TABLE C.10: ESTIMATION OF FUTURE LAND FOR COMMUNITY FACILITIES(target for new area)

LEVEL	I	II	III	IV	IV total	III total
POPULATION	1,000	5,000	20,000	100,000	100,000	20,000
HOUSEHOLDS	164	820	3,279	16,393	16,393	3,279
FACILITIES	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
EDUCATION		nursery 0.65	secondary 1.62	college 3.24	24.3	4.2
		primary 0.65			12.9	2.6
HEALTH		dispensary 0.24	health centre 1.21	hospital 2.43	13.4	2.2
		maternity 0.24			4.9	1.0
ADMINISTRATION			branch office 0.40	adm. office 4.05	6.1	0.4
RECREATION	play lot 0.2	children's park 0.49	neighbour. park 1.21	district park 4.86	44.9	8.0
			sports stadium 0.73		3.6	0.7
			cinema 0.12		0.6	0.1
COMMUNITY	meeting rm 0.12	meeting hall 0.12	community hall 0.24		15.8	3.2
RELIGIOUS		religious 0.20		religious 2.02	6.1	0.8
URBAN SERVICE			post office 0.16		0.8	0.2
			tele. exchange 0.16		0.8	0.2
			police station 0.65		3.2	0.6
			bus/rail station 0.32		1.6	0.3
			public toilet 0.03		0.2	0.0
COMMERCIAL	shops 0.07	shopping street 0.49	supermarket 2.43	shopping centre 7.28	36.4	5.8
total	0.44	3.08	9.30	21.4	175.6	30.3

TABLE C.11: EXISTING POPULATION AND BUILT UP AREA IN 1990

		(*1) Total Area (ha)	(*2) Population (person)	(*3) B/U area (ha)	(*4) Built up Area Ratio	(*5) G. Density (p/ha)	(*6) N. Density (p/ha)
GREATER DHAKA	Urban	26,307	4,441,994	11,914	45%	169	373
	(Muni'ty)	10,917	3,916,033	7,741	71%	359	506
	Rural	1,220	30,639	291	24%	25	105
	Total	27,527	4,472,633	12,205	44%	162	366
NARAYANGANJ	Urban	8,821	1,049,610	4,232	48%	119	248
	(Muni'ty)	1,992	312,019	1,364	68%	157	229
	Rural	1,274	61,006	374	29%	48	163
	Total	10,095	1,110,616	4,607	46%	110	241
TONGI	Urban	2,430	138,196	1,032	42%	57	134
	(Muni'ty)	3,688	141,256	1,047	28%	38	135
	Rural	1,338	4,813	25	2%	4	193
	Total	3,768	143,009	1,057	28%	38	135
KERANIGANJ	Urban	2,427	220,878	735	30%	91	301
	Rural	14,608	220,910	1,493	10%	15	148
	Total	17,035	441,788	2,228	13%	26	198
SAVAR	Urban	5,652	131,496	2,058	36%	23	64
	Rural	14,403	215,598	1,828	13%	15	118
	S. Rural	4,263	19,176	289	7%	4	66
	Total	24,318	366,270	4,176	17%	15	88
TOTAL	Urban	45,637	5,982,174	19,971	44%	131	300
	(Muni'ty)	16,597	4,369,308	10,152	61%	263	430
	Rural	37,105	552,142	4,301	12%	15	128
	Total	82,742	6,534,316	24,273	29%	79	269

Notes; (*3) includes residential, commercial, industrial, institutional, road and other urban use, and village

(*4)=(*3)/(*1), (*5)=(*2)/(*1), (*6)=(*2)/(*3)

Source; JICA

TABLE C.12: FUTURE POPULATION AND BUILT UP AREA IN 2010

		(*1) Total Area (ha)	(*2) Population (person)	(*3) B/U area (ha)	(*4) Built up Area Ratio	(*5) G. Density (p/ha)	(*6) N. Density (p/ha)
GREATER DHAKA	Urban	26,307	8,587,236	21,046	80%	326	408
	Rural	1,220	1,673	483	40%	1	3
	Total	27,527	8,588,909	21,529	78%	312	399
NARAYANGANJ	Urban	8,821	2,506,773	7,138	81%	284	351
	Rural	1,274	51,663	410	32%	41	126
	Total	10,095	2,558,436	7,548	75%	253	339
TONGI	Urban	2,430	652,914	1,944	80%	269	336
	Rural	1,338	5,817	189	14%	4	31
	Total	3,768	658,731	2,133	57%	175	309
KERANIGANJ	Urban	2,427	457,252	2,000	82%	188	229
	Rural	14,608	355,939	1,812	12%	24	196
	Total	17,035	813,191	3,812	22%	48	213
SAVAR	Urban	5,652	410,268	4,503	80%	73	91
	Rural	14,403	367,131	2,551	18%	25	144
	Rural Sp	4,263	34,481	458	11%	8	75
	Total	24,318	811,880	7,511	31%	33	108
TOTAL	Urban	45,637	12,614,443	36,631	80%	276	344
	Rural	37,105	816,704	5,902	16%	22	138
	Total	82,742	13,431,147	42,533	51%	162	316
*Flood Management Area		32,842	782,223	5,444	17%	24	144

Notes; (*3) includes residential, commercial, industrial, institutional, road and other urban use, and village
(*4)=(*3)/(*1), (*5)=(*2)/(*1), (*6)=(*2)/(*3)
Source; JICA

TABLE C.13 EXISTING LAND USE OF THE FUTURE URBAN AREA IN 1990

	Res'tial	Com'cial	Industry	Institution	Others	Road	Village	Agr'ture	Water	Total
GREATER DHAKA										
Area(ha)	5,892	466	344	1,123	1,610	1,744	735	11,181	3,212	26,307
Ratio	22%	2%	1%	4%	6%	7%	3%	43%	12%	100%
NARAYANGANJ										
Area(ha)	1,463	120	357	105	240	423	1,525	4,080	508	8,821
Ratio	17%	1%	4%	1%	3%	5%	17%	46%	6%	100%
TONGI										
Area(ha)	273	55	304	22	27	83	267	1,348	50	2,430
Ratio	11%	2%	12%	1%	1%	3%	11%	55%	2%	100%
KERANIGANJ										
Area(ha)	243	4	21	1	130	42	295	1,466	226	2,427
Ratio	10%	0%	1%	0%	5%	2%	12%	60%	9%	100%
SAVAR										
Area(ha)	294	37	69	784	518	98	258	3,301	292	5,652
Ratio	5%	1%	1%	14%	9%	2%	5%	58%	5%	100%
TOTAL										
Area(ha)	8,166	681	1,095	2,035	2,524	2,391	3,079	21,377	4,289	45,637
Ratio	18%	1%	2%	4%	6%	5%	7%	47%	9%	100%

Notes; Other Urban in the table includes graveyard, urban openspace, cantonment and Road includes major road, airport, railway satation etc.
Source; JICA

TABLE C.14 FUTURE LAND USE OF THE FUTURE URBAN AREA IN 2010

	Resi'tial	Com'cial	Industry	Ins'tion	Other U	Road	Village	Agri'ture	Water	Total
GREATER DHAKA										
Area (ha)	11,116	879	444	3,685	2,253	2,662	8	1,912	3,349	26,307
Ratio	42%	3%	2%	14%	9%	10%	0%	7%	13%	100%
NARAYANGANJ										
Area (ha)	3,332	293	833	1,349	599	732	0	565	1,118	8,821
Ratio	38%	3%	9%	15%	7%	8%	0%	6%	13%	100%
TONGI										
Area (ha)	822	60	471	321	69	203	0	200	286	2,430
Ratio	34%	2%	19%	13%	3%	8%	0%	8%	12%	100%
KERANIGANJ										
Area (ha)	784	84	231	409	251	213	28	86	342	2,427
Ratio	32%	3%	10%	17%	10%	9%	1%	4%	14%	100%
SAVAR										
Area (ha)	1,748	184	151	1,086	736	389	209	974	176	5,652
Ratio	31%	3%	3%	19%	13%	7%	4%	17%	3%	100%
TOTAL										
Area (ha)	17,801	1,500	2,129	6,849	3,907	4,198	245	3,736	5,270	45,637
Ratio	39%	3%	5%	15%	9%	9%	1%	8%	12%	100%

Notes; Other Urban in the table includes graveyard, urban openspace, cantonment and Road includes major road, airport, railway satation etc.
Source; JICA

