

(3) Master Plan Area

The Preliminary Study Area is divided into the Master Plan Area and the remaining area which part of the Urban Control Area. Taking into account the definition of Urban Control Area, the future population growth rate of the remaining area is estimated to be the natural growth rate which is published under NSO.

According to this, the future population of the remaining area is estimated as 150,000 persons in 2000.

On the other hand, the future population of Master Plan Area is estimated as 2,350,000 persons in 2000.

The result of this projection is summarized in Fig. E.5 and Table E.5.

Table E.5 Projected Population for the Master Plan Area

| | 1980 | 1990 | 2000 |
|------------------------|-----------|-----------|-----------|
| Bangkok Metropolis | 5,070,000 | 6,400,000 | 7,700,000 |
| Preliminary Study Area | 1,160,000 | 1,790,000 | 2,500,000 |
| Master Plan Area | 1,060,000 | 1,660,000 | 2,350,000 |

3.2 Future Land Demand

Future urbanized area and each land use area are estimated from the Development Policy and the projected population.

(1) Future Urbanized Area

In order to project the future urbanized area in the Master Plan Area up to the year 2000, the urbanized area in the Preliminary Study Area is first estimated. The following two methods are adopted to estimate the future urbanized area in the Preliminary Study Area:

- 1) Estimation of the relationship between the existing population density and the built-up proportion in the Districts.

- 2) The trend of urbanized areas from 1960 to 1980. Results of these projections are summarized in Fig. E.6. It is considered reasonable to adopt 230 km^2 as the medium projected urbanized area for the Preliminary Study Area.

On the other hand, the future urbanized area in the Master Plan Area is estimated as:

- 1) Present urbanized area in the outer Master Plan Area which is included in the Urban Control Area is 14 km^2 .
- 2) The outer Master Plan Area should not be developed till 2000 by the definition of Urban Control Area.
- 3) According to these steps, the future urbanized area in the outer Master Plan Area will be reserved as 14 km^2 in 2000.
- 4) 216 km^2 ($230 \text{ km}^2 - 14 \text{ km}^2$) is adopted for the future urbanized area in 2000.

These results can be shown in Fig. E.6.

(2) Each Land Use

Each land use is estimated as follows:

1) Commercial and Parks

Future commercial area and parks are estimated in proportion to the future population as 14 km^2 each.

2) Industrial and Institutional

Under the Development Policy, existing industrial and institutional areas are reserved as 3 km^2 and 22 km^2 respectively.

3) Residential

Remaining area in the urbanized area is projected as the residential area.

These results are summarized in Table E.6.

Table E.6 Land Use in the Master Plan Area, 2000

| | Existing | | 2000 | |
|-----------------------------------|-----------------|------|-----------------|------|
| | km ² | % | km ² | % |
| A. Urbanized Area | 134 | 51.5 | 216 | 83.1 |
| 1. Commercial | 6 | 2.3 | 14 | 5.4 |
| 2. Industrial | 3 | 1.1 | 3 | 1.1 |
| 3. Medium-low density residential | 97 | 37.3 | 163 | 62.7 |
| 4. Institutional | 22 | 8.5 | 22 | 8.5 |
| 5. Park, Sports Ground, etc. | 6 | 2.3 | 14 | 5.4 |
| B. Agricultural and Open Space | 126 | 48.5 | 44 | 16.9 |

3.3 Land Use Plan

The land use plan is proposed by the Study Team as shown in Fig. E.7 from the result of the study under following consideration:

1) Past Trend of Urbanization

Urbanization will be expanded from the centre to surrounding areas in same pattern as in the past.

2) Population Density

Population density is high in Bangkok. Generally population increase stops when density reaches as high as 400 to 500 persons per hectare whilst the existing density of the Master Plan Area is on average only 50 persons per hectare. Hence, there is much room in the Master Plan area for a population increase.

3) Road Plan

As there is no authorized city plan, the urban development by the private sector has taken place mainly along the streets, a road plan is one of the key items for a future land use pattern.

4) No Flood Damage

As presented in Chapter 6, main report the conservation of a storm water retention area could save a considerably high investment cost of the flood protection and drainage system. Hence, high flood-prone areas are recommended to retained as storm water retention areas.

