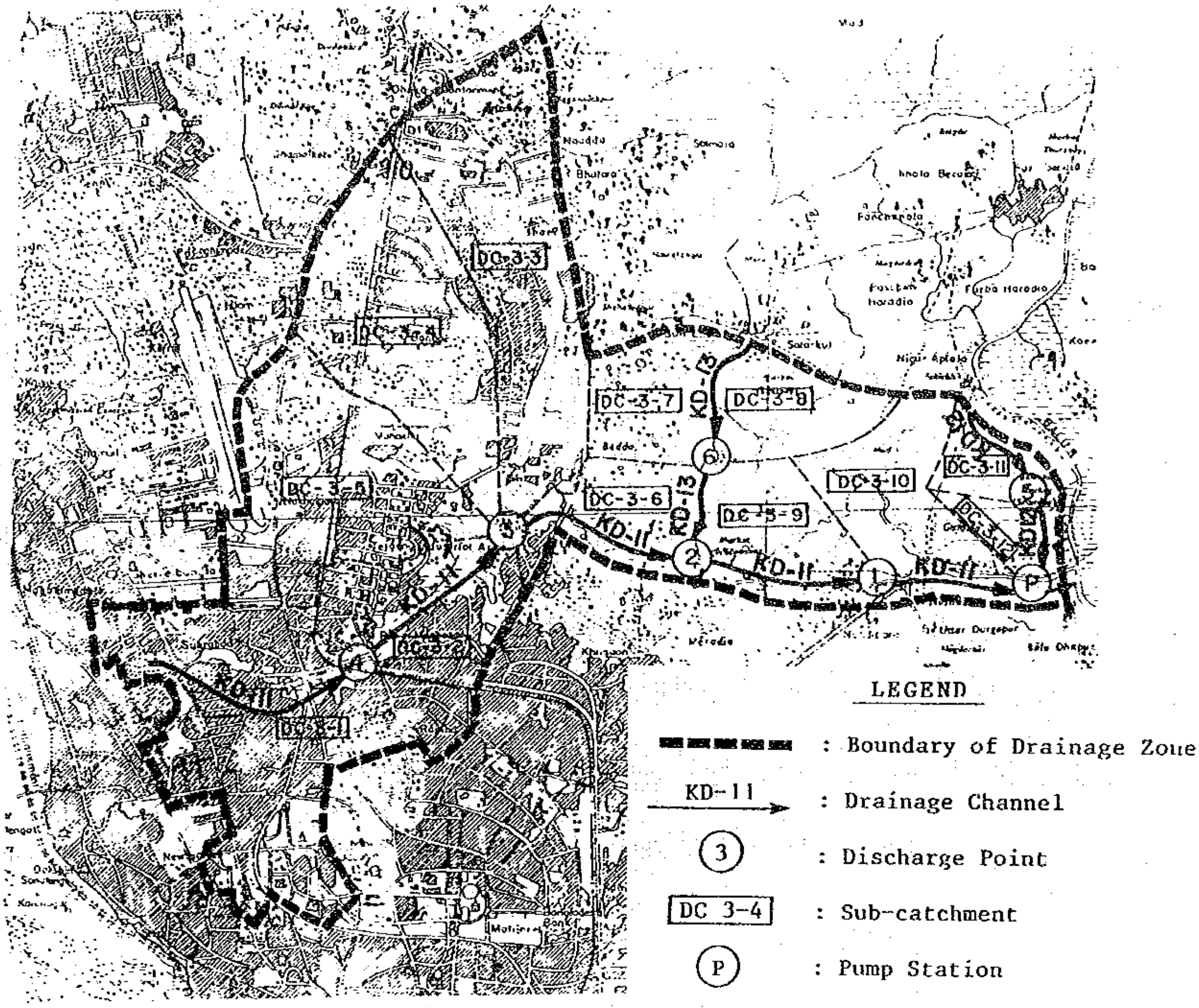


DRAINAGE CHANNELS AND SUB-CATCHMENTS

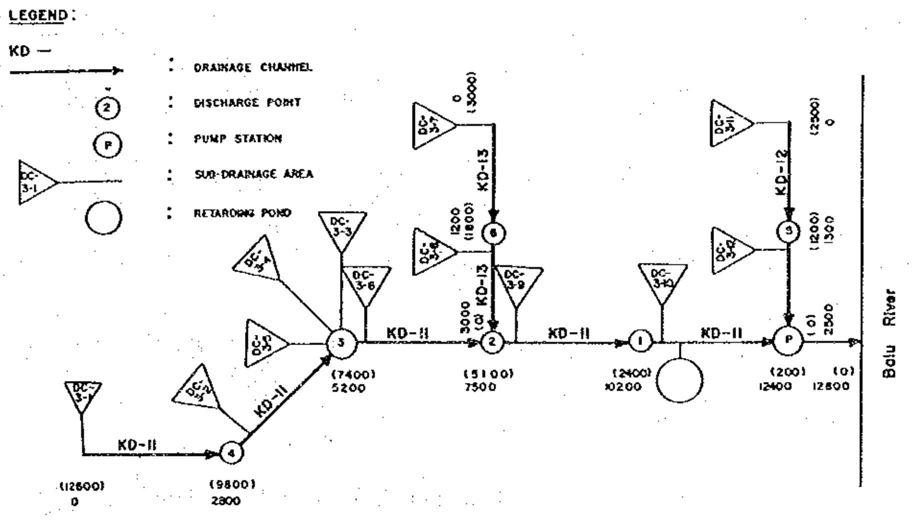


PROPOSED SIMULATION MODEL

FIG. 3.10(1) DRAINAGE CHANNELS AND SUB-CATCHMENTS, AND PROPOSED SIMULATION MODEL OF SUB-DRAINAGE ZONE DC-2



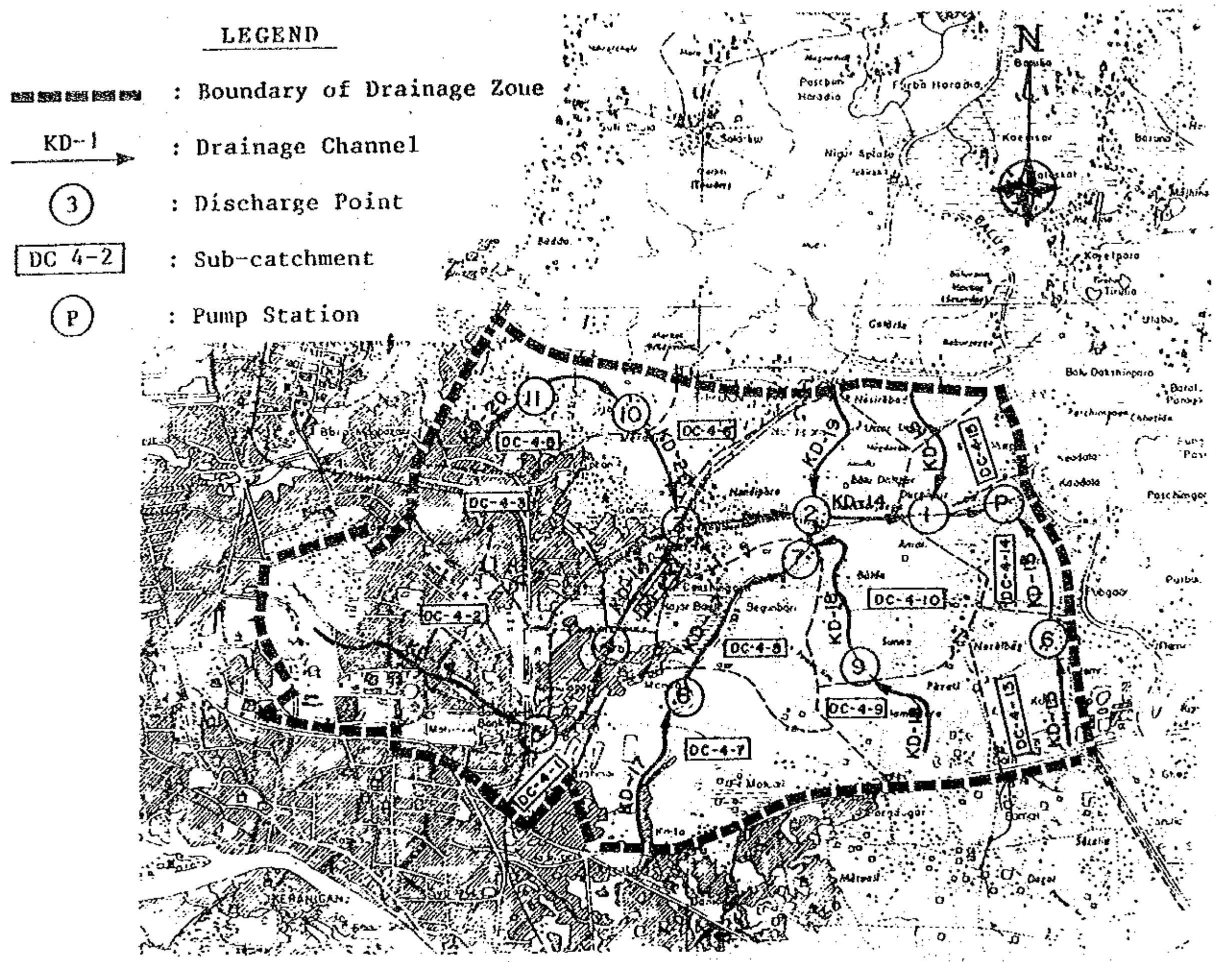
DRAINAGE CHANNELS AND SUB-CATCHMENTS



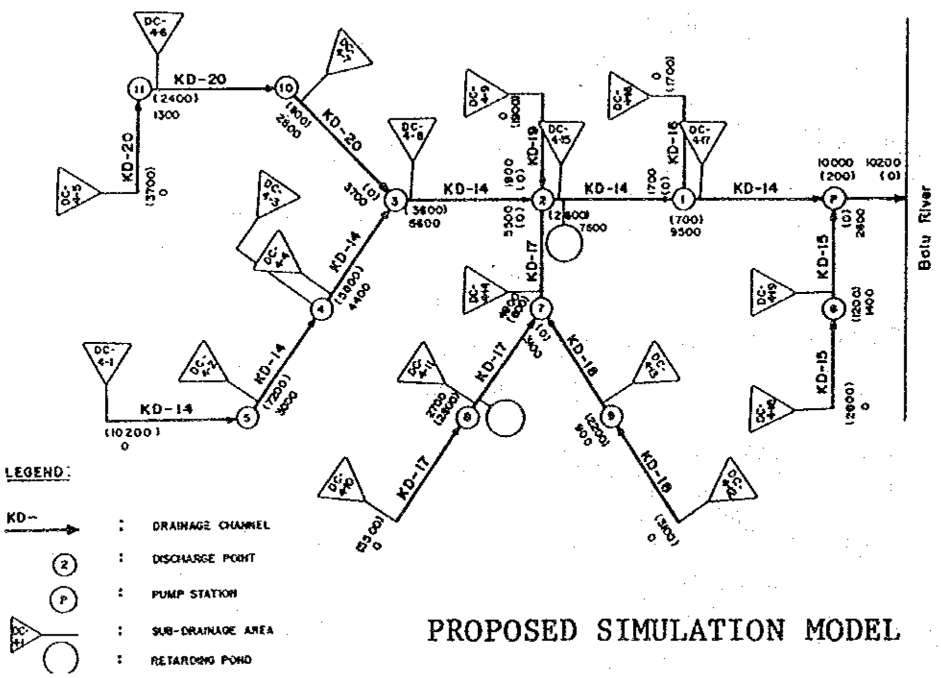
PROPOSED SIMULATION MODEL

FIG. 3.10(2)	DRAINAGE CHANNELS AND SUB-CATCHMENTS, AND PROPOSED SIMULATION MODEL OF SUB-DRAINAGE ZONE DC-3