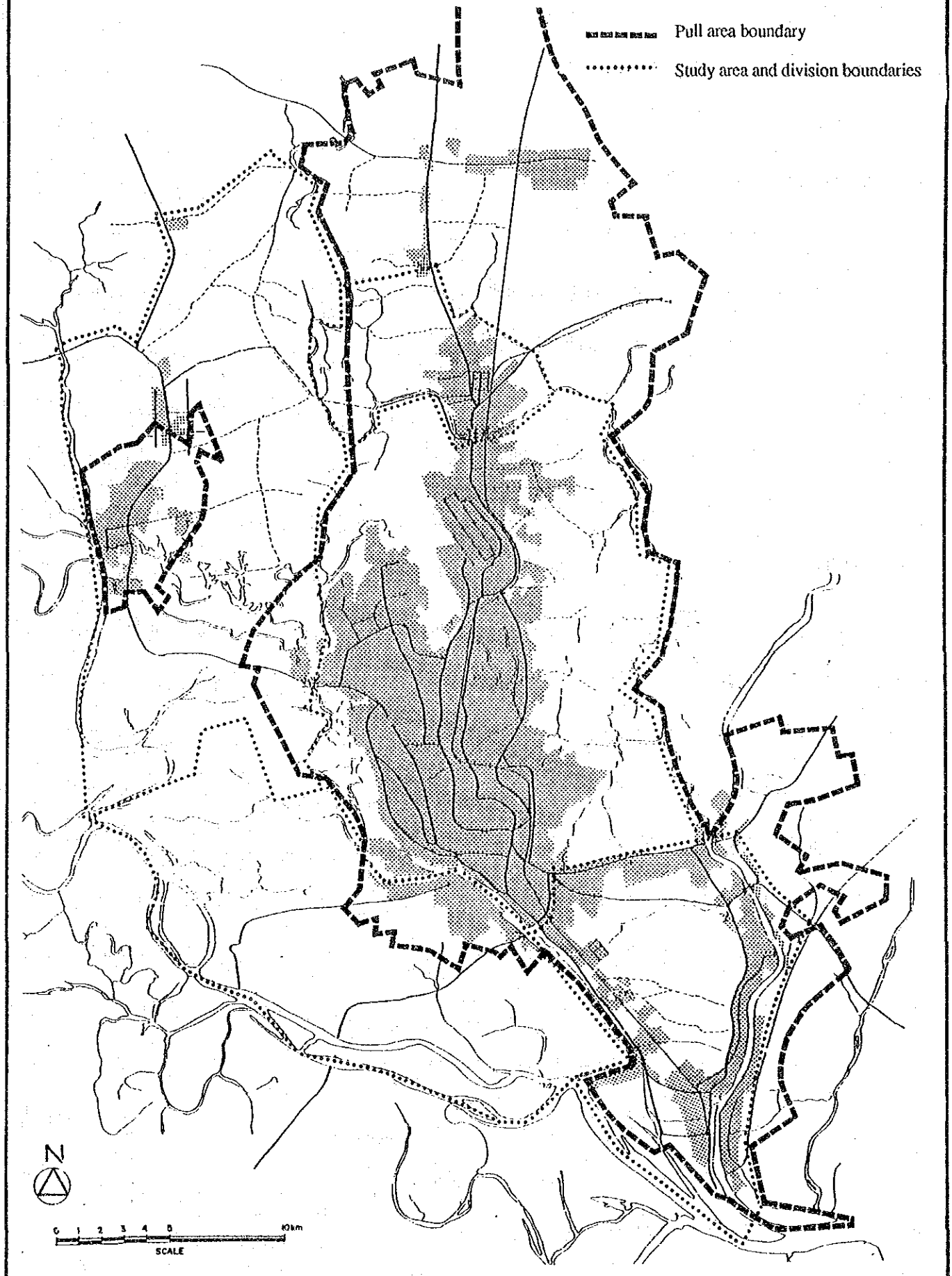

FIG. C.1 PULL AREA STUDY AREA AND DIVISION BOUNDARIES

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

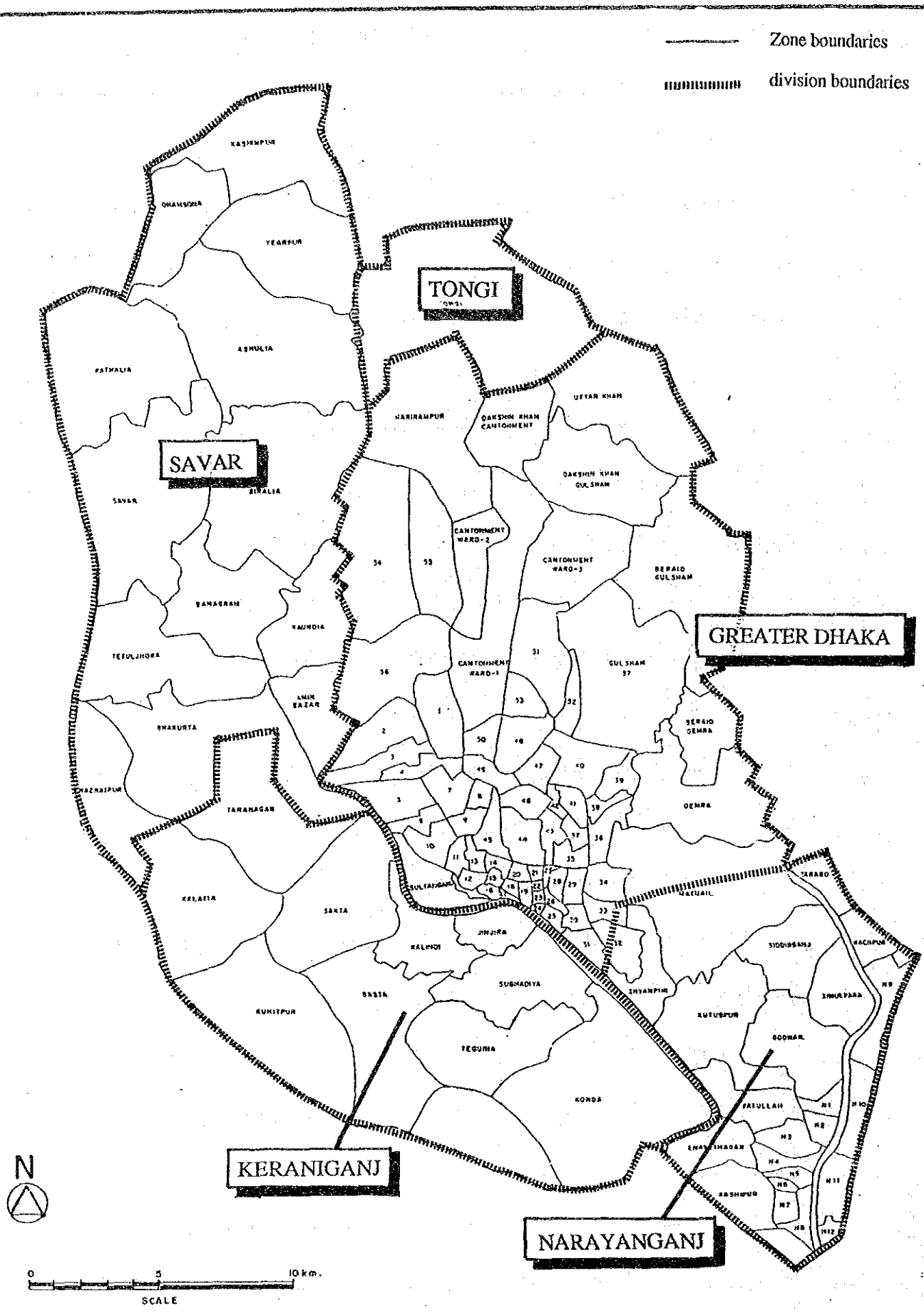

FIG. C.2 ZONES AND DISTRICT BOUNDARIES

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

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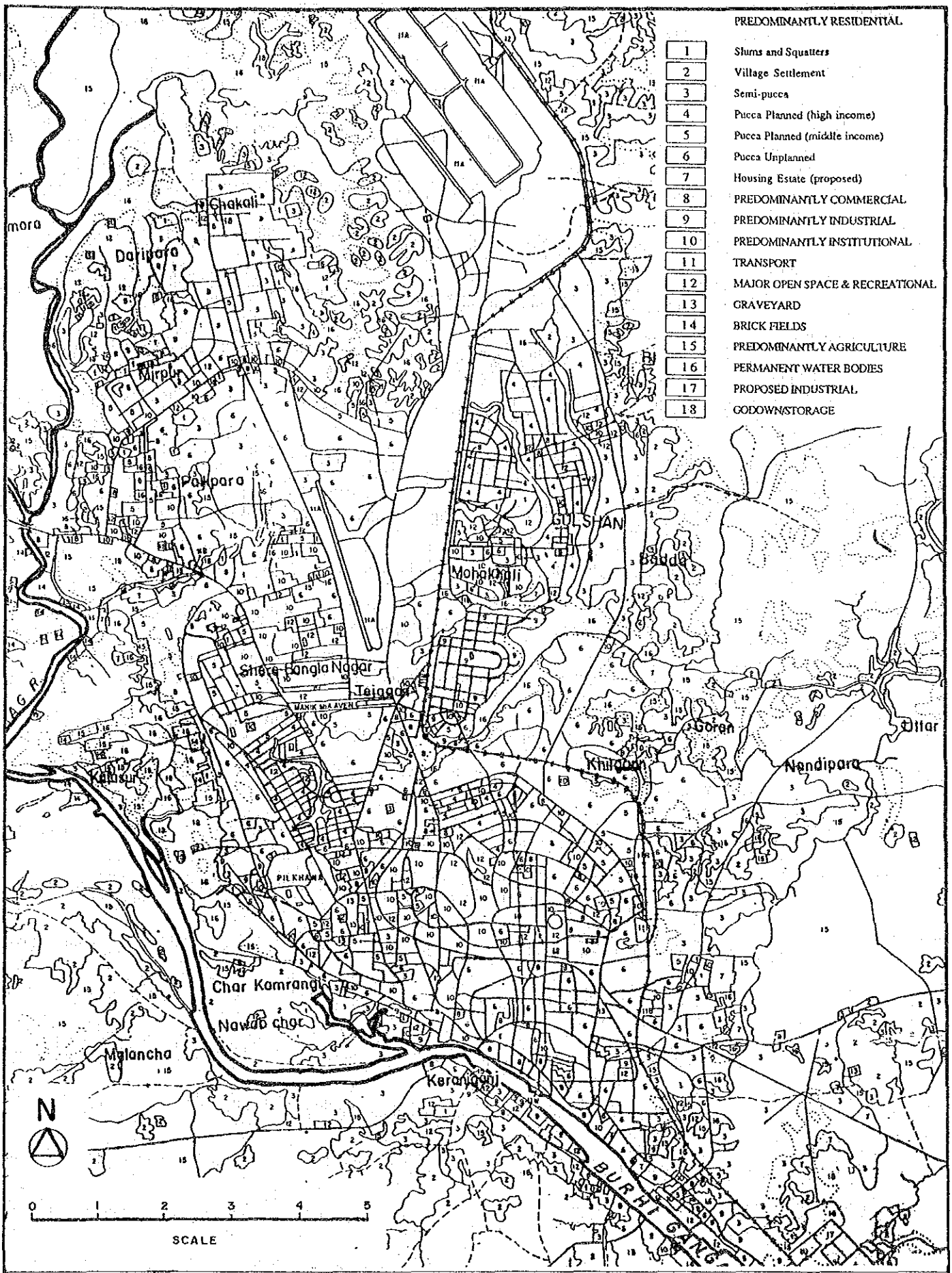

FIG. C.3A EXISTING LAND USE : GREATER DHAKA

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

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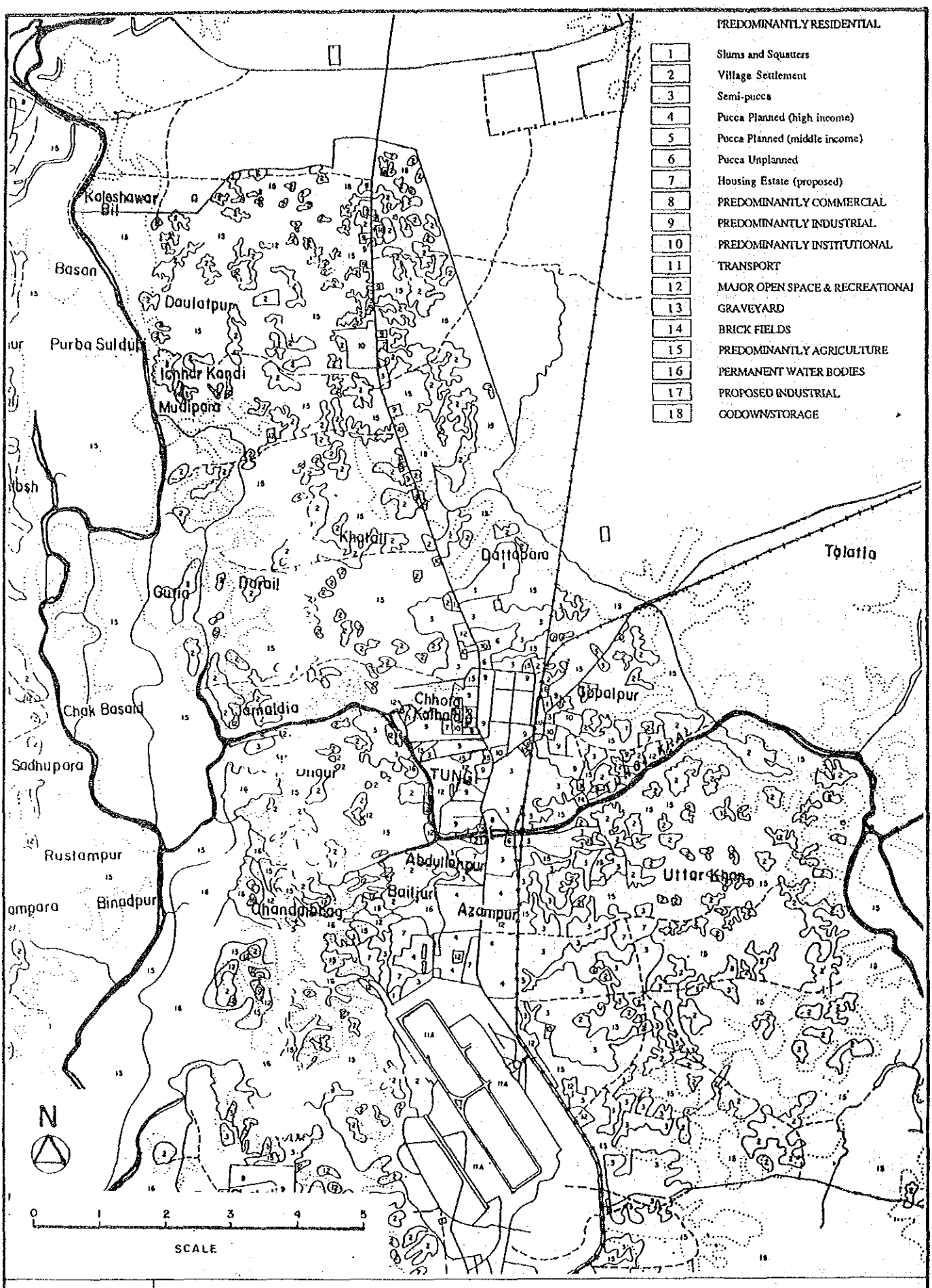

FIG. C.3B EXISTING LAND USE : TONGI

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

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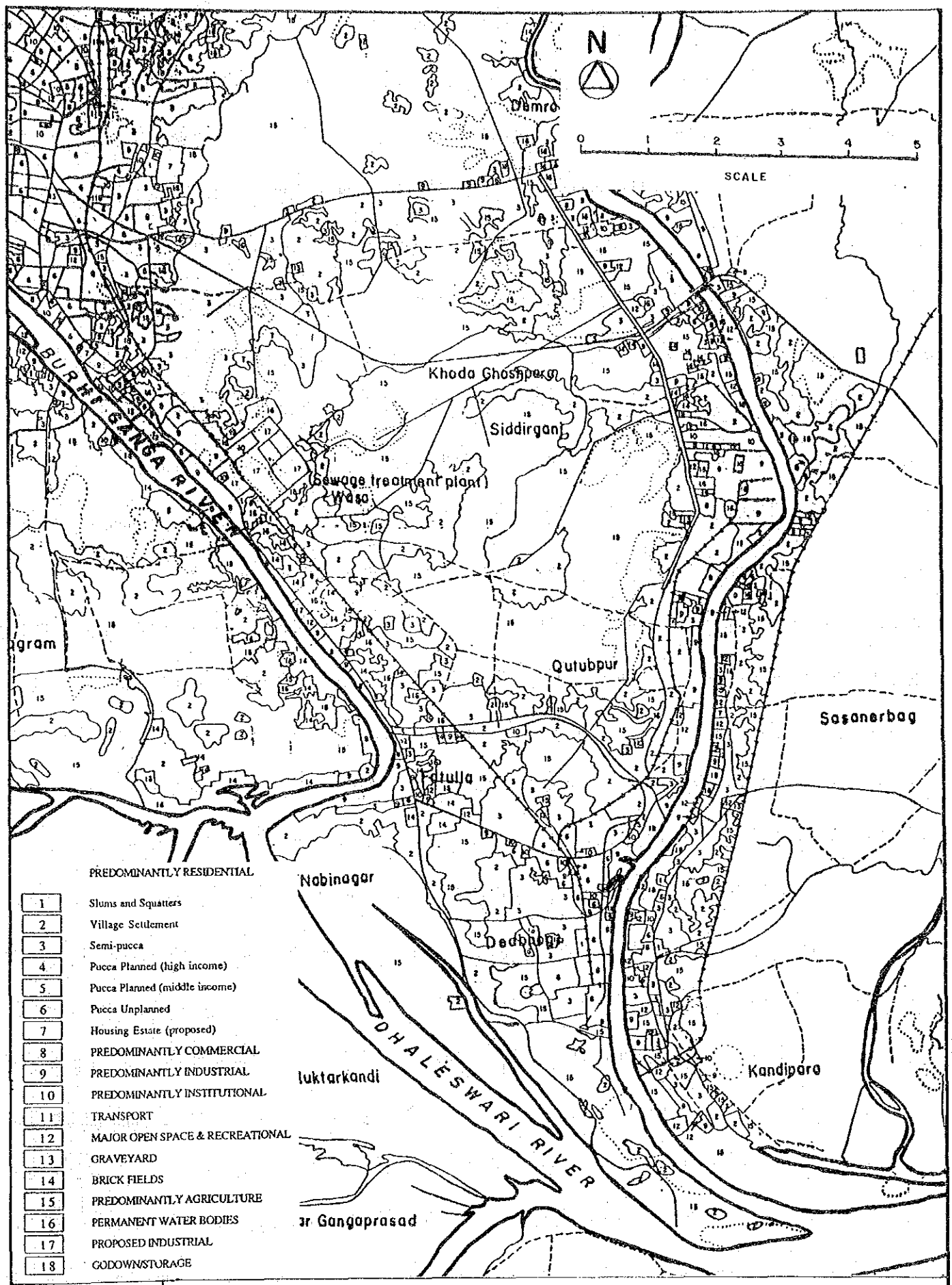

