JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

ROYAL IRRIGATION DEPARTMENT
KINGDOM OF THAILAND

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

FINAL REPORT

Vol. 1 : EXECUTIVE SUMMARY

AUGUST 1999

CTI ENGINEERING INTERNATIONAL CO., LTD.
I N A C O R P O R A T I O N

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The cost estimates in this Study are based on the price levels indicated below and expressed in Thai Baht according to the following exchange rates:

US$1.00 = Thai Baht 36.5 = Japanese Yen 115.7

As of December 1998

COMPOSITION OF FINAL REPORT

Vol. 1 EXECUTIVE SUMMARY

Vol. 2 MAIN REPORT

Vol. 3 SUPPORTING REPORT (1/2) (SECTOR I to VI)

SECTOR I HYDROLOGY AND FLOOD SIMULATION

SECTOR II SOCIOECONOMY

SECTOR III LAND USE

SECTOR IV GEOLOGY AND SOIL MECHANICS

SECTOR V FLOOD DAMAGE

SECTOR VI FLOOD MITIGATION PLAN

Vol. 4 SUPPORTING REPORT (2/2) (SECTOR VII to XV)

SECTOR VII RIVER IMPROVEMENT PLAN

SECTOR VIII INTEGRATED DAM OPERATION PLAN

SECTOR IX FARMLAND WATER MANAGEMENT PLAN

SECTOR X URBAN DRAINAGE PLAN

SECTOR XI INSTITUTION AND ORGANIZATION

SECTOR XII PRELIMINARY DESIGN, COST ESTIMATE AND CONSTRUCTION PLAN

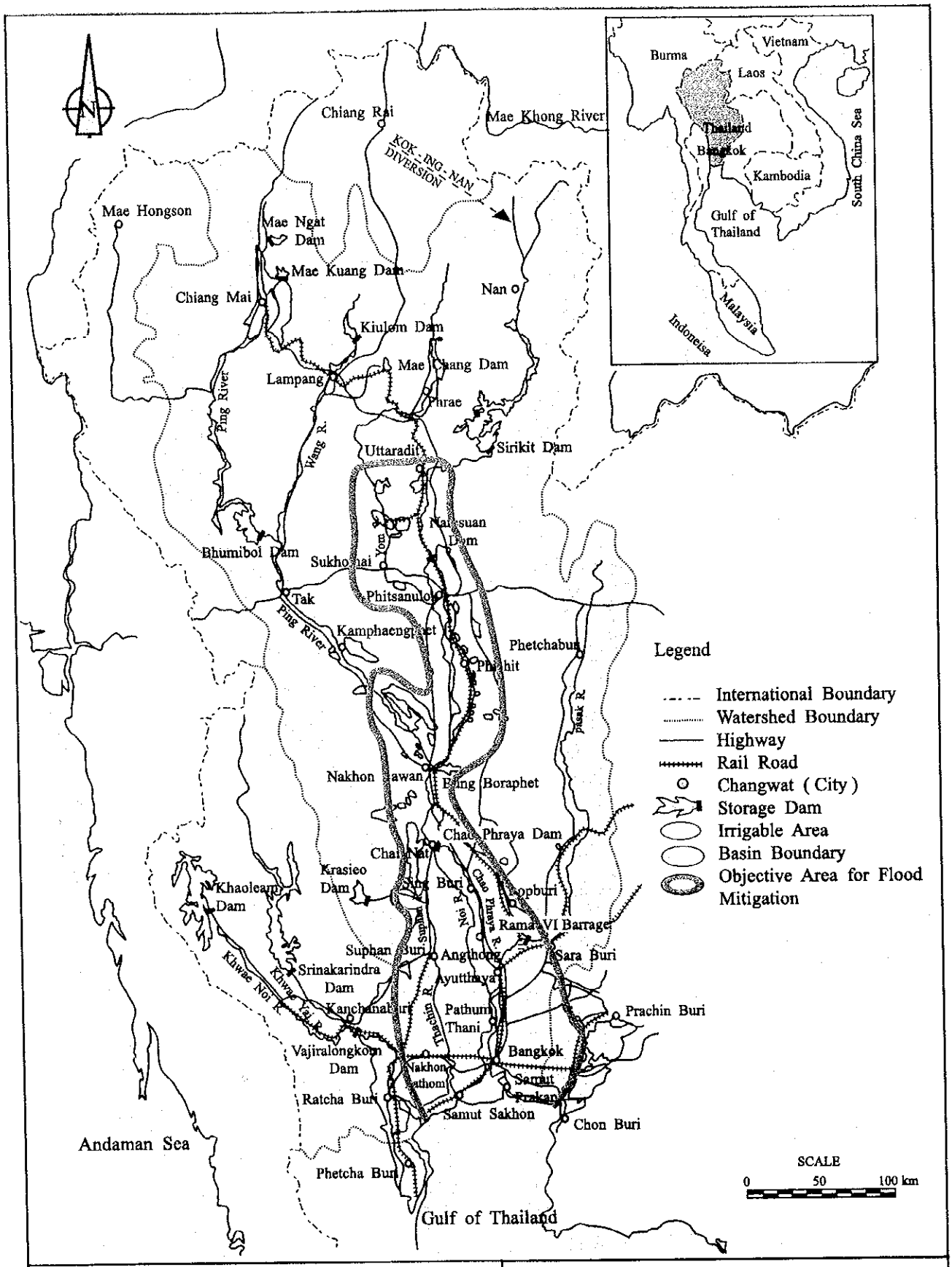
SECTOR XIII ECONOMIC EVALUATION

SECTOR XIV ENVIRONMENTAL CONSIDERATION

SECTOR XV TOPOGRAPHIC SURVEY

Vol. 5 DATA BOOK

Vol. 6 EXECUTIVE SUMMARY (in Thai)