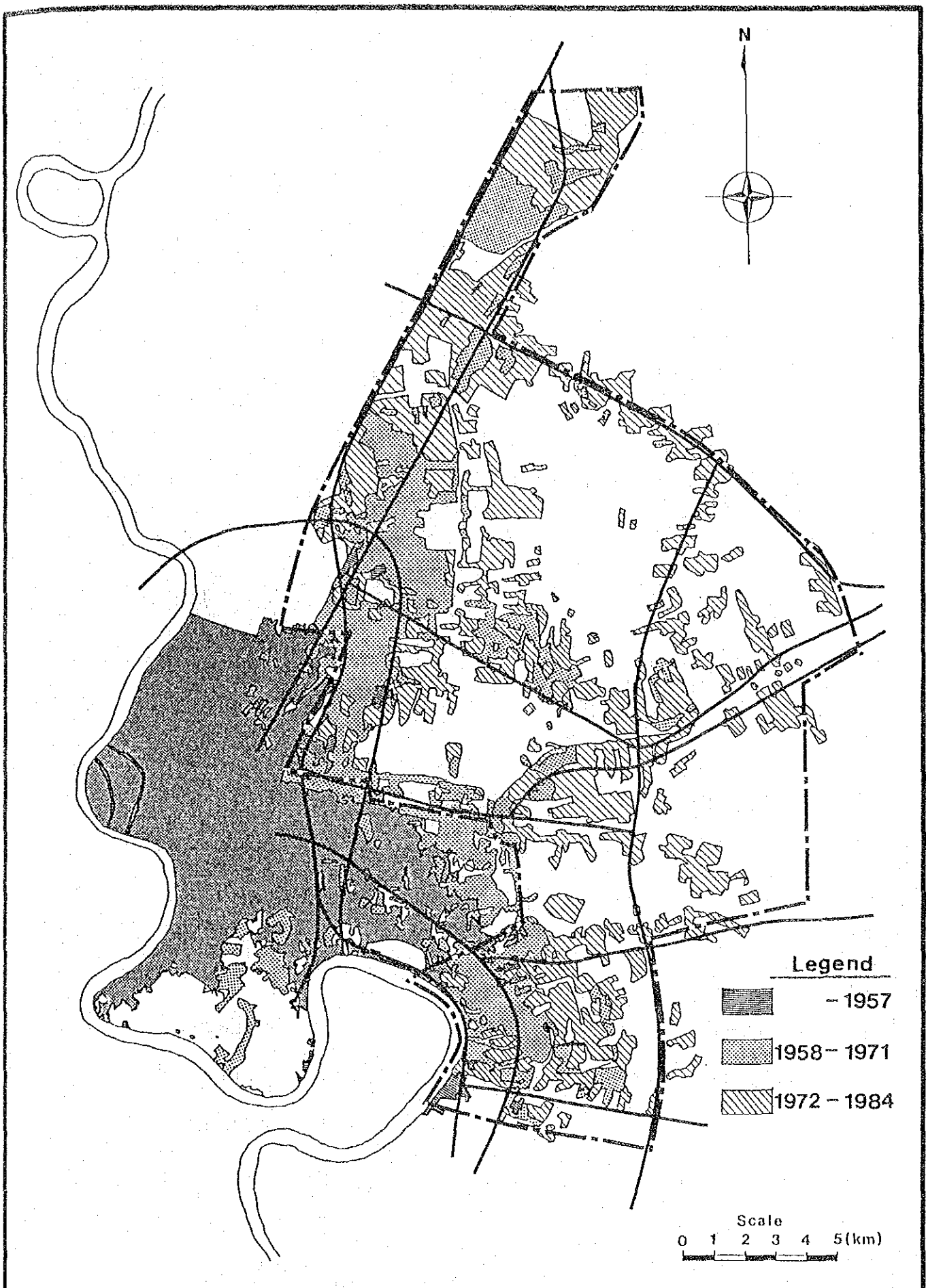


Fig. E.1

PAST TREND OF URBANIZED AREA IN MASTER PLAN AREA

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

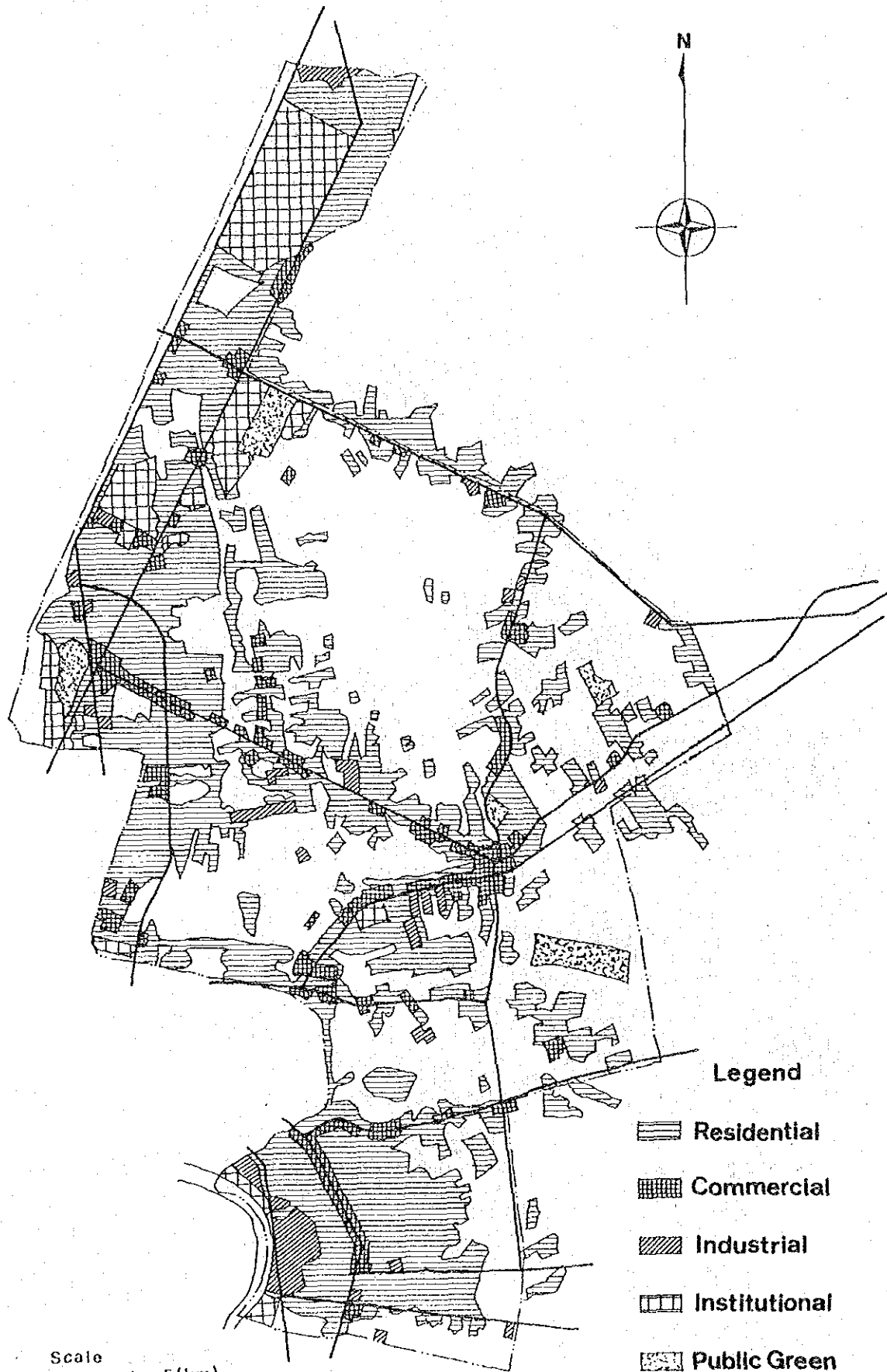


Fig. E.2

LAND USE IN MASTER PLAN AREA IN 1983

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

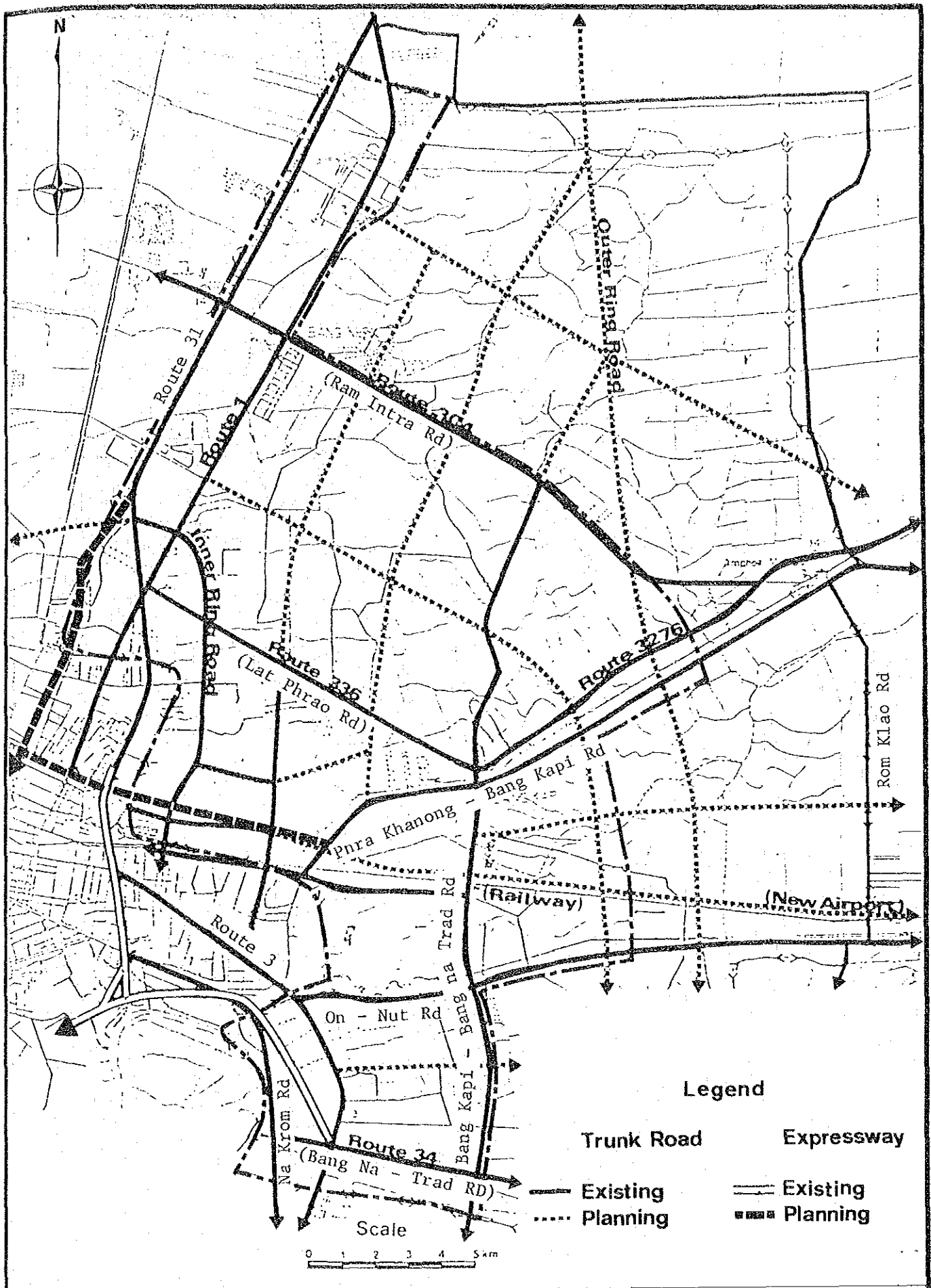
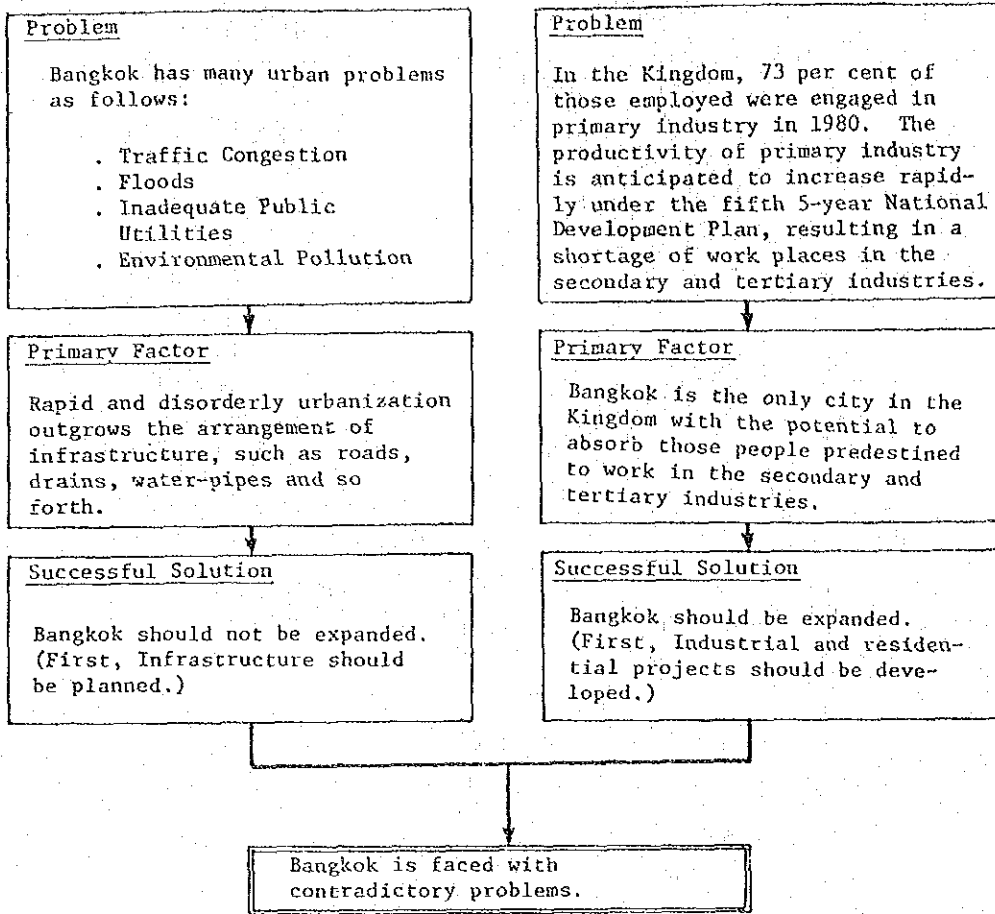


Fig. E.3

TRUNK ROAD NETWORK

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



To resolve these contradictory problems, the following three areas should be prepared:

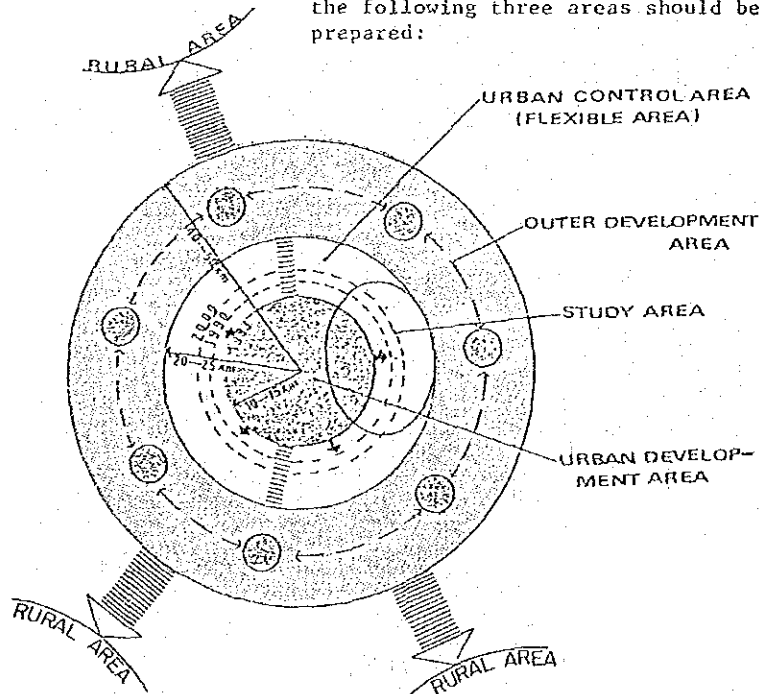


Fig. E.4

DEVELOPMENT POLICY FOR BANGKOK METROPOLIS

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

| Bangkok Metropolis | |
|--------------------|-----------|
| 1980 | 5,070,000 |
| 1990 | 6,400,000 |
| 2000 | 7,700,000 |

| Urban Core Area | |
|-----------------|---------|
| 1980 | 390,000 |
| 1990 | 320,000 |
| 2000 | 270,000 |

| Core Fringe Area | |
|------------------|-----------|
| 1980 | 2,580,000 |
| 1990 | 2,840,000 |
| 2000 | 3,070,000 |

| Suburban Area | |
|----------------|----------------|
| Study Area | Remaining Area |
| 1980 1,160,000 | 1980 940,000 |
| 1990 1,790,000 | 1990 1,450,000 |
| 2000 2,500,000 | 2000 1,860,000 |

- District Name
- . Phra Nakhon
 - . Pom Prap
 - . Sam Phan Thawong

- District Name
- . Patum Wan
 - . Bang Rak
 - . Yannawa
 - . Dusit
 - . Phayathai
 - . Thonburi
 - . Klong San
 - . Bangkok Noi
 - . Bangkok Yai

(Check)

| Estimated figures of the Chulalongkorn University for the Study Area in 2000 | |
|--|-------------|
| 1990 | : 1,850,000 |
| 2000 | : 2,700,000 |