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



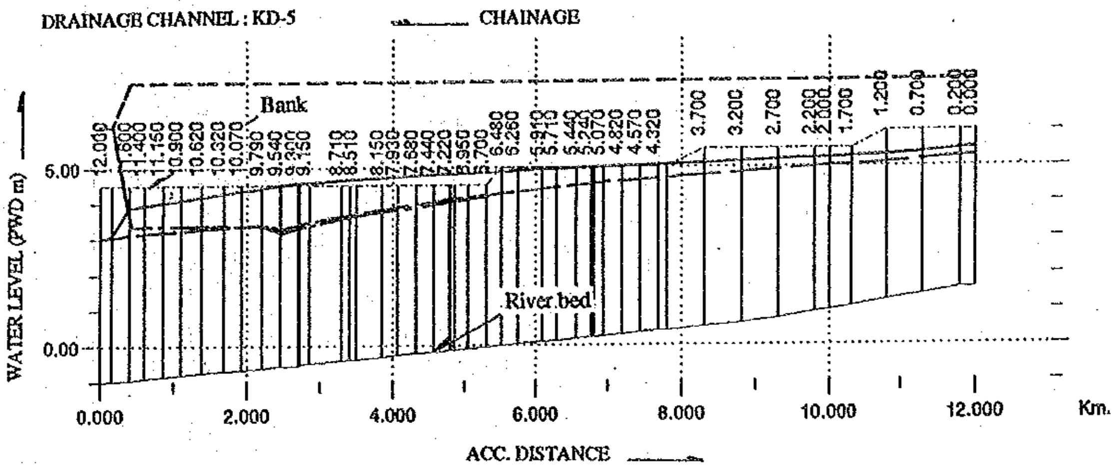
DRAINAGE CHANNELS AND SUB-CATCHMENTS



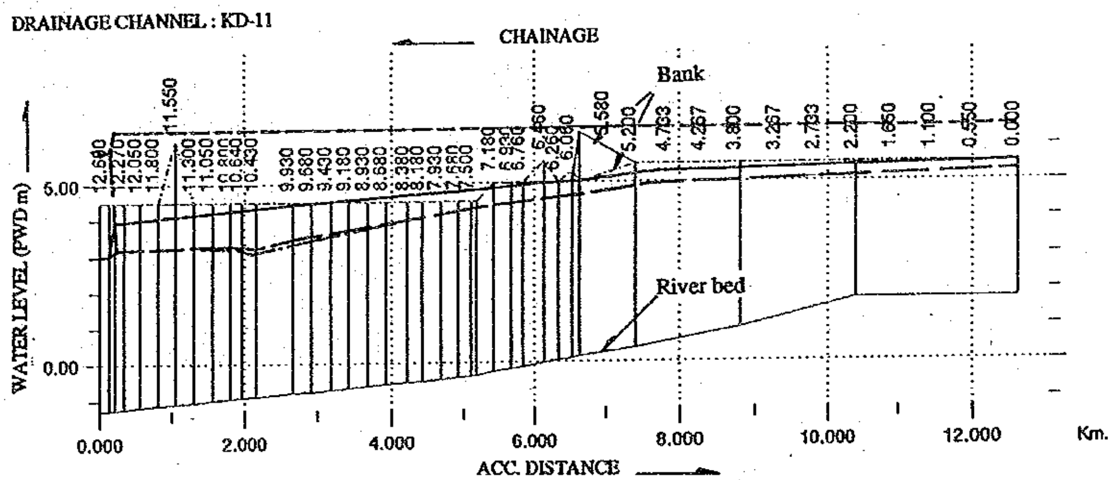
PROPOSED SIMULATION MODEL

FIG. 3.10(3)	DRAINAGE CHANNELS AND SUB-CATCHMENTS, AND PROPOSED SIMULATION MODEL OF SUB-DRAINAGE ZONE DC-3

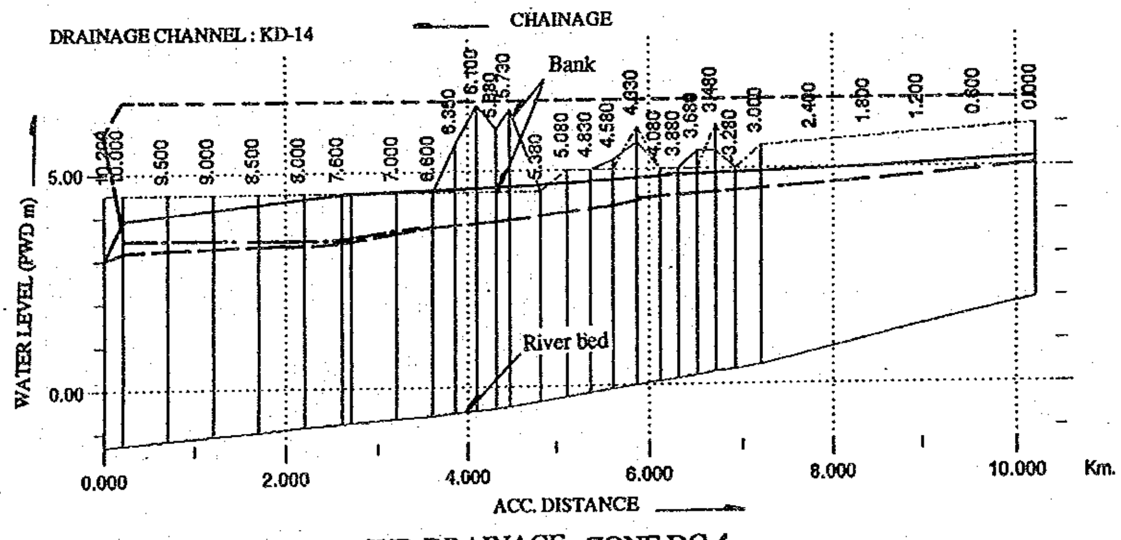
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH



SUB-DRAIANGE ZONE DC-2



SUB-DRAIANGE ZONE DC-3



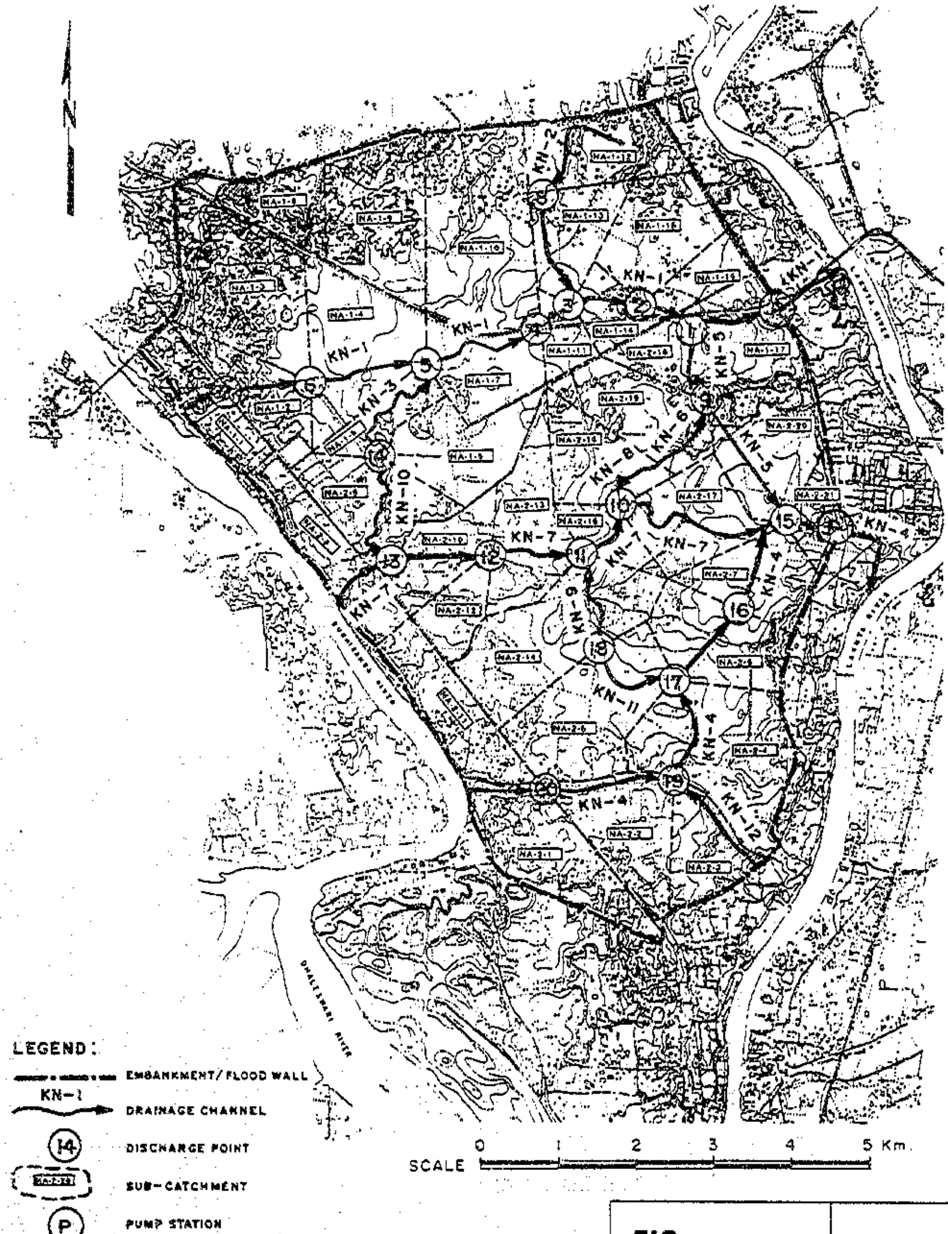
SUB-DRAINAGE ZONE DC-4

LEGEND :