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

GENERAL MAP

CTI ENGINEERING CO., LTD. AND INA CORPORATION

PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Government of Japan decided to conduct the Development Study on Integrated Plan for Flood Mitigation in Chao Phraya River Basin and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Katsuhisa Abe of CTI Engineering International Co., Ltd., and consisting of members from CTI Engineering International Co., Ltd. and INA Corporation, to Thailand, five (5) times between December 1996 and August 1999. In addition, JICA set up an advisory committee headed by Mr. Hidetomi Oi, Development Specialist, JICA, between November 1996 and August 1999, which examined the study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of Thailand, and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Thailand for their close cooperation extended to the team.

August 1999

Kimio Fujita
President
Japan International Cooperation Agency

August, 1999

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

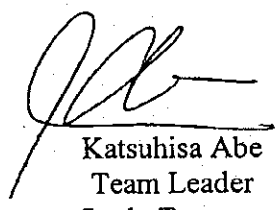
We are pleased to submit herewith the Final Report on the "Study on Integrated Plan for Flood Mitigation in Chao Phraya River Basin" in the Kingdom of Thailand.

Under contracts with JICA, CTI Engineering International Co., Ltd. in association with INA Corporation conducted the Study during the period from December 1996 to August 1999. In conducting the study, particular attention was paid to the formulation of an integrated master plan with the target year 2018, with due consideration on the present situation of Thailand. A feasibility study was also conducted on the urgent and/or priority projects identified through the master plan study.

We would like to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs, the Ministry of Construction, and the Ministry of Agriculture, Forestry and Fisheries, all of Japan. We would also like to express our gratitude to the officials concerned of the Thai Government, as well as the JICA Thailand Office and the Embassy of Japan in Thailand for their cooperation and assistance extended to us during our investigation and study.

Finally, we hope that this report will contribute to the further promotion of the project.

Very truly yours,



Katsuhisa Abe
Team Leader
Study Team on
Integrated Plan for Flood Mitigation in
Chao Phraya River Basin
CTI Engineering International Co., Ltd.

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

OUTLINE OF THE STUDY

1. OBJECTIVES OF THE STUDY

The objectives of the Study are:

(1) To formulate an integrated master plan of flood mitigation in the Chao Phraya River Basin, taking flood damage, agricultural land conservation, water use, land use management, and so on into consideration;

(2) To conduct a feasibility study on the urgent and/or priority project(s) identified through the master plan study; and

(3) To carry out technology transfer to the Thai counterpart personnel in the course of the Study.

2. RIVER BASIN CONDITION

2.1 General Features of Past Major Floods

The Chao Phraya river basin has experienced so many floods, and the 1983 and 1995 floods were the most serious (see Fig. A-1). As seen in Fig. A-2, floods inundate wide areas that have natural retarding functions along the river course. The inundation area is broadly divided into four (4) areas: Upper Central Plain, Nakhon Sawan Area, Higher Delta, and Lower Delta. The inundation in 1995 nearly exceeded 16 billion m^3, which was almost equal to the total active capacity of the Bhumibol and Sirikit dams (refer to Fig. A-2). However, the extensive inundation considerably relieved the urban areas located downstream, like Bangkok, from a catastrophic disaster.

2.2 Main Cause of Flood

The main causes of flooding are the low flow capacities of river channels. The present river channel capacities are between 3,000 and 4,000m^3/s in the stretch near Nakhon Sawan, about 1,300 m^3/s in the upstream near Ayuthaya, about 2,900 m^3/s in the downstream near Ayuthaya, and about 3,600 m^3/s at Bangkok.

In the 1995 flood, dike breaching and overtopping occurred at almost every reach of the Chao Phraya River, its tributaries and distributaries. The estimated flow capacity near Bangkok was about 3,600 m^3/s, which corresponds to about a 3-year return period discharge if confined in the river channel without inundation.

Besides, it is pointed out that several activities such as land use in flood risk areas, development of upstream, operation of flow control facilities such as dams, and

coordination among agencies concerned on flood management are related with the increase in flood damage.

2.3 Flood Damage Condition

Under the foregoing circumstances, flood damage is very severe in the whole basin. According to the flood damage analysis, flood damage in the 1995 flood amounts to about 72 billion baht in the four areas under the present land use condition, while it is 164 billion baht under the future land use condition, as shown in Fig. A-2.

2.4 Ongoing Flood Mitigation Project by Agencies Concerned

To cope with the flooding problem, the agencies responsible for flood mitigation and drainage works have made serious efforts under the following projects:

- Heightening of flood barrier at Bangkok Metropolitan Area by BMA
- Provision of polder system together with the improvement of drainage system by PWD
- River improvement (completed) and drainage system improvement called "monkey cheek project" in delta area by RID
- Loop-cut at Bangkok Port and construction of multipurpose dams by RID

Through these projects, the flood protection level in major urban areas is, in general, expected to increase. However, protection works in the upstream sometimes bring about adverse influences to the downstream; i.e., the protection level in Bangkok is expected to decrease due to the protection works for Pathum Thani and Nonthaburi. For the agricultural areas it is expected that the present low protection level against floods is maintained in the future, but the improvement will not be so much.