Fig. E.5

PROJECTED POPULATION FOR CATEGORIZED AREAS

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

Estimated Population of the Bangkok Metropolis

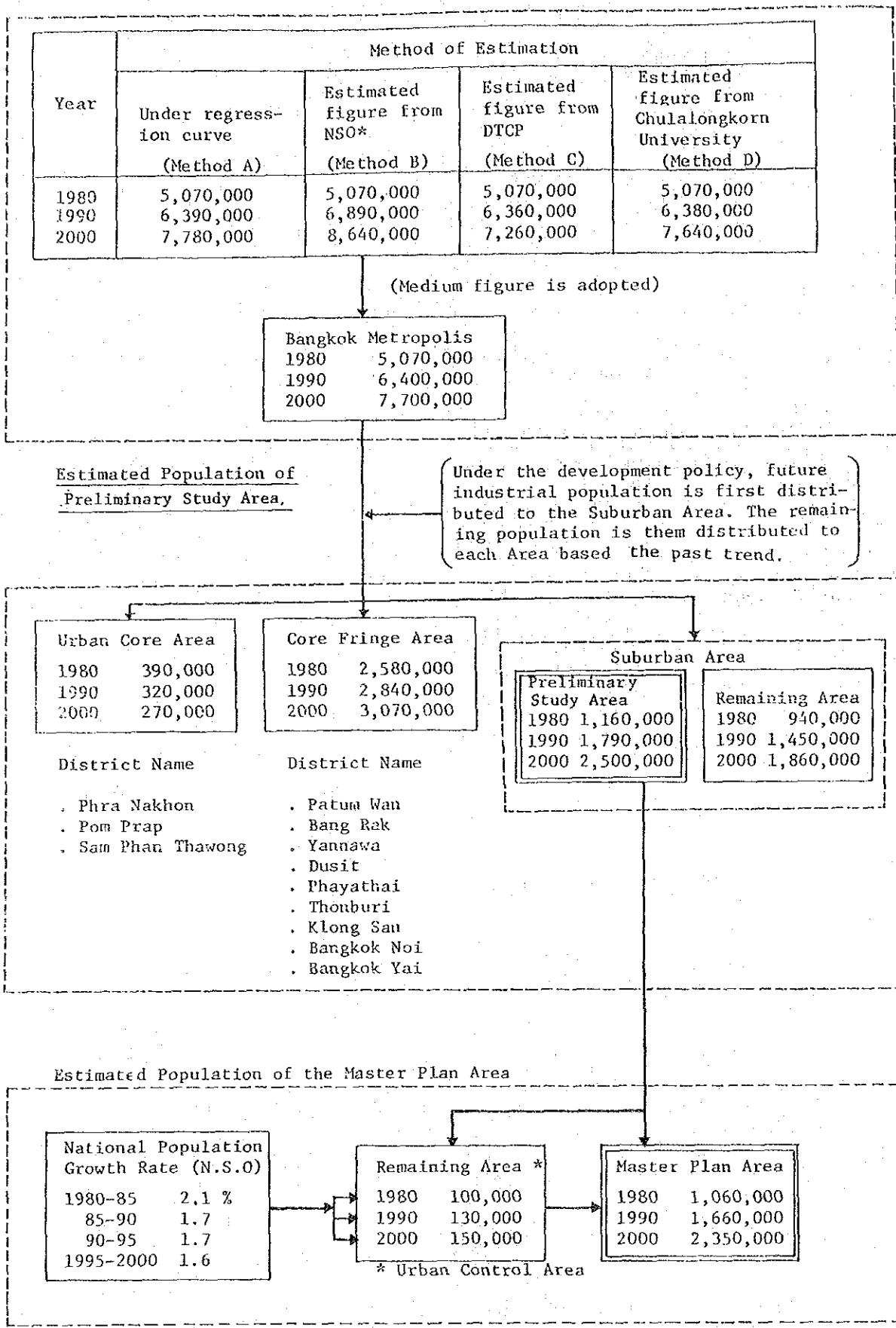


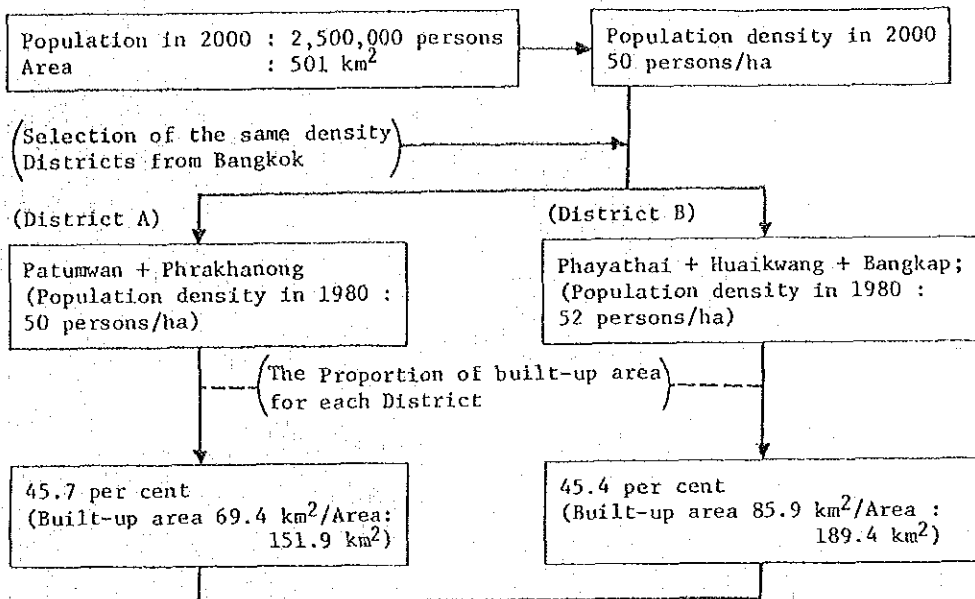
Fig. E.6

PROJECTED POPULATION FOR THE MASTER PLAN AREA

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

(Preliminary Study Area)

Method 1 : Estimation of the relationship between the existing population density and the built-up proportion in the Districts.



The built-up area within the Study Area is estimated to be 45 per cent

The urban area within the Study Area in the year 2000: 225 km²

Method 2 : The trend of built-up areas from 1960 to 1980.

Built-up area within the Study Area
1960 : 47 km²
1970 : 75 km²
1980 : 148 km²

(Regression Curve)

The urban area within the Study Area in 2000 : 242 km²

230 km² is adopted for the future urban area in 2000.

(Master Plan Area)

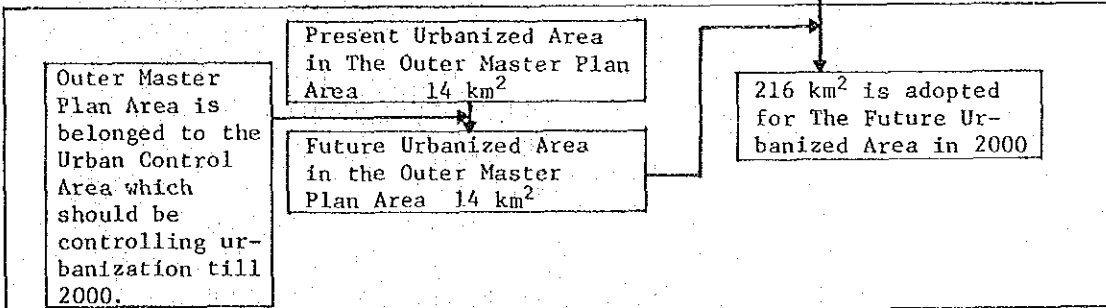
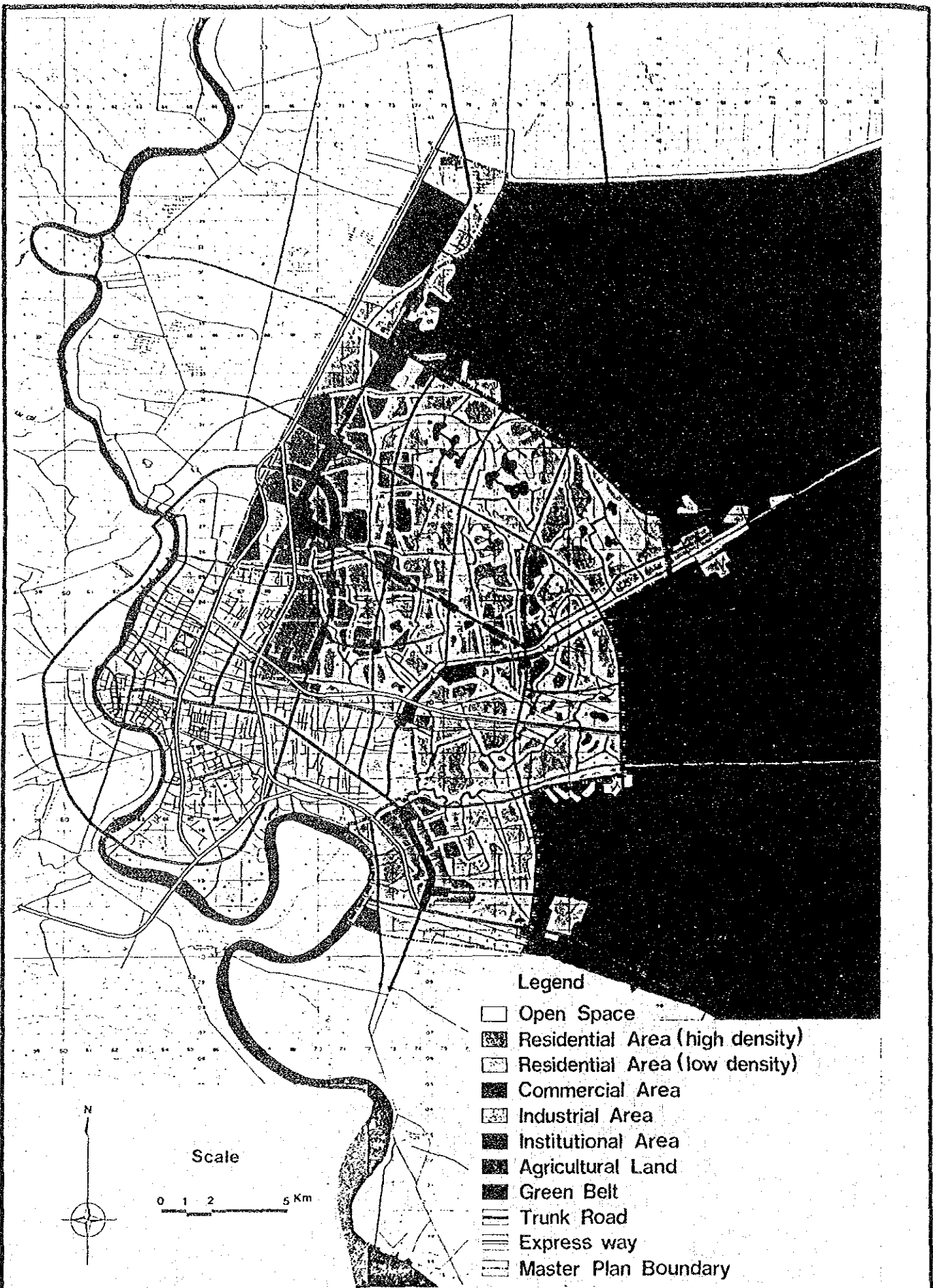


Fig. E.7

ESTIMATION OF THE FUTURE URBANIZED AREA IN THE MASTER PLAN AREA

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



LAND USE PLAN FOR MASTER PLAN AREA, 2000

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

APPENDIX F
HYDROLOGICAL SURVEY

APPENDIX F HYDROLOGICAL SURVEY

Table of Contents

| | | |
|----|--|------|
| 1. | General | F-1 |
| 2. | Data Collection | F-2 |
| | 2.1 Rainfall | F-2 |
| | 2.2 Water Level of Chao Phraya River and Main Klongs | F-9 |
| 3. | Rainfall | F-15 |
| | 3.1 General Characteristics | F-15 |
| | 3.2 Probability | F-22 |
| | 3.3 Rainfall Intensity-Duration Curve | F-22 |
| 4. | Water Level | F-25 |
| | 4.1 River Stage | F-25 |
| | 4.2 Klong Water Level | F-28 |