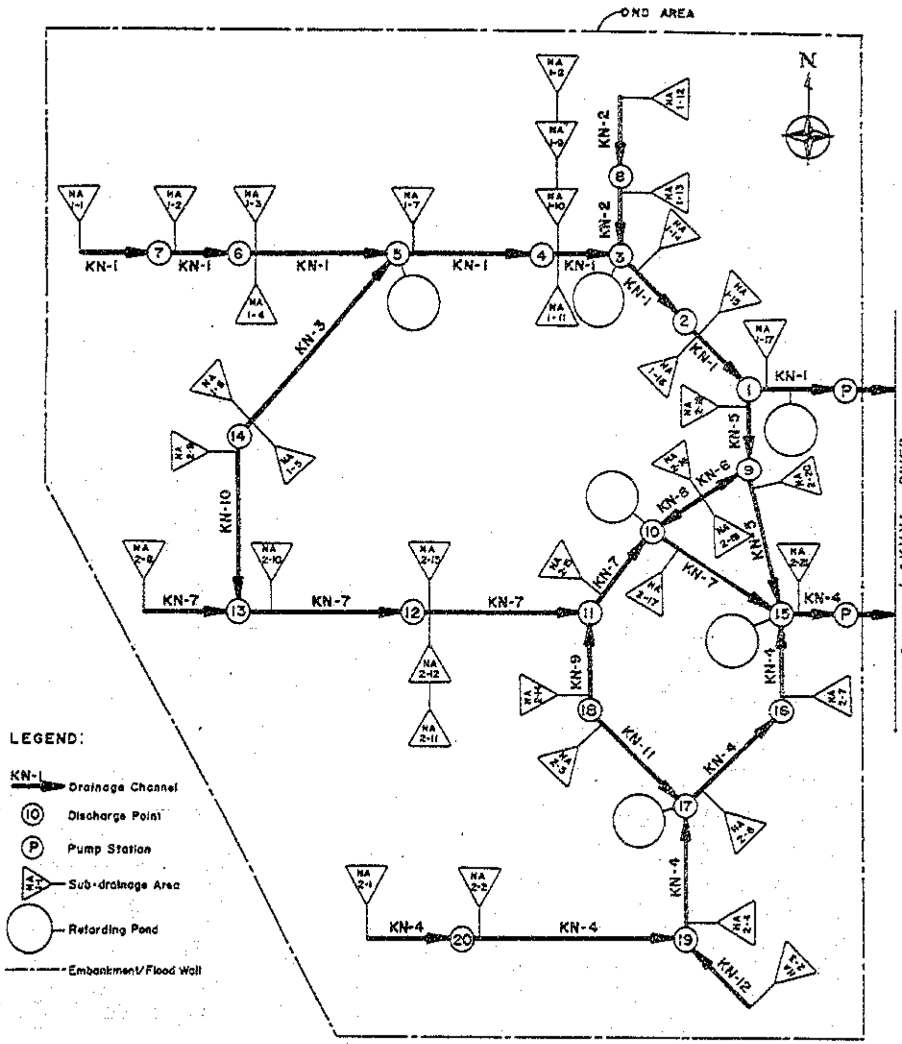
Water Level

- Case 1-1 : Without retarding pond and without pump station
- Case 1-2 : Without retarding pond and with pump station
- Case 2-1 : With retarding pond and without pump station
- Case 2-2 : With retarding pond and with pump station

FIG. 3.11 PROFILE OF SIMULATED PEAK WATER LEVEL OF GREATER DHAKA EAST



DRAINAGE CHANNELS AND SUB-CATCHMENTS OF NARAYANGANJ DND

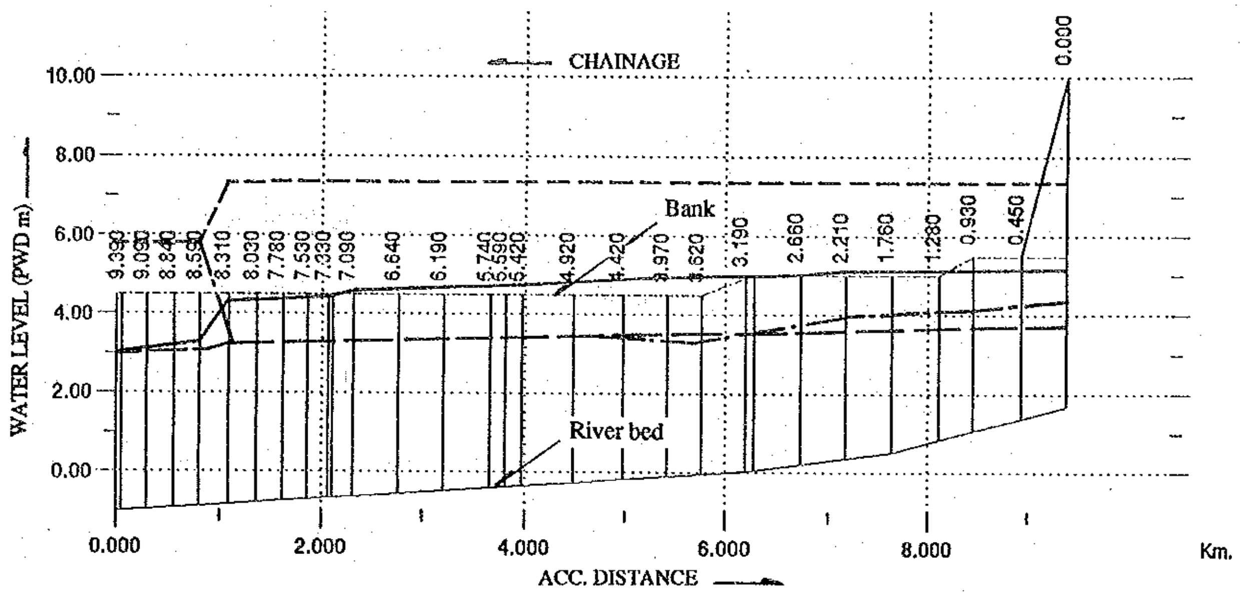


PROPOSED SIMULATION MODEL OF NARAYANGANJ DND

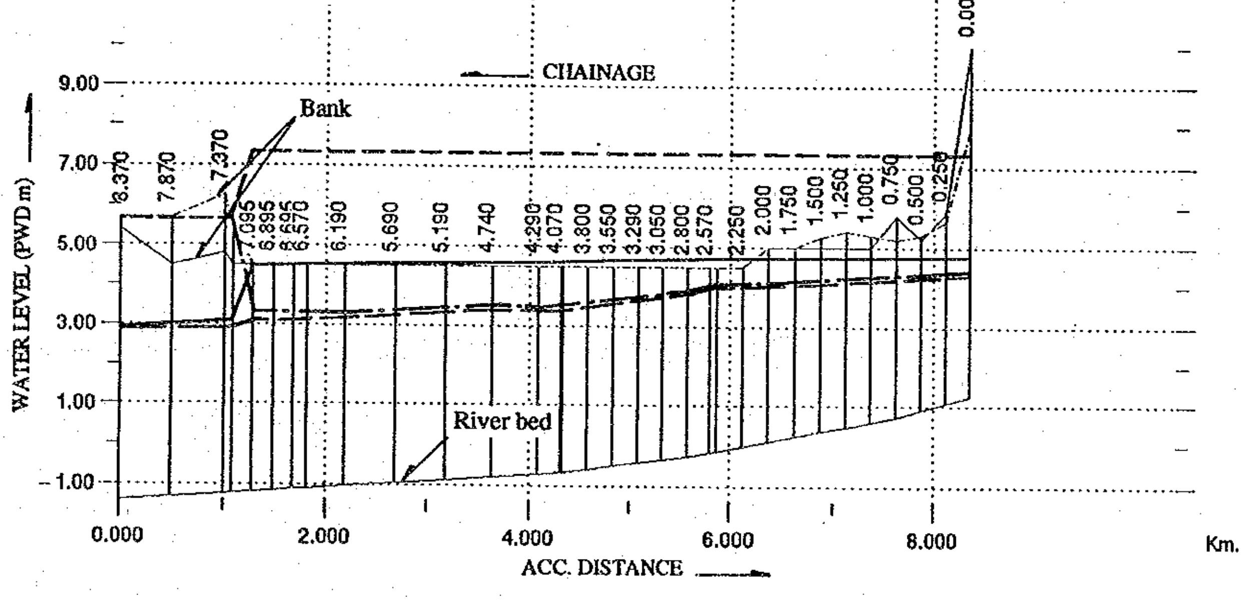
FIG. 3.12 DRAINAGE CHANNELS AND SUB-CATCHMENTS, AND PROPOSED SIMULATION MODEL OF NARAYANGANJ DND

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

DRAINAGE CHANNEL : KN-1



DRAINAGE CHANNEL : KN-4



LEGEND :

Water Level

Case 1-1 : Without retarding pond and without pump station
Case 1-2 : Without retarding pond and with pump station
Case 2-1 : With retarding pond and without pump station
Case 2-2 : With retarding pond and with pump station

FIG. 3.13 PROFILE OF SIMULATED PEAK WATER LEVEL OF NARAYANGANJ DND

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

CHAPTER 4
LAND USE AND URBAN PLANNING

Chapter 4 : Land Use and Urban Planning

4.1 General

The land needed for flood protection measures needs to be protected from further development prior to acquisition. The section outlines development control measures needed, and makes an initial assessment of suitable uses for retarding areas.