2.5 Major Issues considered for Flood Mitigation

Under this situation, the major issues on flood mitigation are emphasized with the following points:

- Increase of flood damage due to basin development in the future.
- Reduction of safety level against floods at Bangkok due to protection works for Pathum Thani and Nonthaburi.
- Continuation of low safety level against floods in agricultural areas.

3. MASTER PLAN STUDY

3.1 Basic Concept of Master Plan Formulation

Considering the major issues on flood mitigation in the Chao Phraya river basin, the basic concepts of master plan formulation are as follows:

- Preservation of the present natural retarding effect to minimize the increase of flood damage in the future through control and guidance on basin development in areas where flood damage is expected. (This concept is the

current global concept of flood mitigation, and is the "monkey cheek" concept being practiced in Thailand.)

- Introduction of suitable measures to assure the safety level against floods at Bangkok and other urban areas and to enhance the safety level in agricultural areas.

3.2 Measures of the Master Plan

The Master Plan is formulated with 2018 as the target year. In general, several measures consisting of structural and nonstructural ones are considered to cope with the flooding problems, as shown in Fig. A-3. As discussed below, specific measures are required to deal with the above-said issues in the Chao Phraya river basin.

3.2.1 Preservation of Present Natural Retarding Effect and Minimization of Increase of Flood Damage

To maintain the present natural retarding effect and to minimize the increase of flood damage, nonstructural measures, especially land use control and guidance, are essential. For the realization of land use control and guidance, flood risk maps are provided, so that all agencies concerned can prepare the development plan based on these maps considering the influence of development. Also, people who are going to develop the land are forewarned through publication of the flood risk maps.

3.2.2 Assurance of Safety Level against Flood at Bangkok and Urban Areas

To assure the safety level of urban areas against floods, nonstructural measures such as the modification of reservoir operation rule, flood forecasting, flood fighting and land use control and guidance are considered, while ring levee with drainage system improvement is applied as the structural measure.

To assure the safety level of a 100-year return period at Bangkok, the following alternatives are proposed in combination with the ring levee provided by PWD, as shown in Fig. A-4:

- Alternative 1, Partial Protection of Pathum Thani and Nonthaburi
- Alternative 2-1, Heightening of Flood Barrier
- Alternative 2-2, Diversion Channel

3.2.3 Enhancement of Safety Level against Flood in Agricultural Areas

To enhance the safety level against flood in agricultural areas, nonstructural measures including the modification of reservoir operation rule, flood forecasting, flood fighting, land use control and guidance, etc., are proposed. On the other hand, the following structural measures are proposed for flood mitigation in agricultural areas: (a) river improvement; and (b) distribution and drainage systems improvement.

The protection level of agricultural areas in the downstream of Chainat could be enhanced to a 10-year return period by a combination of the above measures.

3.2.4 Institutional Arrangement for Implementation of Measures

In principle, the existing agencies concerned will handle these measures under their own responsibilities. To smoothly implement these measures, however, it is necessary to set up a new organization, the River Basin Committee, as the coordination agency among the agencies concerned, because such an organization does not exist at present in the Thai government.

3.3 Economic Evaluation of the Master Plan

In this Study, the Master Plan is formulated by applying such measures as summarized in Fig. A-3. For the protection of urban areas, three (3) alternative measures are proposed as aforementioned. The cost, benefit and economic viability of the measures including these alternatives which can be evaluated in monetary term are as shown below. (The cost and benefit for ring levee are not included, because the project undertaken by PWD is considered as the premise for this Study):

Alter-native	Project Component	Cost (mil. Baht)	Economic Benefit (mil. Baht)	Economic Viability		
				EIRR*	B-C	B/C
Alt. 1	Modification of Dam Operation Rule; Distribution and drainage systems improvement; River Improvement and others, but with partial protection of Pathum Thani and Nonthaburi	6,907 as initial cost and 464 as annual cost	3,268/year	21.1%	5,875 (mil.B)	2.4
Alt. 2-1	Alternative 1 plus Heightening of Flood Barrier and full protection of Phatum Thani, Nonthaburi and Bangkok	8,400 as initial cost and 476 as annual cost	4,838/year	24.0%	9,014	2.9
Alt. 2-2	Alternative 1 plus Flood Diversion, Upgrading of river improvement, and Full protection of Phatum Thani, Nonthaburi and Bangkok	39,896 as initial cost and 671 as annual cost	6,300/year	12.0%	1,427	1.1

* Component of dam operation rule is not included.

The project will bring about many intangible benefits such as the stabilization of people's living condition, decrease of waterborne diseases, increase of work opportunities, and so on. Among the alternatives, the diversion channel can be used for water resources development purposes.

4. FEASIBILITY STUDY

Considering significance and urgency, the following priority projects were selected for the Feasibility Study from among those proposed in the Master Plan study:

- Nonstructural Measures: Land use control and guidance based on the flood risk map, modification of reservoir operation rule, and institutional and organizational arrangement

- Structural Measures: River Improvement (Stage 1) for the protection of agricultural areas

The Feasibility Study was, in principle, conducted by assuming that the target year is the year 2005.

