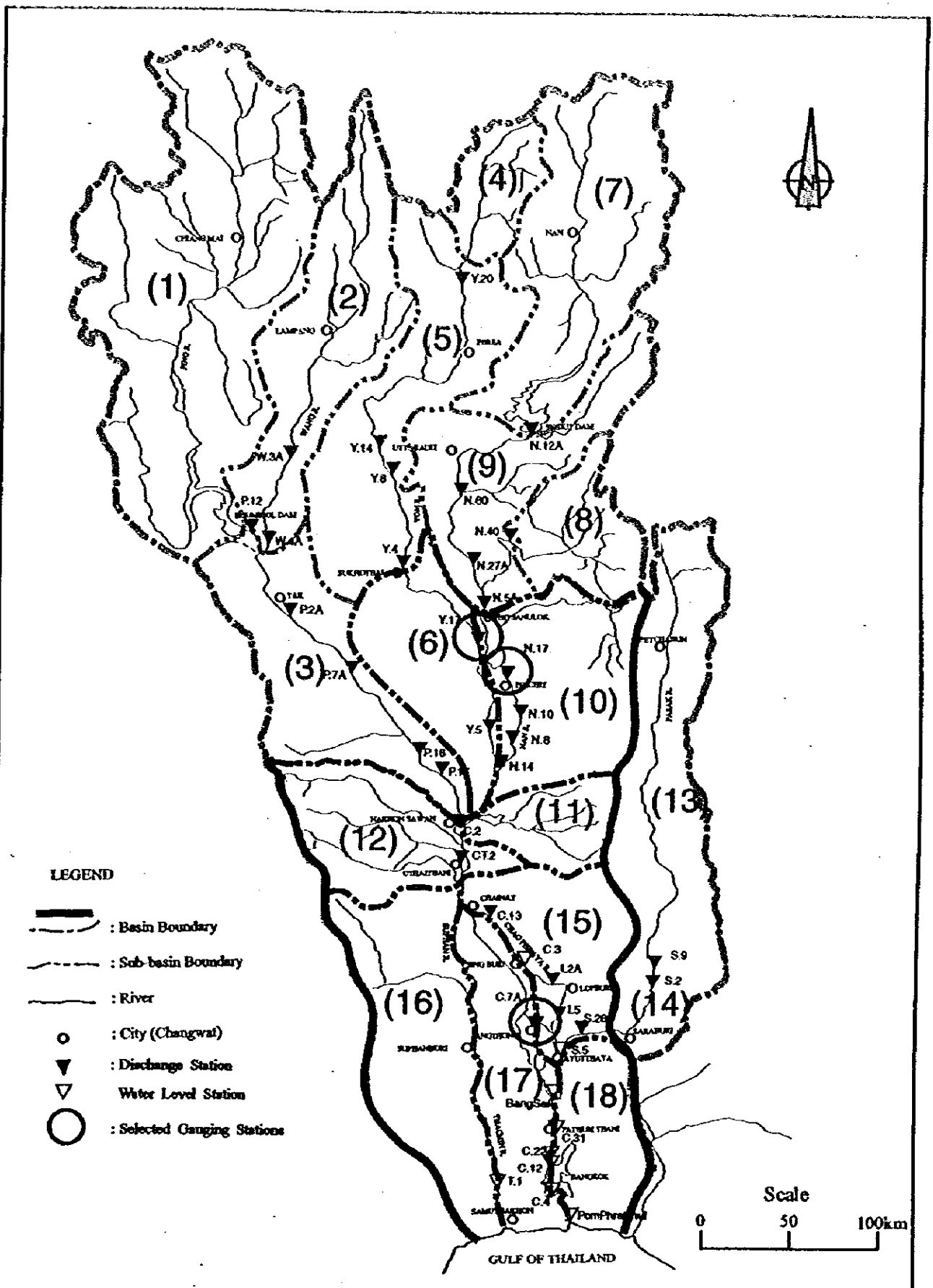
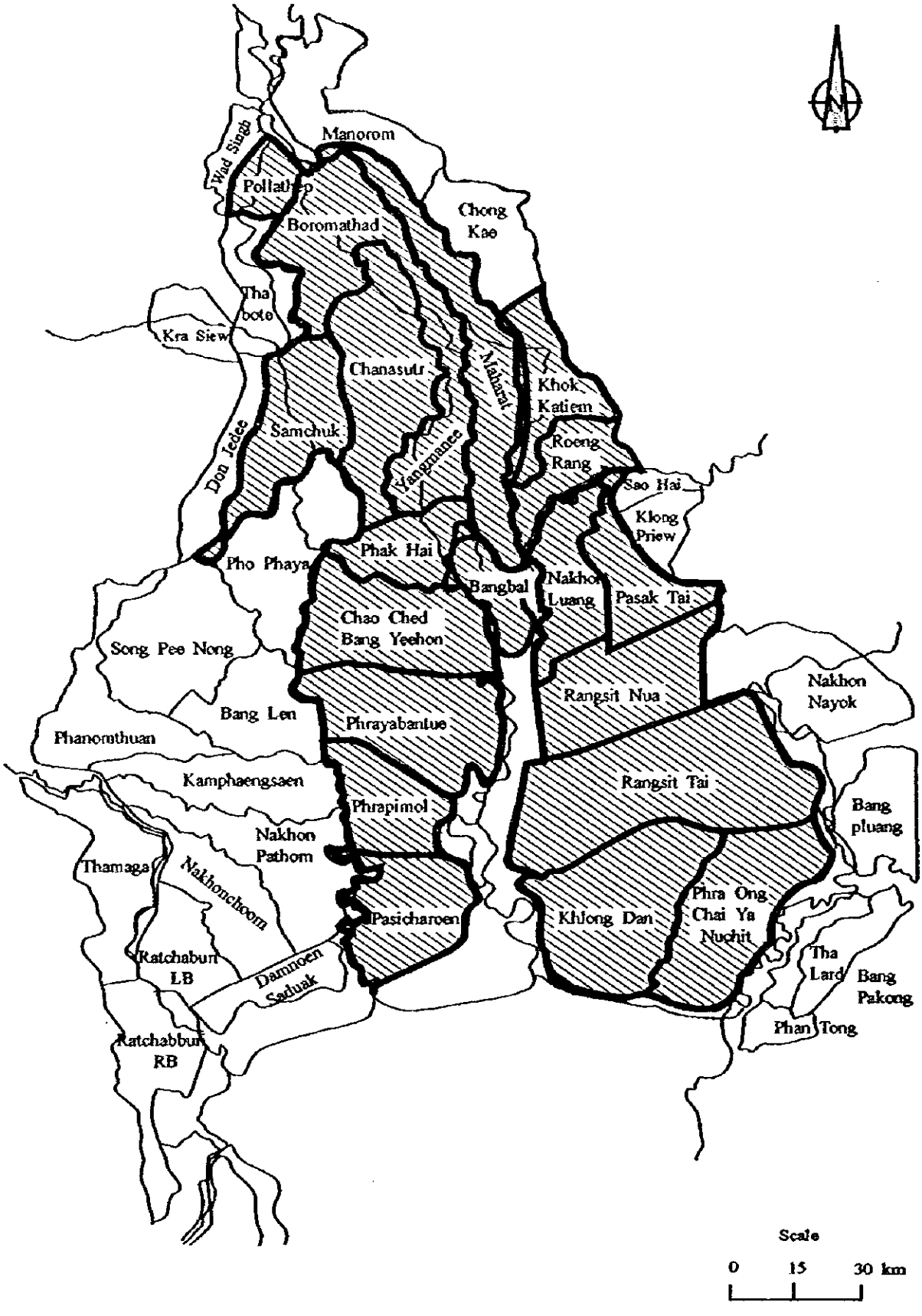
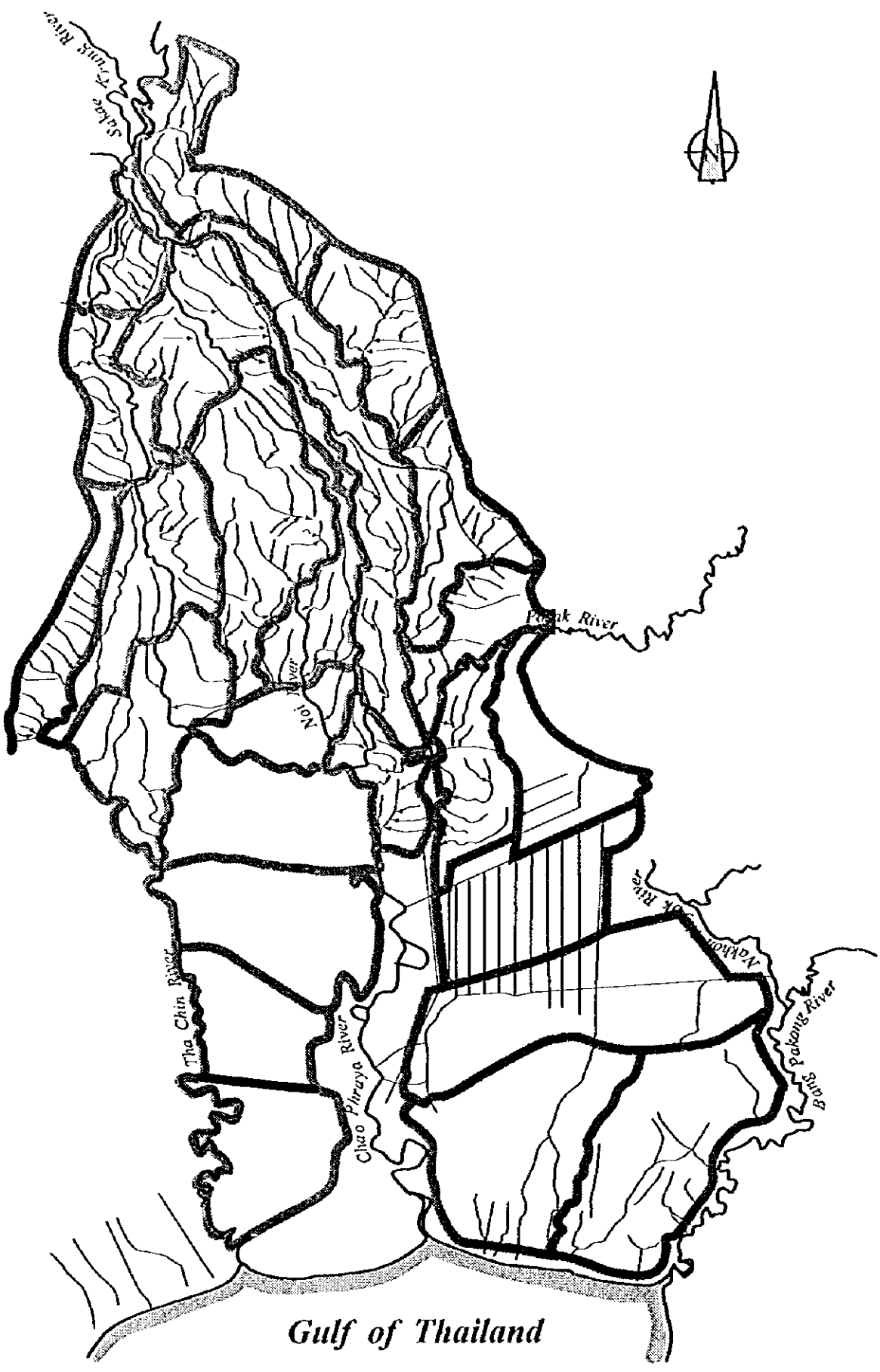


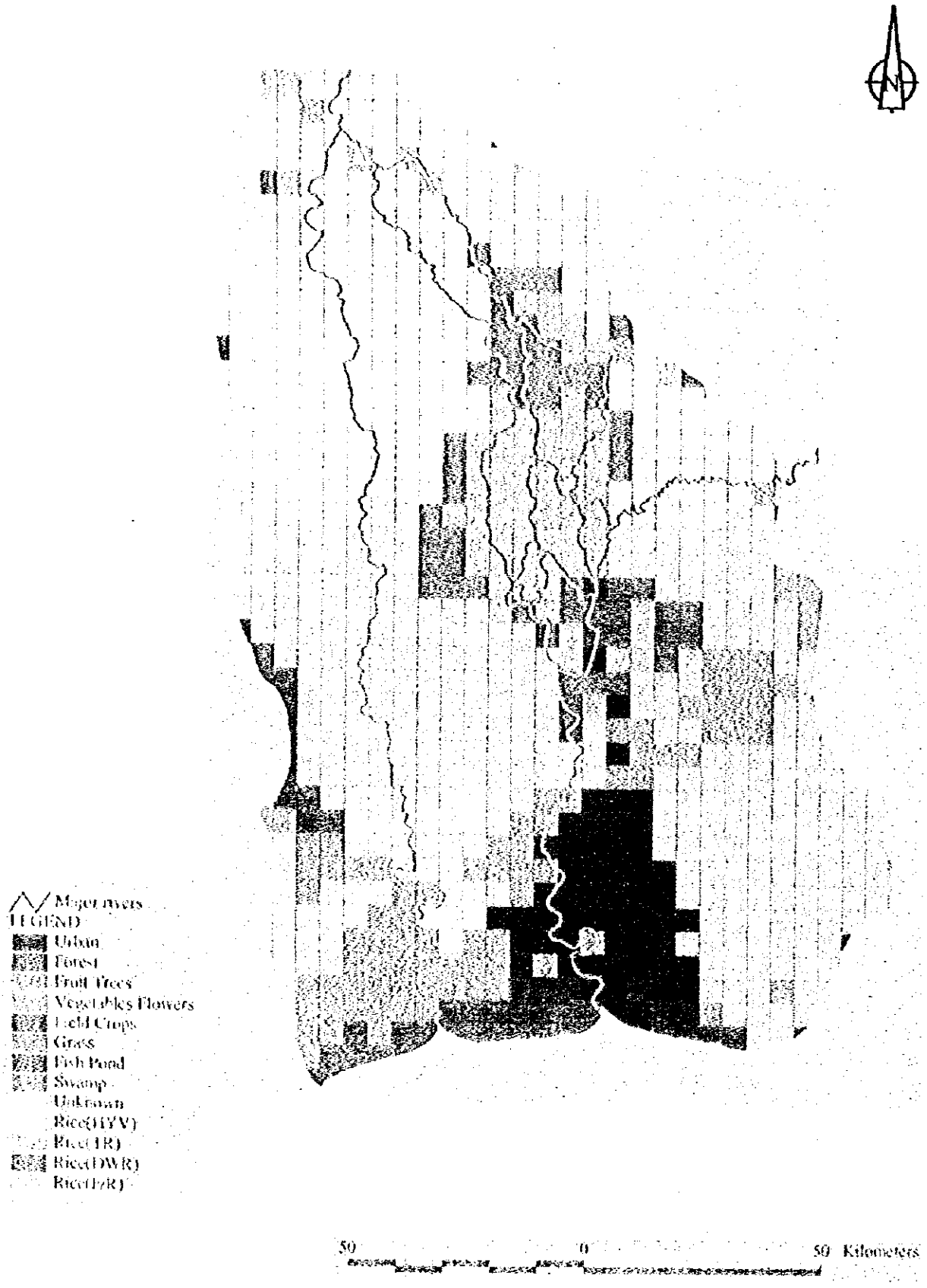
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 6.3.2 AVERAGE RAINFALL BASIN SELECTED GAUGING STATIONS
CTI ENGINEERING CO., LTD AND INA CORPORATION	



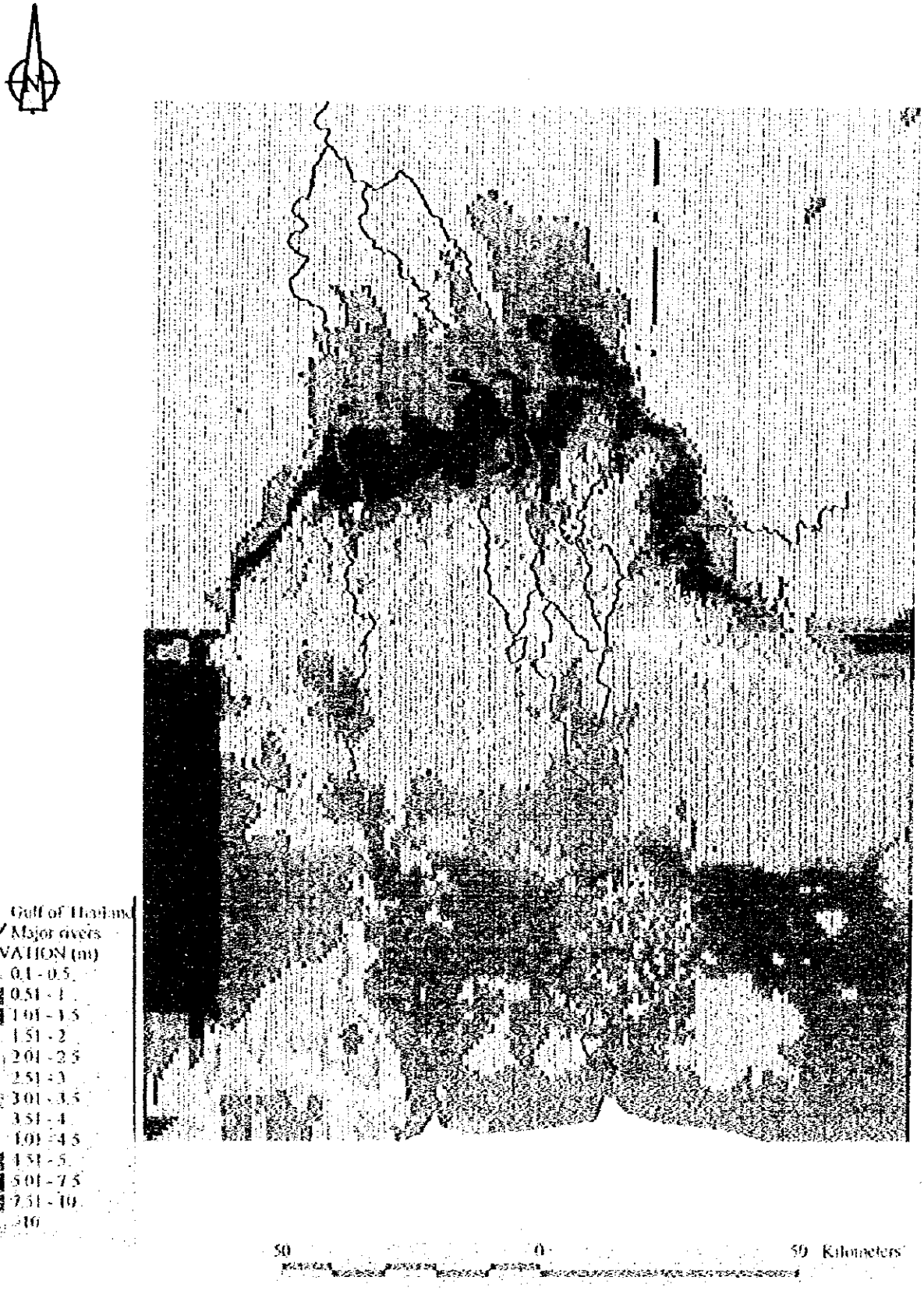
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig.7.1.1 OBJECTIVE AREA FOR DRAINAGE SYSTEM IMPROVEMENT
CTI ENGINEERING CO., LTD AND INA CORPORATION	