The urban development distributed in each area corresponds to the population increase forecast for each of these areas in the periods 1990 - 2000 and 2000 - 2010. These development areas have been drawn on the basis of land suitability, proximity to existing services, existing developments and required flood mitigation/drainage facilities.

4.2 Management of Future Urban Development

4.2.1 Development Pattern

The Development Pattern up to 1990 and land use forecasts for 2000 and 2010 are shown in Figs 4.1 to 4.4.

The Greater Dhaka East is the least developed among the feasibility study areas. This is mostly because, under current conditions, large parts of the central and southern areas are flooded for most of the year.

A considerable peripheral development has taken place during the last decade by means of landfill, especially in the southern portion close to the city centre. The construction of Rampura - Biswa road has also provide a platform for further peripheral development to the east. Further north, in Uttara, RAJUK has initiated sizable developments.

Further planned and unplanned peripheral development may be anticipated during the next decade. However more comprehensive development of the area would be preferred.

The DND has been developed quite rapidly during the last decade, particularly in the northwest corner, because of its proximity to the city areas as well being relatively flood-free. Currently RHD has started Dhaka-Narayanganj road and RAJUK is preparing housing development plans for the area. Further substantial development is anticipated over the next ten years.

The Narayanganj West is much smaller but much more intensively developed. The town area is on relatively high land and developed independent from Dhaka. The major settlement areas are in the south-east and the linear northern area. Density decreases progressively from east to west in the wider part of Narayanganj area. This leaves a small south-western part undeveloped.

4.2.2 The Need for Management

Management and control of land is needed if urban development is to proceed in accordance with a preferred strategy. The flood mitigation and drainage improvement strategy will be a major determinant of the city form. Since this will constitute the major expenditure, to ensure the availability of land where required, it will have to be delineated, and safeguarded. Management and acquisition authority should be sufficient to:

- maintain certain areas in agricultural, recreational and other conservation uses;
- acquire land for flood protection measures,
- control landfilling in areas to be acquired,
- prevent encroachment into land for flood mitigation facilities,
- ensure sufficient protection in low-lying areas by enforcing standards for in fill and road crest heights,
- control/modify particular development proposals that would affect efficient drainage or impede flood water flow.

The required authority/power should be available at the earliest to safeguard the area of land needed for flood control and protection, given the pace of peripheral urban development, and the rate of increase in land prices.

Control and acquisition are complementary measures, but the former is clearly preferable if a choice exists. It is particularly significant that funds for land acquisition will need to be found locally. Thus, as well as making maximum use of control methods to reduce acquisition costs, it is imperative that the government manage to recoup some of the benefits of its investments from the beneficiaries, to allow further development.

4.2.3 Existing Legislation

RAJUK is the planning and development authority for Dhaka metropolitan area. It is authorized to acquire land and prepare improvement schemes of both existing areas and new ones. The legislation that empower government bodies to integrate development projects are listed below ;

(1) Landuse Control and Construction Control :

The East Bengal Construction Act (1952), updated in 1961 and 1986 provides that within any area where Government may extend its application, all construction shall have previous permission from the designated "authorized officer". The Act also empowers the discontinuation of non-conforming use. RAJUK is responsible for control of construction in Dhaka.

The Town Improvement Act 1953 established the Dhaka Improvement Trust (DIT) as a development body with powers to take over, improve, and return land to and from private and municipal owners. For guidance, it was authorized to prepare "schemes" and "zone plans". Planning control took the form of urban on all construction not confirming to such plans. In 1958, references to scheme and zonal plans were replaced by references to a "master plan". At the same time, it was mandated that an official of DIT should be designated as the "authorized officer" for the area within the jurisdiction of DIT. RAJUK (DIT) has the power to approve or reject proposals for building which are not in conformity with the Master Plan. The development control system is minimal, being based on the need to apply for the granting of an exception where a proposal is not in conformity with the plan. But the plan, prepared in 1960, is now clearly outdated and only covers part of the RAJUK area - not including many of the peripheral areas where development pressures are greatest. In this peripheral urban area, RAJUK can prevent / permit development, but decisions are made on an ad hoc basis.

In practice, except in instances where private developers need official approval prior to obtaining a bank loan, most development proceeds without seeking for permission. There is also little control over development by public bodies.

(2) For Land Acquisition :

The Acquisition and Requisition of Immovable Property Act of 1982, with subsequent minor amendment, has replaced previous acquisition acts. The Act aims to ensure the organization requiring land for public and development purposes will decide upon the minimum requirement. RAJUK is the principal single land acquisition and development agency, but the private sector, overall, undertakes most development.

However, the legislation does have drawbacks. The Background Report to the Metropolitan Development Plan Preparation and Management, Dhaka and Chittagong, notes that difficulties arise from :

- high prices, most land that is developable on the urban fringe is privately held. Unless it can be serviced and released at the rate needed for urban growth, its shortage will fuel a continuing rise in land prices. However, as public authorities fail to recover services cost from beneficiaries, they lack the resources to services lent at the rate needed.

- the legal registration system, involving two ministries, the Ministry of Lands and the Ministry of Works, also hinders the efficient and speedy operation of the land market.

- lengthy land acquisition procedures further reduce the capacity to service land at the required rate.

- public sector landowners also contribute to land scarcity / high prices by failing to service and develop land. Public sector agencies hold about half the buildable land in Dhaka. Much remains vacant or under used.

The 1989 Property Emergency Acquisition Act provides for emergency acquisition to control inundation and prevent river erosion. Its duration is restricted to five years, but has so far only been applied in connection with the Jamuna Bridge Construction Project and the existing Dhaka Embankment. The Act attempts to speed up the acquisition process.

(3) For Cost Recovery :

The Betterment Fee Act (1952) allows the government to levy betterment if land value is enhanced as a result of any Government improvement scheme, fixed at one -half the increase in land value.

DMAIUDP notes serious inconsistencies and drawbacks in the legislation :

- it takes no account of increases in value unrelated to the Government improvement,
- it can levy betterment fees for works executed before 1953,
- procedure for determining market value is not laid down,
- there is no guidance for determining the extent of the area within which land values enhanced.

The Town Improvement Act 1953 contains the power to impose a betterment fee on DIT (RAJUK), though the legislation differs in some respect from the Act. The betterment laws have not, in the past, been enforced in Bangladesh.

The Wealth Tax Act of 1963 could (according to DMAIUDP) be used to realize a portion of windfall gains, but is not designed for such purpose and has been ineffective.

The East Pakistan Finance Act 1966 allows a capital gains tax to be collected on profits or gains arising from sale, transfer, or exchange of property. Capital gains are now treated as income, liable to tax. The 1976 Finance Ordinance attempted to reduce evasion by requiring tax authority approval prior to the issue of any document transferring any property valued over Tk. 20,000. As tax on capital gains is collected with income tax, it is not possible to discover how much of the increase in land value is recouped by the method.

The Gift Tax Act 1963 and The Estate Duty Act 1958 also attempt to recoup the unearned increment in land values. DMAIUDP concluded that this goal is unlikely to be achieved by this legislation, with reorganized tax administration and removal of loophole.

It is difficult to see any effective recovery of costs of infrastructure investment/land development by an agency such as RAJUK under the existing legislation as now applied. Without this, effective action to cater for anticipated rapid growth is not possible, in any sector. Indeed, continuing failure to recoup costs, in this urbanization context, means that conditions in the capital will get worse rather than better, as the amount of land and the major infrastructure required cannot be provided in a sensible fashion.

Everyone in the feasibility study area would benefit from flood protection and drainage improvement measures, Everyone should in principle contribute towards the cost. A tax based on the increase in safety and land values (as suggested in the ADB Aid-memorie) would be an equitable measure. It shall reflect the disproportionate benefits that flood protection will bring to some owners (in allowing conversion from rural to urban) as well as the overall increase in land values as a result of flood protection.

4.2.4 Land Improvement Issues :

While this study is chiefly concerned with flood mitigation, certain issues regarding general land improvement guidelines, the determination of responsible authorities etc., needs to be discussed.

Issues which will affect flood mitigation schemes just as they do any other urban development activities are ;

- Legal, administrative and institutional frameworks which apply to urban development in general,
- The institutional structures of the government and a definition of their responsibility,
- Control of land use and land price by zoning,
- Development of land readjustment mechanisms, and
- Betterment taxes based on increase in land value.

There are some specific issues with regard to the flood mitigation project, especially control of huge areas required for retarding areas. They are ;

- The control by speedy zoning by which the existing land use may be frozen.

- Multiple or productive uses of the retarding areas.

- Private or any developers should provide their own retarding areas (approximately 12% of their land to be developed) in each of their housing projects.

- Preparation of zoning master plan for the feasibility area especially newly developing areas should be made by RAJUK incorporating flood protection needs.

4.2.5 Prospects for Improvements

A number of plans and proposals are underway to bring about more efficient land management and cost recovery. They include :

- Proposed Metropolitan Development Plan Study, which will prepare a detailed project plan / structure plan / master plan (incorporating flood protection needs),

- The Southern part of Greater Dhaka East and the DND area would be identified as areas where detailed plans will be given priority,

- FAP 15, "the land acquisition and resettlement study", will identify improvements in acquisition and resettlement procedures within areas under various flood action programmes.

- In connection with FAP 8B, ADB will provide technical assistance in the field of building and land development standards, cost recovery methods and Government land use.

These studies and proposals will examine and make subsequent recommendations with regard to the present inadequacies of current plans and mechanisms in a comprehensive manner. Until comprehensive measures are enacted, existing methods must be used more efficiently.

4.3 Development Control and Multiple Use of Retarding Ponds

4.3.1 Development Control Measures

Development control is required during execution and subsequent management of the flood protection project.

Development control is categorized into the followings :

- On and around flood prevention structures
- Regulation for site development

1) On and Around Flood Prevention Structures

(1) Drainage channel

It is logical to assume that the development pressures will eventually lead to encroachment of the drainage channels. Technically, some setback distance from the drainage channel boundary is required for management of the area.

Technically for the sake of management and maintenance of the drainage channel areas, there is a need to have service roads along them as follows :

- The drainage channels should have roads on both sides.

- Plantation may be provided at the edge of the drainage channels. This would help keep a green belt along the water bodies.

- Some form of fencing should be provided, defending the edge of the channel area (or channel). This would enable better control and discourage encroachment.

(2) Embankment

There will be a great number attracted to the embankment from adjacent slum and squatter areas. The embankment offers a rent-free, flood free opportunity, close to place of work, to those whose other choices are few.