4.1 Nonstructural Measures

4.1.1 Study on the Modification of Reservoir Operation Rule

In the feasibility study, the objective dams were narrowed down to the Bhumibol, Sirikit and Pasak under the condition that the Kok-Ing-Nan diversion project will still not be in operation. This is because the completion year of the Kok-Ing-Nan water diversion project is assumed to be 2012, while the target year of the Feasibility Study is 2005.

In the Feasibility Study, the modification of reservoir operation rule of these three dams was examined under the following principles:

- The discharges from the Bhumibol and Sirikit reservoirs are minimized, while flood damage is observed in the downstream area.
- In the case of Pasak reservoir, the upper rule curve is set up to secure flood mitigation function by maintaining a vacant capacity when the flood peak is observed.

To identify the suitable operation rule curve in accordance with the above principle, several cases of rule curves were set up and, through simulation, the most effective operation rule was selected from the flood mitigation viewpoint.

The project benefit and cost for the modification of reservoir operation rule are estimated as follows:

Item	Average Annual Economic Benefit (million Baht)	Annual Maintenance Cost (million Baht)
Total for three dams	1,038	80

4.1.2 Study on Land Use Control and Guidance

Effective land use control and guidance are essential for flood mitigation, as pointed out in the master plan study. The area where land use control and guidance should be considered was identified based on the three kinds of flood risk map. With such maps, land use control and guidance could be realized through the following:

- Recognition of the flood risk map by the agencies concerned, and publication of the flood risk map to caution on land use in the flood risk area.
- Preparation of land use plan based on the flood risk map so as to minimize the increase of flood damage in the future and to preserve the natural retarding effect.

- Advice and coordination on the provision of public facilities such as roads and airports for the preservation of the present retarding effect, when such public facilities are provided in the flood risk area.

4.1.3 Study on Institutional Arrangement

In the master plan, several measures for flood mitigation are proposed, and the possibility of realizing these measures within the present institutional framework has been examined. To solve the present issues, further institutional arrangement has also been examined.

The agencies responsible for the implementation or realization of measures proposed in the master plan have been studied. Judging from the study results, most of the measures can be handled by the agencies concerned in the present institutional framework, although strengthening or strict enforcement may be required. For some measures, the setup of a River Basin Committee with the following functions will be required:

- Setting up of strategy of integrated flood mitigation.
- Nomination and coordination of agencies concerned.
- Flood disaster management, especially on flood fighting.
- Other functions to enhance the flood mitigation capability, including the role of a flood information center.

4.2 Structural Measure (River Improvement)

In the feasibility study, the possibility of river improvement in the midstream of the Chao Phraya river system from the Chao Phraya Dam to Pathum Thani was further examined to clarify the possible improvement scales and stretches. Through hydraulic analysis and preliminary designing, the major features of river improvement were proposed, as mentioned below.

4.2.1 Project Scale

The project design scale is set at a 3-year return period. The river improvement will then upgrade the safety level of all the problem areas in the midstream to the 3-year level, at least, but will not increase flood damage in the Bangkok metropolitan area.

4.2.2 Improvement Works

The proposed dike alignments are drawn, following the existing dikes or roads to minimize land acquisition. The total length of dike improvement is estimated at 67 km, and 13 regulators are proposed at the intersections of the existing/proposed dikes and khlongs. The total financial cost is estimated at 1,425 million baht, while the annual benefit is estimated at 221 million baht/year.

4.3 Project Evaluation

4.3.1 Economic and Financial Considerations

The economic evaluation has been made only for project components that can be evaluated in monetary term based on the economic cost and benefit; namely, the modification of reservoir operation rule and the river improvement. The results of the evaluation are as shown below.

Item	(1) River Improvement	(2) Modification of Reservoir Operation Rule
EIRR (%)	12.5	-
B-C (million Baht)	28	5,693
B/C	1.0	13.3

As identified from these figures, the economic viability of river improvement is not so high, but the EIRR value is over 12%, which is regarded as the minimum of project viability. In the case of modification of reservoir operation, EIRR is not a suitable index to identify the economic viability. This is because the project will bring about constant benefit and cost from the beginning, so that EIRR is not obtainable. Therefore, only B-C and B/C were used to evaluate economic viability of this project component.

Judging from the figures, the modification of reservoir operation rule will bring about a high economic return.

Also, these project components will bring about many intangible benefits such as the stabilization of people's living condition, decrease of waterborne diseases, increase of work opportunities, and so on.

As for the financial point of view, the source of the cost is assumed to be the government budget, which will be fulfilled by increase of government income resulting from the increase of productivity in the river basin due to flood damage mitigation.

4.3.2 Environmental Impact Assessment

As discussed earlier, the environmental impact assessment (EIA) is necessary only for the river improvement. The EIA has concluded that the river improvement will not cause a serious environmental impact in the project area.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The Master Plan of integrated flood damage mitigation in the Chao Phraya River Basin has been formulated in accordance with the "Monkey Cheek" concept for preservation of the present retarding effect and, also, with the introduction of suitable flood mitigation measures. To realize the Master Plan, several projects have been selected for urgent implementation. For some of the projects, their feasibility have

been examined and confirmed and, for the others, further studies have been undertaken.

In this JICA Study, it is concluded that flood mitigation in the context of the Master Plan is essential for development of the basin and the country as a whole, and the implementation of selected projects is the most effective means to attain the objectives of the Study.