List of Table

| | | |
|--------------|--|------|
| Table F.1(1) | List of Rain Gauge Station | F-4 |
| Table F.1(2) | List of Rain Gauge Station | F-5 |
| Table F.1(3) | List of Rain Gauge Station | F-6 |
| Table F.1(4) | List of Rain Gauge Station | F-7 |
| Table F.2 | List of Rainfall Data Collected | F-8 |
| Table F.3 | List of Existing Water Stage Station | F-11 |
| | (Chao Phraya River) | |
| Table F.4(1) | List of Existing Water Stage Station (Klong) | F-12 |
| Table F.4(2) | List of Existing Water Stage Station (Klong) | F-13 |
| Table F.5 | List of River Stage Data Collected | F-14 |
| Table F.6 | Annual Rainfall in The Study Area | F-16 |
| Table F.7 | Annual Rainy Days in The Study Area | F-17 |
| Table F.8 | Average Monthly Rainfall at Each Station in | F-18 |
| | The Study Area | |
| Table F.9 | Monthly and Annual Rainfall Days in The Study Area ... | F-19 |
| Table F.10 | Monthly Rainfall for Heavy Flooded Year in 1978, 1980, 1982 and 1983 | F-21 |

| | | |
|------------|--|------|
| Table F.11 | Rainfall depth in mm and intensities in mm/hr for | F-23 |
| | various storm durations and return periods | |
| Table F.12 | Constant (a and b) Value in various return period | F-24 |
| Table F.13 | Tidal Information | F-26 |

List of Figures

| | | |
|-----------|--|------|
| Fig. F.1 | Location of Existing and Newly Installed Rain | F-30 |
| | Gauge Stations in and Around The Study Area | |
| Fig. F.2 | Representative Rain Gauge Stations and Thiessen | F-31 |
| | Polygon in The Study Area | |
| Fig. F.3 | Location of Existing Water Level Gauge Stations in ... | F-32 |
| | The Lower Chao Phraya River | |
| Fig. F.4 | Location of Existing and Newly Installed Water | F-33 |
| | Level Gauge Stations in The Main Klong | |
| Fig. F.5 | Annual Rainfall and Rainy Days in The Study Area | F-34 |
| | between 1951 and 1982 | |
| Fig. F.6 | Average Monthly Rainfall and Rainy Days | F-35 |
| | in The Study Area between 1951 and 1982 | |
| Fig. F.7 | Monthly & Accumulated Monthly Rainfall in the Study... | F-36 |
| | Area for Recent Flood Year, 1978, 1980 and 1982 | |
| Fig. F.8 | Weekly Rainfall in the Study Area between | F-37 |
| | Aug. and Sep. in 1978 and 1980 | |
| Fig. F.9 | Weekly Rainfall in the Study Area between | F-38 |
| | Aug. and Sep. in 1982 and 1983 | |
| Fig. F.10 | Average Areal Daily Rainfall in the Study Area | F-39 |
| | between Aug. and Nov. in 1978 and 1980 | |
| Fig. F.11 | Average Areal Daily Rainfall in the Study Area | F-40 |
| | between Aug. and Nov. in 1978 and 1980 | |
| Fig. F.12 | Time Distribution and Frequency of Daily Rainfall | F-41 |
| Fig. F.13 | Probability of Daily, 3-Day, Monthly, 3-Month and | F-42 |
| | Yearly Rainfall in the Study Area | |
| Fig. F.14 | Probability of Daily, 3-Day, Monthly, 3-Month and | F-43 |
| | Yearly Rainfall in the Study Area | |
| Fig. F.15 | Rainfall Intensity-Duration Curves | F-44 |
| Fig. F.16 | Annual H.H.W.L, M.W.L, L.L.W.L and Effect of Land | F-45 |
| | Subsidence on Water Level of Chao Phraya River | |
| Fig. F.17 | Annual H.H.W.L, M.W.L, L.L.W.L and Effect of Land | F-46 |
| | Subsidence of Water Level of Chao Phraya River | |

| | | |
|-----------|---|------|
| Fig. F.18 | Seasonal Changes of Rainfall in the Study Area and ... | F-47 |
| | Water Level at Bangkok Port in 1978 and 1980 | |
| Fig. F.19 | Seasonal Changes of Rainfall in the Study Area and ... | F-48 |
| | Water Level at Bangkok Port in 1982 and 1983 | |
| Fig. F.20 | Operation Record at Phra Khanong Flood Gate and Pump .. | F-49 |
| | between August and November in 1980 | |
| Fig. F.21 | Operation Record at Phra Khanong Flood Gate and Pump .. | F-50 |
| | between August and November in 1982 | |
| Fig. F.22 | Probable Yearly Water Level of Chao Phraya River | F-51 |
| Fig. F.23 | Probable Flood Water Level of Chao Phraya River | F-52 |

Appendix F HYDROLOGICAL SURVEY

1. General

The major hydrological cause of flood in the Master Plan Area was found to be a combination of the following:

- (1) Extreme rainfall
- (2) High water level in the Chao Phraya River
- (3) Inflow from outer areas
- (4) Insufficient drainage capacity

The study presented in this Appendix has been aimed at establishing the hydrological conditions, for a hydraulic study of the drainage system. The following tasks were therefore undertaken:

- (1) Collection of hydrological data, rainfall and water levels in the Chao Phraya River and main klongs.
- (2) Evaluation of the general characteristics of hydrological phenomena.
- (3) Estimation of hydrologic probability using frequency analysis.
- (4) Hydrologic observation of inflow from outer area.

Existing discharge capacity of klongs is estimated in Appendix C.

2. Data Collection

2.1 Rainfall

2.1.1 Existing and Newly Installed Rain Gauge Stations

A large number of rain gauge stations in and around the Master Plan Area have been installed by the Meteorological Department, DDS and other agencies. These stations are using either recording or non-recording type gauges.

DDS collects daily rainfall data from 63 gauging stations which use the rain gauges of the tipping bucket type. Unfortunately, as these stations were only established recently, in 1980 or 1981, rainfall data over a long period is not available.

The data of 73 existing rain gauge stations located around Bangkok area by the Meteorological Department are available. Their locations are indicated in Fig. F.1. Amongst the 73 stations, 12 stations are using automatic recording gauges and the others are non-recording gauges in manual type. Tables F.1 (1) to F.1 (4) list each station. The Core Area in Bangkok has the highest density of stations and west part of the Master Plan Area is also high. However, stations in the east, northeast and southeast parts are few.

In this study, two new automatic recording rain gauges have been installed at the Ramkhamhaeng Stadium and in the north-east at Kanayao police station for the following reasons.

- (a) At present a non-recording station of the manual type is located at Ramkhamhaeng University. It is, however, impossible to obtain the short duration rainfall intensity of 10, 20, 30, 60 minutes duration, which are needed for the hydrological study of the polder.

- (b) As before mentioned, the density of stations at north-east part in the Master Plan Area is very low. So one new rain gauge has been installed as a supplementary station.

2.1.2 Selection of Representative Rain Gauge Stations

It is required to provide reliable information, on not only the maximum spot rainfall but also the average areal rainfall.

In this Study, among 73 stations recorded by the Meteorological Department, 7 stations, i.e., Don Muang, Bang Khen, Bangkok, Bang Na, Bang Kapi, Min Buri and Lat Krabang are selected for the following reasons.

- (a) Judging from the scale of the Preliminary Study Area (501 km^2), 7 stations are adequate for the hydrological study.
- (b) Each station is to be selected in such way that they are evenly distributed over the Preliminary Study Area.
- (c) These stations should have reliable long-period rainfall data.

Their locations are shown in Fig. F.2.

For calculating the average areal rainfall in the Preliminary Study Area, Thiessen method, weighted mean method, is adopted. Fig. F.2 shows the Thiessen polygon and the area controlled by each station.

Table F.I.(1) : List of Rain Gauge Station

| No. | Name of Gauge Station | Name of Agency | Kind of Measuring | Established Year | Available Data | Remarks |
|-----|---|---------------------------|-------------------|------------------|----------------|---------|
| 1 | METEOROLOGICAL DEPARTMENT | METEOROLOGICAL DEPARTMENT | AUTOMATIC | 1965 | Hourly | |
| 2 | YANKAMES VITTHAYAKHOM SCHOOL | | " | 1970 | Daily | CANCEL |
| 3 | KIM NGUAN HUAD SHOP | " | " | 1977 | Daily | |
| 4 | KLANG HOSPITAL | " | " | 1977 | Daily | |
| 5 | PHISICAL TRAINING DEPARTMENT | " | " | 1977 | Daily | |
| 6 | DOMESTIC ANIMAL DEPARTMENT | " | " | 1977 | Daily | |
| 7 | FERTILIZER FACTORY OF BMA | " | " | 1977 | Daily | |
| 8 | RUNG RUANG COMMERCIAL SHOP | " | " | 1977 | Daily | CANCEL |
| 9 | ANALYSIS & EXPERIMENT SECTION OF THAILAND | " | " | 1977 | Daily | |
| 10 | PLUG SEK O'SOD FACTORY | " | " | 1965 | Daily | CANCEL |
| 11 | METEOROLOGICAL DEPARTMENT (BANGNA) | " | " | 1974* | Daily | |
| 12 | DON MUANG AIR PORT | " | " | 1966 | Daily | |
| 13 | BANG KHEN | " | " | 1977 | Daily | |
| 14 | PORT AUTHORITY OF THAILAND | " | " | 1974 | Daily | |
| 15 | PRA KHANONG WATER GAGE | " | NORMAL | 1974 | Daily | |
| 16 | SUKHUMVIT HOSPITAL | " | " | 1974 | Daily | |
| 17 | PRA KHANONG SCHOOL | " | " | 1977 | Daily | |
| 18 | FIRSTONE COMPANY | " | " | 1970 | Daily | |
| 19 | PRA PRADAENG DISTRICT | " | " | 1970 | Daily | |
| 20 | WAT YAI TA IN | " | " | 1974 | Daily | |
| 21 | CHONG NON TRI SCHOOL | " | " | 1974 | Daily | |
| 22 | RATSA BURANA DISTRICT | " | " | 1974 | Daily | |

Table F.1.1.(2) : List of Rain Gauge Station

| No. | Name of Gauge Station | Name of Agency | Kind of Measuring | Established Year | Available Data | Remarks |
|-----|---|----------------|-------------------|------------------|----------------|---------|
| 22 | THAILAND IRON WORK COMPANY | DEPARTMENT | NORMAL | 1977 | Daily | |
| 23 | SOMCHIT SUK SA SCHOOL | " | " | 1974 | Daily | |
| 24 | SOMDEJ CHAO PHRAYA TEACHER COLLEGE | " | " | 1974 | Daily | |
| 25 | KLONG SAN DISTRICT | " | " | 1974 | Daily | |
| 26 | BANGKOK CRISTAIN COLLEGE | " | " | 1974 | Daily | |
| 27 | ARMED FORCE ACADEMY PREPARATORY SCHOOL | " | " | 1974 | Daily | |
| 28 | THAI RED CROSS | " | " | 1977 | Daily | CANCEL |
| 29 | JARUSATHAIN STADIUM | " | " | 1974 | Daily | |
| 30 | MATER DEI SCHOOL | " | " | 1974 | Daily | |
| 31 | PHATUMWAN WATER GAGE | " | " | 1974 | Daily | |
| 32 | MANANGKASILA HOUSE | " | " | 1974 | Daily | |
| 33 | TECHNOLOGY & TRADITIONAL INSTITUTE (PO CHANG) | " | " | 1974 | Daily | |
| 34 | THE ROYAL HOUSEHOLD HALL | " | " | 1977 | Daily | |
| 35 | KOSITI SAMOSORN SCHOOL | " | " | 1974 | Daily | |
| 36 | SRI ULAI SCHOOL | " | " | 1974 | Daily | |
| 37 | MINISTRY OF EDUCATION | " | " | 1974 | Daily | |
| 38 | CHITLADA SCHOOL | " | " | 1974 | Daily | |
| 39 | WAR VETERANS ORGANIZATION OF THAILAND (NEAR VICTORY MONUMENT) | " | " | 1977 | Daily | |
| 40 | CHALERM SART SUKSA SCHOOL | " | " | 1974 | Daily | |
| 41 | BANGKAPHI TRANSFORMER STATION | " | " | 1974 | Daily | |