It would clearly be impossible to remove people sheltering on the embankment immediately after flooding.

From a flood protection point of view, habitation on the embankment should be resisted. To some extent, the numbers may be minimized by speedier land acquisition and resettlement procedures. Clearly, unhindered rights of way for maintenance must be preserved. It is recommended that the Government introduce building controls to restrict development with some 50 meter beyond the edge of the right of way of the embankment so as to preserve a strip of land along the country side of the embankment to accommodate any future roadway and also other type of land uses.

(3) Retarding Area

The retarding area is indispensable for the proposed drainage improvement plan. However it is required mostly in the wet season. During the dry season, the water body will occupy only a small part of the proposed retarding area and open up a large dry area, which may be used for agriculture as ever. The land use of retarding area should be controlled. However it is logical to assume that the development preserves will lead to encroachment of the retarding area. In order to reserve the proposed retarding area, multiple use or productive use of it should be encouraged.

2) Regulation for Site Development

(1) Minimum Height for Development

In addition to control activities associated with suitable land uses, control of minimum land fill levels is needed to ensure flood protection. Development of low-lying areas should be in compatible with the proposed drainage plan.

(2) Required On-site Retarding Area

For RAJUK's approval, the private developers are requested to prepare the public land, which is around 30-40% of the development area. These areas have to be kept for non-housing uses such as commercial, educational, medical and open space. A certain portion of the development area should be allotted to provide their own water storage as on-site retarding ponds.

4.3.2 Multiple Use of Retarding Areas

There will be a total estimated 26 km^2 retarding area. The primary use is for the flood protection, however the compensation cost and legal complications coupled with management issues clearly suggest that there should be certain economic utility for the retarding area. Otherwise enforcement of such concept may not be possible. Maximum multiple usage should be encouraged.

1) Recreation

There is a popular demand for sports pitches. A total of 145 ha was considered to be available for public and semi-public recreation in the city, mostly in newer areas.

The study identified the reservation of large scale outdoor areas for day trips within easy traveling distance of the city as a major recreational requirement. This need is currently being (partly) met to the north of the city but a number of other potential locations were suggested. Within the metropolitan area also, some potential recreational locations were identified. None of these areas are located within the feasibility study areas.

DMAIUDP's underlying concept behind providing recreational space is to use the natural potential of the city environment to create a number of out door recreational spaces. An opportunity exists to use of the most suitable retarding ponds as recreational areas.

Not all the proposed retarding areas should be reserved for such use, and it is probably realistic to select some areas for recreational development.

Provision of the spaces for green, sports, fishing, boating, etc. will be possible at a part of the retarding area, especially in dry season.

The area on the south-eastern edge of the city is identified in DMAIUDP as "urgently requiring planned provision of public open spaces".

The southern compartment-2 and the DND seem to have high priority for recreational development in retarding areas.

2) Agriculture

In the long term, overall, as urban development proceeds, the effects of flood protection will be to reduce the area under agriculture use.

Due to the importance of agriculture on or near the metropolitan area, around 10% of the Greater Dhaka East and the DND feasibility study areas are zoned for agricultural use. In addition to that, it has been estimated in the Master Plan report that 70% of the retarding area would be cultivable for most of the year. Continuing agricultural activities should be encouraged.

3) Fishing ponds

Most flooded areas in Bangladesh are used for fishing. Self-contained ponds are usually fished in a managed fashion, while larger seasonal water bodies are fished in a less organized manner. Currently fish culture is practiced in a number of ponds in Khilgaon and in the DND canal. Less organized fishing takes place in the khal and ponds within the seasonally inundated areas.

Ponds may be leased to entrepreneurs or groups of fishermen by government. If the government leased or purchased land for retarding areas, the original owners could practice fish farming, with advice from the Ministry of Fisheries. Management would need to stock the ponds annually with large fingerlings produced by local hatcheries, as carp needs to reproduce in spawning grounds away from ponds.

At present, the capacity of hatcheries and nurseries in the Dhaka area may be insufficient to produce fingerlings for these areas of fish ponds.

A possible danger would derive from pollution as the city continued to grow. Large inflows of domestic sewerage would consume large amounts of oxygen, resulting in DO levels too low for good yields. Water quality management would thus be crucial. There could be dangers of chemical pollutants due to illegal discharges from industrial areas and from run-off of agrochemical.

For the considerable potential of fish farming in retarding areas, it is recommended that further study be carried out into :

- possible variety of fish and estimates of yield and markets for different types;
- costs and returns ;
- preferred institutional arrangements for managing ponds and nature of advising assistance required ;
- risk from agricultural and industrial effluents;
- prerequisites for further fish culture schemes in the area, in the form of nursery and hatchery requirements.

The importance of maintaining fish production may be gauged from the fact that 70% - 80% of animal protein supplies in Bangladesh is obtained from fish. Fish is also the cheapest form of such animal protein. While the construction of the embankment will likely affect the present pattern of fishing, it does also offer an opportunity for higher yields from culture fishery (aquaculture) or fish farming.

4) Oxidation ponds for sewage treatment

As the existing oxidation pond in Pagla has been provided for purification of sewage water from part of the Old Dhaka area, development of new oxidation ponds serving the other part of urban area and the new urban development area in low land zone would be one of the options for the future sewage treatment in the metropolitan area.

The proposed retarding areas would be potential location to facilitate those oxidation ponds. It is assumed that if all the generated sewage would be treated by new oxidation ponds in the whole feasibility study area, some 1000 ha of such oxidation ponds area is required.

And it is noticed that a multiple use , such as oxidation pond cum fishing pond or oxidation pond cum irrigation, of retarding area is more realistic.

Further investigation on the above options for the multiple use of the retarding area, are strongly recommended.