5.2 Recommendation

(1) Justification of the Master Plan

The Master Plan of integrated flood mitigation in the Chao Phraya river basin has been formulated. Since the realization of the Master Plan is essential for the future development of the basin and the whole country as well, it should be justified as a part of Thailand's National Development Plan.

(2) Strengthening of the Present Organization and Setup of a River Basin Committee

The Master Plan is composed of several project components, most of which are to be undertaken by the agencies concerned within their scopes of responsibility. For the realization of the Master Plan, however, it is recommended that the present organization be strengthened to successfully implement the project components.

For coordination to realize the Master Plan, it is indispensable to promptly set up the River Basin Committee as proposed in the Water Resources Act that is presently under consideration on the national level. Thus, it is also recommended that the setup of the River Basin Committee be expedited.

In case the prompt setting up of the River Basin Committee is difficult under the current movement to restructure the existing organization, it is suggested that an ad-hoc committee be set up by the existing agencies concerned, as a tentative solution, to cope with the flood mitigation issues caused by lack of coordination.

(3) Selection of Alternative Measures

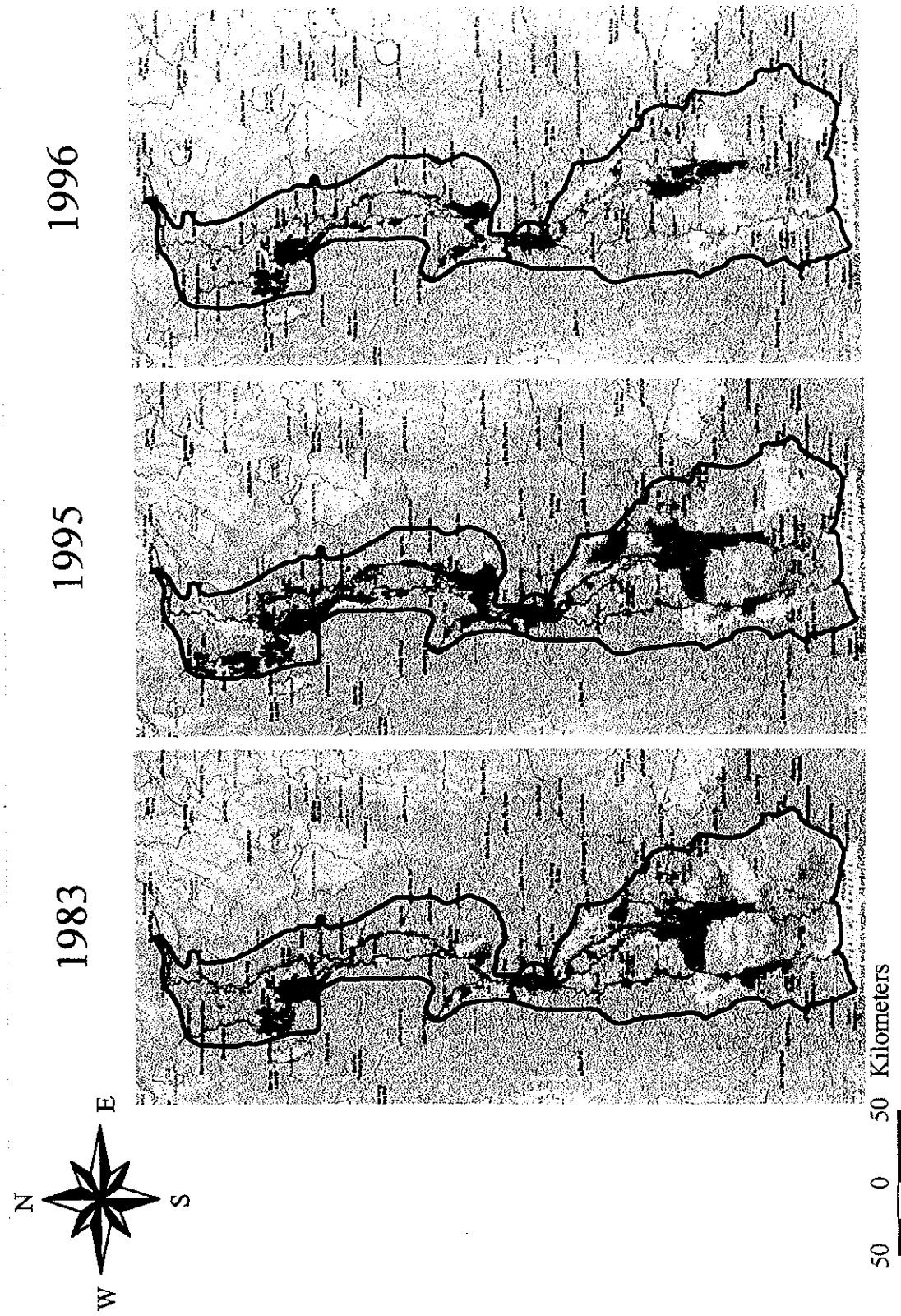
In the Master Plan, alternative measures (Alternative 1, 2-1 and 2-2) have been proposed to assure the safety level of protection for urban areas in the downstream, especially Pathum Thani, Nontaburi and Bangkok. Since it has been difficult to select the most suitable alternative due to significant issues involved, it is recommended that further discussions be made as early as possible to select the most acceptable for all concerned. In the discussion for realization of the study results, it is necessary for all concerned in the Thai side to recognize that further study shall be done before construction of diversion channel. Also, social and environmental assessment for the heightening of flood barrier in Bangkok shall be conducted in detail before construction.