FIG. C.3C EXISTING LAND USE : NARAYANGANJ

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

JICA

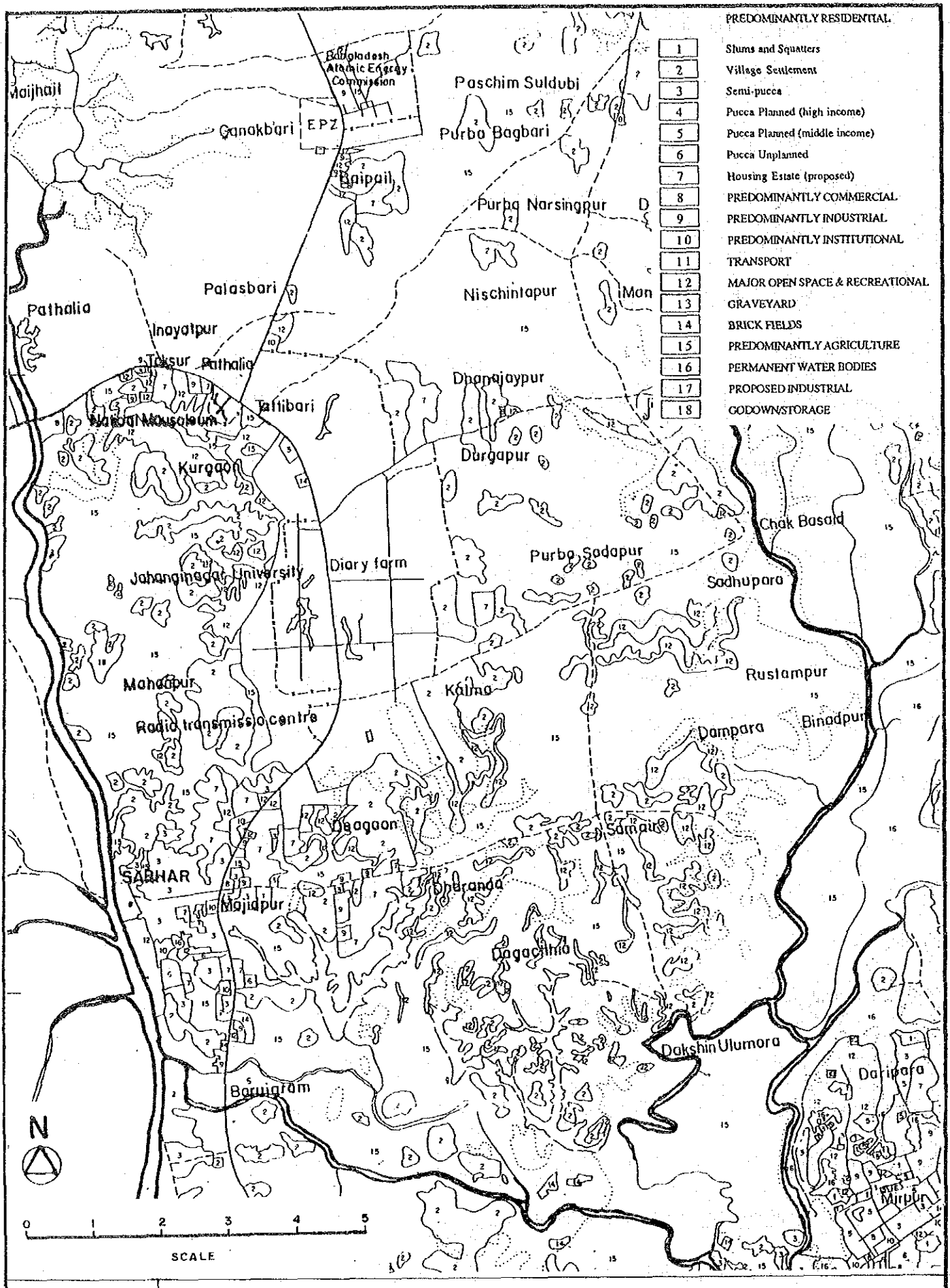

FIG. C.3D EXISTING LAND USE : SAVAR

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

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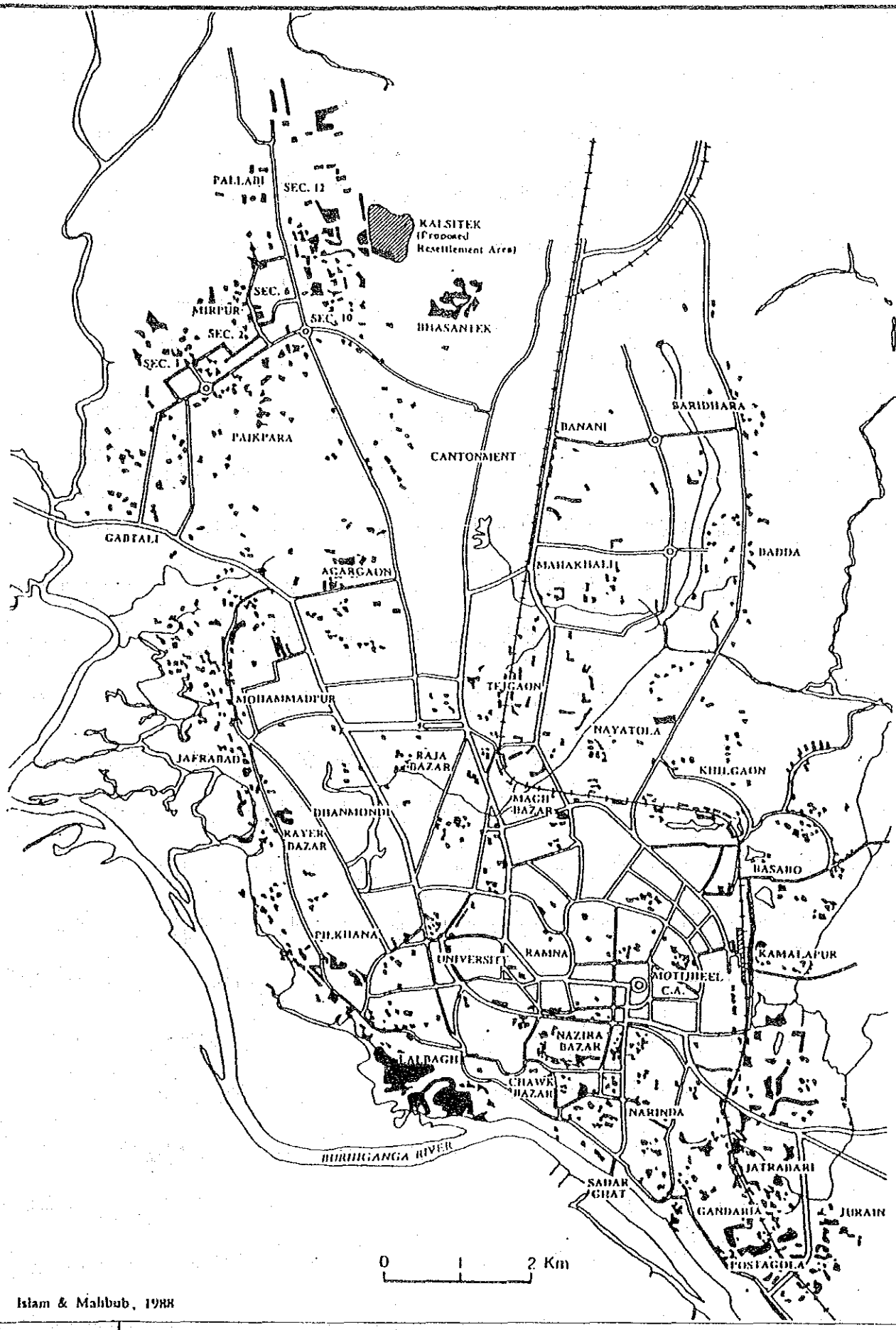

FIG. C.4 SLUM AND SQUATTER SETTLEMENTS 1988

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

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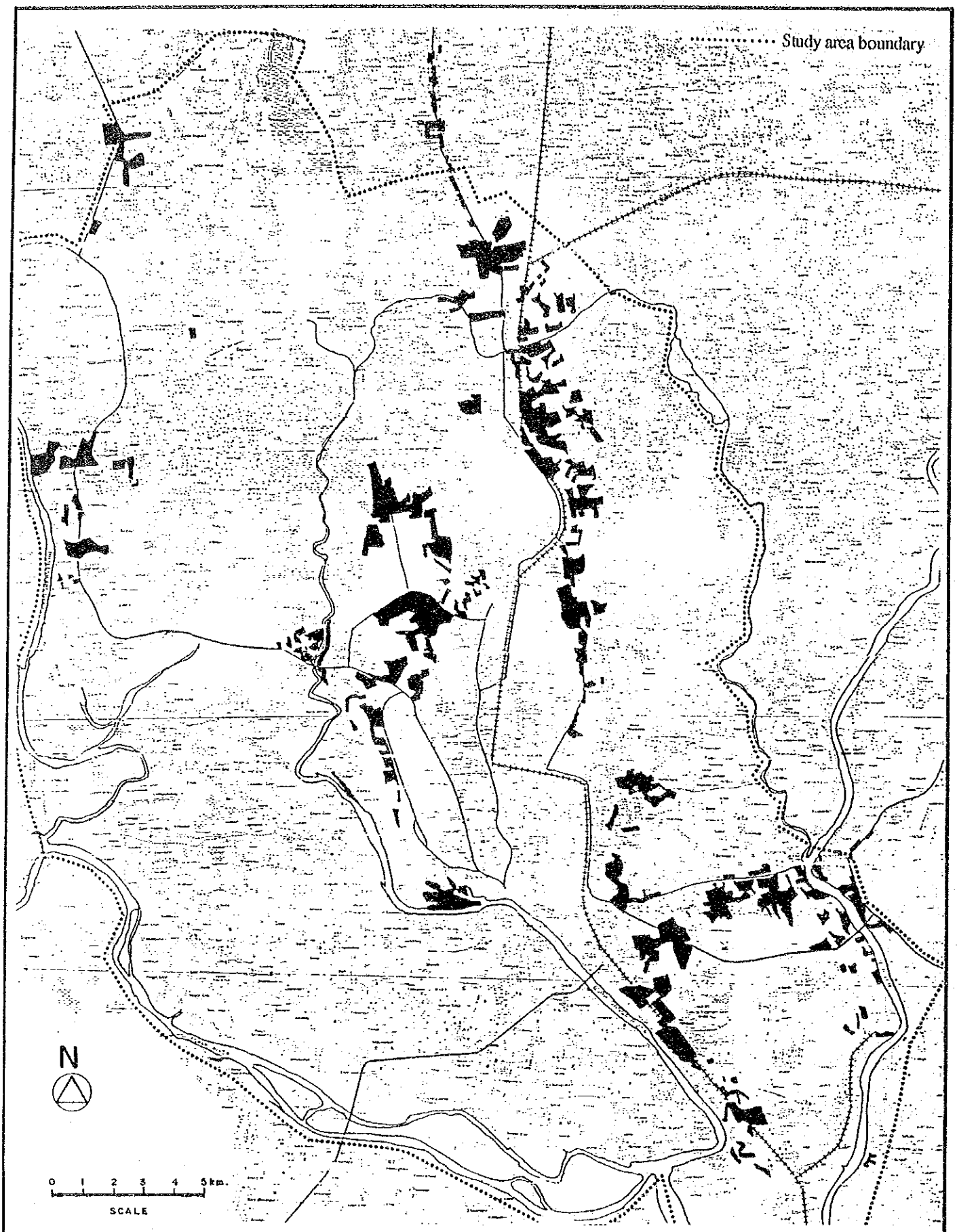