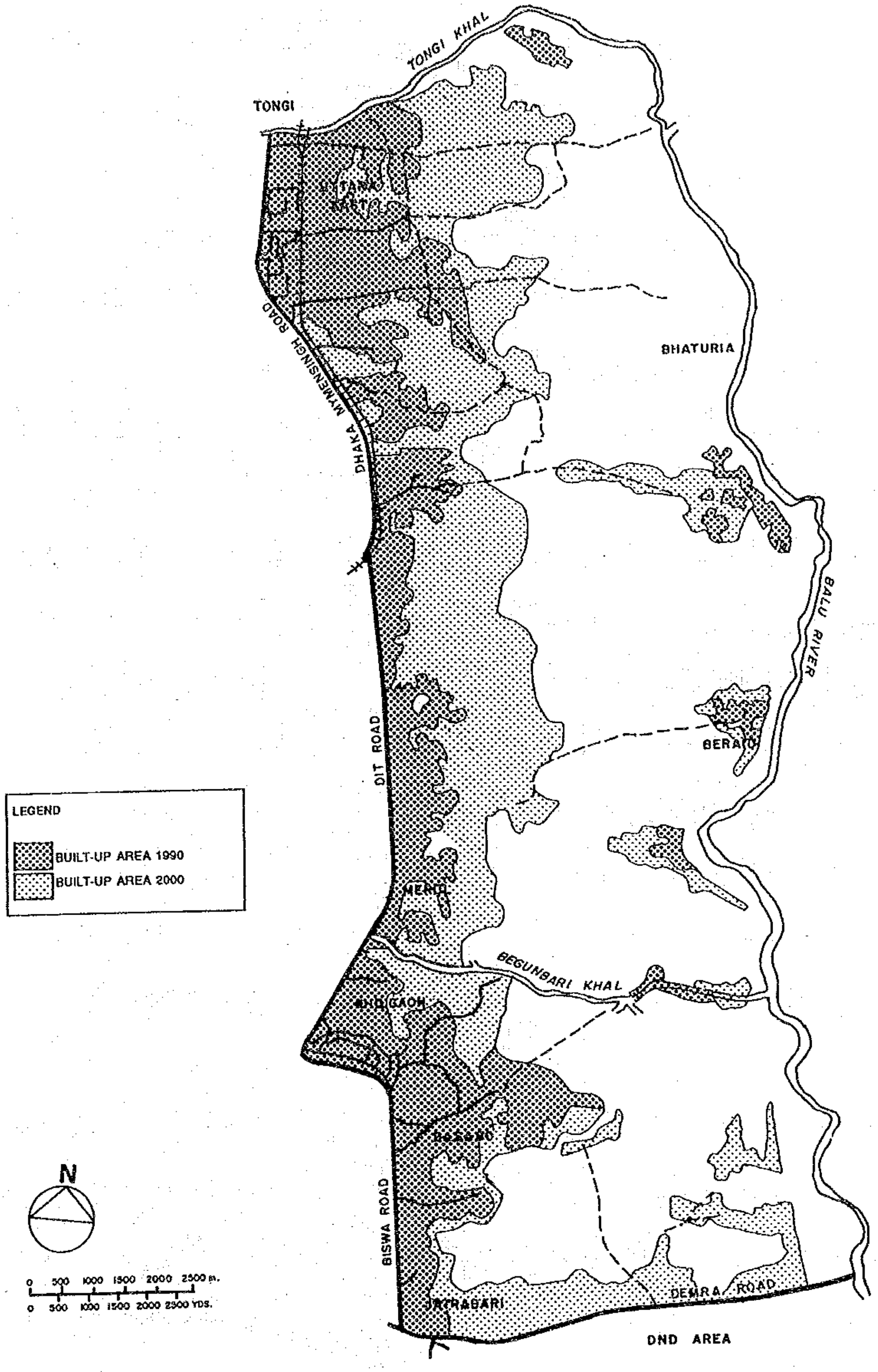


FIG. 4.1 BUILT-UP AREA 1990/2000 : GREATER DHAKA EAST

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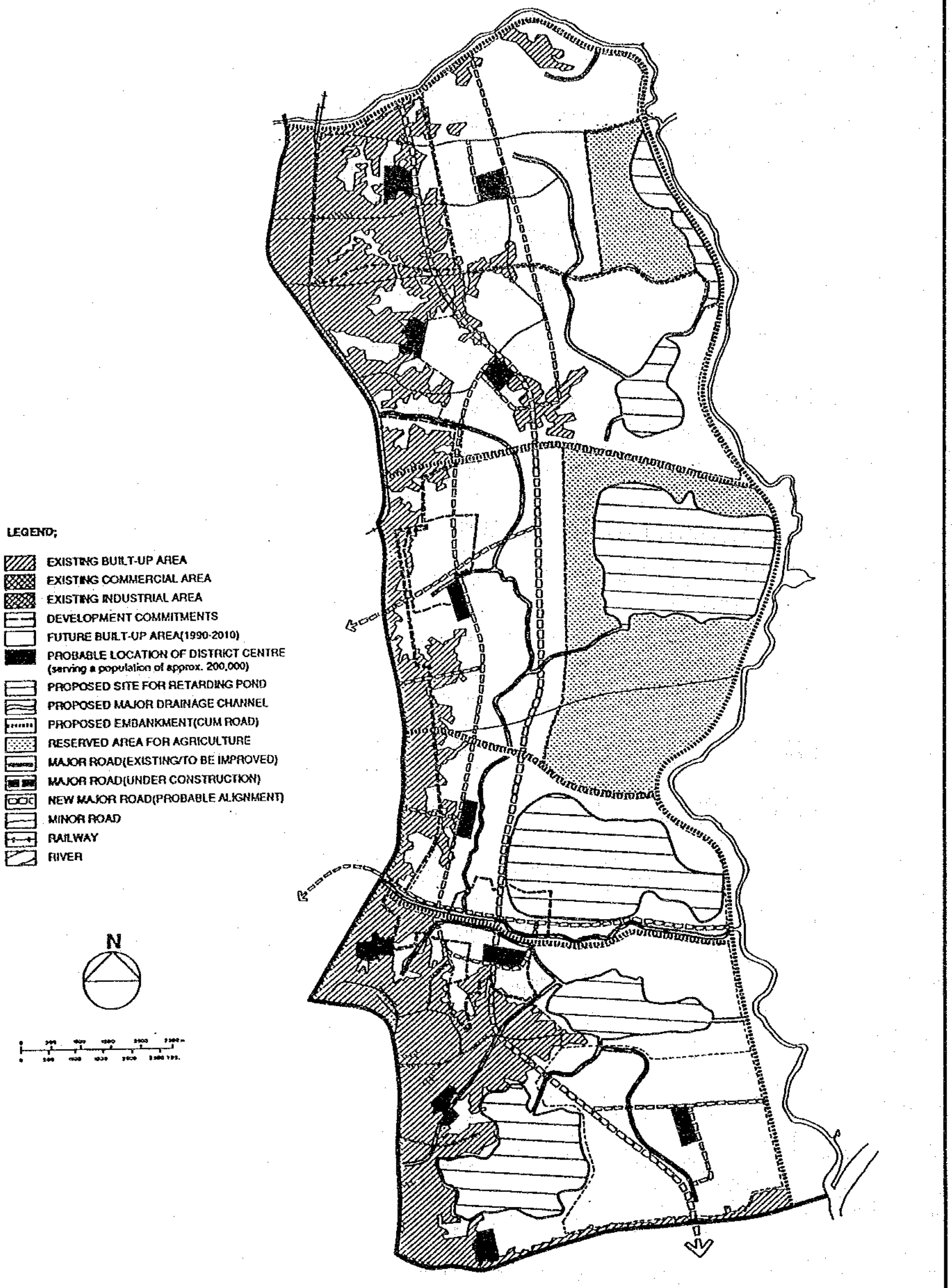

FIG. 4.2 INDICATIVE LAND USE MAP, 2010 : GREATER DHAKA EAST

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

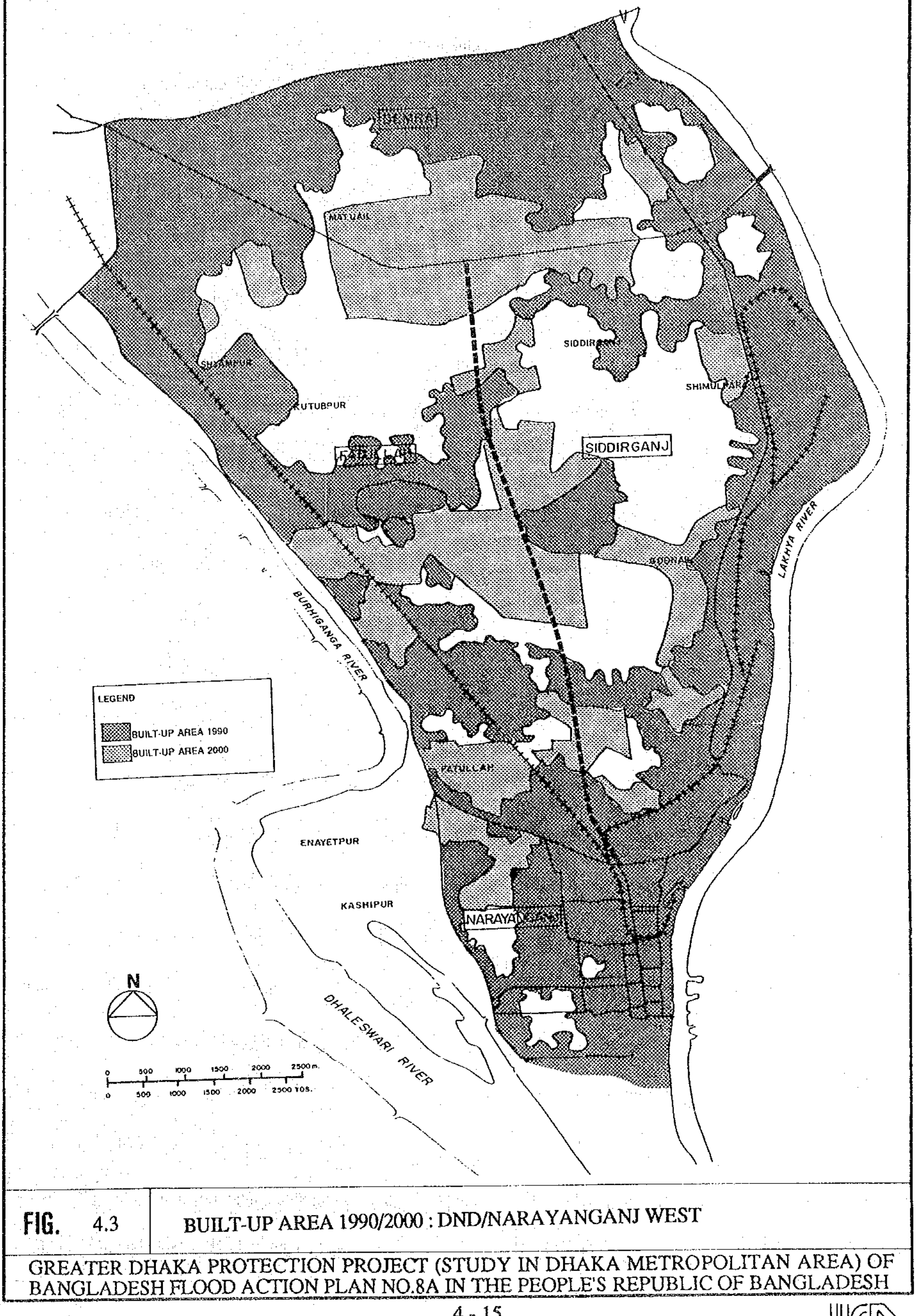

FIG. 4.3 BUILT-UP AREA 1990/2000 : DND/NARAYANGANJ WEST

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

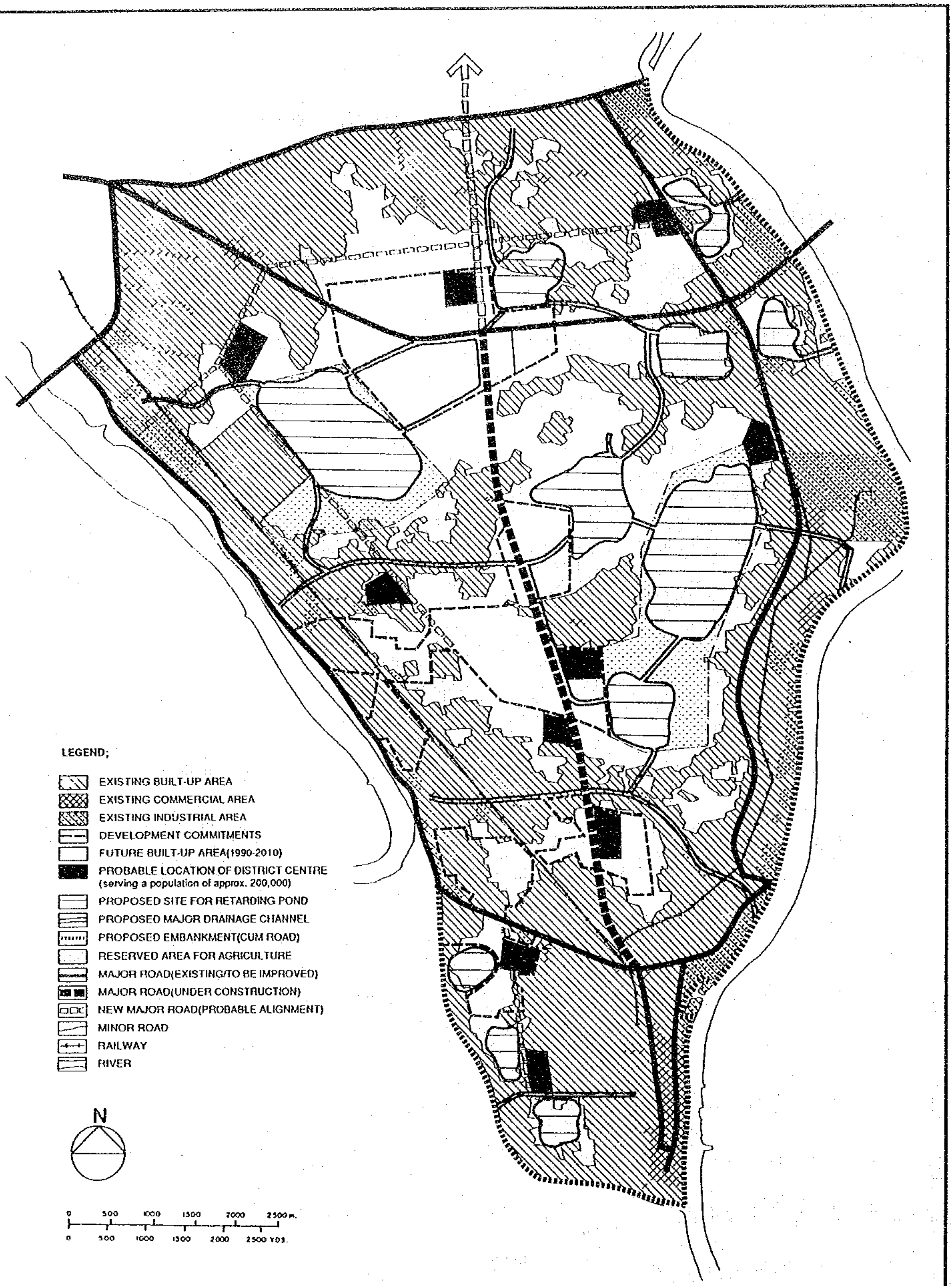

FIG. 4.4 INDICATIVE LANDUSE MAP OF NARAYANGANJ DND/WEST, 2010

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

CHAPTER 5
FLOOD DAMAGE ANALYSIS

Chapter 5 : Flood Damage Analysis

5.1 Flood Condition

5.1.1 General

During the Phase I (Preliminary Review Stage) and the Phase II (A Master Plan Study Stage), a questionnaire survey on "external and internal floods" in the study area of 850 km^2 was carried out. The survey on external floods was executed on the last three floods of the 1987 flood, the 1988 flood and the 1990 flood. The 1990 flood was considered as an "annual flood". The survey on internal floods was done on the annual flood and the worst one.