(4) Implementation of Priority Projects

In the framework of the Master Plan, four (4) priority projects have been selected; namely, modification of reservoir operation rule, land use control and guidance, institutional and organizational arrangement, and river improvement. Since all of these priority projects are essential to promote the flood mitigation in the Chao Phraya river basin from the technical, social and environmental points of view, it is recommended that these projects be promoted to the next stage of implementation as early as possible.

(5) Further Study on Flood Mitigation in Agricultural Areas

As the measures for flood mitigation in agricultural areas, river improvement works and drainage system and distribution system improvement have been proposed. The process of system improvement was introduced in the Master Plan study, and only the river improvement works were covered in the feasibility study. To mitigate the flood damage in agricultural areas, however, it is also necessary to promote the distribution and drainage system improvements in parallel with the implementation of river improvement works. Thus, it is recommended that a further study on these system improvement works should be undertaken as early as possible.



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAOPHRAYA RIVER BASIN	Fig. A-1 PAST INUNDATION MAP
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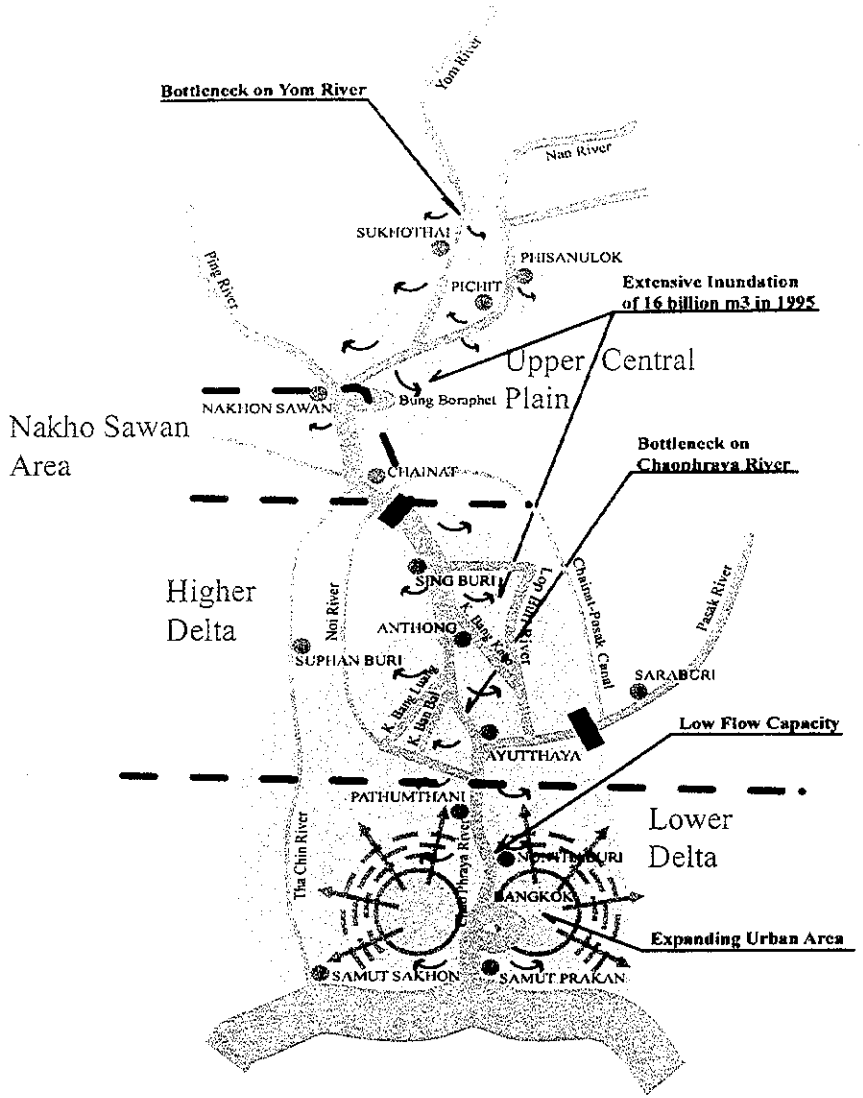


River and Flooding Condition

Area	River	Stretch	Flow Capacity (m^3/s)	Inundation Volume in 1995
Upper Central Plain	Nan	Phisanulok to Chao Phraya River	1,000 to 2,000	5 billion m^3
	Yom	Sukhothai to Nan River	50 to 1,100	
Nakhon Sawan Area	Chao Phraya	Nakhon Sawan to Chainat	2,500 to 4,500	1 billion m^3
Higher Delta	Chao Phraya	Chainat to Ayutthaya	4,200 to 1,300	7 billion m^3
Lower Delta	Chao Phraya	below Ayutthaya	2,900 to 3,200	3 billion m^3
	Chao Phraya	BMA Flood Barrier *	3,600	