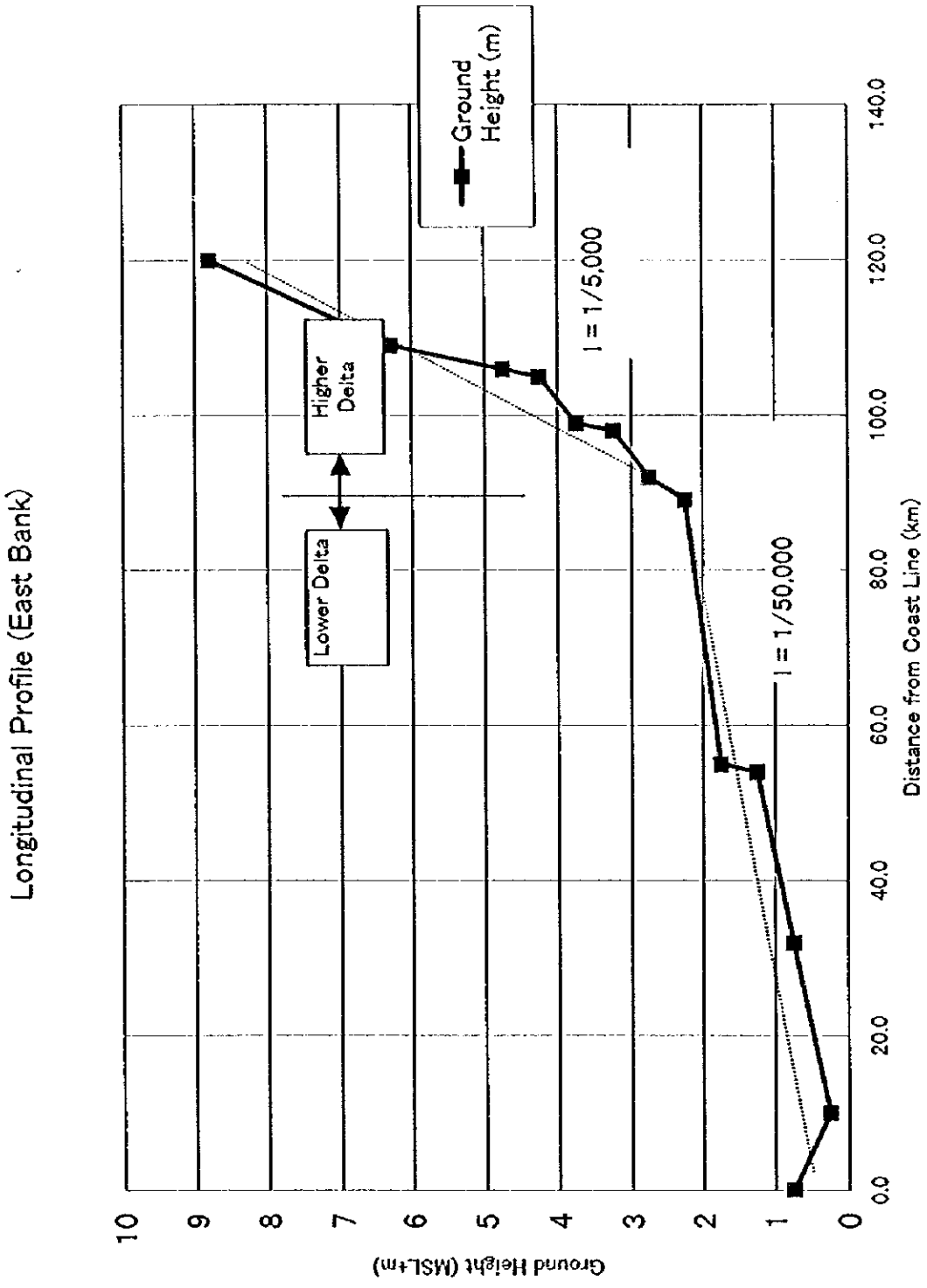
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 7.1.2 DRAINAGE CANAL NETWORK
CTI ENGINEERING CO., LTD AND INA CORPORATION	



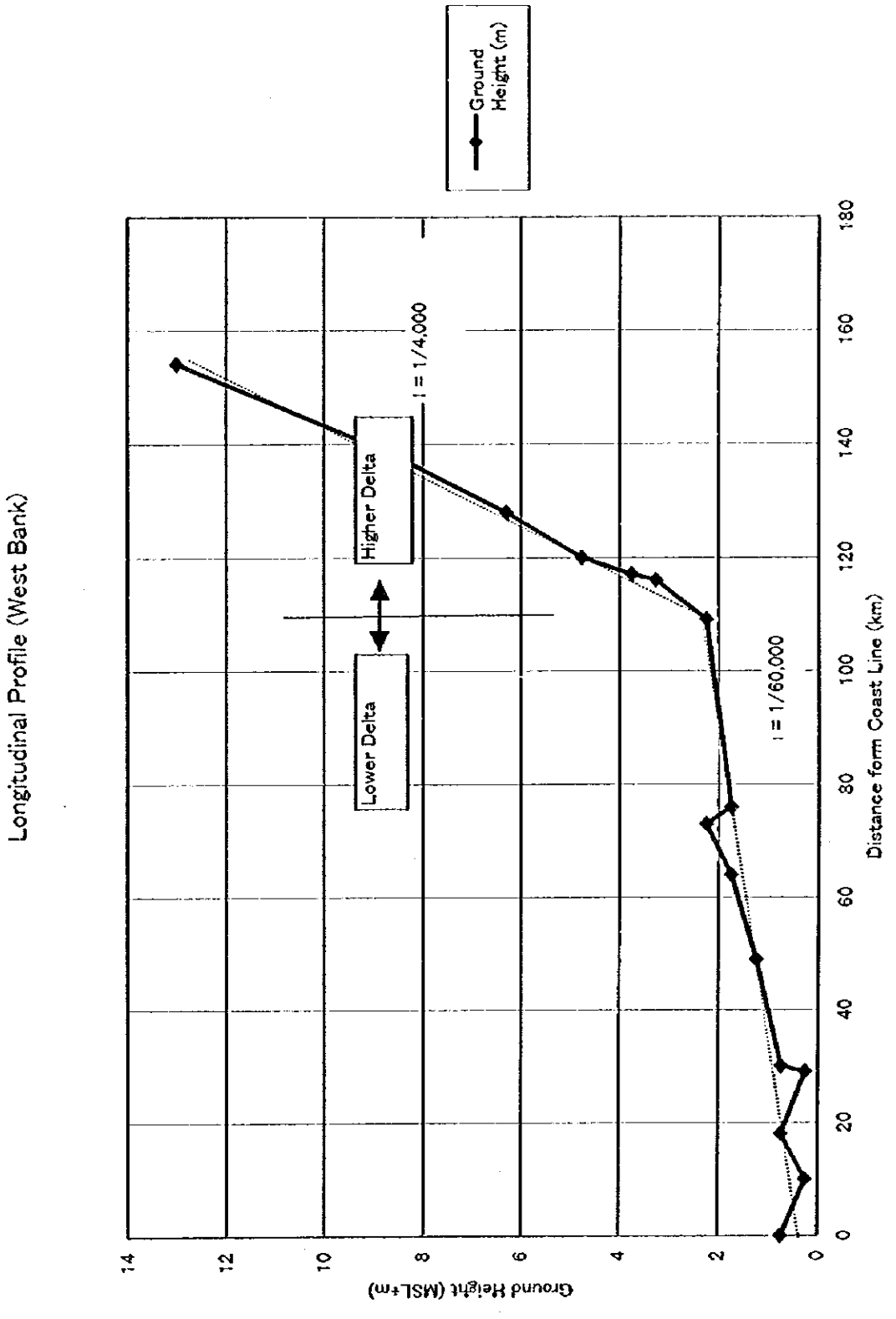
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 7.2.1 LAND USE MAP
CTI ENGINEERING CO., LTD AND INA CORPORATION	



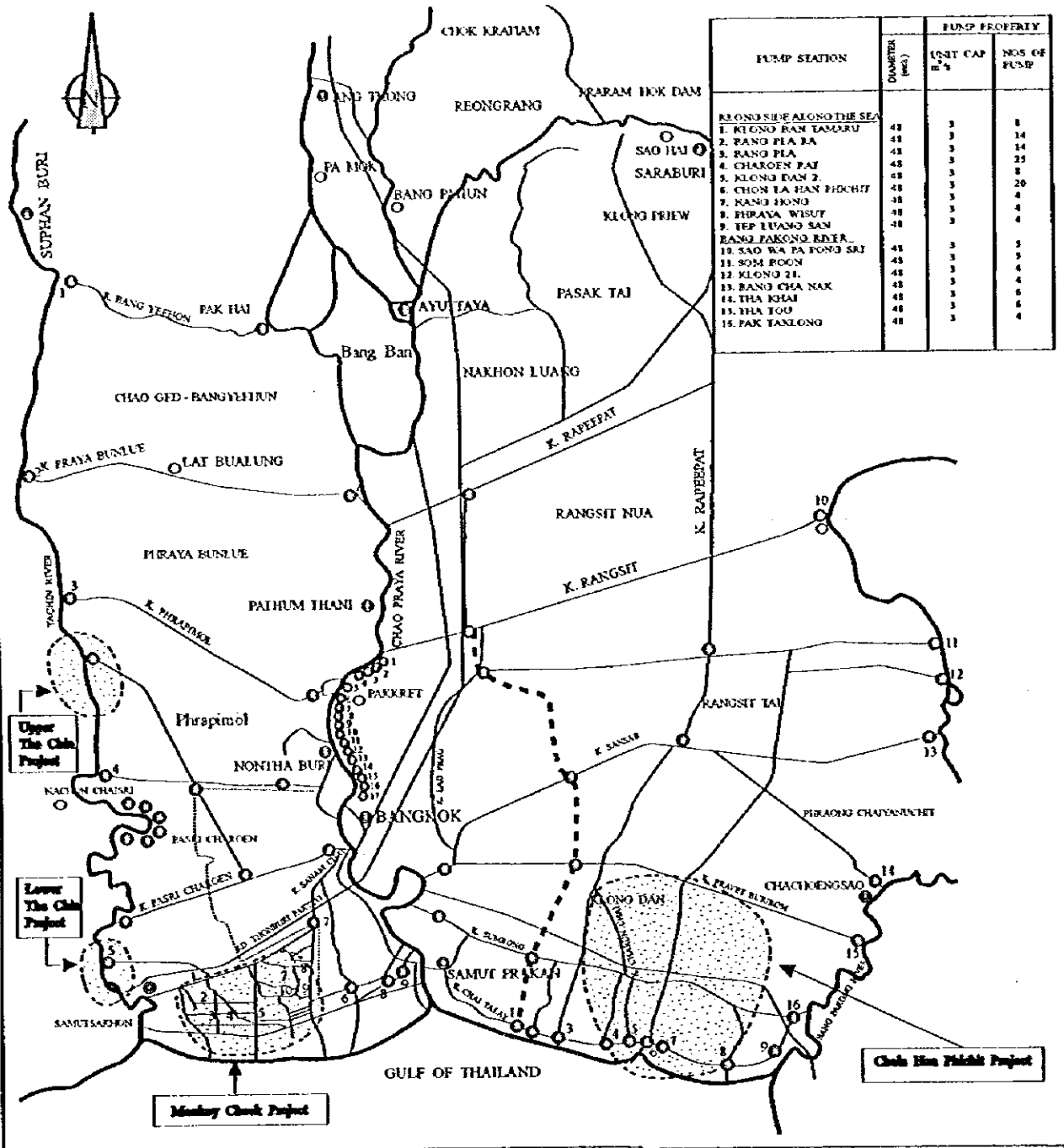
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 7.2.2 LAND ELEVATION MAP
CTI ENGINEERING CO., LTD AND INA CORPORATION	



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN CTI ENGINEERING CO., LTD. AND INA CORPORATION	Fig. 7.2.3 (1/2) LOMGTUDINAL PROFILE



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN CTI ENGINEERING CO., LTD. AND INA CORPORATION	Fig. 7.2.3 (2/2) LONGITUDINAL PROFILE



PUMP STATION	PUMP PROPERTY		
	DIAMETER (mm)	UNIT CAP m³/s	NOS OF PUMP
KLONG SIDE ALONG THE SEA			
1. KLONG BAN TAMARU	48	3	8
2. BANG PLA BA	48	3	14
3. BANG PLA	48	3	14
4. CHAROEN PAT	48	3	25
5. KLONG DAN 2	48	3	8
6. CHON LA HAN PHOBIT	48	3	20
7. KANG HONG	48	3	4
8. PHRAYA WISUT	48	3	4
9. TEP LUANG SAN	48	3	4
BANG PAKONG RIVER			
10. SAO WA PA PONG SRI	48	3	5
11. SOM POON	48	3	5
12. KLONG 21	48	3	4
13. BANG CHA NAK	48	3	4
14. THA KHAI	48	3	6
15. THA TOU	48	3	6
16. PAK TANLONG	48	3	4

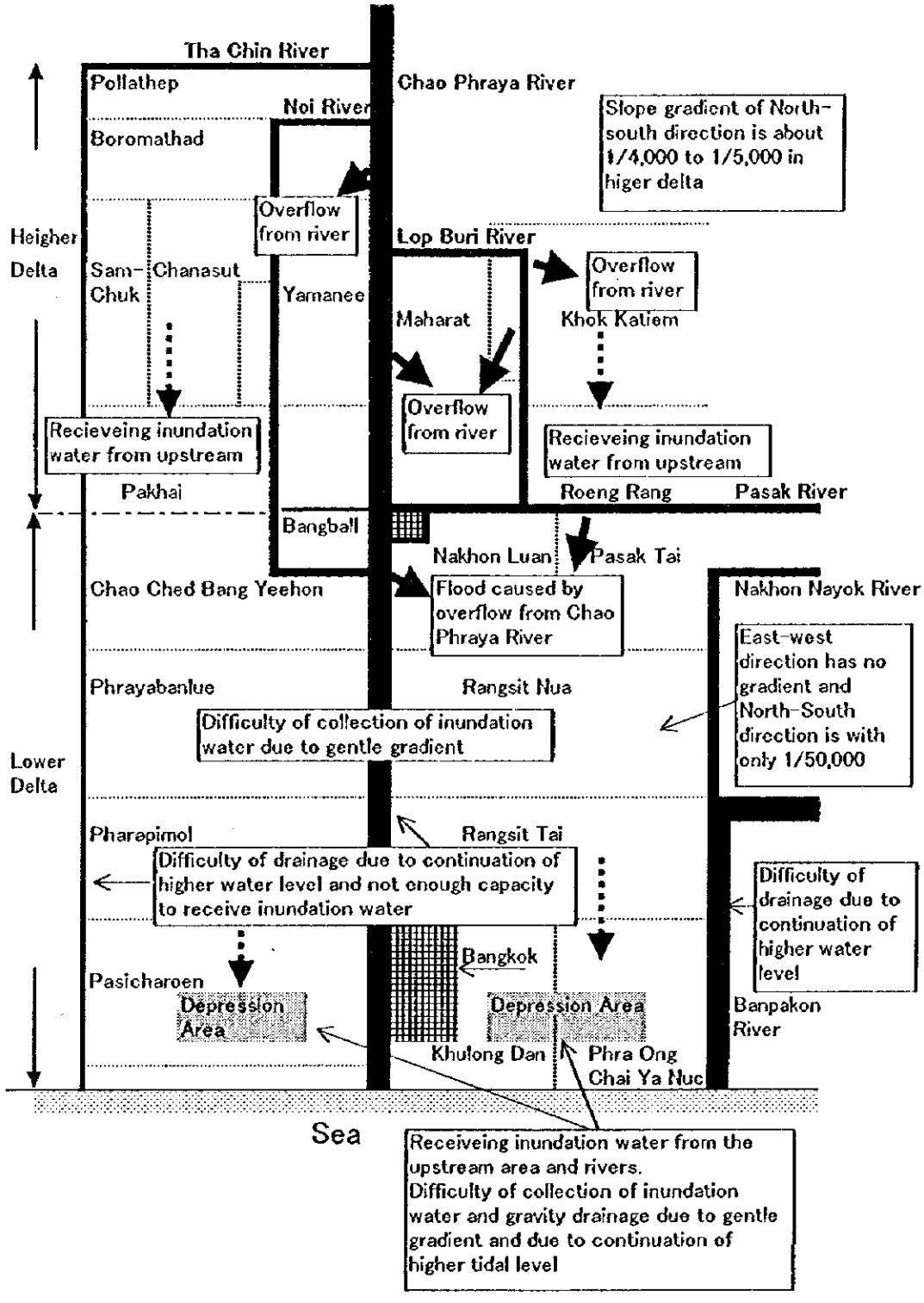
PUMP STATION	PUMP PROPERTY		
	DIAMETER (inch)	UNIT CAP m³/s	NOS OF PUMP
EAST BANK			
1. KLONG BAN TAI	48	3	3
2. BAN KAO	24	1	2
3. BAN PHUNG	48	3	3
4. BANG PAD NAI	48	3	3
5. WAT KHLANG KET	20	0.5	3
6. BANG TARAT	48	3	4
7. BANG THAOLANCE	48	3	2
8. BANG SUE NOI	20	0.5	3
9. BANG KA SOR	20	0.5	3
10. BANG SUE NOI	48	3	2
11. MA KHAM PRONG	20	0.5	3
12. BANG PHRACK 2	20	0.5	3
13. BANG PHRACK	48	3	2
14. BANG TA NOW SRI	48	3	2
15. BANG KHUN THIAN	20	0.5	3
16. BANG MOON NAK	20	0.5	3
17. BANG KHEN KAO	48	3	3
18. BANG KHEN MAI	48	3	4

PUMP STATION	PUMP PROPERTY		
	DIAMETER (inch)	UNIT CAP. m³/s	NOS OF PUMP
THACHIN RIVER			
1. BANG YEEHON	48	3	8
2. PHRAYA BUNLUE	48	3	8
3. PHRAPIMOL	48	3	8
4. KLONG MAHA SAWAT	48	3	6
5. KLONG SRI WA PA SAWAT	48	3	4
6. KLONG CHOK KRABU	24	1	2
THE SIDE ALONG THE SEA			
7. KLONG RATCHAMONTRI	48	3	3
8. KLONG SUAN	48	3	6
9. KLONG KRA OOM	48	3	3