FIG. C.5 MAIN URBAN GROWTH AREAS, 1983/84 TO 1990/91

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

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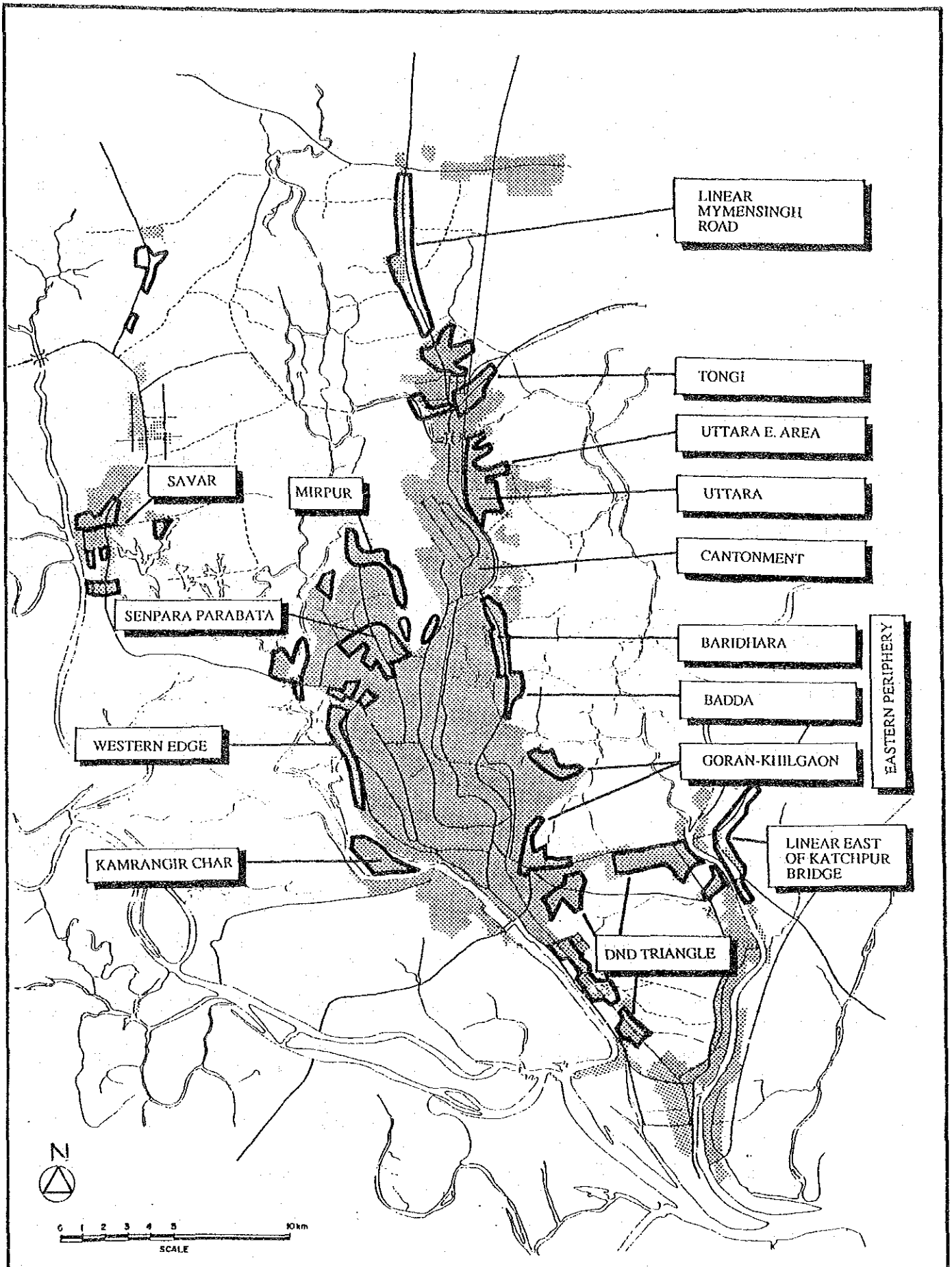

FIG. C.6 MAJOR DEVELOPMENT AREAS, 1981 - 1990

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

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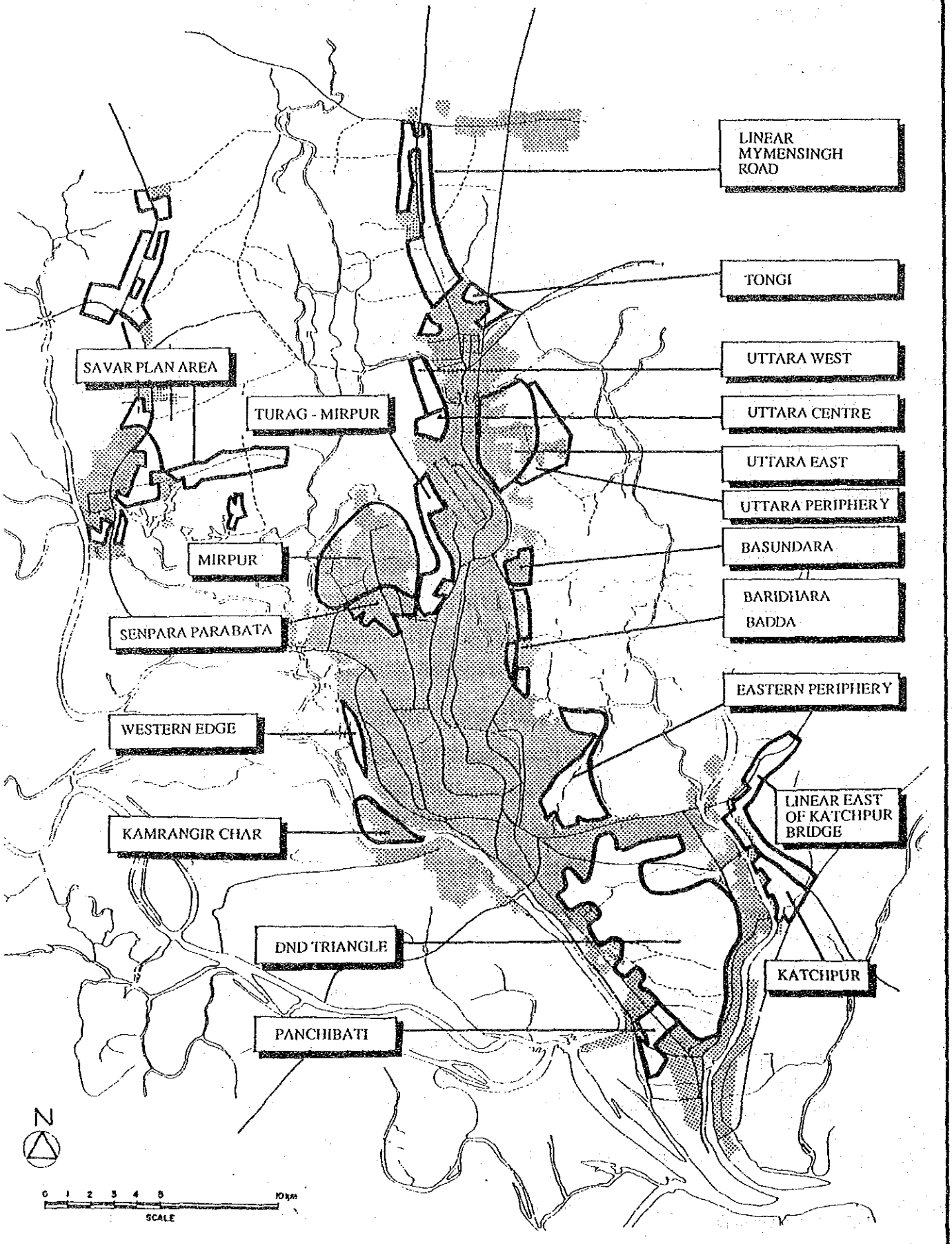

FIG. C.7 MAJOR DEVELOPMENT AREAS, 1990 - 2000

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

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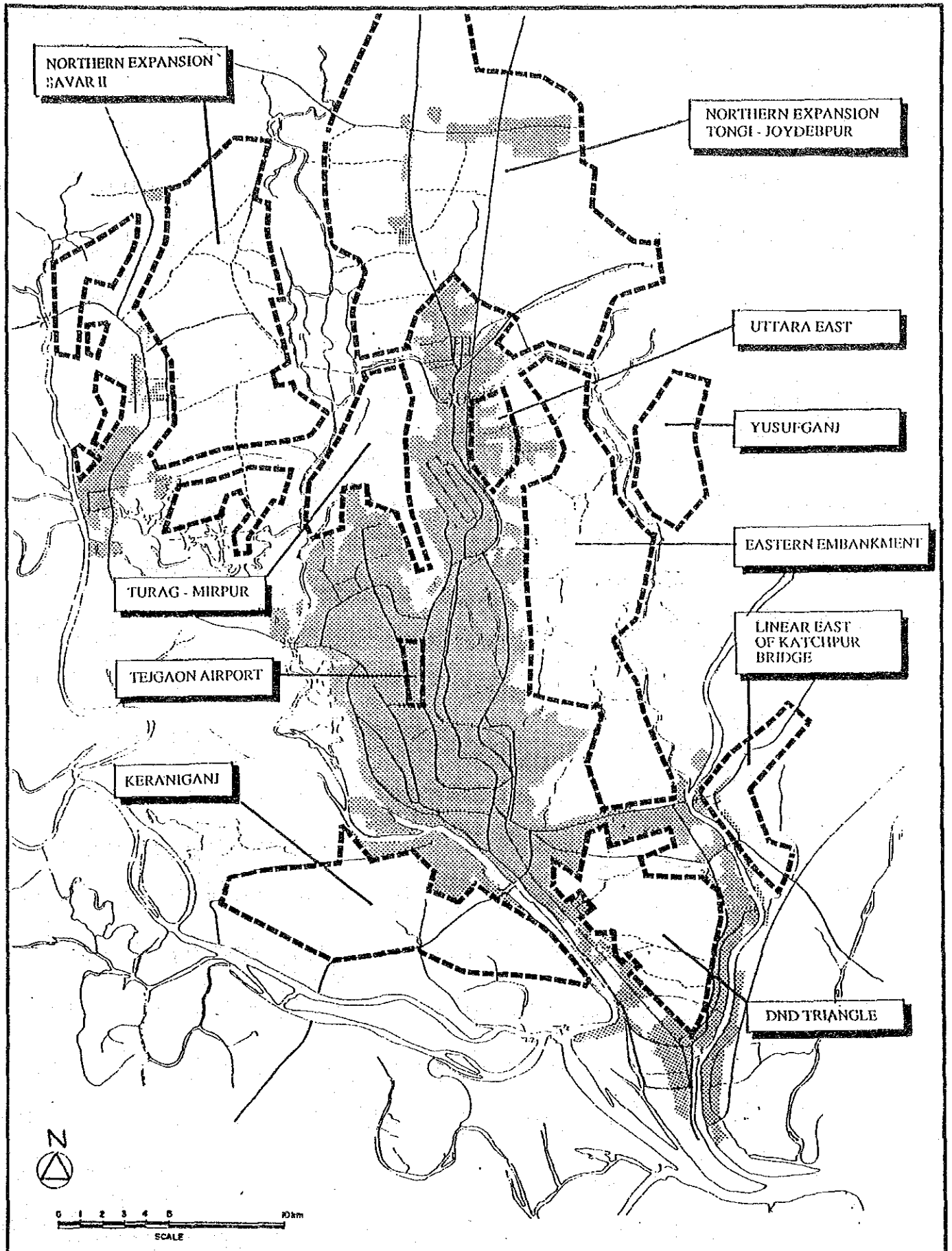

FIG. C.8 POTENTIAL URBAN DEVELOPMENT AREAS, POST 2000

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

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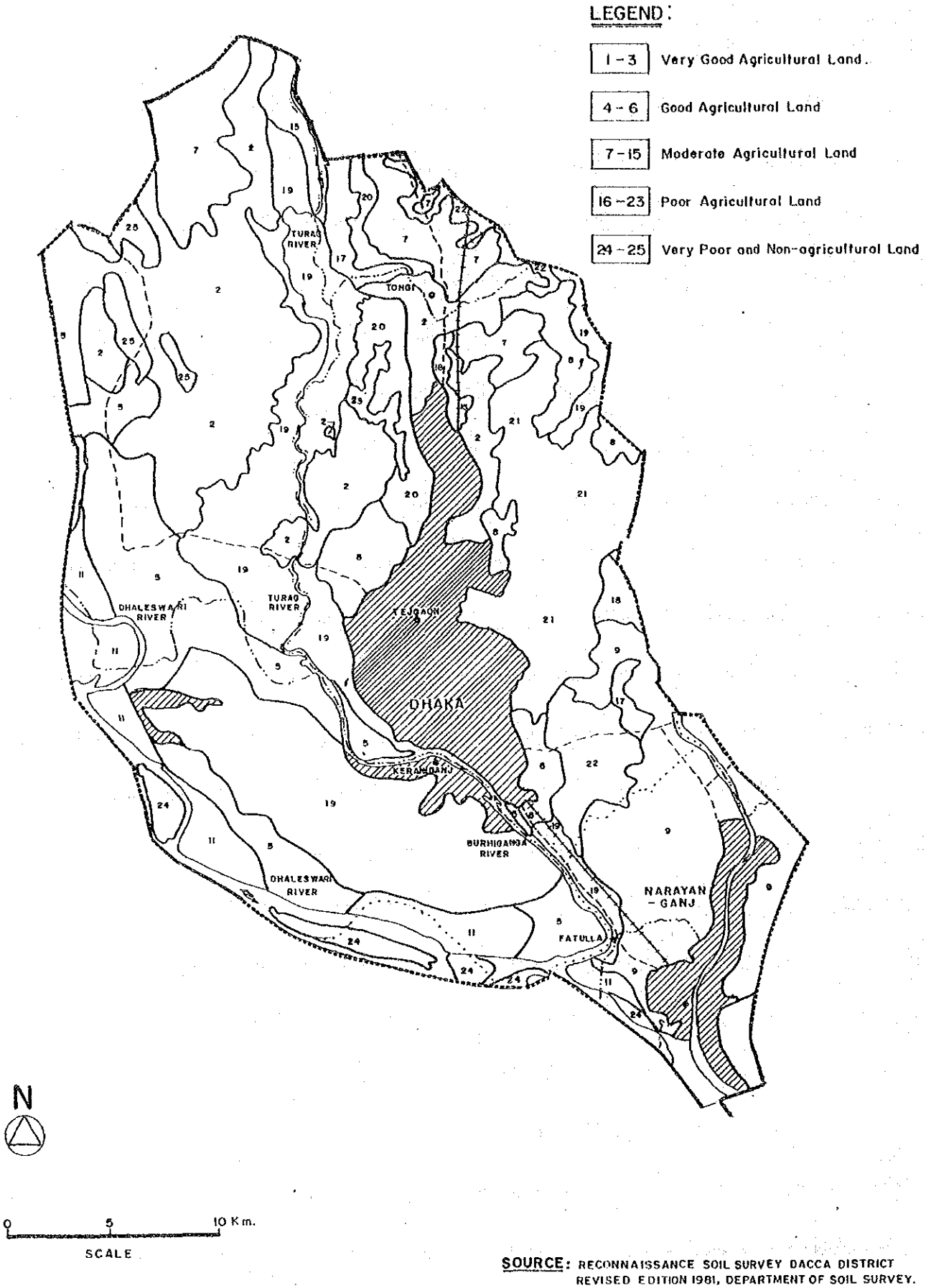

SOURCE: RECONNAISSANCE SOIL SURVEY DACCA DISTRICT REVISED EDITION 1981, DEPARTMENT OF SOIL SURVEY.