Table F.1.(3) : List of Rain Gauge Station

| No. | Name of Gauge Station | Name of Agency | Kind of Measuring | Established Year | Available Data | Remarks |
|-----|------------------------------------|----------------|-------------------|------------------|----------------|---------|
| 42 | KEHANAKORN HOUSING | DEPARTMENT | NORMAL | 1977 | Daily | |
| 43 | THUNG SETTHI VILLAGE | " | " | 1977 | Daily | CANCEL |
| 44 | BANGPLI TRANSFORMER STATION | " | " | 1956 | Daily | |
| 45 | LAT KRABANG DISTRICT | " | " | 1956 | Daily | |
| 46 | MINBURI DISTRICT | " | " | 1956 | Daily | |
| 47 | KLONG KUM SCHOOL | " | " | | Daily | |
| 48 | BANGKAPHI DISTRICT | " | " | 1956 | Daily | |
| 49 | RAMKHAMHAENG UNIVERSITY | " | " | 1974 | Daily | |
| 50 | CHANG KOL WITHAYA SCHOOL | " | " | 1974 | Daily | |
| 51 | KHUA KARUN NURSE SCHOOL | " | " | 1977 | Daily | |
| 52 | SIAM COMMERCIAL SCHOOL | " | " | 1974 | Daily | |
| 53 | SAMAKKEE SUTHAWART SCHOOL | " | " | 1977 | Daily | |
| 54 | YOTHIN BURANA SCHOOL | " | " | 1974 | Daily | |
| 55 | PUBLIC RELATION SCHOOL | " | " | 1974 | Daily | |
| 56 | CIVIL AVIATION TRAINING CENTER | " | " | 1974 | Daily | |
| 57 | DIN DEANG (DEPARTMENT OF SANITARY) | " | AUTOMATIC | 1970 | Daily | |
| 58 | CHAN HOON BAMPHEN SCHOOL | " | | | | CANCEL |
| 59 | KURU SAPHA PRINTING OFFICE | " | NORMAL | 1977 | Daily | |
| 60 | WAT BUNTHONG LANG SCHOOL | " | " | 1977 | Daily | |
| 61 | PATAWIKORNWITHAYA SCHOOL | " | " | 1977 | Daily | |
| 62 | TA KE DA FACTORY | METEOROLOGICA | " | 1977 | Daily | |
| 63 | WAT NUANCHAN (WAT = TEMPLE) | DEPARTMENT | " | 1977 | Daily | |
| 64 | BANLAIPRAO SCHOOL | " | " | 1970 | Daily | |

Table F.1.1.(4) : List of Rain Gauge Station

| No. | Name of Gauge Station | Name of Agency | Kind of Measuring | Established Year | Available Data | Remarks |
|-----|---|----------------|-------------------|------------------|----------------|---------|
| 65 | CHAN KASEM TEACHER COLLEGE | DEPARTMENT | NORMAL | 1974 | Daily | |
| 66 | MM. SUB DIVISION CAR CENTER | " | " | 1974 | Daily | |
| 67 | PHATHOMNINET SCHOOL | " | " | 1977 | Daily | |
| 68 | ELECTRICAL SUPPLY AUTHORITY | " | " | 1974 | Daily | |
| 69 | KEMAPHIRA TARAM SCHOOL | " | " | 1970 | Daily | |
| 70 | NONTHABURI PROVINCE OFFICE | " | " | 1974 | Daily | |
| 71 | NONTHABURI TECHICAL INSTITTUTE | " | " | 1974 | Daily | |
| 72 | NONTHABURI OVERSEAS RADIO RECEIVING STATION | " | " | 1974 | Daily | |
| 73 | CHEST HOSPITAL | " | " | | | CANCEL |
| 74 | ATOMIC ENERGY FOR PEACE | " | " | 1974 | Daily | |
| 75 | LAT PLA KAO SCHOOL | " | " | 1977 | Daily | |
| 76 | POLICE AVIATION DIVISION | " | " | 1977 | Daily | |
| 77 | BANGKHEN HEALTH CENTER | " | " | 1977 | Daily | |
| 78 | MAUNG THONG HOUSING | " | " | | | CANCEL |
| 79 | WAT LAKSI SCHOOL | " | " | 1977 | Daily | |
| 80 | WAT RATNIYOMTAM SCHOOL | " | " | 1977 | Daily | |
| 81 | BAN NUA MON SCHOOL | " | " | 1979 | Daily | |

Table F.2 List of Rainfall Data Collected

| No. | Type of Data | Length of Record |
|-----|---|------------------|
| 1. | Location map of rain gauge stations belong to Meteorological Dept. in Bangkok Area | |
| 2. | Annual and monthly rainfall in Bangkok Area | 1951 - 1983 |
| 3. | Daily rainfall data at | |
| | (1) Daon Muang | 1951 - 1983 |
| | (2) Bang Khen | 1967 - 1983 |
| | (3) Bangkok Metropolis | 1951 - 1983 |
| | (4) Bang Na | 1966 - 1983 |
| | (5) Bang Kapi | 1956 - 1983 |
| | (6) Min Buri | 1956 - 1983 |
| | (7) Lat Krabang | 1957 - 1983 |
| | (8) 43 stations | 1978, 1980, 1982 |
| 4. | Hourly rainfall data at Bangkok Metropolis | 1965 - 1982 |
| 5. | Annual maximum rainfall of durations varying from 5 mm. to 24 hours at Bangkok Metropolis | 1937 - 1982 |

2.1.3 Collection of Data

Annual, monthly and daily rainfall data at 7 stations are collected. Hourly and rainfall intensity data in the very short duration at Bangkok Station, the only such place where this kind of data is available around Bangkok, are collected. The list of all rainfall data collected is presented in Table F.2.

2.2 Water Level of Chao Phraya River and Main Klongs

2.2.1 Existing and Newly Installed Water Level Gauge Stations

(1) Chao Phraya River

At present, 12 existing water stage stations which belong to the Port Authority of Thailand (PAT), Hydrographic Department of Royal Thai Navy (HDRTN) and Royal Irrigation Department (RID) are located along the Lower Chao Phraya River from river mouth (0 km) to Bang Sai (110 km). Port Authority of Thailand (PAT) controls the stations in the marine area, downstream of the Chao Phraya River. Most of the stations started observing water stage, list of which is shown in Table F.3.

(2) Main Klongs

Existing water level stations which belong to DDS and RID along the klongs in the core of Bangkok and Preliminary Study Area are located at 30 points.

Most of the stations are located in the core and have been in use for only 2 years except Phra Khanong and Sam Rong Gate Stations of RID. Measurements are made by the usual staff gauge system except for one station (Padung Krung Kasem Pumping Station).

Fig. F.4 shows the location of existing gauging stations, and lists of these stations are shown in Tables F.4 (1) and F.4 (2).

In this Study, twelve new automatic recording water level gauges (eleven Richard type and one water pressure type) have been installed at the hydrologically important points in the Study Area taking into account:

- (a) As mentioned before, most of the DDS's existing gauging stations are inside the core area of Bangkok and there are few gauging stations in the Preliminary Study Area.
- (b) Information on the discharge flow of the main klongs in the directions east to west and north to south is required in the hydrological study.
- (c) The number of existing gauging stations and their data are insufficient to understand the hydraulic phenomenon which will be essential for the analysis.

The location of new gauging stations is indicated in Fig. F.4.

2.2.2 Collection of Data

River stage data were collected through DDS from PAT, HDRTN and RID for the hydraulic analyses. Water level data at main klongs were mainly collected at K. Tan pumping station (DDS), K. Phra Khanong Flood Gate (RID) and K. Sam Rong Flood Gate (RID). The list of all water level data collected is shown in Table F.5.

Table: F.3 List of Existing Water Stage Station (Chao Phraya River)

| No. | Name of Station | Name of Agency | Measuring System | Installed Year | Available Data | Remarks |
|-----|-------------------------|-------------------|------------------|----------------|----------------|---------|
| 1 | Bangkok Bar | Port Authority | Automatic | 1940 | Hourly data | |
| 2 | Fort Phrachul | " | " | " | " | |
| 3 | Pak Nam | " | " | " | " | |
| 4 | Phra Pra Daeng | " | " | " | " | |
| 5 | Bangkok Harbour | " | " | " | " | |
| 6 | Sathu Pradit | " | " | 1977 | " | |
| 7 | Memorial Bridge | RID | " | 1940 | " | |
| 8 | Hydrographic Department | Hydrographic Dep. | | | " | |
| 9 | RID Office | RID | | | " | |
| 10 | Rama VI Bridge | " | | | " | |
| 11 | Pak Kret | " | | | " | |
| 12 | Bang Sai | " | | | " | |
| | | | | | | |
| | | | | | | |

Table: F.4(1) List of Existing Water Stage Station (Klong)

| No. | Name of Station | Name of Agency | Measuring System | Established Year | Available Data | Remarks |
|-----|---|----------------|--------------------|------------------|----------------|----------------------|
| 1. | Rama 4 (Pm) | DDS | normal staff gauge | 1981 | hourly | |
| 2. | Klong Orachorn (Gk) | DDS | " | 1981 | hourly | |
| 3. | Klung Kasem (Pm) | DDS | Automatic | 1977 | hourly | GRAPH |
| 4. | Tewet (Ct) | DDS | normal stags gauge | - | " | Gate is under const. |
| 5. | Bang Lam Phu (Ct) | DDS | " | - | " | DATA COLLECTED |
| 6. | Ong Ang (Ct) | DDS | " | - | " | IN 1981 |
| 7. | Pak Klong Talat (Gk) | DDS | " | - | " | |
| 8. | Pra Pin Klao (Gk) | DDS | " | - | - | |
| 9. | Dusit (Ct) | DDS | " | 1981 | " | Not complete |
| 10. | Samsen (Ct) & Rama 6 (Ps) | DDS | " | 1982 | " | |
| 11. | Victory Monument (Ps) Saphan Phrom Yothi | DDS | " | 1982 | " | |
| 12. | (Ps) & Sump | DDS | " | 1981 | " | |
| 13. | Bang Sue (Ct) | DDS | " | 1982 | " | |
| 14. | Bang Khen (Ct) | DDS | " | 1982 | " | |
| 15. | Chong Non Tri (Ct) | DDS | " | - | - | Not collected data |