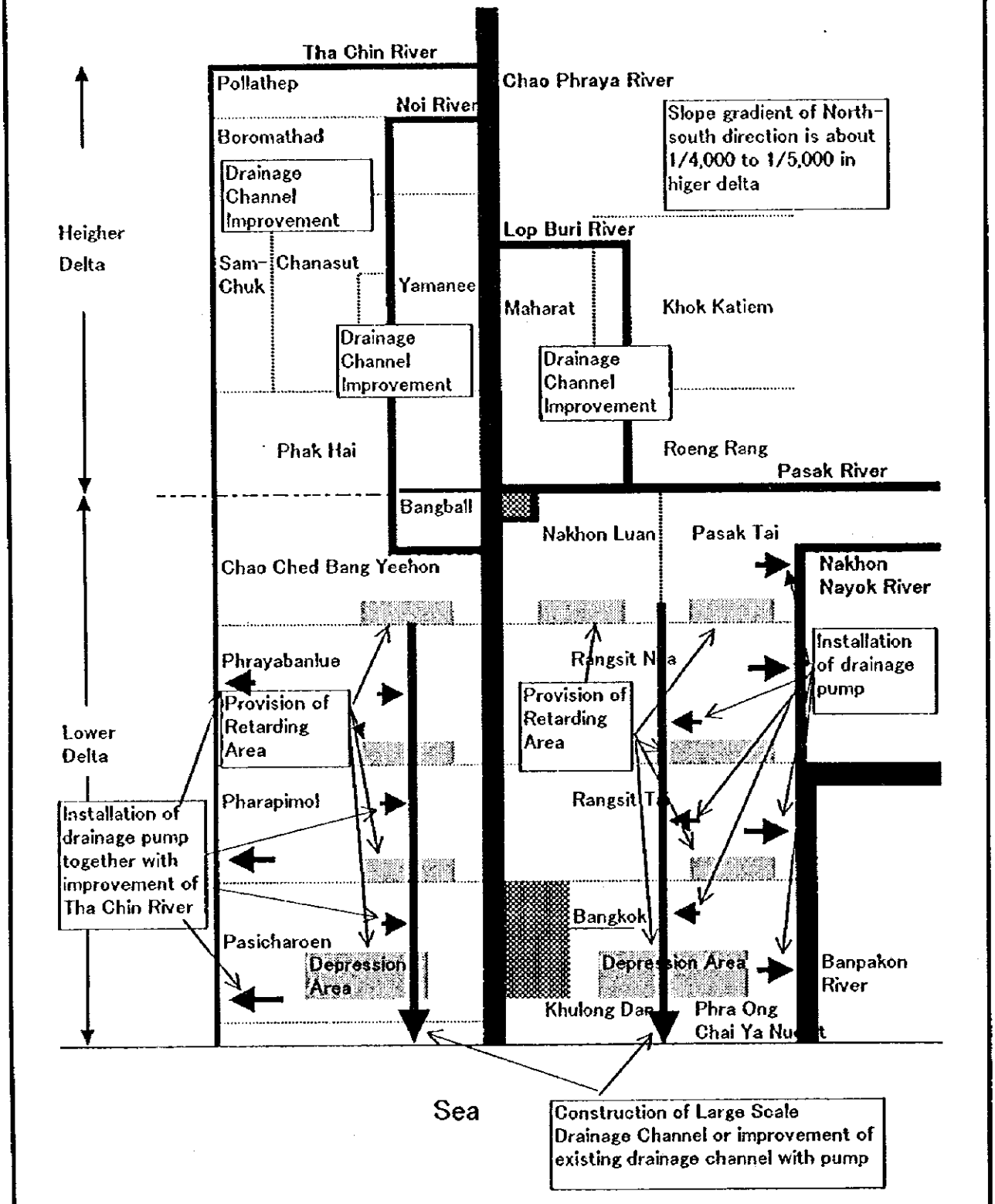
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN

CTI ENGINEERING CO., LTD AND INA CORPORATION

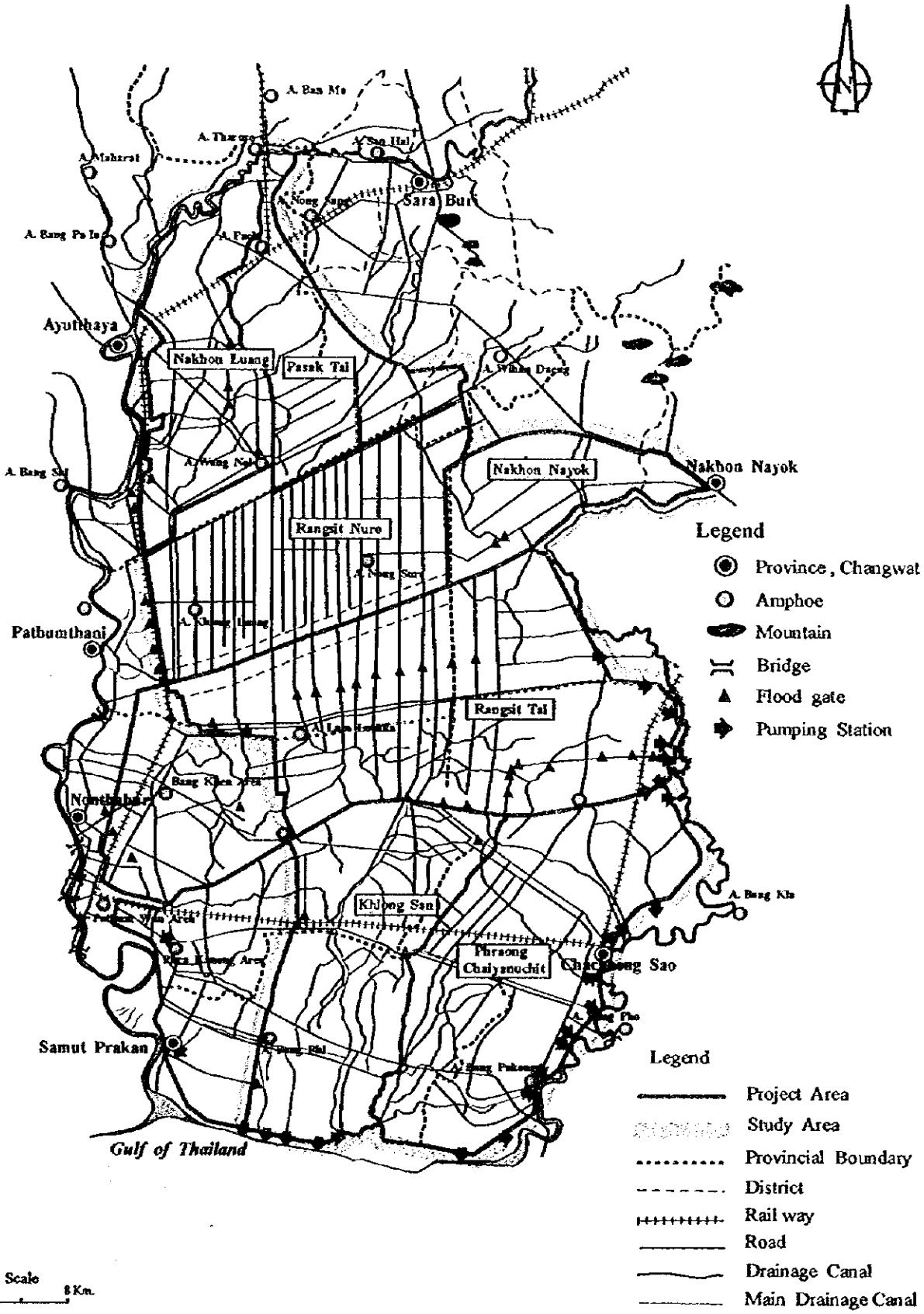
Fig. 7.2.4
DRAINAGE FACILITIES IN LOWER DELTA



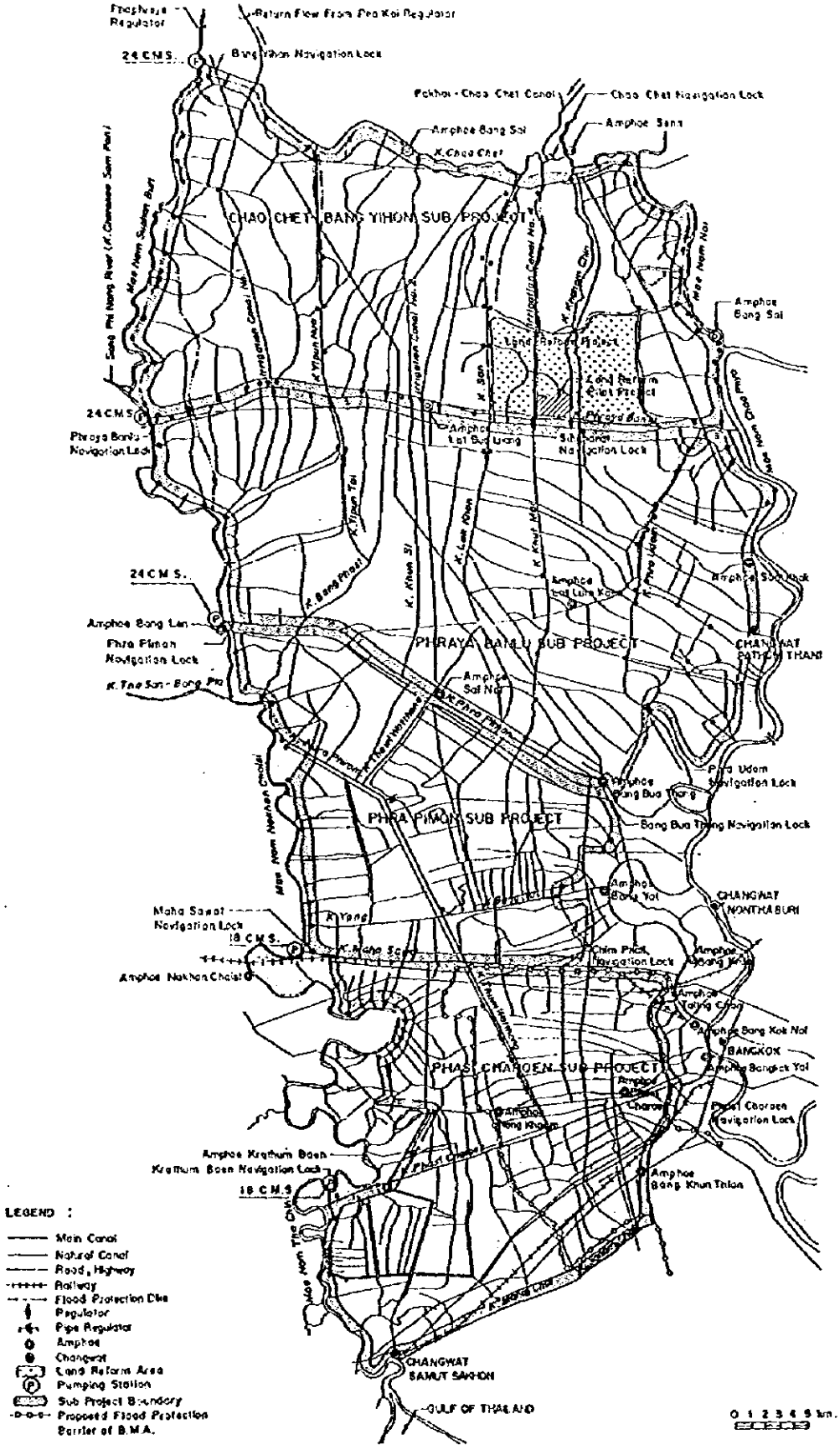
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN	Fig.7.2.5
CTI ENGINEERING CO.,LTD AND INA CORPORATION	MAIN ISSUES OF THE FARMLAND DRAINAGE



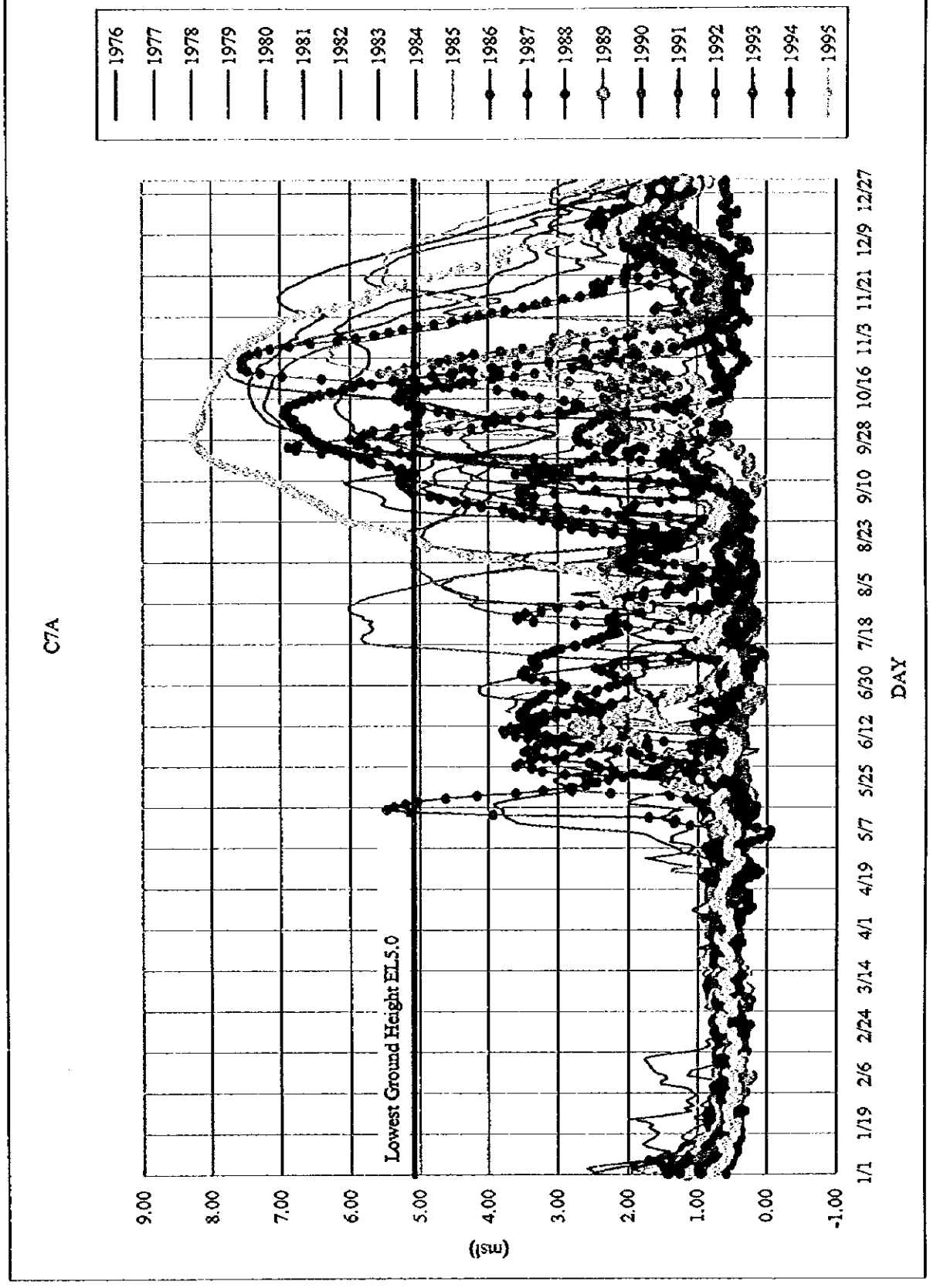
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN	Fig.7.2.6 CONCEIVABLE MEASURES FOR DRAINAGE SYSTEM IMPROVEMENT
CTI ENGINEERING CO.,LTD. AND INA CORPORATION	



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig.7.3.1 DRAINAGE SYSTEM IN EAST BANK
CTI ENGINEERING CO., LTD AND INA CORPORATION	



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 7.3.2
CTI ENGINEERING CO., LTD AND INA CORPORATION	DRAINAGE SYSTEM IN WEST BANK



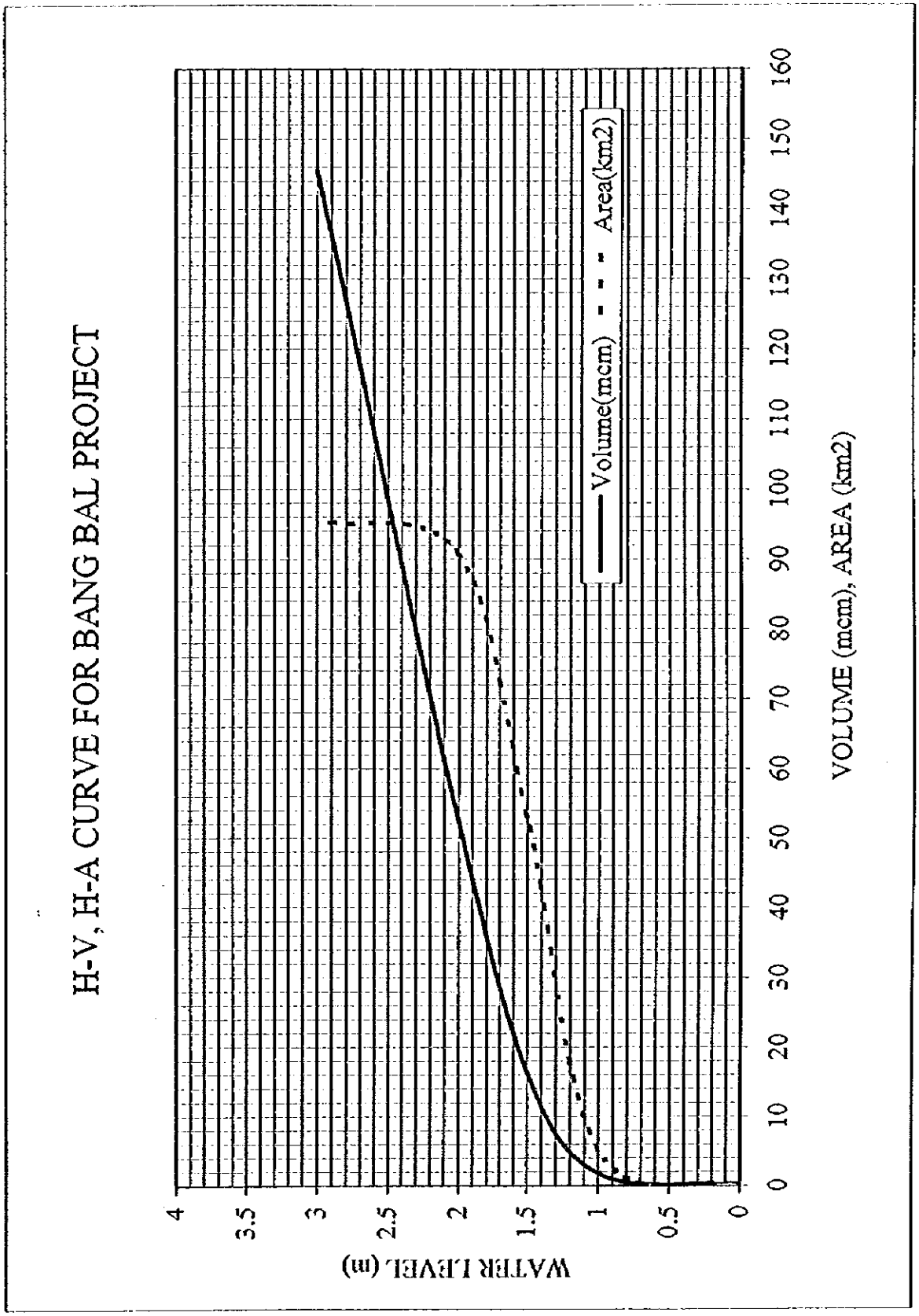
C7A:CHAO PHRAYA RIVER AT ANG THONG

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN	Fig.7.4.1 RIVER WATER LEVEL (ANG THONG)
CTI ENGINEERING CO., LTD. AND INA CORPORATION	