FIG. C.9 LAND CAPABILITY CLASSES

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

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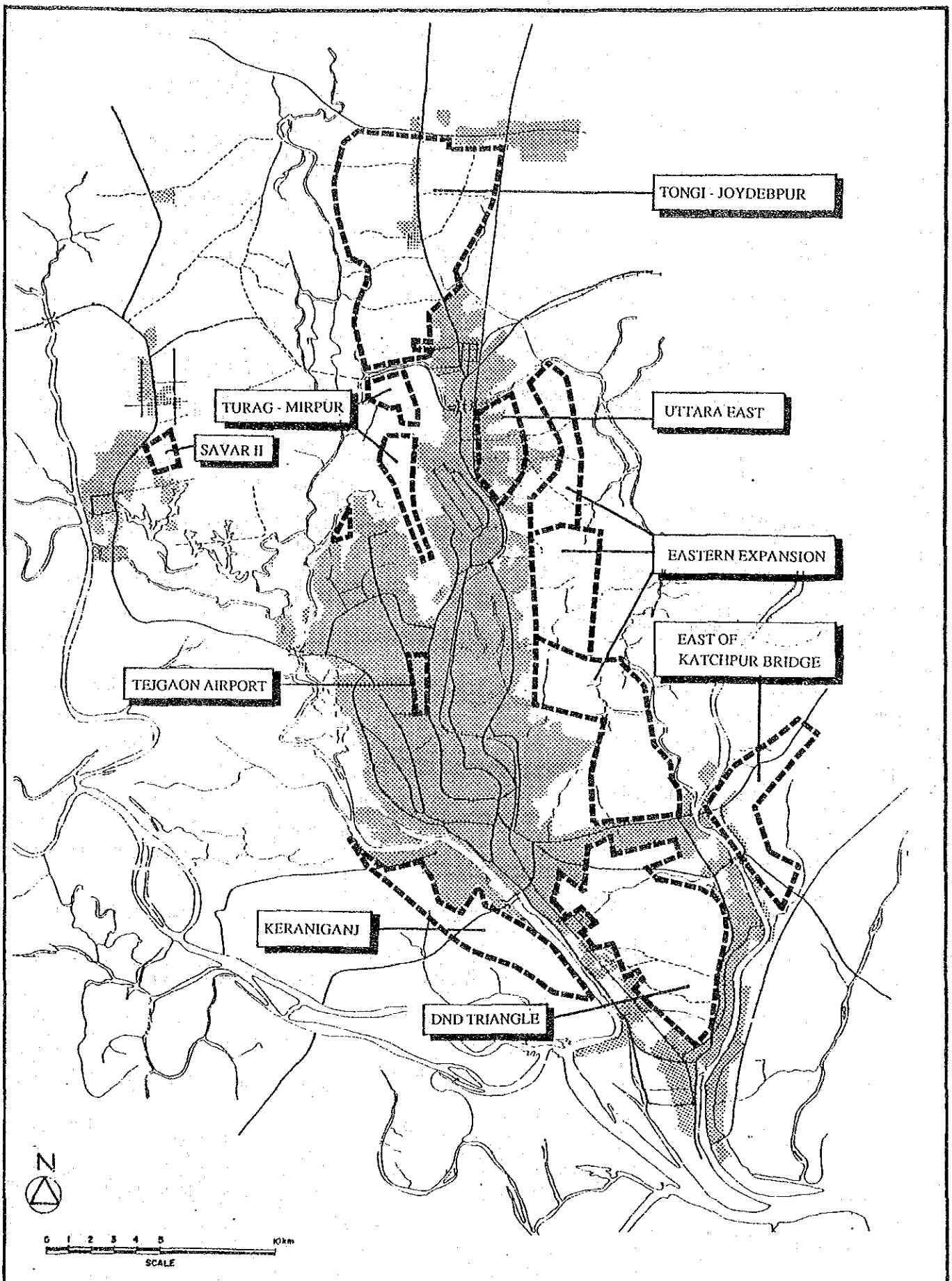

FIG. C.10 PROBABLE DEVELOPMENT AREAS, 2000 - 2010

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

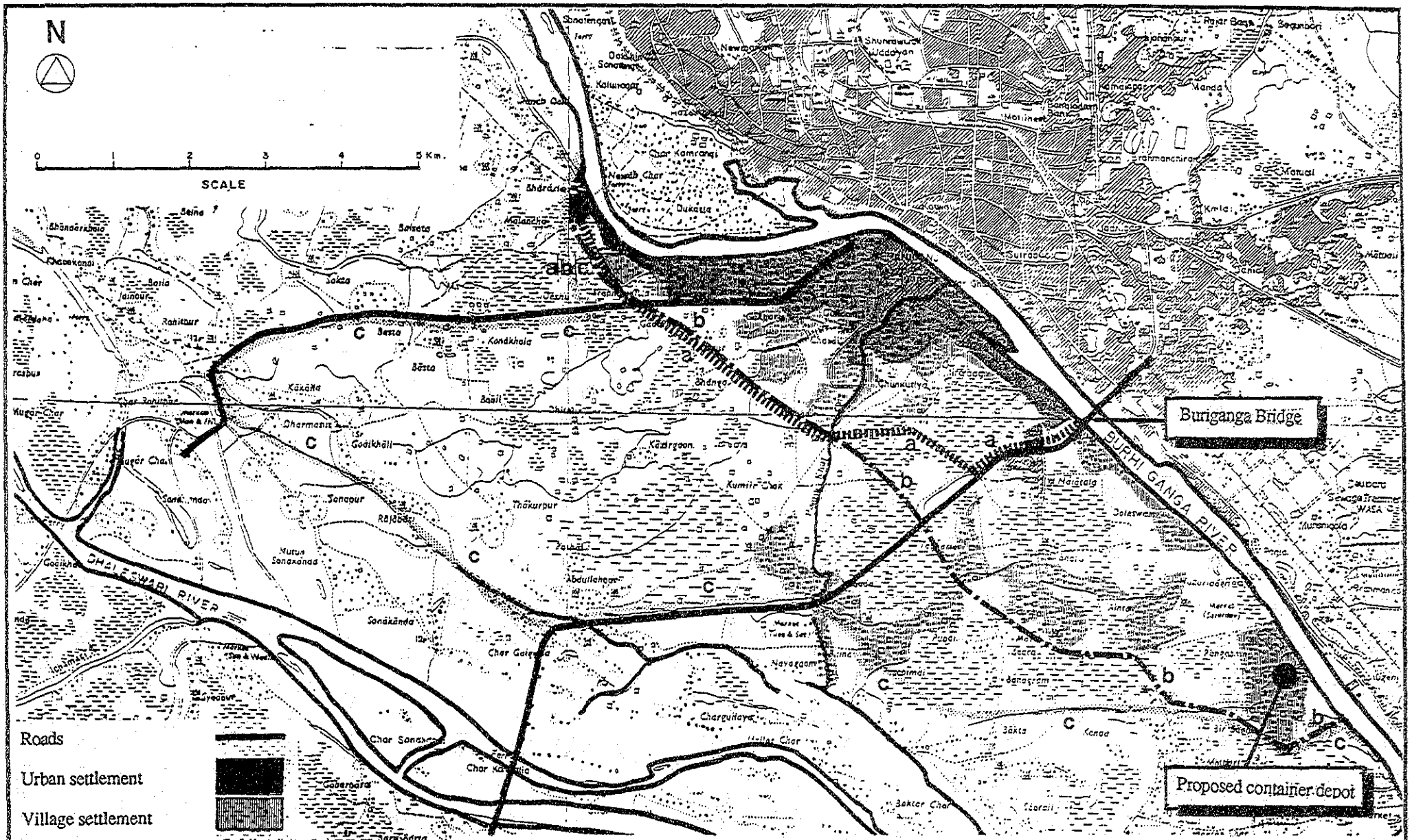

FIG. C.11 ALTERNATIVE EMBANKMENT ALIGNMENT IN KERANIGANJ

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

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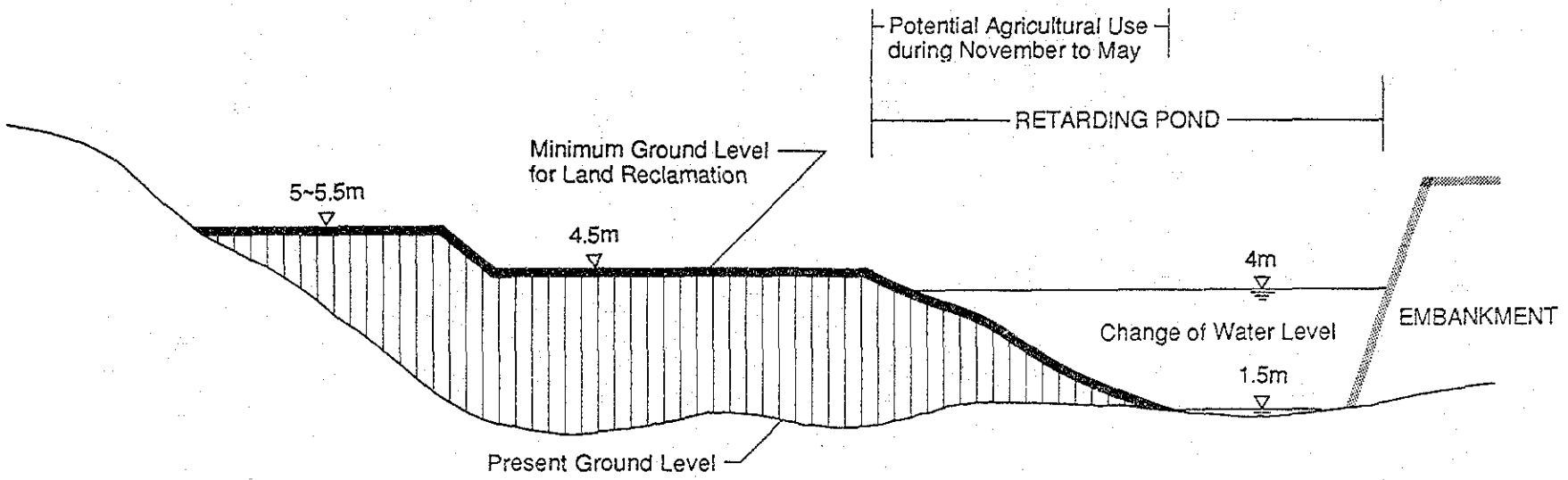

FIG. C.12 TYPICAL SECTION OF LOWLAND DEVELOPMENT ZONE

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

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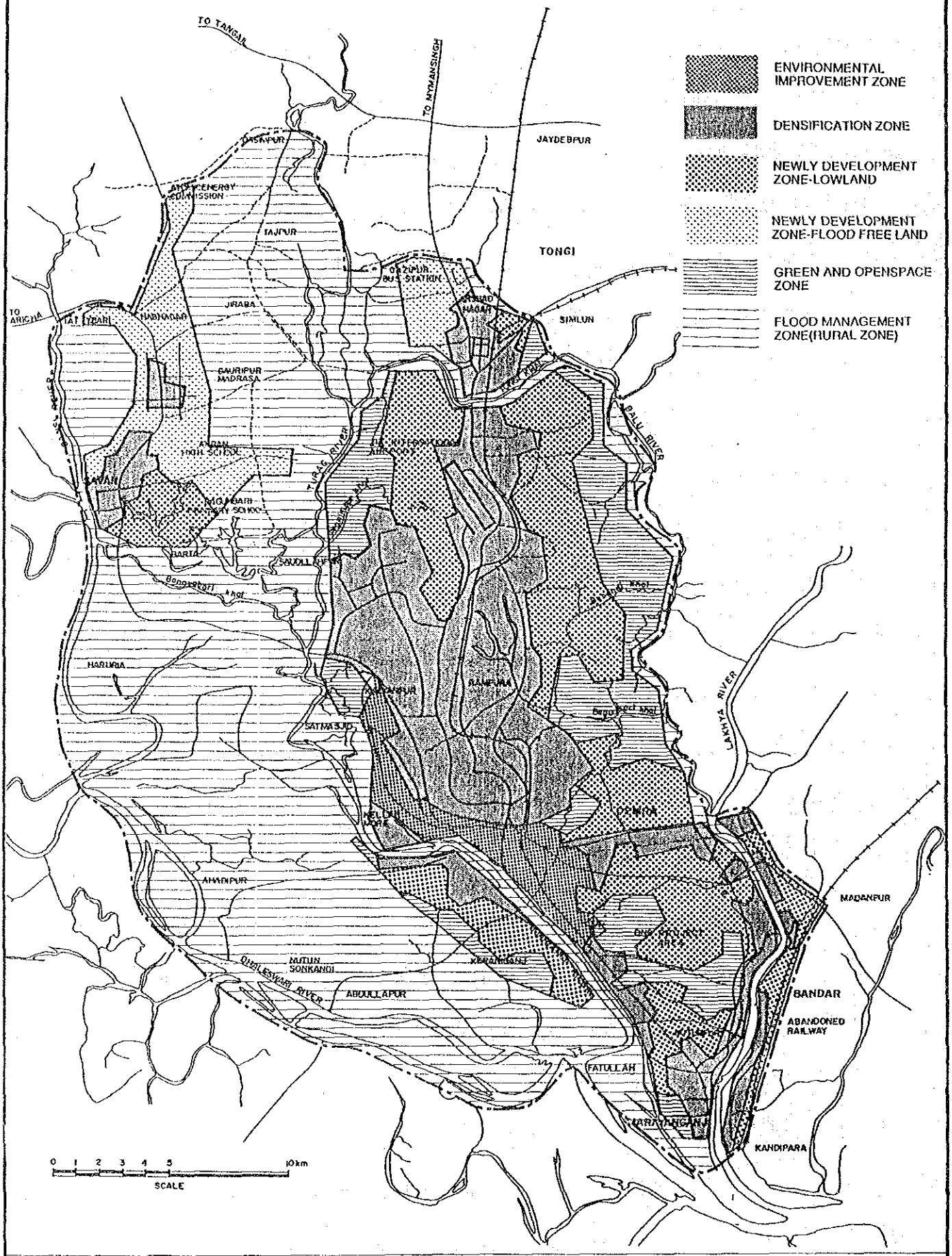