Table:F.4(2) List of Existing Water Stage Station (Klongs)

| No. | Name of Station | Agency | Measuring System | Established Year | Available Data | Remarks |
|-----|-----------------------------------|--------|--------------------|------------------|----------------|--------------------|
| 16. | Nang Lin Chi (P _s) | DDS | normal staff gauge | 1982 | hourly | |
| 17. | Sa Thu Pradit (P _s) | DDS | " | 1982 | " | |
| 18. | Klong Kruai | DDS | " | 1982 | " | |
| 19. | Saem Saep (C _t) | DDS | " | 1981 | " | |
| 20. | Klong Tan (P _s) | DDS | " | 1981 | " | |
| 21. | Ekamai (P _s) | DDS | " | 1982 | " | |
| 22. | Thong Lo (P _s) | DDS | " | 1982 | " | |
| 23. | Asoke (P _s) | DDS | " | 1982 | " | |
| 24. | Praksamakki (P _s) | DDS | " | 1982 | " | |
| 25. | Ban Kluai Thai (P _s) | DDS | " | 1981 | " | |
| 26. | Phra Kanong (P _s) | DDS | " | 1981 | " | |
| 27. | Klong Toi (C _t) | DDS | " | 1981 | " | |
| 28. | Klong Prakanong (C _k) | RID | " | | " | |
| 29. | Klong Kha Cha (C _t) | DDS | " | 1982 | - | Not collected data |
| 30. | Klong Sam Rong (C _k) | RID | " | | | |

Table F.5

List of River Stage Data Collected

| No. | Type of Data | Length of Record |
|-----|---|--|
| 1. | Location map of river stage stations of Lower Chao Phraya River. | |
| 2. | Hourly water levels month Aug.-Nov. at: (1) Bangkok Bar (2) Fort Phrachul (3) Pak Num (4) Phra Pra Daeng (5) Bangkok Port (Bangkok Harbour) (6) Sathu Pradit | 1970, 1975 - 1980 1970, 1975, 1978, 1980 1970, 1975, 1978, 1980 1970, 1975, 1978, 1980 1970, 1975, 1978 - 1983 1978, 1980 |
| 3. | Monthly H.H.W.L, M.W.L and L.L.W.L at: (1) Bangkok Bar (2) Fort Phrachul (3) Pak Num (4) Phra Pra Daeng (5) Bangkok Port (Bangkok Harbour) (6) Sathu Pradit (7) Hydrographic Department (except M.W.L) (8) Memorial Bridge (except M.W.L) (10) RID Sam Sen (except M.W.L) | 1940 - 1982 1940 - 1982 1940 - 1982 1940 - 1982 1940 - 1982 1976 - 1982 1940 - 1982 1940 - 1982 1942 - 1982 |
| 4. | Daily water Levels and discharge-flow at following stations of Chao Phraya River and Pa Sak River (1) Muang Nakhon Sawan (2) Bang Bang Kaeo | 1963, 1963, |

3. Rainfall

3.1 General Characteristics

3.1.1 Annual Rainfall and Rainy Days

According to the collected data between 1951 to 1982, the annual rainfall and rainy days in the preliminary Study Area is approximately 1,300 mm to 1,450 mm and 90 days to 130 days respectively. The former does not give a large difference at each gauging station except Bangkok Station, however, the latter rainfall gives a very different pattern at each station. Average areal annual rainfall in the Preliminary Study Area is calculated approximately 1,360 mm by means of arithmetic mean method. Tables F.6, F.7 and Fig. F.5 show the annual rainfall and rainy days in th Preliminary Study Area.

3.1.2 Monthly Rainfall and Rainy Days

The rainstorm in the Preliminary Study Area is under the influence of the seasonal monsoon wind. The rainy season prevails from mid-May to mid-October as the southwest monsoon brings in a stream of warm moist air from the Indian Ocean. During the rainy season approximately 85% or yearly rainfall is recorded, with 300 mm in September, 150 mm to 200 mm in May, June, July and October.

Tropical storms and depressions reach the Gulf of Thailand in August, September and October. However, the rainfall directly associated with these storms has much less intensity than the rainfall associated with the southwest monsoon.

Average monthly rainfall and rainy days in the Preliminary Study Area are shown in Tables F.8, F.9 and Fig. F.6.

Table F.6 Annual Rainfall in The Study Area

Unit : mm/year

| Station Year | Don Muang | Bang Khen | Bangkok | Bang Na | Bang Kapi | Minburi | Lat Krabang | Average Study Area |
|-----------------|-----------|-----------|---------|---------|-----------|-----------|-------------|--------------------------|
| 1951 | 1827.0 | - | 1647.0 | - | - | - | - | 1737.0 |
| 1952 | 1827.1 | - | 1516.0 | - | - | - | - | 1671.6 |
| 1953 | 1586.7 | - | 1584.0 | - | - | - | - | 1585.4 |
| 1954 | 1290.7 | - | 1495.0 | - | - | - | - | 1392.9 |
| 1955 | 1354.5 | - | 1508.8 | - | - | - | - | 1431.7 |
| 1956 | 1954.7 | - | 1371.9 | - | 1637.9 | 1618.8 | 1650.4 | 1646.7 |
| 1957 | 2051.0 | - | 1956.7 | - | 1843.4 | 2049.8 | 1835.9 | 1947.4 |
| 1958 | 1169.7 | - | 1296.5 | - | 1193.4 | 1342.4 | 1309.3 | 1262.3 |
| 1959 | 1544.1 | - | 1273.8 | - | 1592.0 | 1341.5 | 1277.5 | 1405.8 |
| 1960 | 1436.8 | - | 1646.0 | - | 801.2 | 1387.8 | 1401.5 | 1334.5 |
| 1961 | 1418.6 | - | 1449.2 | - | 987.3 | 1191.0 | 1581.5 | 1325.5 |
| 1962 | 1544.0 | - | 1377.0 | - | 1610.0 | 1343.0 | 1679.6 | 1510.7 |
| 1963 | 1513.0 | - | 1540.5 | - | 1616.5 | 1675.1 | 1821.2 | 1633.3 |
| 1964 | 1404.8 | - | 1858.6 | - | 1400.3 | 1612.5 | 1329.3 | 1521.1 |
| 1965 | 1302.0 | - | 1702.6 | - | 1756.8 | 1329.9 | 1533.4 | 1524.9 |
| 1966 | 1260.7 | - | 1667.3 | 1004.6 | 1394.4 | 896.3 | 1675.1 | 1316.4 |
| 1967 | 1454.1 | 1116.7 | 875.5 | 1133.3 | 1013.8 | 976.8 | 984.7 | 1079.3 |
| 1968 | 1250.9 | No Report | 1320.0 | 1334.9 | 1351.9 | 1558.6 | 1289.1 | 1350.9 |
| 1969 | 1193.5 | 1318.9 | 1135.0 | 1097.8 | 1055.9 | 1011.2 | 1127.9 | 1134.3 |
| 1970 | 1902.2 | 1492.6 | 1885.0 | 1408.9 | 1585.9 | 1706.0 | * 931.9 | 1558.9 |
| 1971 | 1223.9 | 1546.1 | 1483.9 | 1316.8 | 1402.1 | 1259.5 | * 753.4 | 1283.7 |
| 1972 | 1478.8 | 1827.3 | 1652.3 | 1682.7 | No Report | No Report | No Report | 1660.3 |
| 1973 | 901.0 | 1053.7 | 1089.9 | 1186.0 | 888.4 | 1225.9 | *575.2 | 1057.5 |
| 1974 | 1127.7 | 1399.6 | 1519.1 | 1213.0 | No Report | 1161.0 | No Report | 1284.1 |
| 1975 | 945.0 | 1538.0 | 1377.8 | 1114.6 | 1451.4 | 1552.1 | *483.9 | 1329.8 |
| 1976 | 1177.6 | 1652.8 | 1634.7 | 1535.2 | 1337.8 | 1530.4 | *421.2 | 1478.1 |
| 1977 | 885.8 | 1011.8 | 1040.1 | 1112.6 | 542.9 | 845.8 | *343.0 | 906.5 |
| 1978 | 1246.2 | 1100.2 | 1236.4 | 1300.8 | 1426.1 | 1362.7 | *479.4 | 1278.7 |
| 1979 | 584.9 | 967.9 | 1133.4 | 1134.3 | 1019.4 | 916.0 | *301.5 | 959.3 |
| 1980 | 1331.5 | 1407.7 | 1471.0 | 1279.9 | 1421.6 | 1416.5 | *434.7 | 1387.9 |
| 1981 | 1209.6 | 1380.2 | 1592.7 | 1506.5 | 1255.2 | 1440.6 | No Report | 1397.5 |
| 1982 | 1087.8 | 1615.9 | 1829.6 | 1453.7 | 1729.6 | 1443.4 | No Report | 1526.7 |
| Annual | 1358.9 | 1361.9 | 1474.0 | 1283.4 | 1334.0 | 1353.5 | 1364.6 | 1361.5 |

Note 1. The data in marked * should be not considered for calculating the Average Annual Rainfall.

2. Annual Rainfall in Study Area is calculated in arithmetic mean method.

Source : Meteorological Department

Table F.7 Annual Rainy Days in The Study Area

Unit : day/year

| Station Year | Don Muang | Bang Khen | Bangkok | Bang Na | Bang Kapl | Minburi | Lat Krabang | Average Study Area |
|-------------------|-----------|-----------|---------|---------|-----------|-----------|-------------|--------------------------|
| 1951 | 130 | | 126 | | | | | 128 |
| 1952 | 145 | | 143 | | | | | 144 |
| 1953 | 159 | | 152 | | | | | 156 |
| 1954 | 127 | | 132 | | | | | 130 |
| 1955 | 141 | | 126 | | | | | 134 |
| 1956 | 148 | | 137 | | 88 | 95 | 79 | 109 |
| 1957 | 140 | | 133 | | 79 | 86 | 87 | 105 |
| 1958 | 110 | | 125 | | 71 | 74 | 69 | 90 |
| 1959 | 124 | | 118 | | 61 | 74 | 93 | 118 |
| 1960 | 114 | | 123 | | 44 | 63 | 89 | 87 |
| 1961 | 143 | | 136 | | 81 | 72 | 81 | 103 |
| 1962 | 121 | | 121 | | 100 | 67 | 72 | 96 |
| 1963 | 132 | | 131 | | 92 | 78 | 78 | 102 |
| 1964 | 117 | | 150 | | 90 | 75 | 74 | 101 |
| 1965 | 126 | | 143 | | 97 | 100 | 80 | 109 |
| 1966 | 137 | | 141 | 85 | 100 | 112 | 96 | 112 |
| 1967 | 122 | 111 | 122 | 120 | 83 | 110 | 85 | 108 |
| 1968 | 124 | No Report | 118 | 115 | 79 | 106 | 64 | 101 |
| 1969 | 118 | 128 | 123 | 131 | 95 | 103 | 53 | 107 |
| 1970 | 133 | 136 | 153 | 147 | 99 | 92 | * 54 | 116 |
| 1971 | 119 | 117 | 132 | 129 | 80 | 78 | * 31 | 98 |
| 1972 | 113 | 112 | 146 | 131 | No Report | No Report | No Report | 126 |
| 1973 | 110 | 107 | 125 | 125 | 58 | 118 | *34 | 107 |
| 1974 | 113 | 123 | 139 | 116 | No Report | 87 | No Report | 116 |
| 1975 | 120 | 128 | 130 | 116 | 72 | 91 | *32 | 110 |
| 1976 | 119 | 120 | 139 | 123 | 80 | 104 | *24 | 114 |
| 1977 | 96 | 98 | 107 | 88 | 46 | 67 | *25 | 84 |
| 1978 | 114 | 128 | 133 | 102 | 74 | 93 | *37 | 107 |
| 1979 | 72 | 80 | 95 | 86 | 50 | 55 | *24 | 93 |
| 1980 | 108 | 106 | 109 | 90 | 88 | 94 | *36 | 99 |
| 1981 | 124 | 126 | 145 | 123 | 63 | 112 | * | 116 |
| 1982 | 110 | 134 | 139 | 125 | 83 | 107 | * | 116 |
| Annual Average | 123 | 117 | 131 | 115 | 78 | 89 | 74 | 104 |

- Note
1. The data in marked * should be not considered for calculating the Average Annual Rainy Days.
 2. Annual Rainy Days in Study Area is calculated in arithmetic mean method.