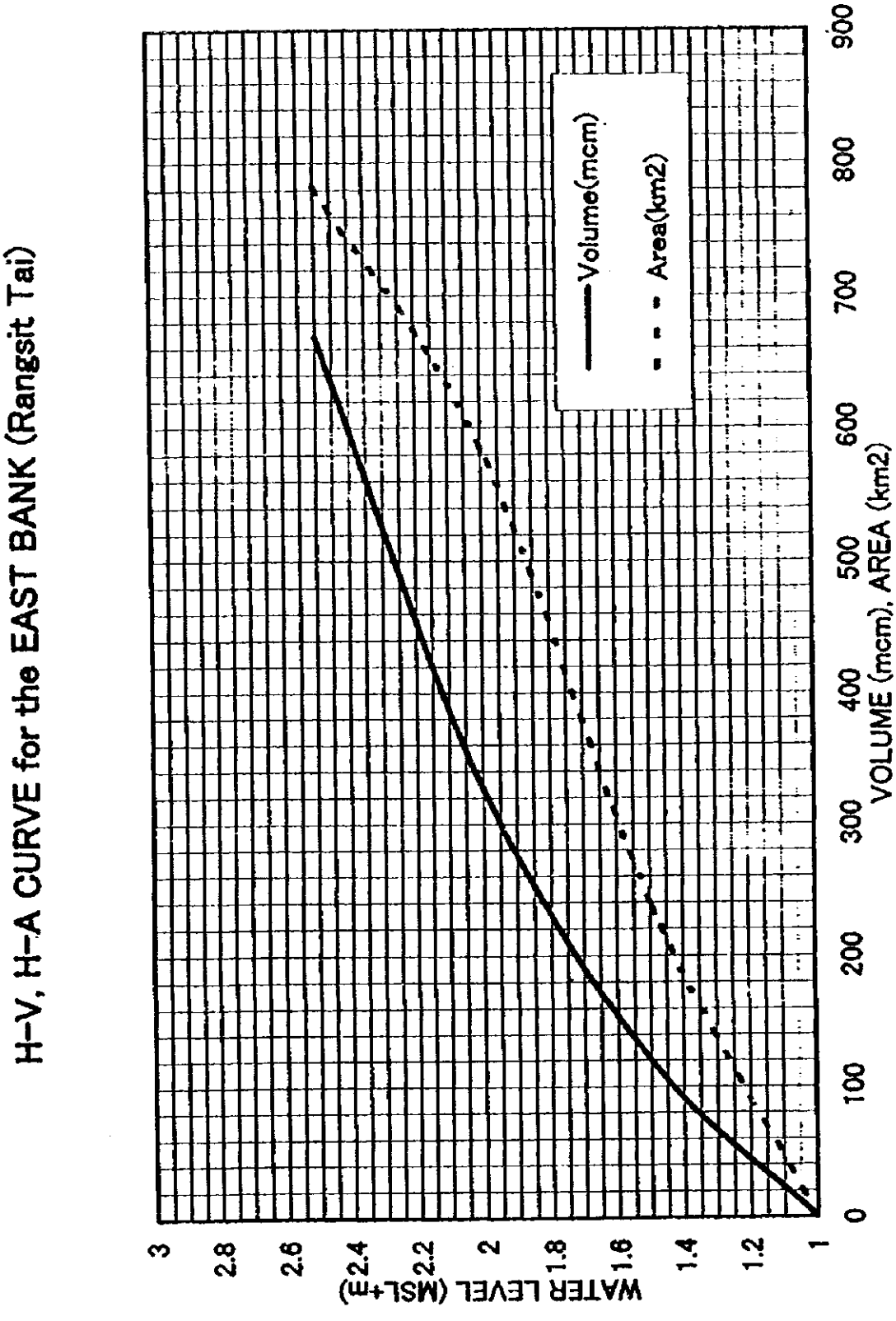
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN	Fig.7.4.2 (1/3) ACCUMULATED RAINFALL IN 1983
CTI ENGINEERING CO., LTD. AND INA CORPORATION	

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN	Fig.7.4.2 (2/3) ACCUMULATED RAINFALL IN 1988
CTI ENGINEERING CO., LTD. AND INA CORPORATION	

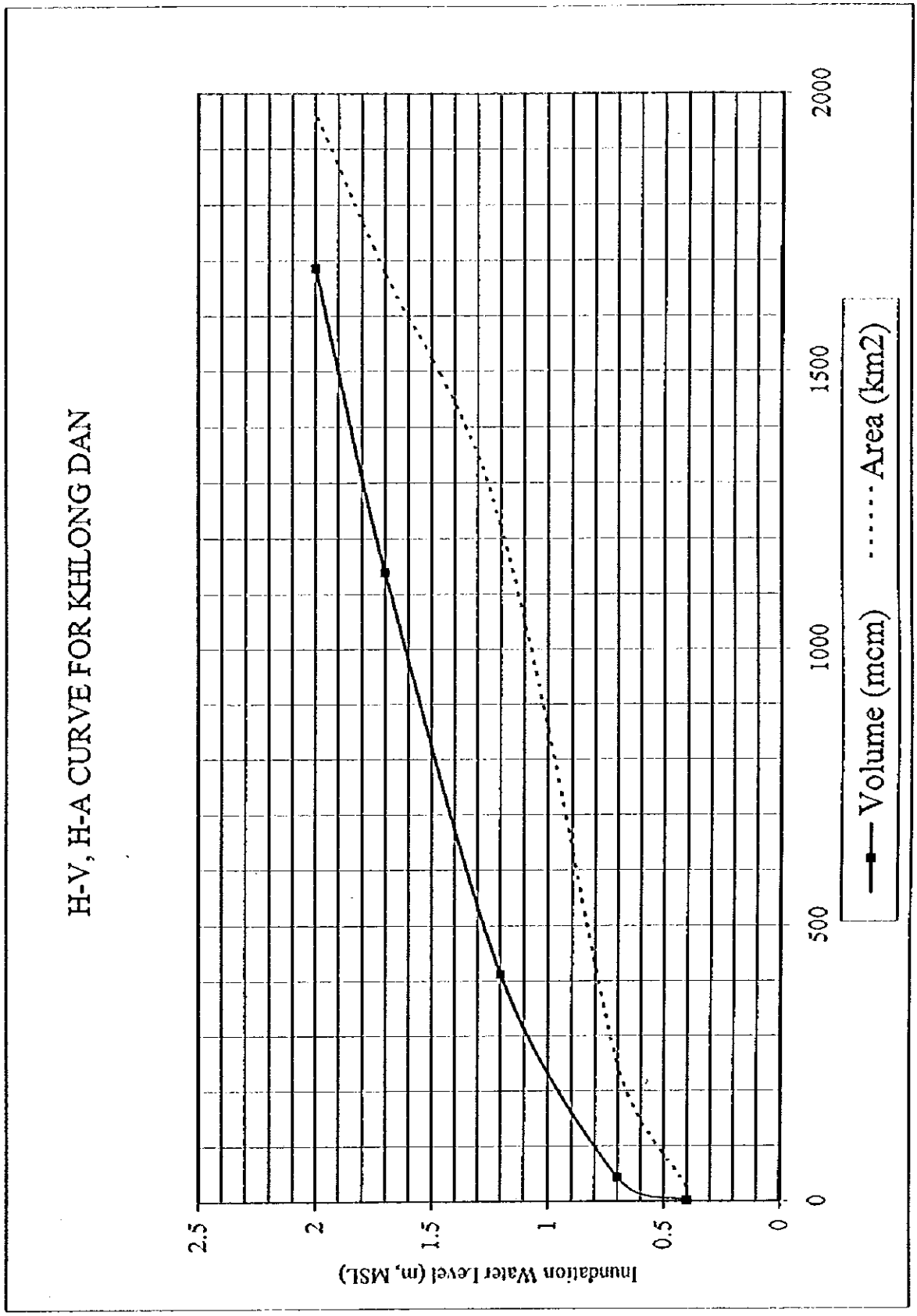
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN CTI ENGINEERING CO., LTD. AND INA CORPORATION	Fig.7.4.2 (3/3) ACCUMULATED RAINFALL IN 1995



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN	Fig.7.4.3 (1/3) H-A, H-V CURVE FOR BANG BAL PROJECT
CTI ENGINEERING CO., LTD. AND INA CORPORATION	

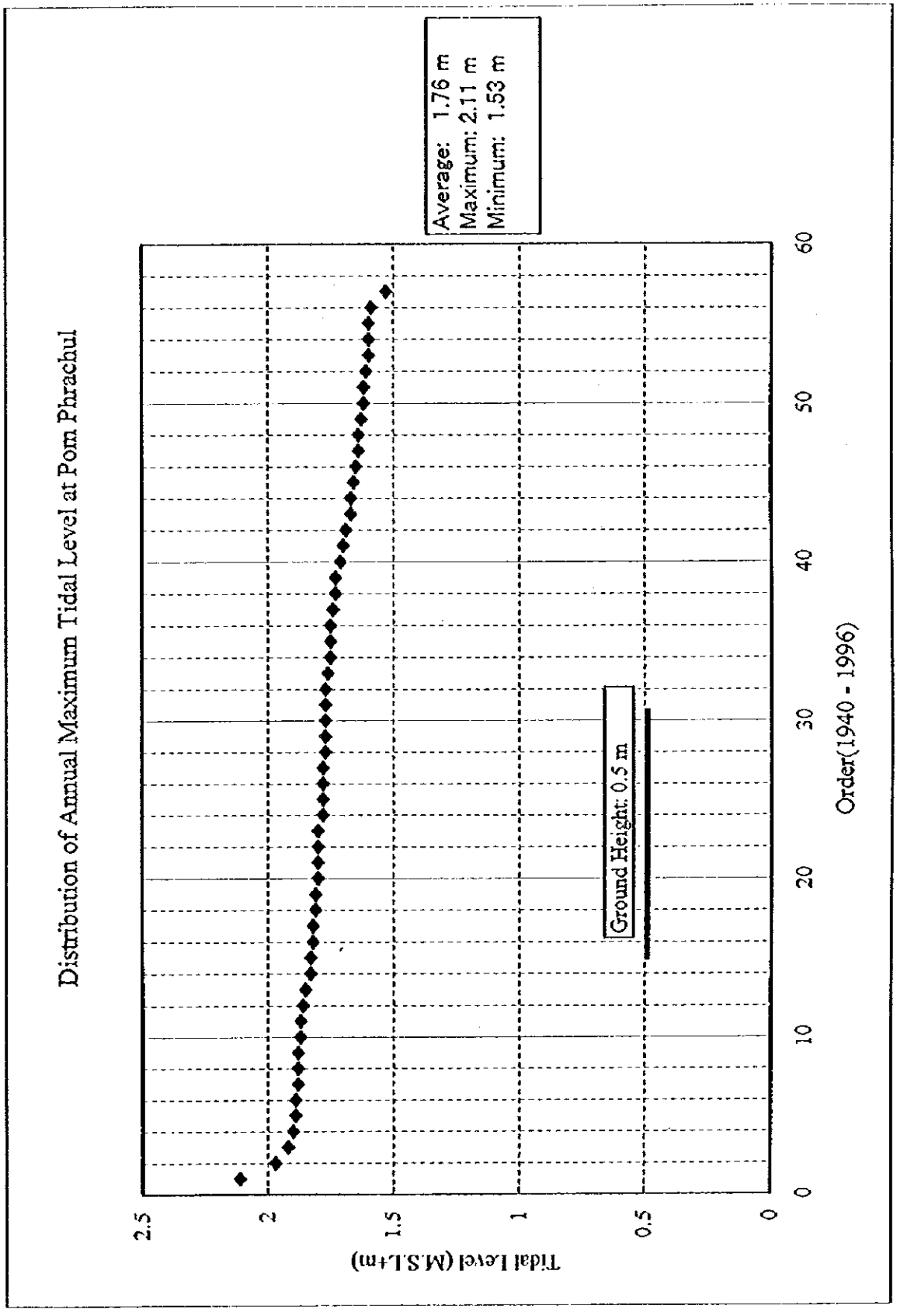


STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 7.4.3 (2/3) H-V, H-A CURVE FOR THE EAST BANK
CTI ENGINEERING CO., LTD AND INA CORPORATION	



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN	Fig.7.4.3 (3/3) H-A, H-V CURVE FOR KHLONG DAN PROJECT
CTI ENGINEERING CO., LTD. AND INA CORPORATION	

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN CTI ENGINEERING CO., LTD. AND INA CORPORATION	Fig.7.4.4 DISTRIBUTION OF WATER LEVEL



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN CTI ENGINEERING CO., LTD. AND INA CORPORATION	Fig.7.4.5 DISTRIBUTION OF TIDAL LEVEL

Study Area	Division of Area	Name of Project Area	Priority	Implementation Schedule				
				1998–2000	2001–2005	2006–2010	2011–2015	2016–2018
Higer Delta	Northern Part surrounded by Thachin and Noi Rivers	Boromathad	2-4-4					
		Samdhuk	2-4-3					
		Chanasut	2-4-2					
		Phak Hai	2-4-1					
	Area surrounded by Noi and Chao Phraya Rivers	Boromathad	2-3-4					
		Yamanee	2-3-3					
		Phak Hai	2-3-2					
		Bang Bal	2-3-1					
	Area surrounded by Chao Phraya and Lop Buri	Maharat	2-1-2					
		Khok Katiem	2-1-1					
	Area surrounded by Lop Buri and Pasak Rivers	Khok Katiem	2-2-2					
		Roeng Rang	2-2-1					
Lower Delta	East Bank Area	Nakhon Luang	1-1-5					
		Pasak Tai	1-1-6					
		Rangsit Nua	1-1-4					
		Rangsit Tai	1-1-3					
		Khlong Dan	1-1-1					
		Phra Ong Chai Ya Nuchit	1-1-2					
	West Bank Area	Chao Chod Bang Yeehon	1-2-4					
		Phrayahantue	1-2-3					
		Phraypimol	1-2-2					
		Pashicharoen	1-2-1					

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN

CTI ENGINEERING CO.,LTD. AND INA CORPORATION

Fig.7.5.1

PRIORITY OF DRAINAGE SYSTEM IMPROVEMENT

SECTOR X

URBAN DRAINAGE PLAN

SECTOR X : URBAN DRAINAGE PLAN

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1. INTRODUCTION

1.1 Urban Areas in the Flood Plain

Most of the provincial capitals including Bangkok and densely populated areas in the flood plane of the Chao Phraya River Basin are located along the major rivers such as Yom, Nan, Suphanburi (Tha Chin), Lopburi and Chao Phraya as shown in the general map. These urban areas are very vulnerable to be damaged from floods because of their locations, the change of life style and insufficient flood protection facilities. In view of the flood plain of the Basin, the Bangkok Metropolitan Area and the Samut Prakan Province, located in the lower reaches of the Chao Phraya River, are the most densely populated areas, and used to suffer from floods more frequently than the other area. Therefore, strenuous efforts for countermeasures of flood protection had been made and these areas are consequently protected by polders and relevant facilities. In 1995 and 1996, the Chao Phraya River Basin received severe damage, especially the downstream of Nakhon Sawan Province to Nonthaburi Province. The provinces of upper reaches and the perimeter areas in the plain were also received damage from floods to some extent in 1995 and in 1996.

1.2 Government Agencies Concerned

The flood protection and drainage systems for urban areas are taken care of the following two agencies;

- Bangkok Metropolitan Area----------BMA
- Urban areas in other provinces--------PWD

In respect of the flood protection and drainage system of Bangkok and its vicinity, a number of plans, studies and designs have been prepared by the BMA. The PWD also carried out the study of flood protection and drainage system on the seven provinces, i.e. Nakhon Sawan, Chainat, Sing Buri, Ang Thong, Ayuthaya, Pathum Thani and Nonthaburi as the first priority areas to be implemented. The other urban areas are also covered by the PWD's master plan for 67 provinces and the results came out at the latter stage of the Study of Integrated Plan for Flood Mitigation in Chao Phraya River Basin (Hereinafter refereed to as the Study).

1.3 Objectives of the Sector Report on Flood Protection and Drainage for Urban Areas

The objectives of this sector report on flood protection and drainage for urban areas are to summarise the existing flood protection facilities and the relevant studies and projects in order to take these items into consideration for the Study, the data of which are mainly obtained from the BMA, the PWD and several provincial capitals and municipalities.

The urban areas to be discussed here are;

i) Area Protected by BMA - Bangkok

ii) Area Protected by PWD - Samut Prakan

iii) Area Protected by PWD / First priority areas (Nakhon Sawan, Chainat, Sing Buri, Ang Thong, Ayuthaya, Pathum Thani and Nonthaburi)

iv) Area Protected by PWD / Second Group of Community (Sukhothai, Uttaradit, Phitsanulok, Phichit, Uthai Thani, Suphanburi, Samut Sakhon, Nakhon Pathom and Lopburi)

2. AREA PROTECTED BY BMA

2.1 General

Bangkok is located on the flat deltaic area of Chao Phraya River at a distance extending from some 27 to 56 km from its mouth. The Metropolitan Area has a ground level of 1.0~1.5 m above the mean sea level on average. Klongs developed in and around Bangkok used to have an effective drainage system before the rapid urbanisation and no serious damage by floods had occurred. In accordance with rapid urbanisation and land subsidence of Bangkok, floods became significant social problems and caused large amount of damages estimated as follows;

Year	Damaged Area	Amount of Damage (million baths)
1975	Bangkok	1,100
1980	Central Bangkok	450
1982	Central Bangkok	No data available
1983	Greater Bangkok	6,597

Source: Flood Forecasting System in the Chao Phraya River Basin, JICA, 1987

The flood damage in recent years has decreased because the flood protection and drainage system in Bangkok has been improved to a certain extent since the 1983 flood. The flooded area in 1983 is shown in Fig. 2.1.1 - ①. The 1995 flood was the biggest flood in a period of 13 years after the 1983 flood, the flood damage was far less than that of the 1983 because the flood protection and drainage facilities such as dikes, gates and pumps were provided after 1983. Flood damage in 1995 was mainly concentrated in the lower areas along the banks of the Chao Phraya River and the suburbs outside the protection dike, as shown in Fig. 2.1.1 - ②.

2.2 Existing Condition

(1) Flood Protection System

(a) Flood Barrier Alignment

The principal dikes on the Bangkok and its vicinity is shown in Table 2.2.1 and Fig. 2.1.1 ③ & ④ and the present situation of these dikes is described as follows;

(i) East Bank

• North : The alignment follows K. Rangsit, from Chao Phraya River to Phrahol Yothin Rd., then along this road in southern direction till Soi 58 (the beginning of the King's Dike).

• North / East : Kings Dike forms northern and eastern flood barrier alignment. The Dike continues until it reaches to the sea, however, its last part is no longer function. In addition, several sections of the dike are badly damaged because of housing and factory development and road construction etc.

• West : The alignment follows embankments, roads, etc. on the left bank of Chao Phraya River. Some roads are located at considerable distance from the river.

• South : The alignment is not clearly defined.

(ii) West Bank

• North : The alignment follows K. Maha Sawat and the Southern Railway.

• East : The alignment follows embankments, roads, etc. on the right bank of Chao Phraya River. Some roads are located at considerable distance from the river.

• West /South : The embankment of Puttamonthom and Bang Bon Road generally forms western and southern flood barrier alignment.

• South : The alignment is not clearly defined with that of the Samut Prakan.

(b) Polders

The areas on the east have been divided into 10 polder units with a total area of 278 km^2 and the areas on the west have been divided into 5 units with 93 km^2 as follows.

East Bank			West Bank		
No.	Location	Area (km^2)	No.	Location	Area (km^2)
E-1	Bang Khen	29	W-1	Thongburi Khl.	14
E-2	Sam Sen	19	W-2	Bangkok Yai	13
E-3	Krung Kasem	13	W-3	Bangkok Noi	21
E-4	Rama IV	20	W-4	Taling Chan	10
E-5	Yan Nawa	15	W-5	Rat Burana	35
E-6	Sukhumvit	23	-	-	-
E-7	Bang Na	31	-	-	-
E-8	Huay Khwang	12	-	-	-

E-9	Hua Mak	9	-	-	-
E-10	Eastern Area	107	-	-	-
Total		278	Total		93

(2) Drainage System

(a) Klongs

The klongs are classified as the main and the secondary ones. The former ones are used for navigation, whereas the latter are tributaries of the main klongs in most cases.

(i) East Bank

The main klongs are the largest open drains with cross-sections varying in width from 25 to 35 m and water depths from 1.5 to 4.0 m and these are listed in the following table. Klongs are used as drains which convey both storm water and sewage discharge either by means of pumping or by free gravity flow into the Chao Phraya River. In the densely populated areas, in particular, the klongs are heavily contaminated. In dry season, water is taken into some klongs from Chao Phraya River for dilution and the downstream pump stations are operated to drain the diluted water into the River.