FIG. C.13 BROAD ZONING MAP

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

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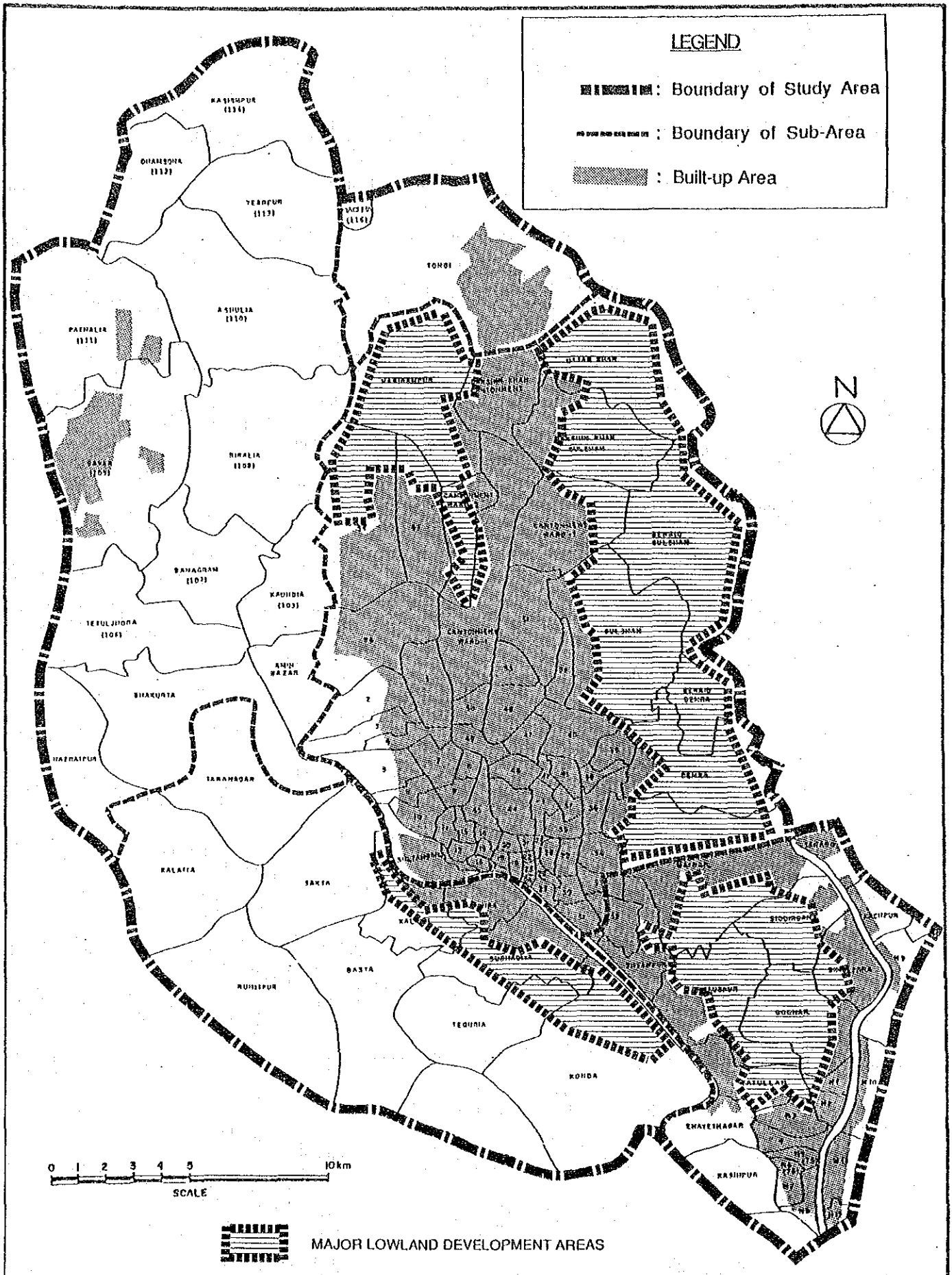

FIG. C.14 MAJOR LOWLAND DEVELOPMENT AREAS

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

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REQUIRED COMMUNITY FACILITIES AND AREA

COMMUNITY LEVEL		II		III
POPULATION		6,000 persons		20,000 persons
HOUSEHOLDS		1,000 hh		3,300 hh
DWELLING		760 units		2,520 units
CENTRE FACILITIES		units		units
Education	nursery	1	secondary school	1
	primary school	1		
Health	Dispensary	1	health centre	1
	maternity/childcare	1		
Administration			branch office	1
Recreation	children's park	1	neighbourhood park	1
			sports stadium	1
			cinema	1
Community			community hall	1
Religious	mosque	1		
Urban Services			post office	1
			telephone office	1
			police station	1
			bus station	1
			public toilet	1
Commercial	shopping street	1	supermarket	1
ROAD				
DRAINAGE				
Minimum Required Areas (ha)		3.56		11.2