Source : Meteorological Department

Table F.8 Average Monthly Rainfall at Each Station and in the Study Area

Unit : mm/month

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Averages |
|-------------|------|------|------|------|-------|-------|-------|-------|-------|-------|------|------|-----------------|
| Don Muang | 6.9 | 19.2 | 31.6 | 62.3 | 162.8 | 154.3 | 164.4 | 205.8 | 287.1 | 212.8 | 37.5 | 14.2 | 1358.9 |
| Bang Khen | 8.7 | 10.5 | 22.3 | 85.6 | 186.5 | 164.4 | 188.6 | 190.4 | 280.2 | 157.1 | 50.3 | 17.3 | 1361.9 |
| Bangkok | 9.7 | 29.7 | 28.3 | 71.3 | 194.1 | 158.3 | 171.1 | 197.2 | 334.0 | 223.3 | 47.5 | 9.0 | 1474.0 |
| Bang Na | 10.8 | 30.0 | 19.3 | 70.3 | 195.4 | 135.5 | 134.3 | 160.0 | 275.5 | 174.9 | 65.2 | 12.2 | 1283.4 |
| Bang Kapi | 13.1 | 26.2 | 18.6 | 75.5 | 163.5 | 150.0 | 161.8 | 191.4 | 295.1 | 193.6 | 32.5 | 12.7 | 1334.0 |
| Minburi | 10.9 | 23.1 | 13.5 | 84.4 | 194.3 | 155.6 | 157.7 | 185.5 | 288.9 | 190.1 | 36.4 | 13.1 | 1353.5 |
| Lat Krabang | 7.5 | 23.9 | 12.7 | 75.6 | 191.3 | 154.2 | 165.6 | 216.3 | 293.7 | 193.9 | 37.2 | 14.5 | 1386.4 |
| Study Area | 9.7 | 23.2 | 20.9 | 75.0 | 184.0 | 153.3 | 163.4 | 192.4 | 293.5 | 192.2 | 43.8 | 13.3 | 1364.6 |

Note The period of monthly rainfall data in each station to be used is as follows.

- . (1) Don Muang : 1951 - 1982 (32 years)
- . (2) Bang Khen : 1967, 1969 - 1982 (15 years)
- . (3) Bangkok : 1951 - 1982 (32 years)
- . (4) Bang Na : 1966 - 1982 (17 years)
- . (5) Bang Kapi : 1956 - 1971, 1973, 1975 - 1982 (25 years)
- . (6) Minburi : 1956 - 1971, 1973 - 1982 (26 years)
- . (7) Lat Krabang : 1956 - 1971 (16 years)

Source : Meteorological Department

Table F.9 Monthly and Annual Rainfall Days in the Study Area

Unit : day/month

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Average |
|-------------|-----|-----|-----|-----|------|------|------|------|------|------|-----|-----|----------------|
| Don Muang | 1.2 | 2.3 | 3.0 | 6.2 | 14.6 | 15.2 | 17.6 | 19.5 | 20.9 | 15.2 | 5.7 | 1.5 | 122.9 |
| Bang Khen | 1.1 | 1.6 | 2.3 | 6.1 | 14.7 | 15.3 | 16.7 | 18.1 | 19.6 | 13.7 | 6.3 | 1.3 | 116.8 |
| Bangkok | 1.6 | 3.0 | 3.3 | 6.6 | 15.8 | 16.8 | 18.3 | 20.5 | 21.3 | 16.8 | 5.9 | 1.3 | 131.2 |
| Bang Na | 0.9 | 2.6 | 3.0 | 5.7 | 14.8 | 14.7 | 16.1 | 16.8 | 19.1 | 14.8 | 5.4 | 1.2 | 114.8 |
| Bang Kapi | 0.6 | 1.0 | 1.1 | 3.6 | 10.0 | 9.7 | 11.6 | 12.5 | 15.3 | 9.4 | 2.6 | 0.6 | 78.0 |
| Minburi | 0.5 | 1.3 | 1.4 | 4.1 | 11.8 | 10.8 | 13.5 | 14.3 | 16.3 | 10.9 | 3.1 | 0.6 | 88.6 |
| Lat Krabang | 0.3 | 1.4 | 0.6 | 3.8 | 10.0 | 8.6 | 10.1 | 11.8 | 15.3 | 9.1 | 2.4 | 0.7 | 74.1 |
| Study Area | 0.9 | 1.9 | 2.1 | 5.2 | 13.1 | 13.0 | 14.8 | 16.2 | 18.3 | 12.8 | 4.5 | 1.0 | 103.8 |

Note The period of monthly rainfall data in each station to be used is as follows.

- (1) Don Muang : 1951 - 1982 (32 years)
- (2) Bang Khen : 1967, 1969 - 1982 (15 years)
- (3) Bangkok : 1951 - 1982 (32 years)
- (4) Bang Na : 1966 - 1982 (17 years)
- (5) Bang Kapi : 1956 - 1971, 1973, 1975 - 1982 (25 years)
- (6) Minburi : 1956 - 1971, 1973 - 1982 (26 years)
- (7) Lat Krabang : 1956 - 1971 (16 years)

Source : Meteorological Department

3.1.3 Rainfall in Recent Heavy Floods

The recent heavy floods in Bangkok occurred in 1964, 1975, 1978, 1980, 1982 and 1983. In this Study, four heavy floods in 1978, 1980, 1982 and 1983 are selected as typical floods and monthly, weekly and daily rainfall data presented in Table F.10, Fig. F.7 to Fig. F.11 were collected.

For weekly and daily rainfall, areal variation of precipitation is observed and heavy rainfall, which is of rather short duration, is clearly observed to occur usually in a small limited area. In the hydrological analyses for the short term rainfall, it is, therefore, necessary to consider the areal characteristic of precipitation.

3.1.4 Duration and Time Distribution

The study of duration and time distribution for heavy rainfall was carried out by using 52 samples having values of more than 60 mm/day and 15 samples above 90 mm/day based on the hourly data at Bangkok Station between 1965 and 1980.

It is found that a rainfall duration having high frequency is within 9 hr. As for seasonal characteristics, the rainfall from April to July has a high frequency of short duration rainfalls and that of August to November has high frequency of both short duration and long duration. Fig. F.12 shows the time distribution and frequency of daily rainfall in Bangkok area.

Table P.10 Monthly Rainfall for Heavy Flooded Year in 1978, 1980, 1982 and 1983

Unit : mm/month

| Station | Item | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|-------------------------|---------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------------|-------|------|--------|
| Don Huang | Average | 6.9 | 19.2 | 31.6 | 62.3 | 162.3 | 154.3 | 164.4 | 205.8 | 287.1 | 212.8 | 37.5 | 14.2 | 1359 |
| | 1978 | 6.1 | 103.3 | 0 | 18.0 | 237.7 | 79.7 | 294.7 | 96.1 | 289.9 | 117.6 | 3.1 | 0 | 1246 |
| | 1980 | 0 | 0 | 12.7 | 22.5 | 96.9 | 238.4 | 89.2 | 196.6 | 394.3 | 224.3 | 56.6 | 0 | 1332 |
| | 1982 | 0 | 0 | 27.5 | 157.6 | 153.7 | 198.7 | 95.6 | 93.9 | 156.4 | 172.1 | 30.7 | 1.4 | 1088 |
| | 1983 | 0 | 0 | 0 | 0 | 198.6 | 135.3 | 160.5 | 414.3 | 237.2 | 267.0 | 44.2 | 15.0 | 1522 |
| Bangkhen | Average | 8.7 | 10.5 | 22.3 | 85.6 | 186.5 | 164.4 | 188.6 | 190.4 | 280.2 | 157.1 | 50.3 | 17.3 | 1362 |
| | 1978 | 32.0 | 57.5 | 0 | 41.6 | 173.3 | 116.1 | 307.3 | 73.9 | 239.7 | 48.9 | 9.9 | 0 | 1102 |
| | 1980 | 0 | 0 | 25.4 | 42.2 | 117.5 | 336.7 | 158.5 | 157.8 | 325.0 | 176.2 | 68.4 | 0 | 1408 |
| | 1982 | 0 | 0.5 | 82.2 | 179.5 | 238.2 | 225.1 | 230.2 | 144.6 | 183.6 | 272.4 | 57.6 | 2.0 | 1616 |
| | 1983 | 0 | 0 | 5.5 | 0 | 172.8 | 169.2 | 185.6 | 515.7 | 430.5 | 350.7 | 160.7 | 14.9 | 2006 |
| Bangkok | Average | 9.7 | 29.7 | 28.3 | 71.3 | 194.1 | 158.8 | 171.1 | 197.2 | 334.0 | 223.3 | 47.5 | 9.0 | 1474 |
| | 1978 | 23.5 | 103.6 | 1.0 | 13.0 | 245.3 | 255.2 | 135.1 | 81.9 | 274.7 | 102.5 | 0.6 | 0 | 1236 |
| | 1980 | 0 | 0.3 | 4.0 | 52.5 | 29.9 | 267.5 | 205.5 | 200.6 | 352.3 | 324.5 | 33.9 | 0 | 1471 |
| | 1982 | 0 | 19.7 | 176.0 | 223.2 | 235.5 | 187.8 | 199.2 | 220.7 | 254.8 | 248.8 | 44.3 | 19.6 | 1830 |
| | 1983 | 0.3 | 0 | 29.0 | 0 | 47.7 | 161.4 | 230.2 | 574.5 | 453.8 | 487.7 | 131.8 | 13.6 | 2130 |
| Bang Na | Average | 10.8 | 30.0 | 19.3 | 70.3 | 195.4 | 135.5 | 134.3 | 160.0 | 275.5 | 174.9 | 65.2 | 12.2 | 1283 |
| | 1978 | 51.7 | 140.5 | 0 | 8.4 | 249.7 | 132.8 | 91.3 | 58.1 | 484.8 | 74.7 | 8.8 | 0 | 1301 |
| | 1980 | 0 | 0 | 3.8 | 61.1 | 22.9 | 242.5 | 66.3 | 275.6 | 259.4 | 326.2 | 22.1 | 0 | 1280 |
| | 1982 | 0 | 11.7 | 51.1 | 157.7 | 148.1 | 182.5 | 193.7 | 171.5 | 194.9 | 242.0 | 98.5 | 2.0 | 1454 |
| | 1983 | 0 | 0 | 46.2 | 0 | 35.4 | 112.3 | 104.8 | 556.7 | 293.4 | 325.7 | 128.8 | 0 | 1603 |
| Bang Kapi | Average | 13.1 | 26.2 | 18.6 | 75.5 | 163.5 | 150.0 | 161.8 | 191.4 | 295.1 | 193.6 | 32.5 | 12.7 | 1334 |
| | 1978 | 147.5 | 92.0 | 0 | 40.2 | 233.8 | 114.1 | 220.6 | 95.5 | 340.3 | 139.7 | 2.4 | 0 | 1426 |
| | 1980 | 0 | 0 | 0 | 38.5 | 117.2 | 342.5 | 124.3 | 202.9 | 300.6 | 273.8 | 20.8 | 0 | 1421 |
| | 1982 | 0 | 0 | 105.0 | 159.7 | 108.7 | 147.1 | 172.8 | 176.4 | 323.1 | 334.5 | 102.7 | 0 | 1730 |
| | 1983 | 0 | 0 | 0 | 0 | 124.1 | 107.0 | 157.3 | 510.6 | 335.2 | out of order | 251.1 | 0 | 1564 |
| Minburi | Average | 10.9 | 23.1 | 13.5 | 84.4 | 194.3 | 155.6 | 157.7 | 185.5 | 288.9 | 190.1 | 36.4 | 13.1 | 1354 |
| | 1978 | 15.9 | 129.4 | 0 | 96.2 | 239.7 | 76.6 | 170.0 | 110.9 | 376.2 | 121.4 | 25.4 | 0 | 1363 |
| | 1980 | 0 | 0 | 20.9 | 85.7 | 133.9 | 165.8 | 202.7 | 143.0 | 315.2 | 335.5 | 13.8 | 0 | 1417 |
| | 1982 | 0 | 0 | 34.6 | 136.7 | 188.3 | 194.6 | 178.2 | 206.4 | 312.2 | 162.8 | 29.6 | 0 | 1443 |
| | 1983 | 0 | 0 | 0 | 0 | 208.3 | 134.4 | 157.5 | 304.8 | 320.1 | 205.7 | 85.8 | 0 | 1417 |
| Average Area & Rainfall | Average | 9.7 | 23.2 | 20.9 | 75.0 | 184.0 | 153.3 | 163.4 | 192.4 | 293.5 | 192.2 | 43.8 | 13.3 | 1365 |
| | 1978 | 60.0 | 103.8 | 0 | 43.8 | 229.1 | 110.1 | 212.6 | 90.0 | 321.4 | 119.2 | 9.5 | 0 | 1319 |
| | 1980 | 0 | 0 | 11.2 | 50.8 | 100.9 | 269.5 | 137.5 | 191.5 | 318.9 | 274.3 | 32.9 | 0 | 1388 |
| | 1982 | 0 | 2.6 | 70.1 | 189.0 | 164.4 | 184.2 | 175.0 | 166.7 | 252.9 | 246.6 | 65.1 | 1.7 | 1517 |
| | 1983 | 0 | 0 | 8.5 | 0 | 146.7 | 130.3 | 158.6 | 460.4 | 331.5 | 213.8 | 104.6 | 5.2 | 1560 |