(ii) West Bank

The klong network systems on the west bank are used for navigation, irrigation and drains. The main klongs are predominantly running in an east - west direction. These klongs are K. Maha Sawat, K. Phasi Charoen, K. Sanam Chai and K. Sanpha Samit, which are utilised as the main waterways for inland navigation between Bangkok and the western provinces. The following klongs are mainly running in an north - south direction ; K. Thawee Wattana is the main conveyance canal of the Phasi Charoen irrigation project. K. Ratchmontri is both a navigation and a drainage canal. K. Lat Luang is a navigation short cut canal of the Chao Phraya loop cut at Phra Pradaeng which is also used for water supply and drainage canal. K.Rat Phinit Chai is for drainage, navigation and saline water supply to the northernmost shrimp farmers. Some minor klongs are used as drains which convey both storm water and sewage discharge either by means of pumping or by free gravity flow into the Tha Chin River, Chao Phraya River and the Sea through the main klongs. The klongs of the northern agricultural, residential and industrial areas are the sources of contamination. The main klongs are listed in the following table;

No.	East Bank	West Bank
1	K.Prem Prachakon	K. Maha Sawat
2	K.Bang Khen-K.Latyao	K. Phasi Charoen

3	K Lat Phrao-K Song	K. Thawee Wattana
4	K Bang Sue	K. Ratchmontri
5	K Sam Sen	K. Bang Nam Chot
6	K Padung Krung Kasem	K. Lat Luang
7	K Mahanak-K Saen Saep	K. Om
8	K Tan	K Suan
9	K Phra Khanong	K. Sanam Chai
10	K Bang Na	K Rat Phinit Chai
11	K Bang Chan-K Phraya Suren	-
12	K Lat Bua Khao	-

(b) Pump Stations

Some pump stations are operated in order to maintain the water quality in the klong in the dry season. Water is pumped up from Chao Phraya River at upstream of the klongs for dilution and drained into the River by pumping.

(i) East Bank

The pump stations are installed to evacuate stormwater and sewage from the main klongs to Chao Phraya River, from inundated area to klongs, from klongs to retention ponds during storm and vice versa after storm. The total capacity of existing pump stations amounts to be 452 m3/s approximately (refer to the Table 2.2.2). The figures mentioned in the table denote the nominal installed capacity and the actual capacity is in the order of 60 to 80 % of the nominal installed capacity. The additional pump capacity on the east bank is 101 m3/s.

(ii) West Bank

The pump stations are installed to evacuate stormwater and sewage from the polder area to Chao Phraya River and the adjacent main klongs. The total capacity of existing pump stations amounts to be 240 m3/s approximately (refer to the Table 2.2.2). The figures mentioned in the table denote the nominal installed capacity and the actual capacity is in the order of 60 to 80 % of the nominal installed capacity. The additional pump capacity on the west bank is 70 m3/s.

(c) Regulators and Gates

Gates are installed to regulate water levels or control discharge at the pump stations or in the klongs. The general feature of regulators and gates on both banks are listed in Table 2.2.3.

(i) East Bank

The regulators installed along the King's dike belong to RID. These regulators are mainly installed for keeping the water to a certain level in order to irrigate the paddy field surrounding the king's dike. The water level records on both side of the regulators are to be transmitted to FCC.

(ii) West Bank

The canal system in the West Bank is still served for irrigation and navigation. Some of them are used for the navigation purposes.

(d) Retention Area

The retention area is the key to alleviate the immediate runoff during heavy rainfall in a densely populated area such as the East Bank. There are still many existing ponds on the East Bank of Chao Phraya River, especially in the eastern part of Bangkok. The main public ponds are classified by ownership as public, military or belonging to BMA and the inventory of these ponds are tabulated in Table 2.2.4.

2.3 Related Plan and Project

(1) Previous Studies

In respect of the flood protection and drainage system of Bangkok and its vicinity, a number of plans, studies and designs have been prepared as shown in Table 2.3.1 and 2.3.2.

(2) Relevant Project

The BMA has continuously made vital efforts to protect the Metropolis from floods and to improve the drainage condition, based on the various studies listed in Table 2.3.1 and 2.3.2. The main efforts concentrated in the actual construction works were as follows;

- • Polder dikes along the periphery of urban areas of both right and left banks of the Chao Phraya River.
- • Flood barriers along the both banks
- • Drainage pump stations with flood forecasting system
- • Improvement of drainage canals

The BMA is now constructing a flood barrier along the both banks of the Chao Phraya River to protect the Metropolitan area as shown in Fig. 2.3.1 - ①. The crest elevation of EL. 2.75 ~ 3.00 m was determined in due consideration of the probable high water level of 100-year return period (EL.1.9 ~ 2.5 m), freeboard (0.5 m), estimated land subsidence (0.2 m in 2006), and public

opinion with respect to convenience and aesthetic condition. The location and the crest elevation are listed as follows;

Location	Crest Elevation (m MSL)	
	NEDECO	BMA Final
Klong Bang Khen~Krungthong Bridge	3.1~3.2	3.00
Krungthong Bridge~Memorial Bridge	3.0	2.80
Memorial Bridge~Taksin Bridge	2.9	2.75
Taksin Bridge~Rama IV Bridge	2.8	-
Rama IV Bridge~Wat Yothin Paradit	2.6	-

In addition, the adopted drainage system for the eastern sub-urban Bangkok, recommended by NEDECO, is shown in Fig. 2.3.1 - ②. The system is to interconnect the main klongs network, intercorporate potential and additional retention ponds, tunnel and the existing pump stations through the following configuration;

• Prem Prachakon Polder

- Retention ponds
- Pracharat tunnel with a capacity of 30 m^3/s
- Bang Khen pump station with total capacity of 30 m^3/s consisting of;

  One existing P.S. capacity - 9 m^3/s

  New P.S. capacity - 21 m^3/s

- Bang Sue existing working capacity - 30 m^3/s

• Eastern Polder

- Retention ponds (existing, additional)
- Phra Khanong pump station consisting of;

  Existing nominal capacity of 105 m^3/s

  Additional capacity of 50 m^3/s

The drainage system component is summarised in Table 2.3.3.

(3) BMA Flood Control Centre

After receiving serious flood damage in 1983, the BMA has been strengthening the drainage capacity of the city through installation of 20 pump stations and 11 regulating gates including improvement of the old facilities.

These drainage facilities require an integrated operation system in order to effectively manage and operate the facilities and minimise conflicts in gate operation. Thus, in 1989, the Flood Control Centre was set-up in the BMA Building and 26 monitoring stations were installed in and around the city with assistance from the Japanese Government. Many of the facilities are being rehabilitated and improved by BMA, replacing the old equipment with upgraded ones.

The concept of Flood Control Centre, telemetry system and block diagram is illustrated in Fig. 2.3.1 - ③ & ④

3. AREA PROTECTED BY PWD / SAMUT PRAKAN PROVINCE

3.1 General

Samut Prakan Province is located at the estuary of the Chao Phraya River, between south of BMA and the Gulf of Thailand, and divided East and West by the River. The Province has an area of 1,004 km^2, which is divided 5 districts and one sub-districts (King Amphur). The ground level of the Province is generally low and the area is always affected by the flood mainly caused by the high tide during the rainy season. Polder system together with regulators and pumps has been taken to protect the area. The polders are composed of dikes, roads and retaining walls.

The flood protection and drainage facilities are almost constructed except for 3 pump stations, one in the East and the other 2 in the West. These three pump stations are to be completed by 1999. There are 4 polders in the East and 5 in the West. The boundary of BMA and Samut Prakan Province runs through some polders in the West. These facilities are generally designed in 100 years for polders and 5 years for drainage system.

3.2 Existing Condition

(1) Facilities on the East Bank

Four (4) polders namely Samrong, Bang Nang Kreng, Pak Nam (Capital district) and East Bank Mitigation Area covers the area of 236 km^2. The PWD installed 8 drainage pump stations with regulators along the Chao Phraya River and 1 pump station with regulator is now under construction. The total capacity of 9 pump stations are 60.5 m^3/s. The drainage pump capacity to the Chao Phraya River is 55.0 m^3/s. Sixteen (16) regulators are also installed along the River. The RID owns 2 pump stations at the end of irrigation drainage canals, one in Samrong Polder and the other in East Bank Mitigation Area. The King's Dike along King Kaeo-Lat Kra Bang Rd. is not recognisable because of the land subsidence. The location of polders, relevant pump stations and regulators are shown in Fig. 3.2.1. The relevant pump stations and regulators are listed in Table 3.2.1.

(2) Facilities on the West Bank

The five (5) polders are namely Bang Kajao, Ratburana, Bang Kru, Ta Kwen and West Bank Mitigation Area, which covers the area of 124 km^2. The PWD

installed 7 drainage pump stations with regulators along the Chao Phraya River and two 2 pump stations with regulators are now under construction. On top of this, one existing pump station is under renovation to increase its pump capacity. The RID also owns one pump station with regulator, and one regulator in Ratburana Polder. The total capacity of 10 pump stations are 59 m³/s. The drainage pump capacity to the Chao Phraya River is 59.0 m³/s. Thirty (30) regulators including RID's one are installed along the River. The location of polders, relevant pump stations and regulators are shown in Fig. 3.2.1. The relevant pump stations and regulators are listed in the Table 3.2.1.

3.3 Related Plan and Project

(1) Samut Prakan Flood Protection Work

The budget of 2,844.35 million Bahts had been allocated for the flood protection and drainage work during the last 11 years (1986~1996). The ongoing project is as follows;

- Bang Kajao Flood Protection and Drainage Work

The detailed design was carried out in 1993 by the Science Research and Technology International Institute with the budget of 11 million Bahts. Pump stations and discharge structures were designed based on the 5 year-return period The designed crest level of the dikes was determined as follows;

Design Condition	Crest Elevation
High water level in 100 year-return period	+1.900m
The crest elevation of dikes along Chao Phraya	+2.500m
Inside the dikes	+2.200m

The construction of Bang Kajao Polder Project had been commenced on 1994, Oct. and to be completed on April, 1997. The major works have been completed, however, some structural works are still under construction and to be terminated in 1999. The construction was divided two packages as follows ;

Package No.	Contract Price	Contractor	Contract Period
No. 1	260 million Bahts	Shino-Thai Engineering & Construction Co. Ltd	900
No.2	240 million Bahts	Contractor / Chai Pitak Jointventure	900

4. AREA PROTECTED BY PWD / FIRST PRIORITY AREAS

In 1995 and 1996, the Chao Phraya River Basin received severe damage, especially the downstream of Nakhon Sawan Province to Nonthaburi Province. Therefore, the PWD carried out the Study of Flood Protection and Drainage System on the seven provinces, i.e. Nakhon Sawan, Chainat, Sing Buri, Ang Thong, Ayuthaya, Pathum Thani and Nonthaburi as the first priority areas to be implemented. The Study involved the feasibility study and the detailed design on the selected - densely populated areas (mainly the provincial capitals) and completed in October, 1997. The consultants commissioned the study by the PWD were as follows;

Province	Consultant
Nakhon Sawan	Progress Technology Consultants*
Chai Nat	Team Consulting Engineers*
Sing Buri	Vast Technical Engineering Consultant*, Asia Consultant*
Ang Thong	PAL Consultants*, Creative Technology*, PCB Technology*
Ayuthaya	Span Company Ltd., VEGA Engineering Consultants*
Pathum Thani	PAL Consultants*, Creative Technology*
Nonthaburi	Team Consulting Engineers*

Note: * = co., ltd.

4.1 Nakhon Sawan Province

4.1.1 General

The Nakhon Sawan Province, the area of which is 9,598 km^2, is situated in the lower northern region and serves as the centre of trade and goods transportation for the northern region. The general topography of the Province is mostly lowland area, whereas the central area lies along the Ping, Yom and Nan Rivers, the tributaries of Chao Phraya River. Under the Seventh National Economic and Social Development Plan, the Province has been designated as the growth centre for the Region. In the past few years, the economy of the province has been developed steadily. Among 13 districts in the Province, seven districts including Nakhon Sawan Municipality were damaged seriously by the floods in 1995 and 1996. These were Nakhon Sawan, Chumsaeng, Lat Yao, Kao Liao, Krok Phra, Phayuha Khiri and Banphot Phisai. The damage on the other districts were not so serious. The flood damage of these districts in 1996 is listed in Table 4.1.1. The Nakhon Sawan Municipality and its vicinity were selected for the Feasibility and Detailed design, whereas the preliminary design was carried out for the rest of the six districts.

4.1.2 Existing Condition

(1) Nakhon Sawan Municipality

(a) Flood Damage

The Nakhon Sawan Municipality covers an area of 27.87 km^2 with the population of 109,708. The commercial and residential areas of the

Municipality lie on the right bank of the Ping and the Chao Phraya River. The floods of the Municipality were mainly caused by the overflow from the Ping, Nan and Chao Phraya rivers. Inundation depth of 1995 flood was 0.6 m as average (the deepest point: 1.5 m). In 1996, the inundation depth was not clear, but was lasted for months. Both floods caused serious damage to the Municipality. The flood damage in 1995 is reported as follows;

- Amount of damage ; 500 Million Bahts*
- No. of houses damaged : 15,324
- Inundation area : About 75% of the Municipality area as shown in Fig. 4.1.1 - ①.

* Source : Nakhon Sawan Municipality Office

The flood damage in the Nakhon Sawan District (except for the Municipality) is not less than 100 Million Bahts**.

** Source : Detailed Design of Flood Protection System for Nakhon Sawan Province (PWD)

(b) Historical Flood

The floods in Nakhon Sawan Municipality were recorded in the years of 1970, 1980,1995 and 1996. The flood in 1970 was occurred because of no protection dikes along the River banks of Ping and the Chao Phraya. Outside of the dike was flooded in 1980.

(c) Existing Flood Protection Facility

There are two stretches of flood protection facilities facing to the Rivers in the Municipality. In front of the market in the commercial area, at the confluence of Ping and the Chao Phraya River, on the right bank, around 980 m of concrete dike (retaining wall) with the height of 1.6 m had been constructed. The crest of the dike was set at the same elevation of the flood level in 1995. On the other hand, a concrete-step dike has been made with the length of around 400 m, in front of the Provincial Hall, on the right bank of the Chao Phraya River. Other type of protection facility are now under construction mainly on the right bank the Chao Phraya River. In the western part of the Municipality, a levee was constructed and connected to Highway No. 1 and the road 11055 in order to prevent the floods from the western tributaries of the Chao Phraya River. The levee length is around 2,300 m.

(d) Existing Drainage Facility

The existing drainage system in the municipal area mainly consists of street drains. The system is employed to the densely populated areas only, i.e. the commercial and government office areas located on the right bank of the Ping and Chao Phraya River and is capable of draining the water from the catchment area into these two rivers. 19 pump stations

with 26 pumps are furnished in order to evacuate the flooded water and the size of these pumps are as follows;

Diameter (inch)	6	8	10	12	Total
Number of Pump	4	7	10	5	26

The Lake Somboon, located in the centre of the Municipality and served as the recreation area (Sawan Park), is utilised as a retarding pond to a certain extent. During the dry season, the water is pumped into the pond from Chao Phraya River in order to improve the water quality and the diluted water is drained to the River by gravity.

(e) Flood Fighting

In 1995, drainage pumps were hired from the Provincial RID and other government offices. In 1996, only the pumps owned by the municipality were used to evacuate the flooded water. The pumps were operated for around three months from September, with almost 24 hours a day. The expense for flood fighting in 1995 was 100 Million Bahts. The equipment for flood fighting owned by the Municipality is as follows;

Drainage pumps-26 units, Backhoe, Truck, Dump truck, Loader, Grader, Road roller

(2) Chumsaeng Municipality

In 1996, the number of houses affected by the flood in Chumsaeng District was around eight thousand seven hundred and recorded biggest number in the Province. The Municipality is located on the right bank of the Nan River, however it also receives the flood damage from the Yom River because its location is close to the confluence of the both Rivers. The flood damage in the Chumsaeng was around 73 Million Bahts* in 1995.

(3) Lat Yao Sanitary District

The district is located in the foot of the western highland, around 40 km west of the Nakhon Sawan Municipality. The flood damage in 1996 was mainly road and farm land with the area of twelve thousand hectare (paddy field was around 95%)*

(4) Kao Leio Sanitary District

The District was inundated with the depth of 0.5~1.0 m and affected more then four thousand houses * in 1996. The Sanitary District is located on the left bank of the Ping River.

(5) Krok Phra Sanitary District

In 1996, the number of houses affected by the floods was little less than eight thousand houses * in the District. The Sanitary District is located on the right bank of the Chao Phraya River.

(6) Phayuha Khiri Sanitary District

Nine sections of Chao Phraya River bank and four thousand five hundred houses * in the District had been damaged in 1996. The Sanitary District is located on the left bank of the Chao Phraya River.

(7) Banphot Phiasai Sanitary District

In 1996, two sections of irrigation canal, around two thousand houses and nineteen thousand hectare of firm land (paddy field is 98% approximately) had been damaged in the District. The district is located on the right and left bank of the Ping River. The flood damage in Banphot Phisai is around 31 Million Bahts* in 1995.

* Source : Detailed Design of Flood Protection System for Nakhon Sawan Province (PWD)

4.1.3. Related Plan and Project

(1) Nakhon Sawan Municipality

The new drainage and flood protection system covers the area of 124.8 km^2 (divided into 6 areas), including the vicinity of the municipal area, as shown in Fig. 4.1.1 - ②. The system is planned based on the built - up area map as shown in Fig. 4.1.1 - ③. The detailed design is carried out for the centre of the Municipality (Divided area 1 in Fig. 4.1.1 - ②). The results of the detailed design is summarised in the following table;

	Facility	Unit	Quantity	Estimated Cost
1	Flood Protection Barrier			575.86
	Embankment	m	10,470	
	Dike	m	7,260	
2	Drainage System			493.49
	Storm Sewer	m	60,212	
3	Pumping Station			405.70
	Pumping Station	Station	9	
	Combined Sewer Outflow	Station	3	
4	Total : Cost (Mil. Bahts)			1,475.05

On the other hand, the Nakhon Sawan Municipality has a plan to build a park by encroaching the Yuan Island, located at the confluence of the Ping and the Nan Rivers. Thus, one of the river course on the left bank of Chao Phraya is to be closed. From the viewpoint of river engineering, such kind of plan should be carefully studied in order not to affect the function of rivers, especially the flood flow capacity of the river section at the confluence.

(2) Other Districts

The flood protection system for the other districts are summarised in the following table;

District	Facility	Quantity	Unit	Unit Price (B / m)	Const. Cost (Mil. Bahts)	Protection Area	Figure of Planning
Chumsaeng	Dike	3,000	m	30,000	90.00	2.4 km²	Fig. 4.1.3 - ②
Lat Yao	Dike (On both banks)	2,300	m	30,000	69.00	1.6 km²	Fig. 4.1.3 - ③
Kao Leio	Dike	1,320	m	30,000	39.60	1.5 km²	Fig. 4.1.2 - ③
	Raised Road (H= 0.5 m)	1,350	m	3,000	4.95		
		1,050	m	3,600	3.78		
				Total	48.33		
Krok Phra	Dike	1,300	m	30,000	39.00	2.8 km²	Fig. 4.1.2 - ①
	Raised Road (H= 1.0 m)	2,700	m	3,600	9.72		
				Total	48.72		
Phayuha Khiri	Dike	1,500	m	30,000	45.00	1.8 km²	Fig. 4.1.2 - ②
	Raised Road (H= 0.5 m)	600	m	3,000	1.80		
	Raised Road (H= 1.0 m)	500	m	3,600	1.80		
				Total	48.60		
Banphot Phiasai	Dike	4,000	m	30,000	120.00	1.5 km²	Fig. 4.1.3 - ①
	Raised Road (H= 0.5 m)	5,600	m	3,000	16.80		
				Total	136.80		

4.2 Chai Nat Province

4.2.1 General

The Chai Nat Province, the area of which is 2,469 km², is situated on the north of the Central Region. The general topography of the Province is mainly flood plains formed by the three major rivers, the Chao Phraya, Tha Chin and Noi River. The latter two rivers branch off to the right bank of the Chao Phraya River at Makhamthad by Pholatep regulator and Borommathat by Borommathat regulator respectively. Western part of the Province, especially west of the Tha Chin River, is covered with hilly area. There are 6 districts in the Province and the Chao Phraya River runs through Manorom, Wat Sing, Chai Nat and Sanphaya District, tha Chin River runs through Wat Sing and Hankha District, and the Noi River runs through Sankhaburi District. There are several irrigation projects in the Province and the RID used to construct flood protection dikes in parallel with the Chao Phraya River. The elevation of these dikes are as follows;

Location	Section	Type of Dike	Elevation (m. MSL)
Right bank	Borommathat / Pholatep	main dike	19.0~20.0
Right bank	Tha Chai / Hat Tha Sao	main dike (road) along the River	17.5~18.6

Left bank	Manorom / Chai Nat	main dike (road) apart from the River	20~23
Left bank	Chai Nat / Sanphaya	main dike (road) along the River	-
Left bank	Manorom/ Chai Nat Dam	minor dike (road) along the River	17.2

The latter one was constructed by the Office of Accelerated Rural Development, PWD and the local authorities. In 1995, around 0.5~1.0 m of sand bags were piled on the RID dike from Chai Nat to Sing Buri, the right bank of the Chao Phraya River at Sanphaya district, in order to protect the irrigation area from the spilled water of Chao Phraya River. On the left bank of the Chao Phraya River, the firm land along the Maharat Canal down to Lopburi was also flooded. In 1996, the western hilly area receives heavy rainfall which caused flooding in the irrigation project area of Wat Sing and damages on the irrigation facilities.