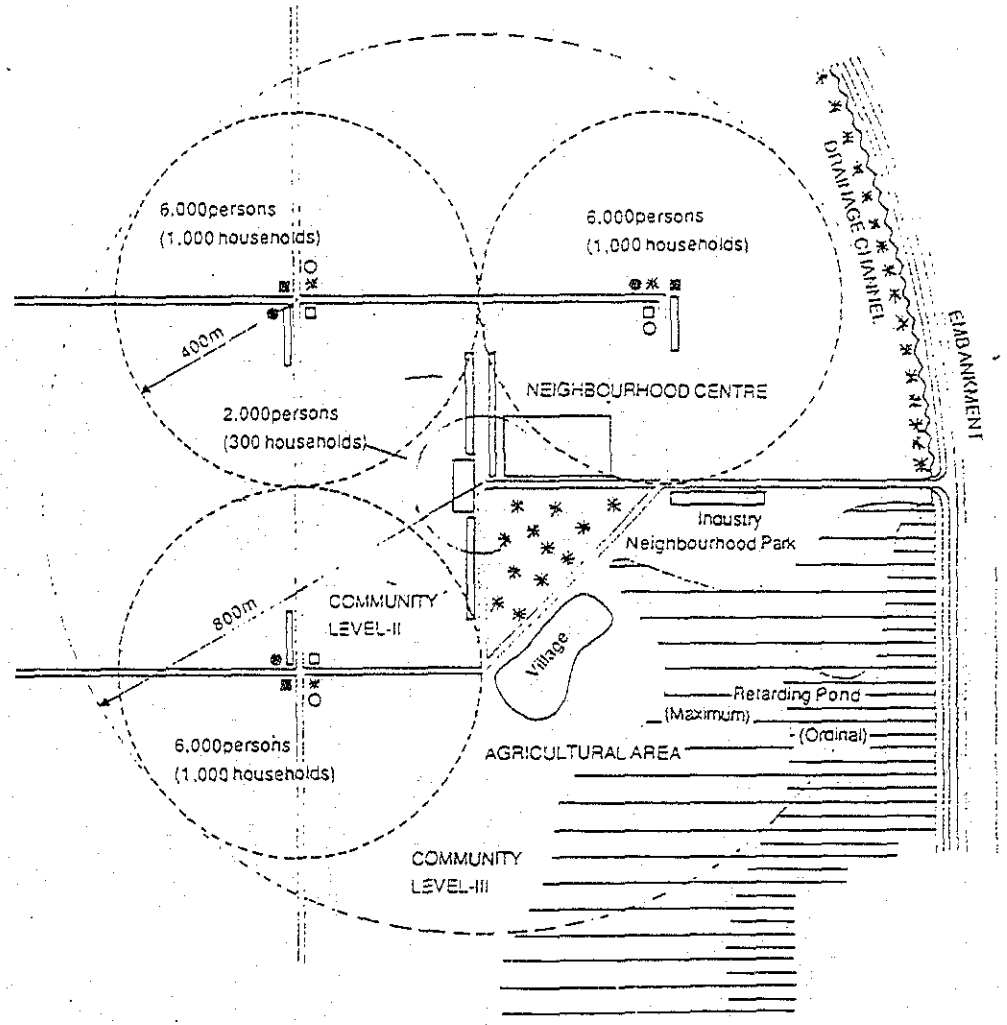

FIG. C.15 PROPOSED MODEL DEVELOPMENT UNIT

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

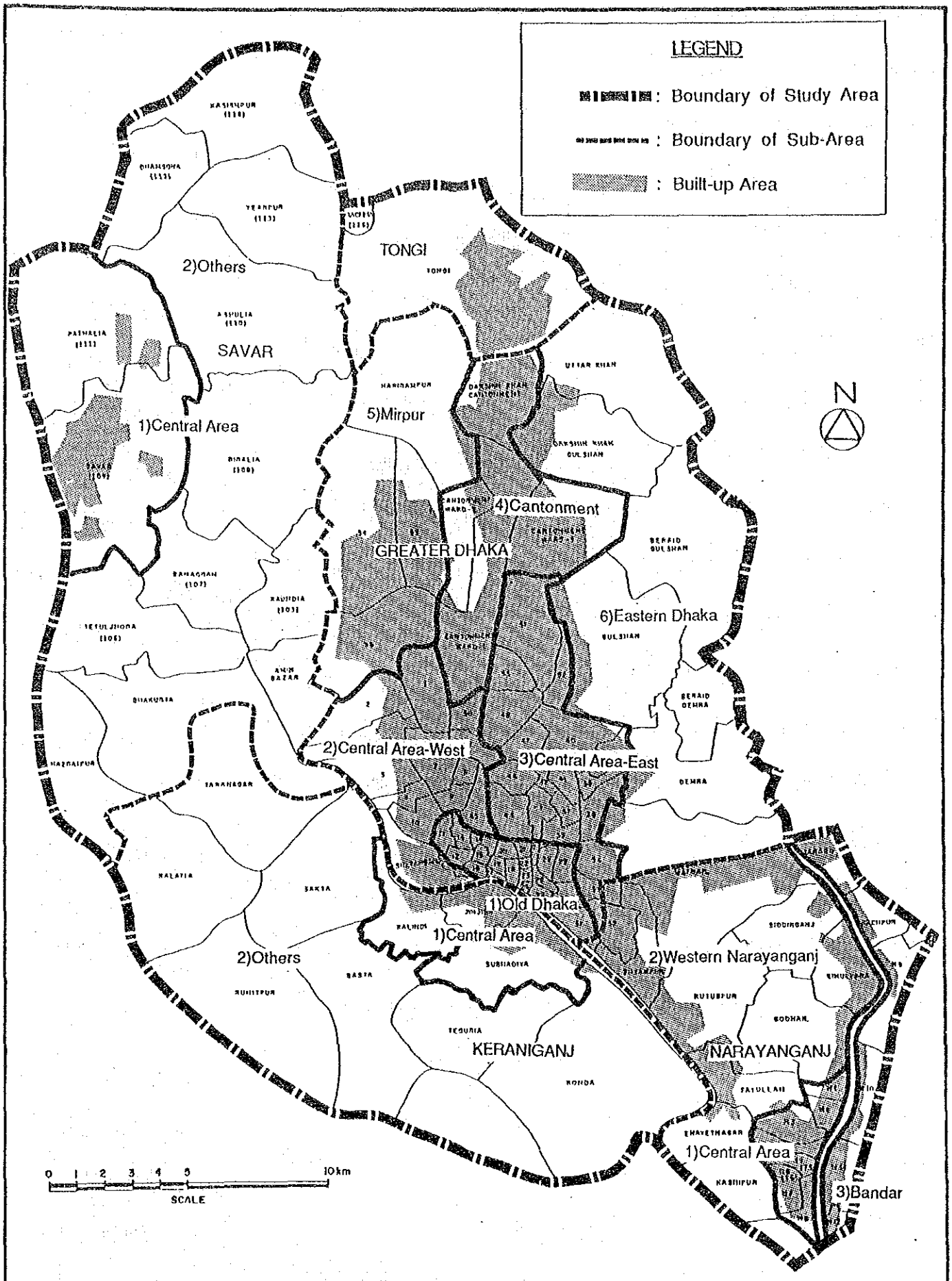

FIG. C.16 BUILT-UP AREA, 1990

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

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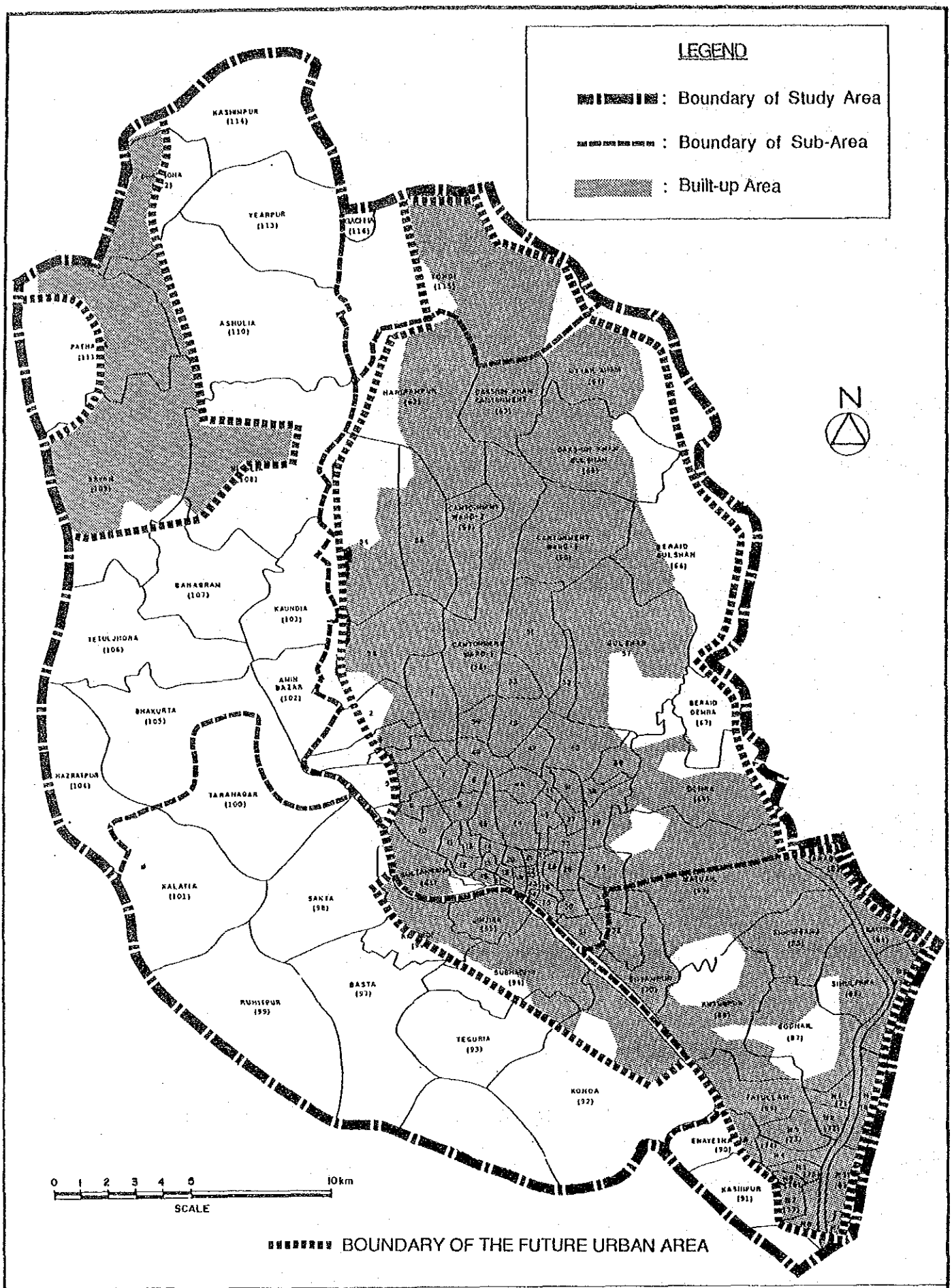

FIG. C.17 BUILT-UP AREA, 2010

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

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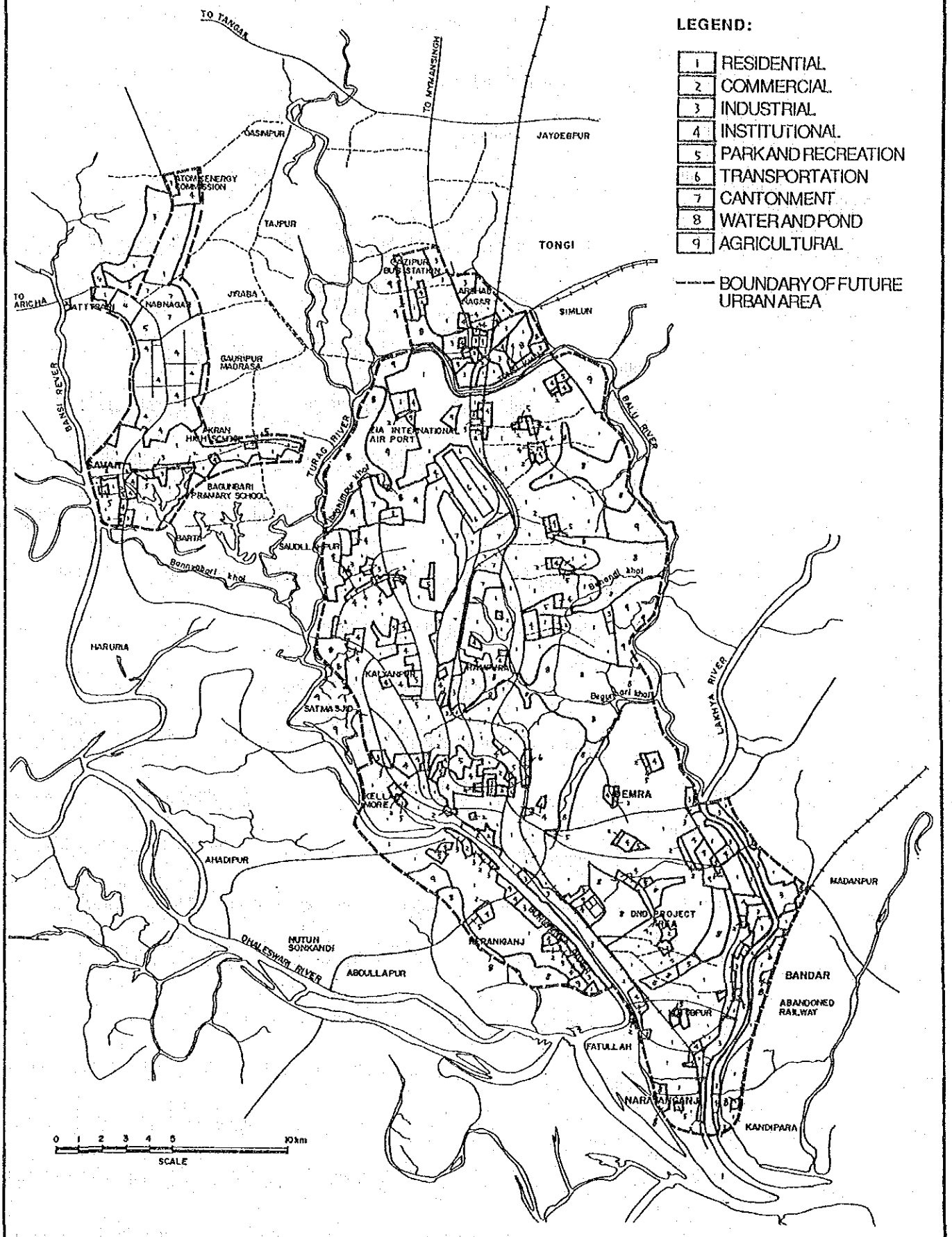

FIG. C.18 LAND USE MAP, 2010

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

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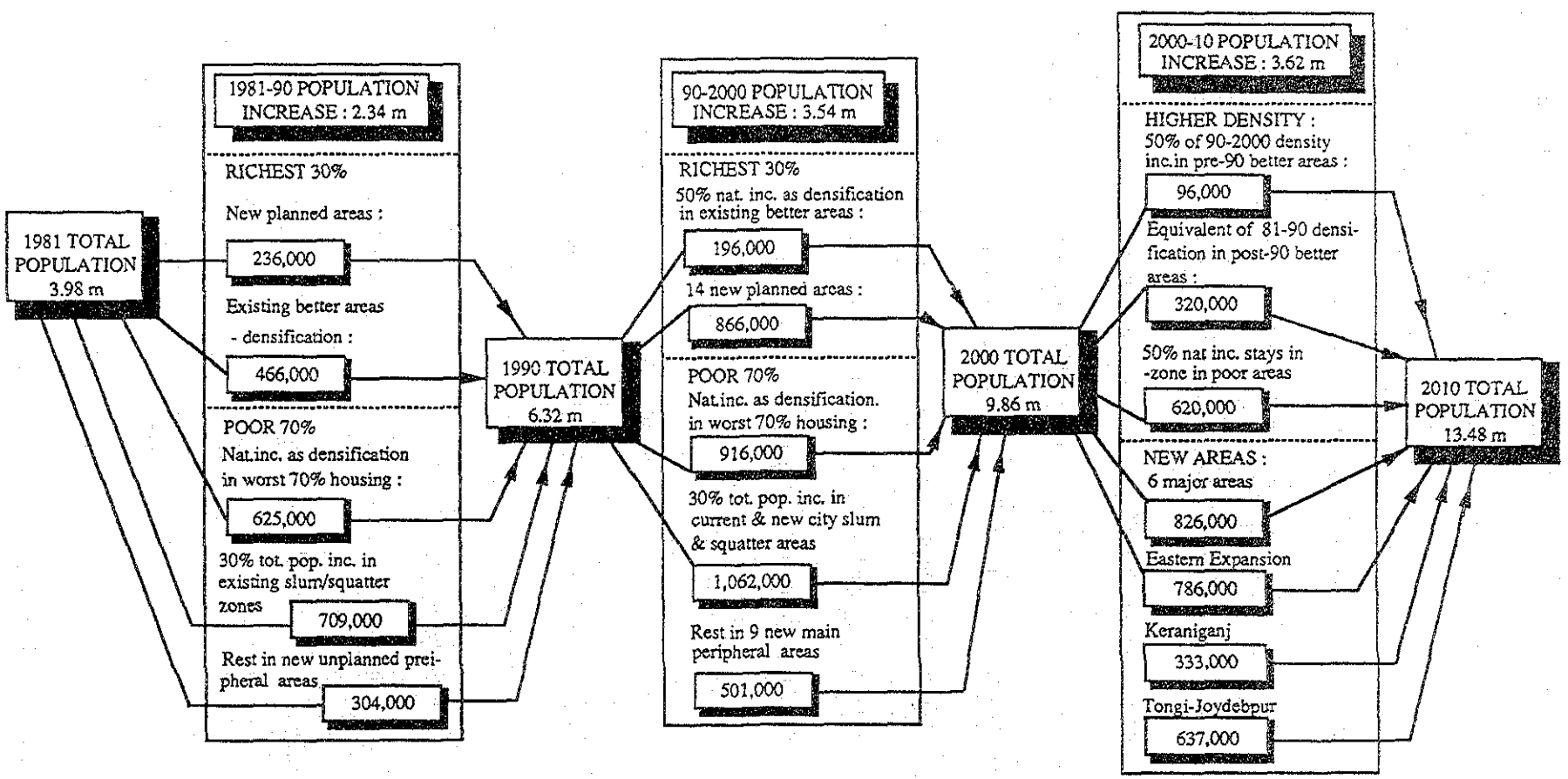

FIG. C. 19 DHAKA METROPOLITAN 'PULL' AREA : DISTRIBUTION OF POPULATION GROWTH

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

JICA

SUPPORTING REPORT D

HYDROLOGY

SUPPORTING REPORT D
HYDROLOGY

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SUPPORTING REPORT D: HYDROLOGY

1. River System

The study area is surrounded by tributaries and distributaries of three famous international rivers of the Ganges, the Brahmaputra and the Meghna Rivers as shown in Fig. D.1.

The catchments of the Ganges, the Brahmaputra and the Meghna River basins reach up to five (5) countries. They are Bangladesh, India, Nepal, China and Bhutan. The catchment areas of these three rivers are as follows :

(1)	Ganges River (at the confluence with the Jamuna River)	:	977,000 km^2
(2)	Brahmaputra - Jamuna River (at the confluence with the Ganges)	:	580,000 km^2
(3)	Meghna River (at the confluence with the Padma River)	:	77,000 km^2

Only 7.5 % of the catchment area of these three rivers lies in Bangladesh.

The river system of the study area is composed of the Dhaleswari River, the Bansi River, the Turag River, the Balu River,the Buriganga River, the Lakhya River and their tributaries. They are tributaries and distributaries of the Ganges and the Brahmaputra Rivers. The river system with gauging stations is shown on Fig. D.2.

The water levels in those rivers are likely to be affected not only by discharge from the Brahmaputra - Jamuna River and local rainfall, but at times also by backwater from the Meghna River, if there are a heavy rain in the north eastern part of Bangladesh and high tide in the Bay of Bengal at the same time.

The floods in the study area are usually caused by heavy rainfall and high water levels of surrounding rivers, by the intensity of monsoon rainfall, snow melting in the Himalayas and high water levels in Brahmaputra - Jamuna River, the Ganges and the Meghna River.

The river system in the study area is composed of seven rivers and one big khal. They are listed below:

(1)	Dhaleswari River	:	Distributary of the Jamuna River
(2)	Bansi River	:	- ditto -
(3)	Turag River	:	Distributary of the Old Brahmaputra River
(4)	Buriganga River	:	- ditto -
(5)	Balu River	:	Tributary of the Lakhya River
(6)	Lakhya River	:	Distributary of the Old Brahmaputra River
(7)	Karnatali River	:	Distributary of the Dhaleswari River and jointing with the Turag River
(7)	Tongi Khal	:	Connecting the Turag River with the Balu River

In addition to these, the Dhaleswari River has a big tributary called the Kaliganga River. Though the Kaliganga River locates outside of the study area, it is necessary to consider the flood discharge of the Kaliganga River.