*: On-going Project

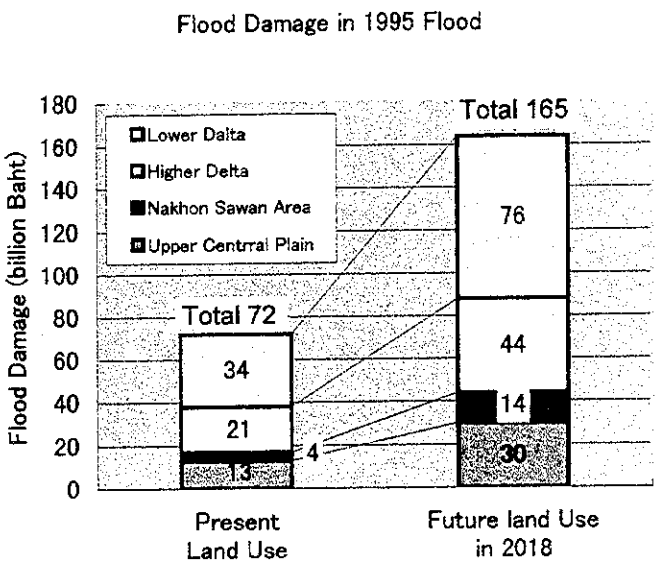
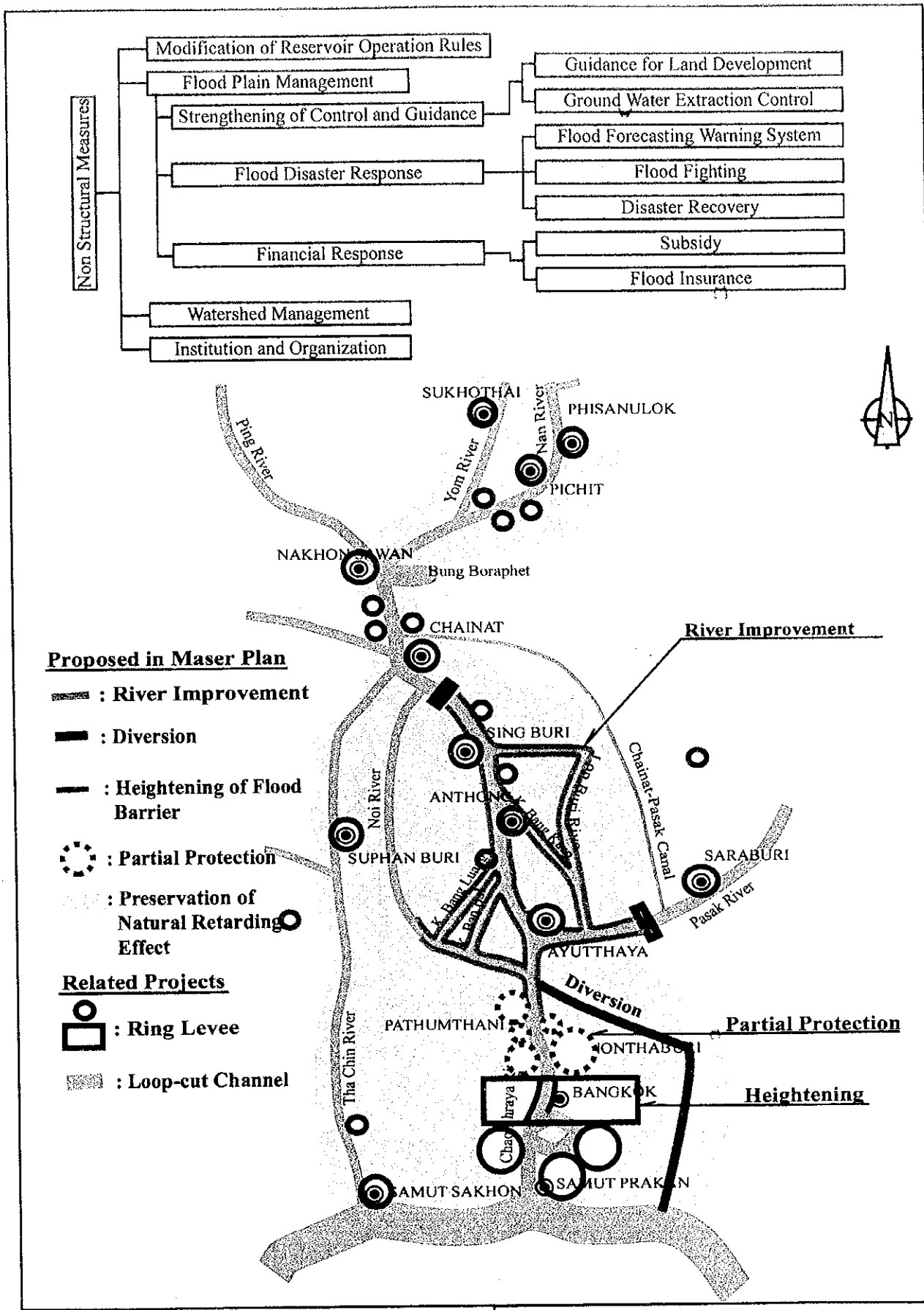