The Provincial Capital, Chai Nat Municipality and Wat Sing Municipality are the major urban area and suffered from floods in 1995 and 1996. Therefore, these two municipal areas were selected for the study of the drainage and flood protection system by PWD. The expense for flood fighting had been spent 6 Million Bahts in 1995 and 4 Million Bahts in 1996.

4.2.2 Existing Condition

(1) Chai Nat Municipality

The Chai Nat Municipality and the town planning area cover 56.5 km^2, located at about 6 km upstream of the Chai Nat Dam. The commercial area of the Municipality lies on the left bank of the Chao Phraya River. The Municipality has the area of 6.06 km^2 and the population of 15,872. As the water level of the Chao Phraya River is regulated by the Dam, the upstream area is sometimes flooded severely, especially in 1995. The flooded area in 1995 is shown in Fig. 4.2.1 - ①.

(a) Historical Flood : Flooded years were in 1983, 1995 and 1996.

(b) Recorded Flood Level

In 1995, the maximum recorded flood volume at Chao Phraya Dam was 4,557 m^3/s while the discharge capacity of the dam is at 3,300 m^3/s. The peak water level was around 17.5 m. MSL. Northern part of municipality on both banks of Chao Phraya River were inundated with the depth of 2 m in 1995 and 1996.

(c) Existing Flood Protection Facility

The ground elevation of Chai Nat and its upstream area is around 16 m. MSL and the road constructed along the Chao Phraya River with the elevation of 17.2 m. MSL will help for the minor floods.

(d) Existing Drainage System

The Chai Nat and its upstream area is around 16 m. MSL of their ground level and the normal regulated water level of Chao Nat Dam is at 16.5 m. MSL. Therefore, the water in the area can't be drained into the River by gravity during the rainy season. The existing drainage condition of low - dense area is as follows.

(i) Right bank area such as the Polathep Irrigation Project Area

The area is in agricultural or low - densely populated one where there is no flood protection facilities and the water will be drained into the drainage canals of RID (Suphanburi Drainage Canal No. 1).

(ii) Left bank area such as the Manarom Irrigation Project Area

The area is in agricultural or low - densely populated one where there is no flood protection facilities and the water will be drained into the drainage canals of RID (Chai Nat-Pasak Drainage Canal No. 1).

(iii) A. Muang Chai Nat Municipality (Left bank area)

There are two existing pump stations and additional one is to be planned to install.

(e) Flood Fighting

As for the commercial area, residents normally protect themselves from the floods. Municipality prepare fuel for pumps, sand bags, other type of dike materials, equipment, food, etc. Around 5 million Bahts (mainly fuel for pumps) were spent for 1995, 1996 respectively. Flood damage amounted to be 86 million Bahts in 1996.

(2) Wat Sing Municipality

The Wat Sing Municipality and the town planning area cover 32.3 km^2, located at about 10 km upstream of the Chai Nat Municipality. The Municipality lies on the left bank of the Chao Phraya River and has the area of 2.0 km^2 and the population of 3,936.

(a) Historical Flood : Flooded years were in 1983, 1995 and 1996.

(b) Existing Flood Protection Facility

The surrounding roads of the centre of the Municipality serves as the polder for the flood protection barrier, however their elevation is not adequate enough.

4.2.3 Related Plan and Project

(1) Chai Nat Municipality

The new drainage and flood protection system including the vicinity of the Chai Nat municipal area, are as shown in Fig. 4.2.1 - ②. The results of the detailed design for the municipality and its vicinity, i.e. Amphoe Muang Chai Nat Municipal District Polder, Ban Kluay District Polder, Tha Chai District Polder and Had Tha Sao District Polder are summarised in Table 4.2.1. The new system is based on the present and future land use plans which are shown in Fig. 4.2.2.

(2) Wat Sing Municipality

The new drainage and flood protection system is as shown in Fig. 4.2.1 - ③ and the results of the detailed design for the municipality are summarised in Table 4.2.1. The present and future land use plans are shown in Fig. 4.2.3.

4.3 Sing Buri Province

4.3.1 General

The Sing Buri Province , the area of which is 823 km^2, is situated in the upper Central Plain. The general topography of the Province is mostly lowland area traversing by the three rivers, namely the Chao Phraya, Noi and Lop Buri. The Lop Buri River branches off from the Chao Phraya River at the southern boarder of the Sing Buri Municipality. Since the Province is located downstream of the Chao Phraya Dam, the flooding and inundation of the districts along the Chao Phraya River depend on the spilled water from the Dam. Flooded years were in 1983, 1995 and 1996 and the floods have occurred more frequently with increasing severity. The followings are the historical flood data of the Province;

Year	Date	Flood Condition
1995	Sept. 11~ Oct. 1	Severely flooded
1996	Sept. 20~ Oct. 3	Tropical Storm "Willi"
1996	Oct. 13	Chao Phraya Dam-spill out 3,249 m^3 / s
1996	Oct. 30~ Nov. 8	Depression, heavy rainfall & the Dam-spill out 2,551 m^3 / s

(1) Flood Damage

In 1995, the flood was the most severe one in Sing Buri history, causing the greatest flood loss to the Province, particularly Sing Buri municipality, In Buri and Phrom Buri Districts located along the Chao Phraya River. In addition, three districts, Bangrachan, Kaybangchan & Thachang, were inundated because of the heavy rainfall. The laterite embankment road of the Chai Nat -

Ayuthaya Canal was in rather bad condition, making it difficult to raise its crest elevation during the flood, therefore, the irrigable areas on the left bank suffered from extensive damage and the flood spread down to communities in southern Sing Buri.

(2) Flooding Condition

Three districts, In Buri, Sing Buri and Phrom Buri Districts located along the Chao Phraya River were hit by the overbank flood from the River in 1995. The flooding condition were distinguished as following three stages;

(a) Stage I

The flood inundated the area between the Chao Phraya River and RID flood protection dike, starting from the northern districts of In Buri, Sing Buri and Phrom Buri.

(b) Stage II

The water level of the Chao Phraya River rose higher and the flooded water flow over the RID flood protection dike into the east bank. The flood area extends to Highway No. 32 (or the A 1 - highway). The west bank is fairly protected.

(c) Stage III

With a rise of water level, the flood flow into Chaing Rak and Ban Rai Canals, and the culvert under Highway No. 32. The rapid change caused floods in farm areas in the eastern side of the Province. Roads to some villages were not passable. In southern part of the Province, the water from the Lop Buri River submerged five sub-districts. The Province was inundated for 45 days before the flood receded.

The overflow level above the River bank in 1996 was as follows;

Date	Overflow Level	Flood Condition
Oct. 14	In Buri / 0.92 m	-
Oct. 15	Sing Buri District / 0.28 m, Phrom Buri District / 0.73 m, The Lop Buri River / 1.01 m	-
Oct. 30~ Nov. 8	-	Flooding & inundation
Nov. 12	-	Flooded water receded

4.3.2 Existing Condition

(1) Sing Buri Municipality

The Municipal has 21,879 population in 1996 and covers 7.81 km^2. The commercial area and the Municipal office is located on the right bank of the Chao Phraya River, while the Provincial office, the City hall and some new residential area are built on the left bank. The right bank is well developed and densely populated. The Provincial office is in charge of the water supply and

the ground water on the left bank is used as raw water for supplying mainly the Municipality. The location of the well is around 500 m apart from the River and 200 m in depth. Land subsidence is not reported yet. On the other hand, there is no sanitary treatment system and it drained into the River by gravity

(a) Recorded Flood Level

The overflow level from the Chao Phraya River into the Municipality was used to be 11.5~ 12.0 m (MSL). The peak flood level in the Municipality was recorded as follows;

Year	1978	1980	1983	1994	1995	1996
Flood Level	11.59 m	11.85 m	11.84 m	10.27 m	12.56 m	12.40 m
Remarks	-	-	-	-	Sept.11~Oct.1	-

(b) Flood Damage

In 1996, Flooded area was 3 km^2 while the municipality covers 7.81 km^2. The damage was 9,331 people, 2,403 houses, 63 public roads etc. (The damage were estimated to be 23 million Bahts).

(c) Existing Flood Protection Facility

Flood protection dike has been constructed on the right bank of the Chao Phraya River, mainly in front of the commercial and office area, with the distance of 2,500 m approximately

(d) Existing Drainage Facility

The municipality had operated two permanent drainage pumps (10 inches in diameter, electric) and five temporary pumps (diesel) from Provincial RID in 1995. The operation period was approximately 45 days in 1995.

(e) Flood Fighting

In 1995, the Municipality could prevent overbank flow by building flood protection dikes.

(2) In Buri Sanitary District

In Buri District located in the north of Sing Buri Municipality has an area of 320 km^2 with the population of 61,066 in 1995. In Buri Sanitary District is one of ten administrative sub-districts and has the area of 4 km^2 with the population of 7,915 in 1995 and 8,582 in 2015.

(3) Prom Buri Sanitary District

Prom Buri District with the area of 84 km² consists of seven administrative sub-districts and two sanitary districts, namely Bang Nam Chico and Pak Bang are included. Bang Nam Chico sanitary district has the area of 18 km² with the population of 4,522 in 1995 and 6,985 in 2015 while the Pak Bang sanitary district has 12.8 km² with 3,182 in 1995.

4.3.3 Related Plan and Project

(1) Sing Buri Municipality

The new drainage and flood protection system of the municipal area is shown in Fig. 4.3.1 - ① and the outline of these facilities and estimated costs are tabulated in Table 4.3.1. The new system is based on the present and future land use plans which are shown in Fig. 4.3.2.

(2) In Buri Sanitary District

The new drainage and flood protection system of the sanitary district is shown in Fig. 4.3.1 - ② and the outline of these facilities and estimated costs are tabulated in Table 4.3.1.

(3) Prom Buri Sanitary District

The new drainage and flood protection system of two subdivided sanitary districts is shown in Fig. 4.3.1 - ③ & ④ and the outline of these facilities and estimated costs are tabulated in Table 4.3.1.

4.4 Ang Thong Province

4.4.1 General

The Ang Thong Province , the area of which is 968 km², is situated in the upper Central Plain. The general topography of the Province is mostly lowland area (about 3~6 m. MSL) traversing two major rivers, namely the Chao Phraya and Noi River. The Province used to have flood damage from September to November. The municipalities of Ang Thong and Pamok and Chaio District located near the banks of Chao Phraya River were severely damaged.

In 1995, Flooded water caused by heavy rain starting from Aug. 22, was spilled from Chao Phraya River and Noi River and inundated Chaiyo, Sing Buri, Pamok, Phothong and Wisetchaicharn. The maximum water level was 2.18 m above the river bank elevation of 6.14 m (MSL) at the Aug Thong City Hall. In 1996, the heavy rain starting from Sept. 27 caused the overflow from Chao Phraya and Noi River and inundated the districts of Chaiyo, Muang, Pamok, Wisetchaicharn and Samko.

4.4.2 Existing Condition

(1) Ang Thong Municipality

The Ang Thong Municipality covers an area of 6.19 km². The offices of the Province and government agencies, a hospital and some residential area are

located on the left bank, whereas the commercial, residential and administrative areas of the Municipality lie on the right bank of the Chao Phraya River. The population of the Municipality is 11,662 as of in 1995.

(a) Historical Flood : Flooded years were in 1983, 1995 and 1996.

(b) Recorded Flood Level

The peak flood level in the Municipality was recorded as follows;

Year	1983	1995						1996
Date	-	Sept.1	Sept.10	Sept 20	Sept. 28	Sept. 30	Oct. 1~2	Oct.13~14
Flood Level	7.73 m	6.23 m	6.86 m	7.95 m	8.25 m	8.32 m	8.3 m	8.32 m
Peak Discharg	-	1,794 m^3/s	2,199 m^3/s	3,349 m^3/s	4,133 m^3/s	-	-	-

The road level is 6.9m (MSL) and the spillway level of the drain is 6.4 m (MSL). The peak flow discharges at Chai Nat Dam were 4,600 m^3/s in 1995 and 3,300 m^3/s in 1996. The flooded area in 1995 is shown in Fig. 4.4.1 - ①.

(c) Cause of Flood

In 1995, the maximum water level was 2.18 m above the river bank elevation of 6.14 m (MSL) at the Aug Thong City Hall. In 1996, the heavy rain starting from Sept. 27 caused the overflow from Chao Phraya and the flooded water washed away 20 to 30 m of dike section on the right bank of Chao Phraya River, located near the northern part of Ang Thong municipality, overflowed on the adjacent road section with around 70 m and inundated the commercial area with the depth of 1.8 m for 2 to 3 days. The irrigation gate located on the right tributary, west of the commercial area, was too low on its crest, therefore, the backwater from Chao Phraya River also caused the inundation at the City centre. The river bank section of Chao Phraya in and around Ang Thong is very sandy and liable to be eroded, therefore, bank slope protection, such as rip raps, gabions, etc are to be required.

(d) Flood Damage

The flood damage on the Municipality was estimated to be 7 to 10 million Baths. Although the peak flow discharge was higher in 1995 at Chai Nat Dam, the damage was bigger in 1996. The rise of water level in 1996 was more fast than that of 1995 during flood and this was one of the reason for receiving much damage.

(e) Flood Fighting

In 1995, the Municipality took some flood protection measures, such as heightening the crest of dikes, concrete walls, etc. as high flood flow was

expected and could manage to protect the City centre (commercial area) from flood. Around 1,000 people were engaged for flood fighting in 1996. The composition of the fighting team was as follows;

Municipal officer-250, military from Lop Buri-250, residents, students, etc.

The Municipality anticipates that they could save annual budget for flood fighting amounting to 10~20 Million Bahts if the construction of permanent structure for flood protection is completed.

(2) Pamok Municipality

The Municipality located southern part of the Province has the area of 26.9 km^2 (including surrounding area) and the population of 17,368.

4.4.3 Related Plan and Project

The new drainage and flood protection systems of Ang Thong and Pamok municipalities are shown in Fig. 4.4.1 - ② & ③. The new system is based on the present and future land use plans which are shown in Fig. 4.4.2 for Ang Thong and Fig. 4.4.3 - ① & ② for Pamok. The outline of these facilities and estimated costs are as follows;

Municipality			Ang Thong		Pamok	
Facility		Unit	Quantity	E. Costs	Quantity	E. Costs
Flood Protection	Dike	km	40.74	531.3	38.43	403.32
	River Bank Improvement	km	13.9	651.1	13.33	668.80
Drainage	Gates	Nos.	16	65.7	4	6.28
	Pumping Station	Nos.	10	99.3	6	55.51
	Pipe Drain	km	41.79	297.5	47.43	315.54
	Canal Improvement	km	0.87	6.1	4.28	26.88
		Total		1,651.0		1,476.33
		Contingency 10.0%		165.1		147.64
		Overhead+Tax+Profit 22.0%		399.5		357.27
		Design and Supervision		163.2		194.87
		Grand Total : Cost (Mil Bahts)		2 378.8		2,176.11

4.5 Ayuthaya Province

4.5.1 General

The Ayuthaya Province , the area of which is 2,557 km^2, is situated in the upper Central Plain. The general topography of the Province is mostly lowland area, which is formed by four major rivers as Chao Phraya, Noi, Lop Buri and Pasak Rivers. The last two rivers join together before flowing into the Chao Phraya River, near the old

municipality of Ayuthaya. In 1995, almost all the districts were affected by the flood and the Ayuthaya Municipality District was severely damaged.

4.5.2 Existing Condition

(1) Ayuthaya

The Municipality covers an area of 14.0 km² and has 70,623 population in 1995. The flood started in September, 1995 and the whole Municipality except for some roads was inundated for about 2 months (around 0.3 ~ 1.0 m deep). The flood damage in 1995 was amounted to be 65 million Bahts. No serious flood damage had occurred in the Municipality for around 50 years (before 1995).

(a) Recent flood : 1995, 1996

(b) Flood Fighting

Such measures as dredging the existing canals, construction of concrete walls and dikes, installation of 5 water gates (2 gates by PWD and 3 by Provincial RID) had been taken, the flood in 1996 wouldn't cause much damage to the Municipality. Annual budget for flood fighting / mitigation is around 2 Million Bahts. Based on the flood information, around 200 officers from flood fighting / mitigation, construction and health sections of the Municipality are to be organised for flood fighting team.

4.5.3 Related Plan and Project

The overall drainage and flood protection system of Ayuthaya and its vicinity is shown in Fig. 4.4.3 - ③ and the outline of these facilities and estimated costs are shown in Table 4.5.1. The new system is based on the future land use plan which are shown in Fig. 4.5.1 - ②.

The drainage and flood protection system of Ko Muang ~ Phu Kao Thong (selected areas for the detailed design) is also shown in Fig. 4.5.1 - ① and the outline of these facilities and estimated costs are as follows;

Ko Muang - Phu Kao Thong	Cost (Mil Bahts)		
Facility	Unit	Quantity	Estimated Costs
-Flood Barriers	m	16,030	187.2
- Gate / Regulator etc.	Nos.	10	20.6
- Pumping Station including Mobile Pump	Nos.	4	141.4
- Canal Improvement	cu.m	100,540	2.9
- Main Drain Improvement	m	180	5.0
- Remote Sencing	l. sum	1	3.6
		Total	360.7

Engineering Fee 3.5%	12.6
Grand Total	373.3

Ayothaya	Cost (Mil Bahts)		
Facility	Unit	Quantity	Estimated Costs
- Flood Barriers	m	11,650	56.0
- Gate / Regulator etc.	Nos.	13	11.4
- Pumping Station (12.0 cms.)	Nos.	1	63.3
- Canal Improvement	cu m	112,840	14.2
		Total	144.9
		Engineering Fee 3.5%	5.0
		Grand Total	149.9

4.6 Pathum Thani Province

4.6.1 General

The Pathum Thani Province , the area of which is 1,526 km^2, is situated in the lower Central Plain. The general topography of the Province is very low-lying flat plain where the ground level is about 1~2 m above msl. In 1995, the most severe flood in Pathum Thani history were occurred and 7 districts of the Province were inundated causing the greatest flood loss to the Province. These districts are Amphoe Pathum Thani, A.Sam Khok, A. Lad Lum Kaew, A.Klong Luang, A.Lam Luk Ka, A.Thanya Buri and A.Nong Suar.

4.6.2 Existing Condition

The Province suffers from flood problem almost every year due to large amount of water coming from the northern region along the Chao Phraya River during rainy season and also the tidal effects from the River mouth (usually from October to November). The damage to the Province in 1995 is estimated about 1,276 Million Baht. The Pathum Thani Municipality and other communities located along the River were inundated for 2~3 months.