Water levels of these rivers are the lowest in January - February and the highest in August - September as shown in Fig. D.7.

2. Climate

The climate of the study area is classified as tropical monsoon type, characterized by three seasons : monsoon, post- monsoon and pre-monsoon.

The monsoon season is from May to October. During the monsoon season, 90% of annual rainfall is observed. Post-monsoon is the dry season from November to December. Pre-monsoon is the transition season between the rainy season and the dry season. Some amount of rainfall is observed in the pre-monsoon season (See Fig. D.6.). Annual average rainfall in Dhaka is about 2000 mm.

In the beginning of the monsoon season and the post monsoon season, cyclones with strong winds hit Bangladesh and sometimes causes destructive storm surge in the eastern coastal area. But, Dhaka area is almost always outside the affected area.

Average temperature varies from about 20°C in December and January to about 30°C in April to September. Maximum temperature sometimes exceeds 40°C in March and April.

Monthly average evaporation varies from 80 to 130 mm. It is the lowest in November and the highest in August.

Table D.1 shows the climatic conditions in the Study Area.

3. Hydrological Observation Networks and Available Data

3.1 Rainfall

There are ten (10) active and two (2) closed rainfall gauging stations in and around the study area (See Fig. D.2). They are as follows :

	Station		Remarks
(1)	Dhaka (B.M.D) **	:	Auto recorder (1958-1983)
(2)	Narayanganj (B.M.D) *	:	Closed in 1979
(3)	Dhaka (BWDB, Sta. 9) **	:	Incorporated into Dhaka (B.M.D) in 1985
(4)	Joydebpur (BWDB, Sta. 17) *	:	
(5)	Savar (BWDB, Sta. 31) *	:	
(6)	Narsindi (BWDB, Sta. 76) *	:	
(7)	Bancharampur (BWDB, Sta. 351)*	:	
(8)	Daudkandi (BWDB, Sta. 357) *	:	
(9)	Munshiganj (BWDB, Sta. 365) *	:	
(10)	Narayanganj (BWDB, Sta. 368) *	:	Closed in 1977
(11)	Nawabganj (BWDB, Sta. 412) *	:	

Note: * : Manual
** : Manual and automatic rain gauge

The period of gauging and available data at each gauging station is shown in Table D.2.

There were only two automatic rain gauges in the study area, but they have not been used since 1984.

The others are all measured manually once a day at 9:00 A.M.

3.2 Water Level and Discharge

There are twelve (12) acting water level gauging stations in and around the study area. They are shown in Fig. D.2 and listed as follows :

(1)	Pubail	(BWDB Sta. 7	:	Balu River)
(2)	Demra	(BWDB Sta. 7.5	:	- ditto -)
(3)	Nayarhat	(BWDB Sta. 14.5	:	Bansi River)
(4)*	Mill Barak	(BWDB Sta. 42	:	Buriganga River)
(5)	Hariharpara	(BWDB Sta. 43	:	- ditto -)
(6)	Savar	(BWDB Sta. 69	:	Bansi River)
(7)	Kalatia	(BWDB Sta. 70	:	Dhaleswari River
(8)	Kalagachia	(BWDB Sta. 71	:	- ditto -)
(9)	Rekabi Bazar	(BWDB Sta. 71A	:	- ditto -)
(10)	Demra	(BWDB Sta. 179	:	Lakhya River)
(11)	Meghna Ferry Ghat	(BWDB Sta. 275.5	:	Surma-Meghna River)
(12)	Tongi	(BWDB Sta. 299	:	Tongi Khal)
(13)	Mirpur	(BWDB Sta. 302	:	Turag River)

Note : * : automatic water level gauging station.

There is only one automatic gauging station at Mill Barak. The others are measured manually five times daily at 6:00, 9:00, 12:00, 15:00, 18:00.

Period of gauging and available data at each station is shown in Table D.3.

3.3 River Cross Section

Available river cross sections collected from BWDB and their locations are shown in Fig. D.3.

In addition to these BWDB's cross sections, supplementary river cross section survey was conducted by the Study Team. The locations of the river cross sections surveyed by the Study Team are also shown in Fig. D.3.

4. Major Floods

4.1 Historical Floods

Major floods recorded in the Dhaka Metropolitan area occurred in 1954, 1955, 1970, 1974, 1980, 1987 and 1988.

The maximum water levels at Mill Barak (Sta. 42) and Demra (Sta. 7.5) and Savar (Sta. 69) during the major floods are listed as follows :

ANNUAL MAXIMUM DAILY WATER LEVEL

(Unit : PWD in m)

Flood Year	Demra (Sta. 7.5)	Mill Barak (Sta. 42)	Savar (Sta. 69)
1954	-	7.02	8.17
1955	-	7.05	8.26
1958	-	6.41	-
1970	6.24	6.47	7.99
1974	6.58	6.57	7.80
1980	6.23	6.39	-
1984	6.33	6.00	7.58
1987	6.46	6.60	8.30
1988	7.10	7.54	9.68

Notes 1) The above water levels of Mill Barak (Sta. 42) and Demra (Sta. 7.5) are revised by the results of check survey conducted in 1987 JICA Study (see section 6.1).

Fig.D.4 shows the estimated flow directions of 1970, 1974, 1980, 1984, 1987 and 1988 Floods by using the recorded flood water level.

According to these figures, the flow direction of the Tongi Khal is always west to east.

Furthermore, the flow direction of the Turag River changes from north to south or south to north. This seems to be caused by a balance of discharge from the upstream of the Turag River and the discharge from the Dhaleswari River through the Karnatali River.

However, the flow direction of the Turag River is said to be always from north to south during floods by the inhabitants along the Turag River.

4.2 1988 Floods

1988 Floods was the biggest floods among the recorded floods.

Most of the floods were caused when heavy rainfall was late in the area and coincided with high river stages of the Ganges and Brahmaputra Rivers.

However, this was not the case of the 1988 Floods. It was reported as follows :

"During the last ten days of August and the first seven days of September there was abnormally heavy and intensive rainfall in the northern part of the country as well as in the upper catchment areas in Himalayas.

The water levels in all the rivers rose sharply from 20 August onward and the peak discharges of the Ganges and the Brahmaputra Rivers were reached by 30th August - 02 September.

The ten days rainfall in north east of Bangladesh reached 800mm.

The major flooding of Greater Dhaka continued for about 18 days from August 30 to September 16."

Source : T.G.H.Jansen ; Recommendations to the Committee on Greater Dhaka Flood Control, 1988.

Furthermore, Fig. D.5 shows the flooded area of Bangladesh during 1988 Floods.

According to this figure, the flood volume of the Brahmaputra-Jamuna River was abnormally large. The study area became one of the left bank of the Brahmaputra-Jamuna River during 1988 Floods.

Fig. D.6 and Fig. D.7 shows the monthly rainfall and monthly maximum water level in 1988. Fig. D.8 to Fig. D.9 shows the daily rainfall and daily maximum water level during 1988 Floods. Furthermore, as the peak discharge of the Meghna River and the Padma River occured at the same time, backwater effect of the Meghna River to the rivers in the study area was very strong.

According to these figures, 1988 Floods in and around the study area is characterized as follows;

(1) The monthly rainfall amount of August and September, in 1988 were about 2/3 of annual average monthly rainfall amount. So, the rainfall in the study area seemed not to affect the maximum water level of the rivers so much.

(2) The maximum water level was by far higher than annual average maximum water level. The differences were about 2.6 m at Nayarhat, 1.4 m at Hariharpara, 1.3 m at Pubail, 1.2 m at Demra (Sta. 7.5) and 0.7 m at Kalagachia. This tendency of the maximum water levels of the 1988 Floods coincide with the fact that the 1988 Floods came from the direction of the Brahmaputra-Jamuna River as shown in Fig. D.5.

5. Features of Storm Rainfall

As the local runoff from a khal in the study area is caused by the local storm rainfall, the storm rainfall is an important factor to formulate a storm water drainage plan for the study area.

1) For pump drainage plan

For pump drainage plan, including drainage channel, daily to several day consecutive rainfall are important factors. This is supported by the fact that the 1987 JICA Study selected two day consecutive rainfall of 5-year return period as a design rainfall*).

Source :

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

In this section, frequency analysis for daily to monthly rainfall is conducted using the updated data collected in this Study.

2) For drainage pipes or culverts

In order to design drainage pipes or culverts, rainfall intensity of short duration less than several hours is an important factor as described in 1987 JICA Study.

Updating the rainfall with hourly base cannot be conducted because the automatic recorder of Dhaka (B.M.D) has not been used since 1984. Furthermore Dhaka (BWDB Sta. 9) was incorporated into Dhaka (B.M.D) since 1985.

For this reason, the concept and value for the rainfall with short duration of 1987 JICA Study is also applied in this Study.

5.1 Maximum Rainfall Data

Maximum rainfall data of one day to one month are shown in Table D.4 to Table D.7.

Among these data, the data of following four stations are used.

(1)	Greater Dhaka	:	Dhaka (B.M.D.)
(2)	Narayanganj	:	Narayanganj (B.M.D.)
(3)	Savar	:	Savar (BWDB Sta. 31)
(4)	Tongi	:	Dhaka (B.M.D.) or Joydebpur (BWDB Sta.17)

These four stations have long duration of data especially at Dhaka (B.M.D) of 36 years and are considered to represent the Master Plan Area of Greater Dhaka, Narayanganj, Savar and Tongi respectively.

5.2 Correlation among Rainfall Gauging Stations

Correlation among above four rainfall gauging stations are studied by using two day rainfall data. The results are shown in Fig. D.10.

As shown in this figure, these four stations have no specific correlation.

For this reason, using a point rainfall data to a specific area is more applicable than calculating basin mean rainfall.

5.3 Probable Storm Rainfall

1) Frequency analysis

Frequency analysis is conducted for Dhaka (B.M.D.), Narayanganj (B.M.D.), Savar (BWDB Sta. 31) and Joydebpur (BWDB Sta. 17) by Gumbel-Chow's Method.

The results are shown in TableD.8.

As shown in this table, probable rainfalls of above four stations are almost same for one day and two day rainfall of two year and five year return period.

For this reason, probable rainfall of Dhaka (B.M.D.) of one day and two day rainfall of two year and five year return period can also be applied to Savar, Tongi and Narayanganj.

Fig. D.11 and D.12 shows the probable rainfall of Dhaka (B.M.D.).

Furthermore, the difference in probable rainfall at Dhaka (B.M.D.) between this study and 1987 JICA STUDY of one day and two day rainfall of two year and five year return period is compared as shown below;

PROBABLE RAINFALL AT DHAKA (B.M.D.)

(Unit : mm)

Duration	Return Period	This Study	1987 JICA Study
1 day	2 Year	137	135
	5 Year	184	192
2 day	2 Year	184	183
	5 Year	239	245

As shown above, probable rainfalls are almost same between the two studies

Hence, above values of 1987 JICA Study are also applicable. Furthermore, 1987 JICA Study's values of five year return period are safer values than those of this Study.

2) Design hyetograph for pump drainage plan

In the 1987 JICA Study, the rainfall pattern of the heavy rainfall was studied by using the data collected from the auto recording charts of Dhaka (B.M.D.).

As a result, the duration of heavy rainfalls was found as six hours and accordingly the heavy rainfall pattern was determined.

Furthermore, the design rainfall for pump drainage plan was selected as two days consecutive rainfall with five year return period.

By using the above rainfall pattern and the design rainfall, the design hyetograph for pump drainage plan was determined as shown in Fig. D.13.

In this Study, this design hyetograph is also applied.

5.4 Rainfall Intensity and Duration

In 1987 JICA Study, short duration rainfalls less than two hours were studied.

Frequency analysis for these data was conducted by using the data of short duration rainfalls from the auto recording charts and the rainfall intensity duration curves were formulated.

In this Study, rainfall intensity-duration curves for the time duration less than one day are made by using the above 1987 JICA Study's curves and the updated data of one day rainfall.

The results are shown in Fig. D.14.

5.5 Areal Reduction of Point Rainfall

In order to formulate a storm drainage plan, point rainfall of Dhaka (B.M.D.) is selected.

If a sub-drainage basin is wide like 100 km^2, basin mean rainfall of the sub-drainage basin becomes smaller than the value of the point rainfall.

This reduction from the point rainfall to areal rainfall can be calculated by using areal reduction curves.

Fig. D.15 shows the areal reduction curves.*)

Source :

*) NEDECO ; Master Plan for Drainage and Flood Control of Jakarta, 1973.

In this study, daily rainfall data of Dhaka (B.M.D.) with more than 100 mm/day are picked up from the data between 1970 and 1978. And the daily rainfall data of the same date with the Dhaka's data are picked up for Joydebpur (Sta. 17), Savar (Sta. 31) and Narayanganj (B.M.D.).

Then, isohyetal maps are made for the data with very small rainfall of Joydebpur, Savar and Narayanganj except Dhaka.

By these isohyetal maps, areal reduction rates of the point rainfall at Dhaka (B.M.D.) were calculated. They are plotted in Fig. D.15.

As shown in this figure, the curves developed by NEDECO give a little safer value than the areal reduction rates of Dhaka.

As a result, these curves are applicable to this Study.

6. Features of Flood Water Level

In this section, frequency analysis for the flood water level is conducted.

Prior to the frequency analysis, correlation among water level gauging stations is analysed.

6.1 Maximum Flood Water Level Data

The annual maximum water levels observed at each water level gauging station are shown in Table D.9.

In this table, the data of Demra (Sta. 7.5), Mill Barak (Sta. 42), Tongi (Sta. 299) and Mirpur (Sta. 302) are revised by using the results of check survey conducted in 1987 JICA Study.

The equations for the revision are as follows ;