3.2 Probability

Probability of both spot and average areal rainfall in the Preliminary Study Area against daily, 3-day, monthly, 3-month was calculated to obtain the design rainstorm for the divided polder and overall drainage system.

Based on the annual maximum rainfall, the probability obtained was plotted on lognormal probability paper. The plots are presented in Figs. F.13 to F.14 by the least squares method with Thomas plotting.

It is found that the frequency of average areal rainfall in the Preliminary Study Area is approximately 30% less than that of spot rainfall. This means that a precipitation does not fall over the entire Preliminary Study Area.

3.3 Rainfall Intensity-Duration Curve

Based on the rainfall of short duration at Bangkok Station between 1937 and 1982, the probable rainfall of 5, 10, 15 and 30 minutes and 1, 2, 6, 12 and 24 hours duration were estimated by means of the least squares method with Thomas plotting. The probable rainfall depth for various return periods are summarised in Table F.11.

Table F. 11 Rainfall depth in mm and intensities in mm/hr for various storm durations and return periods

| Return period in Years | Stormduration | | | | | | | | |
|------------------------|-----------------|-----------------|-----------------|-----------------|----------------|-----------------|-----------------|-----------------|----------------|
| | 5 min | 10 min | 15 min | 30 min | 1 hr | 2 hrs | 6 hrs | 12 hrs | 24 hrs |
| 2 | 11.3 (135.5) | 20.2 (121.1) | 25.0 (99.8) | 42.5 (84.9) | 58.7 (58.7) | 72.4 (36.2) | 85.8 (14.3) | 90.0 (7.5) | 93.6 (3.9) |
| 5 | 14.1 (168.9) | 25.3 (152.0) | 31.7 (126.7) | 54.3 (108.6) | 76.0 (76.0) | 95.0 (47.5) | 114.0 (19.0) | 120.0 (10.0) | 122.4 (5.1) |
| 7 | 14.9 (178.3) | 26.9 (161.4) | 33.7 (134.9) | 58.0 (115.9) | 81.5 (81.5) | 102.2 (51.1) | 123.0 (20.5) | 129.6 (10.8) | 134.4 (5.6) |
| 10 | 15.7 (188.3) | 28.4 (170.2) | 35.7 (142.7) | 61.5 (122.9) | 86.8 (86.8) | 109.2 (54.6) | 132.0 (22.0) | 139.2 (11.6) | 144.0 (6.0) |
| 20 | 17.1 (204.9) | 31.0 (185.9) | 39.2 (156.9) | 67.9 (135.7) | 96.5 (96.5) | 122.4 (61.2) | 149.4 (24.9) | 157.2 (13.1) | 163.2 (6.8) |

(--) average rainfall intensities in mm/hr

The rainfall intensity-duration formula was adopted by the Talbat Type.

$$I = \frac{a}{t+b}$$

Where I = rainfall intensity (mm/hr)
 t = duration (min)
 a,b = constant based on the areal characteristics

The constants, a and b, in the rainfall intensity-duration formulas for various return period were estimated by means of the least squares method. The result is indicated in Table F.12.

Table F.12 Constant (a and b) Value in various return period.

| Constant | Return Period in Years | | | | |
|----------|------------------------|-------|-------|-------|--------|
| | 2 | 5 | 7 | 10 | 20 |
| a | 5,690 | 7,600 | 8,230 | 8,850 | 10,040 |
| b | 37 | 40 | 41 | 42 | 44 |

The rainfall intensity-duration curves for various return period are shown in Fig F.15.

4. Water Level

4.1 River Stage

4.1.1 Tidal Range and the Discharge from the Preliminary Study Area

Klongs in the Preliminary Study Area is within the tidal zone of the Chao Phraya River and the discharge from the Preliminary Study Area is affected by the River stage. According to the tidal information presented in Table F.13 (obtained from P.A.T), mean tidal range at Bangkok Port, located at the mouth of Klong Phra Khanong is as follows:

$$\begin{aligned} \text{M.T.R} &= \text{M.H.W} - \text{M.L.W} \\ &= 0.89 - (-0.71) = 1.60 \text{ m} \end{aligned}$$

where, M.T.R = mean tidal range in metres

M.H.W = mean high water level in metres MSL

M.L.W = mean low water level in metres MSL

Judging from the relationship between M.H.W, M.L.W and the existing average ground elevation in the Preliminary Study Area (0.5 m and 0.7 m in the Master Plan and Retention Area respectively) gravity discharge is not always expected. Especially, as the land subsidence is expected to continue further, gravity discharge must gradually be replaced by pump discharge.

4.1.2 Annual H.H.W.L, M.W.L AND L.L.W.L

Annual H.H.W.L, M.W.L and L.L.W.L at five gauging stations (of P.A.T, Hydrographic Dept. and RID) were studied based on the water level data during the period 1940 to 1982. As a result of the study, the following data was determined.

Table F.13 TIDAL INFORMATION

Unit : Meter above Mean Sea Level

| STATION TIDES | BANGKOK BAR | FORT PHRACHUL | PAKNAM | PHRA PRADAENG | BANGKOK HARBOUR | MEMORIAL BRIDGE | HYDROGRA F.L.C. DEPT. | RID OFF. | RAMA VI BRIDGE | PAKKEET | BANGSAI |
|------------------------------------|--------------------|--------------------|--------------------|---------------------------------|--------------------|--------------------|--------------------------|----------|-------------------|---------|--------------------|
| HIGHEST HIGH WATER | +2.28 (1970.12) | +2.22 (1970.12) | +2.04 (1970.12) | +1.93 (1970.12) (1978.10) | +1.93 (1978.10) | +2.27 (1942.10) | +2.42 (1942.10) | | | | +3.99 (1942.10) |
| MEAN HIGH WATER SPRING | +1.41 | +1.39 | +1.35 | +1.31 | +1.28 | | | | | | |
| MEAN HIGH WATER NEAP | +0.95 | +0.94 | +0.97 | +0.95 | +0.95 | | | | | | |
| MEAN HIGH WATER | +0.94 | +0.95 | +0.91 | +0.94 | +0.89 | | | | | | |
| MEAN TIDE LEVEL | +0.09 | +0.13 | +0.11 | +0.17 | +0.23 | | | | | | |
| MEAN SEA LEVEL (KOLAK STANDARD) | +0.00 | +0.00 | +0.00 | +0.00 | +0.00 | +0.00 | +0.00 | | | | +0.00 |
| MEAN LOW WATER | -0.78 | -0.63 | -0.65 | -0.54 | -0.48 | | | | | | |
| MEAN LOW WATER NEAP | -0.88 | -0.83 | -0.75 | -0.72 | -0.71 | | | | | | |
| MEAN LOW WATER SPRING | -1.48 | -1.29 | -1.22 | -1.15 | -1.04 | | | | | | |
| LOWEST LOW WATER | -2.42 (1956.7) | -1.79 (1956.7) | -1.90 (1968.7) | -1.78 (1967.5) | -1.72 (1968.7) | -1.75 (1964.8) | -1.74 (1964.8) | | | | -1.38 (1963.7) |
| MEAN SPRING RANGE | 2.90 | 2.67 | 2.57 | 2.45 | 2.34 | | | | | | |
| MEAN NEAP RANGE | 1.83 | 1.76 | 1.71 | 1.66 | 1.66 | | | | | | |
| MEAN RANGE | 2.44 | 2.24 | 2.18 | 2.04 | 1.99 | | | | | | |

- (a) Annual mean water levels (M.W.L) at three stations of PAT were almost the same as before 1968. However, they have been increasing every year at almost the same rate. Annual MWL of 1983 is higher by 0.3 to 0.4 metres than those of before 1968.
- (b) It is considered that this increase has been caused by land subsidence at the stations. According to a check survey by the Study Team, the mean sea level recorded at Bangkok Port is 0.39 m higher than the corrected actual level in August 1983.
- (c) Therefore, P.A.T's water level data must be adjusted between 1968 and 1983. In this Study, a linear trend was assumed and the data were corrected.
- (d) The data of Memorial Bridge (Hydrographic Dept.) and RID Sam Saem Station, were adjusted based on the NEDECO Report of Core Project in February, 1984.

Annual H.H.W.L, M.W.L, L.L.W.L at five stations between 1940 and 1982 and effect of land subsidence on water level of Chao Phraya River during 1968 to 1982 are shown in Fig. F.17 and Fig. F.18.

- 4.1.3 Seasonal Variation at Water Level in the Chao Phraya River
- The water level in the Chao Phraya River usually begins to rise gradually near the end of August, reaching a peak in November and after that, falling slowly until the end of December. This phenomenon is mainly caused by the run-off from the upper reaches of the Chao Phraya River and the tides in the Gulf of Thailand.

Fig. F.19 and Fig. F.20 present the seasonal variation of the water level at Bangkok Port in the typical flood year, 1978, 1980, 1982 and 1983.