For this feasibility study stage, supplementary flood surveys on flood depth, duration and flood damages have been carried out for the F/S area including a related area of Dhaka City, which belongs to the drainage area of the Balu River.

Both the maximum depth of flooding and its duration relates to the damage to houses, assets and crops. Specifically, duration of inundation is an important factor affecting the degree of damage and inconvenience caused.

The supplementary surveys consist of the followings :

(1) Review of the flood depth and duration survey data in the Master Plan Study according to the land use of each administrative unit, and

(2) Collection of supplementary data and information on flood damages to public utilities and traffic, from RHD, DCC, Bangladesh Railways, Power Development Board, etc.

Concerning the internal flood conditions of zones No. 1 to 53 in the Dhaka Sub-Area, the survey results of the 1987 JICA Study were referred to.

5.1.2 Greater Dhaka East

The survey area covers the Greater Dhaka East (118.62 km^2) and a part of the Greater Dhaka West (47.74 km^2), mostly built-up, which drains off eastwards to the Balu River. The survey area consists of 39 zones based on the administrative division of wards and unions, and shown in Fig.5.1.

1) External Flood

(1) Annual Flood

The total flood area by the annual external flood was estimated at 7,850 ha, 47% of the survey area. No flooding in the built-up area. Most of the agricultural area in Greater Dhaka East is submerged during the flood season, and there are rural villages or settlements likely to be isolated, but still flood free because their house lots are built a little higher than the annual flood stage.

There are only limited cases of flooding by the annual flood. However, it does not mean that the study area is free from the annual flood. The flood depth and duration were surveyed only for houses and assets, which are mostly located on high plots that are safe from annual external floods. The annual flood area is shown in Fig. 5.3.

(2) 1987 Flood

The flood area by the 1987 flood is estimated at 10,716 ha, 64% of the survey area. Within the flood area, the built-up area is estimated at 1,121 ha, 17% of the total built-up area.

During the 1987 flood, the maximum flood depth and duration in the survey area were 0.91m and 22 days respectively, and the average depth and duration were 0.27 m and 7.47 days respectively. Fig. 5.4 shows the flood depth and the flood duration at houses and the flood depth around settlements. Flooded depth around settlement areas were from 0.4 m to 4.0m.

(3) 1988 Flood

The 1988 flood was the most severe to hit the study area. The flood areas were estimated at 13,173 ha, 79% of the survey area. The built-up area of 3,285 ha, 49% of the total built-up area was affected. The maximum flood depth and duration in the survey area were 2.13 m and 65 days respectively. The average flood depth and duration were estimated at 0.72 m depth and 19.66 days respectively.

Fig. 5.5 shows flood depth and duration by the 1988 flood. The flooded depth around rural settlements was estimated from 0.3 m to 4.6 m.

(4) Land use and Flood Area

The relationships between the flood areas and the land use are developed for 1990 and 2010 and shown in Fig. 5.6.

2) Internal Flood

(1) Annual Flood

The internal flood area is estimated at 417 ha, 3% of the survey area. The internal flood area is mostly in the highly built-up areas.

The maximum flood depth and duration are 0.61 m depth and 4 days respectively. Also, the average flood depth and duration are 0.37 m depth and 0.44 days respectively.

(2) Worst Flood

The internal flood areas by the worst flood are estimated at 417 ha, 3% of the survey area.

Fig. 5.7 shows internal inundation areas which are mostly distributed in the highly built-up areas.

The maximum flood depth and duration in the worst internal flood are estimated at 0.91 m depth and 6.0 days, respectively. On the other hand, the average depth and duration of inundation are estimated at 0.54 m and 1.19 days, respectively (refer to Fig. 5.8).

5.1.3 DND and Narayanganj West

1) DND

The DND area is consisting of 14 zones based on administrative divisions of wards and unions which are shown in Fig.5.2.

(1) External Flood

The DND area is mostly free from floods due to the existing embankment. During the 1987 floods, the DND area was not affected. However during the 1988 floods, the DND area was marginally safe from flooding principally due to the timely flood fighting measures such as raising the embankment by sand bags. In fact the flood stage exceeded partly the top of embankment.

(2) Internal Flood

The annual internal flood area is estimated at 410 ha, 7% of the DND area. The maximum flood depth and duration of inundation are 0.15 m depth and 2.0 days, respectively. Also, the average flood depth and duration are 0.13 m and 2.0 days, respectively.

The worst internal flood area is estimated at 410 ha, 7% of the DND area. The maximum depth and duration of inundation by the worst flood were estimated at 0.76 m depth and 7.0 days, respectively. On the other hand, the average flood depth and duration are estimated at 0.28 m and 2.74 days respectively.

2) Narayanganj West

The study area is consisting of 14 zones based on administrative divisions of wards and unions which are shown in Fig.5.2.

(1) External Flood

The total flood area in the annual external flood is estimated at 111 ha, 6% of the Narayanganj West area, however no flooding in the built-up area.

There are only few cases of flooding due to the annual flood. However, it does not mean that the area is free from annual external flood. The flood depth and duration was surveyed on rural settlements, which are mostly located on high plots that are not affected by the annual floods.

The 1987 flood area is estimated at 606 ha, 33% of the Narayanganj West area. The built-up area affected by the flood is 379 ha, 29% of the total built-up area. The maximum flood depth and duration in the Narayanganj West area are estimated at 0.61 m depth and 15.0 days respectively, and the average depth and duration are 0.27 m and 8.11 days, respectively. Fig. 5.4 shows the flood depth and duration at houses of residence and the depth around settlements.

The 1988 flood areas are estimated at 1863 ha. The built-up area affected by the flood is 1312 ha, the whole of the built-up area. The maximum flood depth and duration are 1.63 m and 40.0 days respectively. The average flood depth and duration are estimated at 0.84 m depth and 21.69 days respectively. Fig. 5.5 shows the flood depth and duration. Flood depth around settlements is estimated from 0.8 m to 2.6 m.

(2) Internal Flood

The annual internal flood area is estimated at 87 ha, 5% of the Narayanganj West area. The internal flood areas are distributed mostly in the highly built-up areas. The maximum flood depth and duration are estimated at 0.12 m depth and 0.08 days respectively, and the average flood depth and duration are 0.12 m and 0.08 days respectively.

The worst internal flood area is estimated at 87 ha, 5% of the Narayanganj West areas. The internal inundation areas are located mostly in the highly built-up area. The maximum depth and duration in the worst internal flood are estimated at 0.82 m depth and 2 days, respectively. On the other hand, the average flood depth and duration are estimated at 0.28 m depth and 0.79 days, respectively.

5.2 Flood Damages

Flood damages are calculated for each of the annual, the 1987 and the 1988 external and internal floods. Flood damages take the form of direct damages to houses, shops, industries and institutions, income/profit losses for households, shops and factories, traffic damages, direct damages to infrastructures and profit losses for public enterprises. As a specific example the calculative steps leading to the estimation of the direct damages and income losses to houses by a 1987 - scale flood in Greater Dhaka East are explained in Annex 1 of Supporting Report B.

Direct damages to houses, shops, industries and institutions as well as income / profit losses for households, shops and factories are estimated based on the area, depth and duration of inundation and the unit value and the number of the above-mentioned respective properties.

In estimating the internal flood damages, the results of the "Study on Storm Water Drainage System Improvement Project in Dhaka City" in 1987 were referred to and utilized.

Flood damages are estimated for both the years of 1990 and 2010. Flood damages for 2010 will be greater than those in 1990 because the unit value and number /quantity of properties, the volume of traffic and the quantity of infrastructures will be greater in

2010 than in 1990. Various kinds of flood damages are added together and ultimately they are converted into "average annual flood damages".

5.2.1 Estimated Property Damages and Losses

Direct damages to properties and income/profit losses of economic units were together broadly classified as residential, commercial, industrial, institutional and agricultural damages.

Residential damages consist of damages to buildings, damages to household effects and income losses. Commercial and industrial damages consist of damages to buildings, damages to equipment & inventories and profit losses. Institutional and agricultural damages mean, respectively, damages to buildings and agricultural crops.

(1) Year 1990

There were no annual external flood damages in 1990 in the Study Area. Supposing the 1987-scale flood had hit the Greater Dhaka East area in 1990, damages and losses amounting to Tk. 493.0 million would have been incurred, of which 54.8% and 45.0% would have been accounted for by residential and agricultural damages, respectively. Most of residential damages would have been witnessed in the two southern compartments and agricultural damages around all over the area.

The 1987-scale flood would in 1990 have inflicted damages in the Narayanganj DND area amounting to Tk. 142.9 million, of which 82.0% and 17.7% would have been accounted for by residential and agricultural damages, respectively. Likewise, the same flood would have inflicted damages in the Narayanganj West area amounting to Tk. 75.5 million, of which 82.6% and 17.0% would have been accounted for by residential and agricultural damages, respectively.