4.6.3 Related Plan and Project

In the study of flood protection and drainage system for Pathum Thani Province, 7 polders as shown in Fig. 4.5.1 - ③ were recommended as follows ;

- Pathum Thani (Municipality) Polder
- Bang Luang - Chieng Rak Polder
- Bang Pho Tai - Bang Luang Polder
- Sam Khok Polder
- Ban Phaow Polder
- Klong Preampachalorn - Pahol Yothin Polder
- The area inside the RID irrigation polder

The first three polders were selected for the feasibility study and the location of these polders are shown in Fig. 4.6.1 - ①. The new system is based on the present and future land use plans which are shown in Fig. 4.6.2.

(1) Pathum Thani (Municipality) Polder

The Municipality covers an area of 7.1 km^2 and has 14,680 population in 1995, while the Poledr covers the Municipality, some part of Bang Luang Sanitary District and surrounding communities. The dike around the polder is under the responsibility of PWD and DOH. The gate, pumping station and drainage system are under the responsibility of PWD.

(2) Bang Luang - Chieng Rak Polder

The Polder covers the communities on the left bank of the Chao Phraya River, between the river and Klong Preampachalorn. The dike is under the responsibility of PWD, DOH and ARD. The gate, pumping station and drainage system are under the responsibility of PWD.

(3) Bang Pho Tai - Bang Luang Polder

The Polder covers some part of Bang Luang Sanitary District and surrounding communities. PWD, DOH and RID will be responsible for the dike around the Polder. For the gate, pumping station and drainage system are under the responsibility of RID and PWD.

The outline of these facilities and estimated costs are as follows;

Location of Polder		Pathum Thani		B. Luang / Chieng Rak		B. Pho Tai / B. Luang	
Facility	Unit	Quantity	E. Costs	Quantity	E. Costs	Quantity	E. Costs
-Flood Dike	km	9.88	129.0	13.0	131.9	9.35	117.4
- Gate	Nos.	3	9.5	10	45.4	13	66.8
- Pumping Station	Nos.	2	17.8	7	121.6	2	32.1
- Canal Improvement	km	0.61	19.2			5.42	103.6
- Main Drain Improvement	km	2.61	32.5	20.24	216.5	8.8	99.6
Total (a)			208.0		515.4		419.5
Contingency 10% (b)			20.8		51.5		42.0
Overhead+Profit+Tax 22%			50.3		124.7		101.5
Design & Supervision (6 % of a + b)			13.7		34.0		55.4
Grand Total : (Mil. Bahts)			292.8		725.6		618.4

Note : E. Costs = Estimated Costs

4.7 Nonthaburi Province

4.7.1 General

The Nonthaburi Province, the area of which is 622 km², is situated in the lower Central Plain. The general topography of the Province is mostly lowland area, which is formed by Chao Phraya River. The Province is divided into two banks, i.e. east (left) bank with the area of 82.5 km² and west (right) bank with the area of 539.5 km². The east bank is densely populated with Provincial Capital, Nonthaburi, and Pak Kret Municipality. The west bank, mainly agricultural area, is rapidly changing to the residential area.

4.7.2 Existing Condition

Recently, the floods hit Nonthaburi Province is as follows;

Year	1975	1978	1980	1983	1995
Water level at Phut Bridge	+2.05	-	+1.99	+2.13	+2.27

In 1995 and 1996, the east bank of Chao Phraya River, between the River and the adjacent road, and the west bank were severely inundated because of the large flooded water volume and the high tide. The flooded area in 1995 is shown in Fig. 4.6.1 - ②. The average depth of inundation was 1.0 ~1.5 m during 1~2 months and caused huge damage to the Province. At present, there are thirteen pumping stations with the total capacity of 54.5 m³/ s on the east bank. From Pak Kret to the Rangsit Canal on the east bank, the dike construction along the Chao Phraya River, is on-going with the budget of PWD, while the Highway Dept. also raises their roads of Phibulsongkram and Tivanon (No. 306) as flood protection barriers

4.7.3 Related Plan and Project

In the study of flood protection and drainage system for Nonthaburi Province, 2 polders, west and east, were recommended as shown in Fig. 4.6.1 - ③.

(1) East Bank Polder

The Polder mainly consists of major part of Nonthaburi and Pak Kret District. A part of the Nonthaburi and Pak Kret District extends to the West Bank. The Nonthaburi Municipality covers the area of 38.9 km² with 251,468 population in 1995, while the Pak Kret has 42.7 km² with the population of 137,866. The East Bank Polder is the expansion of the original polder area by shifting the dike line from Phibun Songkhram road to the adjacent river bank, the increased area of which is 3 km². The flood protection system on the east bank polder is summarised, together with the west bank polder in the following table.

Location		Unit	Quantity	Estimated Cost
East Bank	Dike	m	6,454	146.5

	Regulator / Sluice Gate	Nos.	3	7.6
	Pumping Station	Nos.	2	121.4
			Sub-total	275.5
West Bank	Dike	m	40,222	856.4
	Regulator / Sluice Gate	Nos.	141	320.5
	Pumping Station - (20) Navigation Lock - (4)	Nos.	24	1,301.5
			Sub-total	2,478.4
Common	SCADA System	L. sum	1	102.4
Total : Cost (Mil. Bahts)				2,856.8

(2) West Bank Polder

The area covers 150 km^2 consisted of a part of Pak Kret, Bang Bua Thong, Bang Yai, Bang Kruay and Nonthaburi districts, Bang Bua Thong and Bang Kruay Municipalities, Bang Si and Wat Chalor sanitary districts. At present, the polder area is low density residential and agricultural area with the total population of about 237,000 and expected to be low and moderate dense residential area in 2017 with the population increased to be 466,000.

(3) Drainage System

(a) East bank

The drainage capacity of existing thirteen pumping stations are not enough for the next twenty years, therefore, the pumping stations are revised and the total drainage capacity required is to be 139.5 m^3/ s as shown in Table 4.7.1.

(b) West Bank

There are a number of drainage canals and large canals in the west bank area. Therefore, there are no serious problems on drainage in the area at present. When the polders are constructed, the required total drainage capacity is to be 94.5 m^3/ s as shown in Table 4.7.2.

(4) SCADA System

A SCADA system is adopted in order to function the flood protection and drainage system of the Province smoothly. The control centre will be installed in the Provincial Government Office and the information are collected from relevant agencies and flood protection and drainage facilities such as pumping stations and drainage gates.

4.8 Implementation Schedule

(1) Phasing of Project Implementation and Duration of Each Phase

Project implementation generally consists of the following four phases;

- Feasibility Study
- Detailed Design
- Bidding for Construction
- Construction of Project's Components

However, the first two phases were completed mainly on the core areas of the Provincial Capitals. The bidding would require around 3~4 months and the duration of construction phase depends on the type of the project's components.

(2) Year of Commencement

In the Study, the first year of project implementation was set up at 1998, however, the economic situation has been changing in Thailand, and the first year is rescheduled in the year of 2000.

(3) Implementation Schedule

Based on the procedures abovementioned, the implementation schedule is summarised as shown in Table 4.8.1.

5. SECOND PRIORITY AREAS

The provinces of upper reaches and the perimeter areas in the plain are included in the Master Plan for Flood Protection of 49 Areas (refereed to as the Second Group of Community), which is currently conducted by the PWD in March, 1998. The selected urban areas in the flood plain are in the Provinces which were also received damage from floods seriously in 1995 and in 1996, and the total damage of which was not so large because of their locations.

Most of the Provincial Capitals and Municipalities in the surrounding provinces of the Upper Chao Phraya River Basin are developed along the river as the inland navigation used to be the main transportation system in old days. In compliance with the development of riparian urban areas, they began to suffer from flood and the damage became increased.

At the early stage of the Study on Flood Protection and Drainage for Urban Areas, starting from December, 1996, the data and information on the other urban areas along the Upper Chao Phraya River Basin of Yom and Nan River, Tha Chin River and Pasak River were very limited. Therefore, the data collection was made on these urban areas located in the flood plane as listed in the following table and some information is also included here.

Province	Municipality
Sukhothai	Sukhothai Sawankhalok

Phitsanulok	Phitsanulok
Phichit	Phichit Bang Mun Nak Taphan Hin
Suphanburi	Suphanburi Songpeenong
Samut Sakhon	Samut Sakhon

5.1 Sukhothai Province

5.1.1 General

The Sukhothai Province, the area of which is 6,596 km^2, is situated in the Northern region. The general topography of the Province is hilly in the northern area, whereas the central area lies along the Yom River which is the tributary of the Nan River. The inundation and flooding used to occur 5 districts along the Yom River out of 9 districts in the Province. In 1995, floods occurred due to heavy rainfall in the upstream of the Yom River. The peak runoff and overflow from both banks of Yom River as well as sharp floods flowing from Tak and Kham Phaeng Phet Provinces hit to Ban Dan Lan Hoi District and further down to western side of Muang District and Sukhothai Municipality.

Two municipalities, Sukhothai and Sawankhalok, are selected and the details are described as in the followings;

The Provincial Capital, Sukhothai, covers an area of 3.5 km^2 with the population of 21,712 as of 1995. Including the unregistered, the total population becomes around forty thousand. The commercial and residential areas of the Municipality lie on the left bank of the Yom River.

The Municipality of Sawankalok covers an area of 6.457 km^2 with the population of 19,345 along the Yom River.

5.1.2 Existing Condition

(1) Sukhothai Municipality

(a) Flood Damage

The recent flood occurred in 1995, 1996 and 1997 (other year's damage was light). The commercial area was inundated for about 2 months, September and October in 1995, with the highest depth of 1.5 m approximately and 2,000 houses were inundated. In 1996, the western part of the Municipality along the Lampang River, the right tributary of Yom River, was inundated and around 750 houses were received damage (Amount of damage: 970,550 Bahts*). The inundation depth at the western part of the Municipality is around 25 cm and 40 cm in 1995 and 1996 respectively. Inundation area is around 1.5 km^2 both for 1996 and 1997. The Municipality centre had no damage in 1996 because the crest of flood protection dikes along the Yom River were heightened at around 30 to 45 cm with concrete. Around one million Bahts were spent for heightening the crest of the dike. Sand bags were also used for heighten

the flood protection dike as a temporary measure. The estimated flood discharge is 1,200~1,800 m^3/s in 1995, 800~1,000 m^3/s in 1996 and 400 m^3/s in 1997, whereas the overflow depths of flood from the protection dike were 20 cm in 1996 and 30 cm in 1997. The inundation area is shown in Fig. 5.1.1 - ①.

source : Municipality Office

(b) Cause of Flood

The discharge capacity of the Yom River in the Municipality is getting decreasing as the sedimentation on the river bed is getting thicker and the water level during floods is increasing. On the other hand, the RID's culvert located Yom River, south of the Municipality, seems to have small discharge capacity and the backwater from here is considered to be one of the main causes of flood.

(c) Flood Protection Facility

Earth dikes and flood protection dikes of reinforced concrete are aligned along the Yom River, whereas the raised concrete road is laid on the northern border of the Municipality. Earth dikes are now replacing by reinforced concrete dikes.

(d) Drainage Facility

The Municipality owns 7 permanent pump stations with 14 pumps and 7 mobile diesel engine pumps. The detail of these pumps is as follows;

Type of Pump Station	No. of Pump	No. of	Diameter (inch)
Permanent	7	14	6~8
Pump (diesel)	-	6	6
Pump (diesel)	-	1	8

The damaged gates of drainage pipe kept flood lasting for longer time.

(e) Flood Fighting

Twenty one (21) pumps of the Municipality and 4 pumps borrowed from the RID were operated during the past flood. The pump operation term during flood and the budget for flood fighting are as follows;

Year	Pump Operation	Budget (Million Bahts)
1995	3 months	n.a.
1996	3 months	1.2
1997	1.5 months	1.5

(2) Sawankalok Municipalit

(a) Flood damage

The Centre of the Municipality is developed on the natural river bank where the ground elevation is slightly higher than the surrounding area. Therefore, the flood damage is concentrated on the surrounding municipal area as shown in Fig. 5.1.1 - ③. In 1995, from August to September, the Municipality was hit by the 6 peak floods with the duration of 45 days. There were two peaks of floods out of six during that time. The depth of overflow at the embankment was around 20 cm. The damage was 844 houses inundated and the amount was estimated to be 2,431,100 Bahts. There is no flood in 1996 and 1997

(b) Cause of Flood

The flooded water coming from the upstream, passing through the Mae Yom Weir in Phrae Province, of the Municipality hits the surrounding area of the Municipality.

(c) Flood Protection Facility

The river bank protection work has been proceeded as shown in Fig. 5.1.1 - ② and around 2 km of concrete based - riprap bank protection has been completed from 1995 to 1997. The design and construction supervision are made by the Municipality Engineer, whereas the funds are supplied by the (Provincial) PWD.

(d) Drainage Facility

In 1995, the Municipality hired some drainage pumps, listed in the following table, from the Agricultural Co-operatives in order to drain the inundated water. Duration of the pumping was around 21 days. There is no permanent pump stations nor plan.

There are 10 drainage outlets without flap gates on the Yom River, which also cause the inundation during the high flow in the Yom River.

Size of Pump	No. of Unit	Remarks
8 inches	4	Agricultural Co-operatives
4 inches	7	Agricultural Co-operatives

(e) Flood Fighting

In case of flood, the assistance is requested to the Central Government through the Provincial Representatives and the Governor.

5.1.3 Related Plan and Project

(1) Sukhothai Municipality

The proposed drainage and flood protection plan is shown in Fig. 5.1.1 - ① and its details are as follows;

Facility	Location	Description	Const. Cost
Raised Dike	Right bank of Yom Riv.	(D1) H= 1.4 m, L= 2.8 km	30.80
	Left bank of Yom Riv.	(D2) H= 1.4 m, L= 2.5 km	27.50
		(D3) H= 1.4 m, L= 1.2 km	13.20
Pumping Station	North of Lamphun Riv.	(P1) Q= 6 cms.	10.30
	South of Lamphun Riv.	(P2) Q= 8 cms.	13.00
	Left bank of Yom Riv.	(P3) Q= 10 cms.	14.10
Improvement of Gate Regulator	Yom Riv.	13 outlets of drainage pipe, Size: 2.0 x 1.5 m	3.46
Drainage Pipe	Yom Riv.	Circular pipe, Dia.= 1.0 m, L= 12.0 km	87.10
Dredging of Natural Canal	K. Krachong Lamphun Riv.	(d1) Depth= 2.0 m, L= 2.5 km	2.63
		(d2) Depth= 2.0 m, L= 1.2 km	1.26
Total : Cost (Mil. Bahts)			203.34

(2) Sawankalok Municipality

The proposed drainage and flood protection plan is shown in Fig. 5.1.1 - ③ and its details are as follows;

Facility	Location	Description	Const. Cost
Floodwall Dike	Right bank of Yom Riv.	(W1) H= 1.0 m, L= 7.5 km	104.72
	Left bank of Yom Riv.	(W2) H= 1.0 m, L= 8.0 km	109.52
Pumping Station	Right bank of Yom Riv.	(P) Q= 8 cms.	13.00
	Left bank of Yom Riv.	(P) Q= 8 cms.	13.00
Improvement of Gate Regulator	Yom Riv.	5 outlets of drainage pipe, Size: 2.0 x 2.5 m	1.33
Drainage Pipe	Yom Riv.	Circular pipe, Dia.= 1.0 m, L= 15.5 km	93.39
Total : Cost (Mil. Bahts)			334.96

5.2 Uttaradit Province

5.2.1 General

The Uttaradit Province, the area of which is 7,839 km^2, is situated in the Northern region. The general topography of the Province is hilly in the northern area, whereas the central area lies along the Nan River. The flood prone area is 1,625 km^2. Uttaradit town municipality, which has the population of 41,145 in 1995 and covering the area of 96 km^2, is selected and the details are described as in the followings.

5.2.2 Existing Condition

In 1995, the Uttaradit Municipality suffered from floods which were caused by storms

during August to September. The reservoir level of the Sirikit dam rose rapidly during this period and the dam had to release the water in order to provide more flood space in the reservoir for the next inflow. Thus, peak flow from Nam Pad River, the right tributary of Nan River, and the release from the Sirikit joined together and hit the municipality.

5.2.3 Related Plan and Project

The proposed drainage and flood protection plan is shown in Fig. 5.2.1 - ①and its details are as follows

Facility	Location	Description	Const. Cost
Floodwall Dike	Right bank of Nan Riv.	(W) H= 1.5 m, L= 9.0 km	152.56
Pumping Station	Right bank of Nan Riv.	(P) Q= 10 cms.	14.10
Improvement of Gate Regulator	Nan Riv.	5 outlets of drainage pipe Size: 2.0 x 1.5 m	1.33
Drainage Pipe	Nan Riv.	Circular pipe, Dia.= 1.0 m, L= 9.0 km	54.23
Total : Cost (Mil. Bahts)			222.21

5.3 Phitsanulok Province

5.3.1 General

The Phitsanulok Province, the area of which is 10,816 km², is situated on the Northern Region. The general topography of the Province is hilly in the North-eastern area, whereas the middle and southern areas are flat land mainly consisted of the flood plain of the Yom and Nan Rivers. The inundation and flooding used to occur in 4 districts of lower plain area out of nine 9 districts in the Province. The Phitsanulok Municipality area covers 18.26 km² and its population is 78,469. Including the unregistered, the total population becomes around two hundred thousand. The commercial area of the Municipality lies on the left bank of the Nan River. The Phitsanulok Municipality is selected for the Flood Protection and Drainage Master Plan and flood protection guidelines are proposed for three sanitary districts, Bang Rakham, Bang Krathum and Phrom Phiram.

5.3.2 Existing Condition

(1) Phitsanulok Municipality

(a) Flood Damage

Recent flood was occurred in 1995 and 1996. In 1995, the residential area on the right bank (western part) of the Nan River was severely inundated for about one month and around 4,174 houses were inundated as shown in Fig. 5.2.1 - ②. The inundation area was 9.72 km², almost one half of the Municipality. In 1996, the eastern part of the Municipality was inundated and around 100 houses were damaged.

• Road damage: In 1995, thirty eight (38) road sections were damaged and the Municipality received 38 Million Bahts of financial support from DOLA, whereas the amount of that in 1996 was 6 Million Bahts.

• No serious flood damage had occurred in the Municipality for around 50 years (before 1995), although they received flush floods from the eastern mountains, seepage from the Nan River and light inundation's.

(b) Cause of Flood

The flood from the north on Nan River and Kwae Noi River used to hit the Municipality, especially on the right bank of the Nan River. On top of this, the irrigation canal aligned in parallel with the Nan River and the Highway 12, on the right bank, blocks the flooded water and let the direction of flood flow change toward the Municipality.

(c) Flood Protection Facility

In 1995, the following flood protection dikes were constructed;

Location	Length	Height
Behind Rama Cinema	250 m	1.5 m
Behind Panpi Temple	400 m	0.6 m
Behind Rice Mill , (upstream of Wat Yai)	300 m	0.8 m

The Highway 12, on the right bank side of the Nan river, is now raising the road elevation, which may be served as a flood protection barrier.

(d) Drainage Facility

In 1995, 22 pumps were operated for one and half months with 24 hours a day to drain the flooded inland water. In 1996, there is no pump operation for flood fighting. The following pump stations are installed or planned to install;

Purpose	Right Bank	Left Bank
Flood Drain	3	7
Rainfall Drainage	1	5

Feasibility study for the sewerage / sanitary system on Phitsanulok Municipality is carried out by PWD, funded by the Ministry of Science, Technology & Energy in 1997.

(e) Flood Fighting

Southern part of the Municipality, on the left bank of Nan River, sand bags were piled with the average height of 0.5 m on the river bank to prevent overflow in 1995. The expense for flood fighting in 1995 was around two million Bahts. However, there is no flood fighting system and municipality personnel, volunteers from municipality, students from Naresuan University & military were engaged for flood fighting in 1995. Besides, the budget for flood fighting is not allocated annually.

(2) Three Sanitary Districts

(a) Bang Rakham

The Bang Rakham sanitary district is located in low land. The floods after heavy rainfall from the Yom River overflow and stagnates in and around the district.

(b) Bang Krathum

The Bang Krathum sanitary district is located in low land. The floods are caused by heavy rainfall in Petchhabun Mountains and peak runoff from the Wang Thong River. These cause regular flood stagnation in the district.

(c) Phrom Phiram

The Phrom Phiram sanitary district is located in low land with the Nan River and the Klong Prong Nok. In flood season, the overflow from the Nan River inundates the district to a great extent.

5.3.3 Related Plan and Project

(1) Phitsanulok Municipality

The proposed drainage and flood protection plan is shown in Fig. 5.2.1 - ③. The proposed plan is involving three agencies, i.e. PWD, RID and Highway Dept. as follows;

- PWD -

Facility	Location	Description	Const. Cost
Dike	Both banks of Nan Riv. (Very densed community area)	(W) H= 1.2 m, L= 11.9 km (L- shaped wall dike)	189.96
Raised Road	Both banks of Nan Riv.	(R) H= 1.1 m, W= 4.0 m, L= 20.6 km	170.38
Pumping Station	PT- RB- 4 Road. K. Khok Chang / Mittraphap Rd. Mouth of K. I Ong	(P1) Q= 18 cms. (P2) Q= 23 cms. (P3) Q= 18 cms.	42.48 53.70 42.48
Total : Cost (Mil. Bahts)			499.00

- RID -

Facility	Location	Description	Const. Cost
Dike	K. Khok Chang (Community area)	(D2) H= 2.0 m, W= 4.0 m, L= 6.1 km	27.63
Gate Regulator	K. I Ong	Size: 2.5 x 2.5 m	0.5
Dredging	K. Khok Chang (Bypass Rd. ~ K. Khok Chang bridge)	(d) Depth= 2.0 m, W= 5.0 m, L= 2.5 km	1.09
Total : Cost (Mil. Bahts)			29.22

- Highway Dept. -

Facility	Location	Description	Const. Cost
Raised Road	Bypass No.12 (Nan Riv.~ Railway, Irrigation Canal~ Nan Riv.)	(D1) H= 1.5 m, W= 4.0 m, L= 3.9 km	9.04
Total : Cost (Mil. Bahts)			9.04

(2) Three Sanitary Districts

(a) Bang Rakha

The proposed plan is involving three agencies, i.e. PWD, RID and Highway Dept. as follows;

- PWD -

Facility	Location	Description	Const. Cost
Polder (Earth Dike)	Southeast part of Community	(D1) H= 2.5 m, W= 4.0 m, L= 3.3 km	20.00
	Southwest part of Community	(D2) H= 2.0 m, W= 4.0 m, L= 3.2 km	14.59
Raised	Right bank of Yom Riv.	(W) H= 0.7 m, L= 4.1 km	36.83
Pumping Station	Sunthorn Pradit Temple	(P1) Q= 1.0 cms.	5.29
	Mouth of K. Nong Ree	(P2) Q= 5.0 cms.	14.61
Total : Cost (Mil. Bahts)			91.32

- RID -

Facility	Location	Description	Const. Cost
Gate Regulator	K. Nong Ree	Size: 2.0 x 2.5 m	0.39
Dredging	K. Wat Ban Rai~ Yom Riv.	(d) Depth= 2.0 m, W= 5.0 m, L= 3.5 km	0.63
Total : Cost (Mil. Bahts)			1.02

(b) Bang Krathum

The proposed plan is involving two agencies, i.e. PWD and Highway Dept. as follows;

- PWD -

Facility	Location	Description	Const. Cost
Polder (Earth dike)	South of Community	(D1) H= 2.0 m, W= 4.0 m, L= 4.5 km	20.52
Floodwall dike	K. Huai Kaew	(W) H= 1.5 m, L= 2.5 km	42.38
Pumping Station		(P) Q= 8.5 cms.	24.84
Gate Regulator	5- location	Size: 2.0 x 2.0 m	1.64
Total : Cost (Mil. Bahts)			89.38

- Highway Dept. -

Facility	Location	Description	Const. Cost
	North of bypass road	(D2) H= 1.0 m, W= 2.0 m, L= 5.0 km	7.02
Total : Cost (Mil. Bahts)			7.02

(c) Phrom Phiram

The proposed drainage and flood protection plan is summarized as follows;

- PWD -

Facility	Location	Description	Const. Cost
Dike	Left bank of Nan Riv.	(W) H= 1.2 m, L= 3.0 km	41.89
Polder	North of Community	(D) H= 2.0 m, L= 1.5 km	5.25
Pumping St.	Left bank of Nan Riv.	(P) Q= 1.0 cms.	5.92
Total : Cost (Mil. Bahts)			53.06

5.4 Phichit Province

5.4.1 General

The Phichit Province , the area of which is 4,531 km^2, is situated in the Northern region. The general topography of the Province is low plain area mainly consisted of the flood plain of Yom and Nan River. The Provincial Capital, Phichit Municipality, covers an area of 12.02 km^2. The major municipal area of Phichit lies on the right bank of the Nan River and its population is 24,832 as of 1995. There are two more municipalities in the Province, Bang Mun Nak and Taphan Hin.

The Municipality of Ban Mun Nak located along the Nan River covers an area of 2.5 km^2 and its population is 10,258. Main municipality area is located on the left bank of Nan River. The Municipality of Taphan Hin located along the Nan River covers an area of 5.2 km^2 and its population is 22,066. Main municipality area is located on the left bank of Nan River.

Four communities, three of which are town municipalities of Phichit, Bang Mun Nak and Taphan Hin, and one sanitary district of Pho Thale, are selected for the Flood Protection and Drainage Master Plan and the details are described as in the followings.

5.4.2 Existing Condition

(1) Phichit Municipality

(a) Flood Damage

The recent flood was occurred in 1994 (not so heavy), 1995 and 1996. The flooded conditions were almost the same in 1995 and 1996. The depth of inundation in the municipal area was between 10 to 80 cm and its duration was 3 to 25 days. On the left bank of the Nan River, the area of which is scarcely populated, the depth of inundation was 1~1.5m

except for the railway embankment. The inundation area was around 1.4 km² both in 1995 and 1996. In 1995, the amount of damage* was 14.25 million Bahts and 1,832 houses were inundated, whereas the number of population suffered from floods were 12,824 in 1996. The flooded area in and around the municipality is shown in Fig. 5.4.1 - ①.

* Source : Municipality Office

(b) Flood Protection Facility

There is no flood protection facilities in the Municipality.

(c) Drainage Facility

Flooded inland water had drained into Nan River through 8 pumps placed on the right bank (these pumps were borrowed from Provincial Irrigation Dept.). On the left bank of Nan River, eastern part of the Municipality, is scarcely populated and was inundated with the depth of 1.5 m.

(d) Flood Fighting

Budget for flood fighting is not allocated annually. There is no flood fighting system and municipality personnel (mainly from technical division and fire fighting section) and volunteers from municipality (around 400) are to be engaged for flood fighting. The expense for flood fighting (including equipment) in 1995 was around one million Bahts.

In building temporary dikes with earth and sand bags, overflow from Nan River into the Municipality centre located on the right bank was managed to prevent.

(e) Countermeasure

Construction of flood protection dikes along the Nan River. The Si Fai Lake with the surface area of 240 ha. located at the southern border of the Municipality may utilise as a retarding pond.

(2) Taphan Hin Municipality

(a) Historical Flood

Whole municipality area was inundated in 1995 and 1996. In 1995, flooding started from the end of August to Oct. 6th and 14 drainage pumps of 2.5, 5, 6, 8 inches- diameter were operated almost 10~15 hours a day for one month. In 1996, flooding started from the August 7th to Oct. 6th and 14 drainage pumps of 5, 6, 8 inches- diameter were operated for 10~15 hours a day for one month. Around 1,650 houses were received damage.

(b) Flood Protection Facility

Flood protection facilities existing and planned are as follows;

	Left Bank	Right Bank
1	Dike with Flap Gate / Northern border of the Municipality	Raised Road / H = more than 0.7m, Planned at the Northern border
2	Raised Road / L = 940m, H = 0.7m, Budget: 1997, Not yet build	Concrete Dike / L = 250m, H = 1.0m, built
3	Flood Protection Dike / L = 1,500m, H = 0.7m, Planned	-

The existing flood protection facilities are shown in Fig. 5.4.1.

(c) Drainage Facility

In 1995 and 1996, fourteen (14) drainage pumps of 2.5, 5, 6, 8 inches-diameter were operated almost 10~15 hours a day for one month. There is no permanent drainage pump station in the Municipality.

(d) Flood Fighting

The budget for flood fighting in 1995 and 1996 was 300,000 Bahts respectively and new drainage pumps, fuel for emergency vehicles, rice and food for evacuees were purchased out of these budget. The flood fighting system is well organised and the Municipality owns the following equipment:

Equipment	Pick-up truck	Dump trucks	Water pumps	Flat bottom barges	Fire boat
Number	1	3	14	3	2

(3) Ban Mun Nak

(a) Flood Damage

Historical flood was occurred in 1995 and 1996. Flooded water from the Nan River is less hazardous than the flush floods from the left tributaries of Nan River (these tributaries originates in the Petchabun Mountains). In 1995 and 1996, inundated area was 2 km^2, around 2,200 houses were damaged and the amount of damage was 70,000 Bahts*.

* Source : Municipality Office

(b) Flood Protection Facility

There are some river bank protections in the Municipality as shown on Fig. 5.4.2 - ①. Some budget for the construction of reinforced concrete flood protection dike along the Nan River is already prepared.

(c) Drainage Facility

Inundated water was drained to the surrounding low land and swampy area. In 1995, two (2) unit of 8 inches diameter and 9 unit of 4 inches drainage pumps were operated 24 hours a day for one month. In 1996, same equipment has operated for one and half months. There is no permanent drainage pump station. Drainage capacity has improved by replacing pipe drain with box culverts

(d) Flood Fighting

Sand bags and black-paddy ash bags were laid along the river banks with the total distance of about 5 km and 2~5 bags were piled as temporary protection dikes. Ash-filled bags were used in place of sand bags as sand is rather expensive here. In 1995 and 1996, the budget for flood fighting was 280,000 and 310,000 Bahts respectively. The flood fighting system is as follows:

- 50 Municipal officials
- 30 Volunteers
- Sand bags & black-paddy ash bags : over 10,000
- Water pump - 9 units of 4 inches diameter, from RID - 2 units of 8 inches diameter rent from people - 5 units of 4 inches diameter
- Pickup truck - 1

(e) Countermeasures

Construction of flood protection dikes along the Nan River and furnish 3 units of 8 inches diameter drainage pumps.

(4) Pho Thale sanitary district

The area of Pho Thale sanitary district is located in the Yom River Plain. Floods are generally caused by the overflow from the Yom River and its tributaries nearby. In 1995 and 1996, the floods caused the severe inundation on the whole sanitary district. Agricultural area, government offices and other properties received a lot of damage.

5.4.3 Related Plan and Project

(1) Phichit Municipality

The municipality has no flood protection and drainage facility, therefore, the budget is allocated to construct bank protections and roads as shown in Fig. 5.4.1.

iority	Type of Project	Outline of Project	1997	1998	1999
1	Bank Protection	Bank Protection- 950m	15,722	-	-
2	Bank Protection	Bank Protection- 300m	4,965	-	-
3	Road Construction	Concrete Road : L=108m, W=5~8m, A= 620m²	430	-	-
4	Road Construction	Raise Road : L=2,000m, W=5m, Elevation=0.5m	6,941	-	-
5	Road Construction	Concrete Road : L=1,020m, W= 6m, A= 6,120m²	4,247	-	-
6	Road Construction	R.C. Road : L=525m, W= 4~5m, A= 2,367m²	1,643	-	-
7	Road Construction	R.C. Road : L=400m, W=5m, A= 2,367m²	1,388	-	-
8	Bank Protection	Not specified yet	-	15,000	15,000

Unit: 1,000 Bahts , Source : Municipality Office

On the other hand, the proposed plan by PWD is as follows;

Facility	Location	Description	Const. Cost
Floodwall dike	Right bank of Nan Riv.	(W) H= 2.2 m, L= 4.1 km	94.30
Earth dike	Right bank of K. Pak Thang	(D1) H= 2.0 m, L= 2.4 km	10.94
	Left bank of Nan Riv.	(D2) H= 0.7 m, L= 1.0 km	2.03
Raised Road	Left bank of Nan Riv.	(R1) H= 0.5 m, L= 1.0 km	1.98
		(R2) H= 0.5 m, L= 1.2 km	2.37
		(R3) H= 0.5 m, L= 2.6 km	5.14
Pumping Station	Right bank of Nan Riv.	(P1) Q= 8.0 cms. (City hall)	20.90
	Left bank of Nan Riv.	(P2) Q= 6.0 cms. (Railway St.)	15.70
Gate Regulator	2-each on both banks	4 outlets of drainage pipe, Size: 2.0 x 1.5 m	1.06
Drainage Pipe	Nan Riv.	Circular pipe, Dia.= 1.0 m, L= 1.0 km	24.70
Total : Cost (Mil. Bahts)			179.12

(2) Taphan Hin Municipality

The proposed drainage and flood protection plan is shown in Fig. 5.4.1 - ② and its details are as follows;

Facility	Location	Description	Const. Cost
Floodwall dike	Right bank of Nan Riv.	(W1) H= 1.2 m, L= 4.8 km	67.02
	Left bank of Nan Riv.	(W2) H= 1.2 m, L= 3.5 km	48.87
Raised Road	Right bank of Nan Riv.	(R1) H= 1.0 m, L= 0.7 km	2.88
		(R2) H= 1.0 m, L= 0.5 km	1.90
	Left bank of Nan Riv.	(R3) H= 1.0 m, L= 0.8 km	3.16
Pumping Station	Right bank of Nan Riv.	(P1) Q= 4.0 cms.	13.00
	Left bank of Nan Riv.	(P2) Q= 6.0 cms.	15.70
Gate Regulator	1- each on both banks	2 outlets of drainage pipe, Size: 2.0 x 1.5 m	1.06
Drainage Pipe	Nan Riv.	Circular pipe, Dia.= 1.0 m, L= 8.3 km	50.01
Total : Cost (Mil. Bahts)			203.60

(3) Ban Mun Nak Municipality

The proposed drainage and flood protection plan is shown in Fig. 5.4.2 - ③ and the detail is tabulated as follows;

Facility	Location	Description	Const. Cost
Floodwall dike	Right bank of Nan Riv.	(W1) H= 1.4 m, L= 4.2 km	58.64
	Left bank of Nan Riv.	(W2) H= 1.4 m, L= 3.1 km	43.63
Earth dike	K.Kud (Right bank)	(D1) H= 1.4 m, L= 0.5 km	1.66
	Left bank of Nan Riv.	(D2) H= 1.4 m, L= 6.0 km	19.10
Raised Road	Right bank of Nan Riv.	(R1) H= 0.5 m, L= 0.4 km	0.85
Pumping	Right bank of Nan Riv.	(P1) Q= 4.0 cms.	13.00
	Left bank of Nan Riv.	(P2) Q= 6.0 cms. (North of K. Budsabong Tai)	15.70
		(P3) Q= 4.0 cms. (South of K. Budsabong Tai)	13.00
Gate Regulator	3- right, 5- left banks	8 outlets of drainage pipe, Size: 2.0 x 1.5 m	2.13
Drainage Pipe	Nan Riv.	Circular pipe, Dia.= 1.0 m, L= 7.3 km	44.13
Total : Cost (Mil. Bahts)			211.84

(4) Pho Thale Sanitary District

The proposed drainage and flood protection plan is tabulated as follows;

Facility	Location	Description	Const. Cost
Floodwall dike	Right bank of Yom Riv.	(W1) H= 1.2 m, L= 2.1 km	29.32
	Left bank of Yom Riv.	(W2) H= 1.2 m, L= 0.8 km	11.17
Earth dike	Right bank of K. Huai Chan	(D1) H= 1.2 m, L= 1.0 km	3.18
	Hwy. 1067~ K. Pak Rang	(D2) H= 1.2 m, L= 1.0 km	3.18
	K. Pak Rang banks	(D3) H= 1.2 m, L= 1.7 km	5.41
	K. Pak Rang	(D4) H= 1.2 m, L= 2.0 km	6.37
Pumping	Right bank of Yom Riv.	(P1) Q= 4.0 cms. (North of K. Pak Rang)	13.00
		(P2) Q= 4.0 cms. (South of K. Pak Rang)	13.00
	Left bank of Yom Riv.	(P3) Q= 4.0 cms. (District office)	13.00
Gate Regulator	Yom Riv.	2 outlets of drainage pipe, Size: 2.0 x 1.5 m	1.06
Drainage Pipe	Yom Riv.	Circular pipe, Dia.= 1.0 m, L= 2.1 km	12.65
Dredging	K. Pak Rang	(d1) Depth= 2.0 m, L= 1.0 km	1.05

	K. Huai Chan	(d2) Depth= 2.0 m, L= 1.0 km	1.05
Total : Cost (Mil. Bahts)			113.44

5.5 Uthaithani Province

5.5.1 General

The Uthaithani Province, the area of which is 6,730 km^2, is situated in the Northern region. The general topography of the Province is mostly hilly (around 70 %). There are four minor rivers which originate from the mountains in the west and pass through the Province. These four rivers are the Maewong, Klongpho, Thapsalao and Khunkaew Rivers and former three have a dam for irrigation respectively. In 1995, the rainfall from 28 of July to 28 of August caused rapid runoff, which made damage in every district in the Province and inundation in the districts of Sawang - a - rom, Thaptun and Muang. In 1996, the 6 tropical storms with heavy rainfall occurred especially in September and October, and caused rapid runoff from the west to the east down to the Chao Phraya River. In the west, the flush floods destroyed farms, houses and infrastructures such as roads and bridges. The inundation occurred in the east was mainly caused by the backwater from the Chao Phraya River.

The Provincial Capital of Uthaithani is selected for the Study and details are described as in the followings;

The Provincial Capital, Uthaithani, covers an area of 8.2 km^2 with the population of 19,599. The municipality area mainly lies on the right bank of the Sakae Krang River.

5.5.2 Existing Condition

In 1995, from 13th of September to 25th of November, the backwater from Chao Phraya River blocked the flow of Sakae Krang River and around 80 % of the Municipality area was inundated.

5.5.3 Related Plan and Project

The proposed drainage and flood protection plan is shown in Fig. 5.4.2 - ③and its details are as follows;

Facility	Location	Description	Const. Cost
Floodwall dike	Sakae Krang Riv.	(W) H= 1.4 m, L= 4.0 km (Right bank)	63.82
Earth dike	Left bank of K. Tha Pho	(D1) H= 1.4 m, L= 4.0 km	12.73
	North of Municipality	(D2) H= 1.4 m, L= 1.5 km	4.78
Pumping Station	Sakae Krang Riv.	(P) Q= 14.0 cms. (Near Post office)	35.02
Gate Regulator	Sakae Krang Riv.	5 outlets of drainage pipe, Size: 2.0 x 1.5 m	1.33
Drainage Pipe	Sakae Krang Riv.	Circular pipe, Dia.= 1.0 m, L= 4.0 km	24.10
Dredging	K. Tha Pho	(d) Depth= 2.0 m, W= 40.0 m, L= 4.0 km	8.00
Total : Cost (Mil. Bahts)			149.78