Supposing the 1988-scale flood had hit the Greater Dhaka East area in 1990, damages and losses amounting to Tk. 3,086.0 million would have been incurred. Out of them, 76.9%, 14.4% and 8.7% would have been accounted for by residential, commercial / industrial / institutional and agricultural damages, respectively. The same flood would have inflicted damages in the DND area amounting to Tk. 1,864.1 million, of which 72.0%, 23.3% and 4.7% would have been accounted for by residential, commercial / industrial / institutional and agricultural damages, respectively. Similarly, the same flood would have inflicted damages in the Narayanganj West area amounting to Tk.

1,310.8 million, of which 77.5%, 20.9% and 1.6% would have been accounted for by residential, commercial / industrial / institutional and agricultural damages, respectively.

The annual internal flood in 1990 brought on the damages to house buildings and household articles in the Greater Dhaka East area amounting to Tk. 121.0 million. Most of the damages were witnessed in the two southern compartments. The same flood brought on the damages to houses amounting to Tk. 27.3 million and Tk. 0.8 million in the Narayanganj DND and West areas, respectively.

The worst internal flood in 1990 would have brought on the damages to house buildings and household articles in the Greater Dhaka East area amounting to Tk. 257.3 million. The same flood would have brought on the damages to houses amounting to Tk. 43.4 million and Tk. 9.9 million in the DND and the Narayanganj West areas, respectively.

(2) Year 2010

Supposing the annual external flood hit the Greater Dhaka East area in 2010, damages and losses amounting to Tk. 157.6 million would be suffered, most of which would be in the form of income losses of households. The same flood would cause damages amounting to Tk. 7.1 million and Tk. 6.1 million in the Narayanganj DND and West areas, respectively.

If the 1987-scale flood hit the Greater Dhaka East area in 2010, damages and losses amounting to Tk. 2,884.6 million would be suffered, of which 99.2% would be borne by the residential sector. The same flood would cause damages amounting to Tk. 518.8 million and Tk. 229.4 million in the DND and the Narayanganj West areas, respectively. Most of them would be borne by the residential sector.

If the 1988-scale flood hit the Greater Dhaka East area in 2010, damages and losses amounting to Tk. 12,995.7 million would be suffered, of which 88.2%, 11.6% and 0.2% would be borne by the residential, commercial / industrial / institutional and agricultural sectors, respectively.

The 1988-scale flood would in 2010 cause damages in the DND area amounting to Tk. 8,530.8 million, of which 74.3% and 25.6% would be borne by the residential and commercial / industrial / institutional sectors, respectively. The same flood would cause damages in the Narayanganj West area amounting to Tk. 5,678.1 million, of which

63.7% and 36.3% would be borne by the residential and commercial / industrial / institutional sectors, respectively.

If the annual internal flood hit the Greater Dhaka East area in 2010, the damages to house buildings and household articles would amount to Tk. 185.9 million. The same flood would bring on the damages to houses amounting to Tk. 109.1 million and Tk. 2.0 million in the DND and the Narayanganj West areas, respectively.

If the worst internal flood experienced in 1986 hit the Greater Dhaka East area in 2010, the damages to house buildings and household articles would amount to Tk. 389.9 million. The same flood would bring on the damages to houses amounting to Tk. 171.0 million and Tk. 24.4 million in the DND and the Narayanganj West areas, respectively.

5.2.2 Estimated Traffic Damages

1) Impacts of Floods on Vehicle Traffic

Traffic survey was conducted to know the volume of vehicle traffic and major flood vulnerable points in the Greater Dhaka East and the Narayanganj West.

Traffic damage survey was conducted along with traffic survey to know about the average sales, oil cost, incremental time cost, etc., per vehicle by type of vehicles for each type/scale of floods. The number of samples was 30 for each type of vehicles. The survey was conducted mostly in the Greater Dhaka east and related areas.

During the 1988 floods, vehicles could not operate for 20.1 days on average and also they were forces to operate slowly for 38.9 days on average. Likewise, in the 1986 floods which was the worst internal flood, vehicles could not operate for 1.3 days on average and also they operated slowly for 12.9 days on average.

Operating distance per day per vehicle is on average 131.0 km in normal time, while it is 104.7 km in slow-operating flood time. Operating speed is on average 41.5 km per hour in normal time, while it is 30.7 km per hour in flood time.
It is to be noted that operating hours per day per vehicle on average increases from 3.16 hours in normal time to 3.41 hours in flood time, oil consumption per km per vehicle increases from 0.235 liter in normal time to 0.279 liter in flood time and sales per km per commercial vehicle increases from Tk. 11.5 in normal time to Tk. 12.1 in flood time.

2) Estimated Traffic Damages

(1) 1987-scale Flood

Supposing the 1987-scale flood had hit the Greater Dhaka East area in 1990, traffic damages amounting to Tk.86.5 million would have been incurred, most of which would have occurred in the two southern compartments. The same flood would have inflicted traffic damages in the DND and the Narayanganj West areas amounting to Tk. 22.0 million and Tk. 23.2 million, respectively.

Supposing the 1987-scale flood hit the Greater Dhaka East area in 2010, traffic damages amounting to Tk. 256.5 million would be incurred. The same flood would inflict traffic damages in the Narayanganj DND and West areas amounting to Tk. 102.2 million and Tk. 71.4 million, respectively.

(2) 1988-scale Flood

Supposing the 1988-scale flood had hit the Greater Dhaka East area in 1990, traffic damages amounting to Tk.187.3 million would have been incurred, most of which would have occurred in the two southern compartments. The same flood would have inflicted traffic damages in the Narayanganj DND and West areas amounting to Tk. 47.3 million and Tk. 50.5 million, respectively.

Supposing the 1988-scale flood hit the Greater Dhaka East area in 2010, traffic damages amounting to Tk. 551.1 million would be incurred. The same flood would inflict traffic damages in the Narayanganj DND and West areas amounting to Tk. 220.5 million and Tk. 155.1 million, respectively.

(3) Worst Internal Flood

Supposing the 1986-scale flood which is the worst internal flood had hit the Greater Dhaka East area in 1990, traffic damages amounting to Tk.36.5 million would have been incurred. The same flood would have inflicted traffic damages in the Narayanganj DND and West areas amounting to Tk. 10.1 million and Tk. 10.3 million, respectively.

Supposing the 1986-scale hit the Greater Dhaka East area in 2010, traffic damages amounting to Tk. 119.8 million would be incurred. The same flood would inflict traffic damages in the Narayanganj DND and West areas amounting to Tk. 47.0 million and Tk. 32.0 million, respectively.

5.2.3 Estimated Damages to Infrastructures and Profit Losses for Public Enterprises

1) Concept and Methodology

The JICA Study Team conducted interview surveys visiting the officials concerned in RHD, DCC, Dhaka District Council, NMC, Bangladesh Railways, Power Development Board, T&T, DWASA, NWASA, Titas Gas, CAA and other related agencies.

The study team wanted to gather information and data on the direct damages to infrastructures such as roads, bridges, railways, electricity supply facilities, telecommunication facilities, water supply facilities, sewerage facilities, gas supply facilities and the airport in each of the 5 types/scales of floods for each of the 3 areas. Also, the study team wanted to collect information and data on profit losses for public enterprises such as Bangladesh Railways, Power Development Board, T&T, DWASA, NWASA, Titas Gas and CAA.

The basic approach to the estimation of direct damages to infrastructures was the establishment of total quantity (length or number), construction cost per unit quantity and the ratio of repair cost to construction cost for each type of infrastructures. By combining these three factors direct damages to infrastructure will be arrived at.

The direct damages to infrastructures and profit losses for public enterprises for 2010 were forecast based on the projected number of properties such as houses, shops, factories and institutions.

2) Estimated Damages and Losses

(1) Direct Damages to Infrastructures

Direct damages to infrastructures in the Greater Dhaka East area was found to total Tk. 41.5 million in the annual external flood, Tk. 68.7 million in the 1987 flood, Tk. 458.1 million in the 1988 flood, Tk. 22.6 million in the annual internal flood and Tk. 58.1 million in the worst internal flood. Damages were concentrated in the two southern compartments.

Direct damages to infrastructures in the DND area totaled Tk. 1.4 million, Tk. 1.4 million, Tk. 22.4 million, Tk. 7.8 million, Tk. 10.3 million in the annual external, the 1987, the 1988, the annual internal and the worst internal floods, respectively.

Likewise, direct damages to infrastructures in the Narayanganj West area summed up to Tk. 5.5 million for the annual external flood, Tk. 17.5 million for the 1987 flood, Tk. 134.2 million for the 1988 flood, Tk. 19.1 million for the annual internal flood and Tk. 31.9 million for the worst internal flood.

Supposing the annual external flood hit the Greater Dhaka East area in 2010, direct damages to infrastructures amounting to Tk.133.7 million would be incurred. Likewise, the 1987-scale, the 1988-scale, the annual internal and the worst internal floods would inflict damages amounting to Tk. 221.1 million, Tk. 1,474.5 million, Tk. 72.9 million and Tk. 186.9 million, respectively. Damages will still predominate in the two southern compartments, but the growth of damages in the two northern compartments will be conspicuous.

Supposing the annual external flood hit the DND area in 2010, direct damages to infrastructures amounting to Tk.6.6 million would be incurred. Likewise, the 1987-scale, the 1988-scale, the annual internal and the worst internal floods would inflict damages amounting to Tk. 6.6 million, Tk. 106.0 million, Tk. 36.9 million and Tk. 48.8 million, respectively.

Supposing the annual external flood hit the Narayanganj West area in 2010, direct damages to infrastructures amounting to Tk.17.4 million would be incurred. Likewise, the 1987-scale, the 1988-scale, the annual internal and the worst internal floods would inflict damages amounting to Tk. 55.3 million, Tk. 422.8 million, Tk. 60.3 million and Tk. 100.7 million, respectively.

(2) Profit Losses for Public Enterprises

It was found out that profit losses for public enterprises are not marked compared to direct damages to infrastructures.

The 1987 and 1988 floods are estimated to have caused profit losses amounting to Tk. 6.2 million and Tk. 43.0 million respectively for public enterprises in the Greater Dhaka East area. Likewise, the two floods caused profit losses amounting Tk.1.1 million and Tk. 8.0 million respectively for public enterprises in the Narayanganj West area.

Supposing the annual external flood hit the Greater Dhaka East area in 2010, profit losses amounting to Tk. 1.5 million would be suffered by public enterprises. Likewise, the 1987-scale, 1988-scale, the annual internal and the worst internal floods would bring on profit losses amounting to Tk. 20.3 million, Tk. 138.6 million, Tk. 1.0