Fig. A-2 PRESENT FLOODING SITUATION



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. A-3 MAJOR PROPOSED MEASURES
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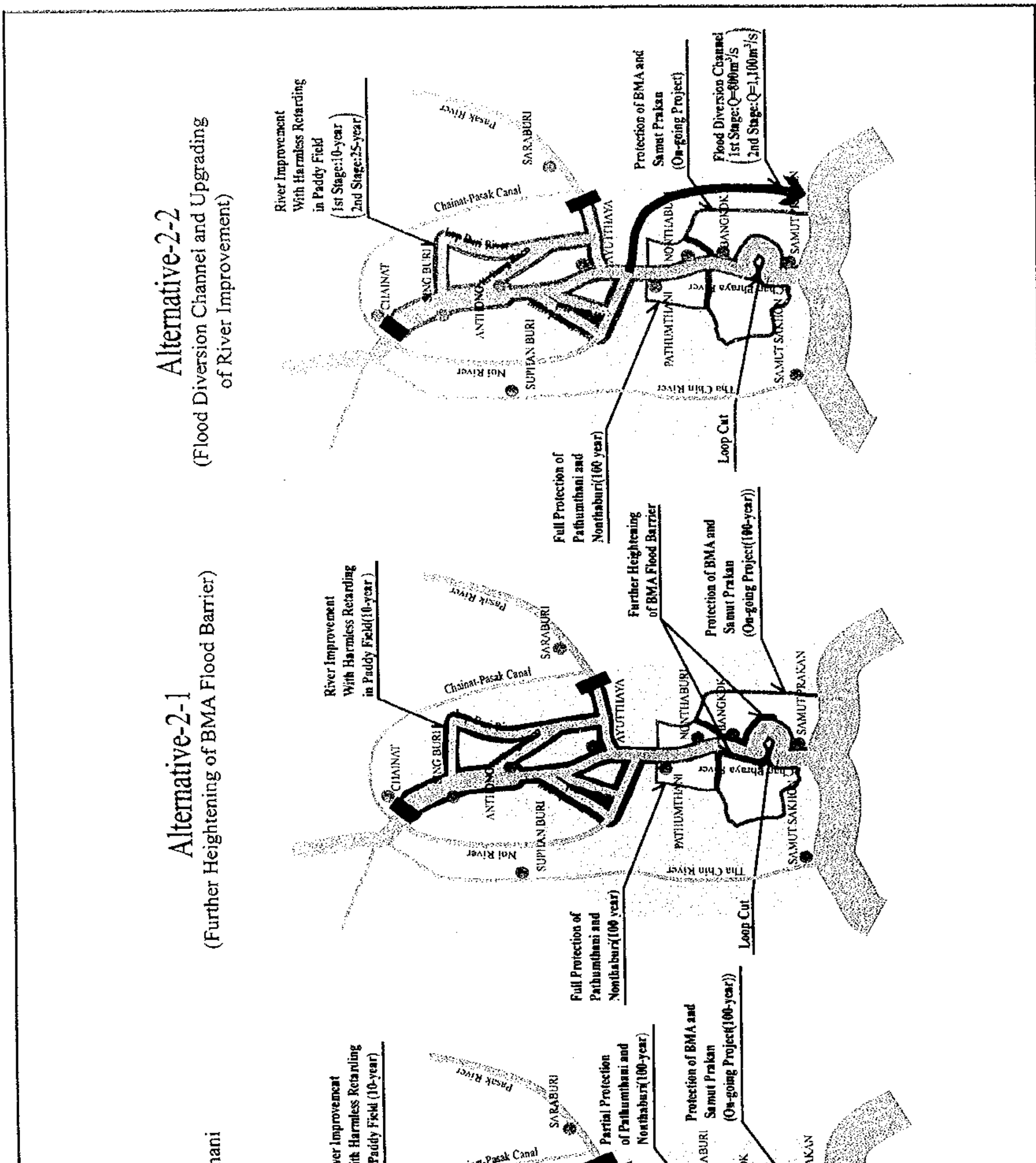

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. A-4 ALTERNATIVES
CTI ENGINEERING CO., LTD AND INA CORPORATION	

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

FINAL REPORT

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ABBREVIATIONS

Thailand Government / Agencies

AIT	:	Asian Institute of Technology
ALRO	:	Agricultural Land Reform Office
BMA	:	Bangkok Metropolitan Administration
CAT	:	Communication Authority of Thailand
DDS	:	Department of Drainage and Sewerage, BMA
DEDP	:	Department of Energy Development and Promotion
DF	:	Department of Fisheries
DIW	:	Department of Industrial Works
DOH	:	Department of Highway
DOLA	:	Department of Local Administration
DPW	:	Department of Technical and Economic Cooperation
DTCP	:	Department of Town and Country Planning
EGAT	:	Electricity Generating Authority of Thailand
GOT	:	Government of the Kingdom of Thailand
HD	:	Harbor Department
H&D	:	Hydrographic Department
IEC	:	Irrigation Engineering Center, RID
LAD	:	Local Administration Department
MD	:	Meteorological Department
MOAC	:	Ministry of Agriculture and Cooperative
MOI	:	Ministry of Interior
MOSTE	:	Ministry of Science, Technology and Environment
NESDB	:	National Economic and Social Development Board
NEB	:	National Environmental Board
NSO	:	National Statistic Office
OARD	:	Office of Accelerated Rural Development
OEPP	:	Office of Environmental Policy and Planning
PAT	:	Port Authority of Thailand
PTD	:	Post and Telegraph Department
PWD	:	Public Works Department
RFD	:	Royal Forest Department
RID	:	Royal Irrigation Department
SRT	:	State Railway of Thailand
TOT	:	Telecommunication Organization of Thailand
FFC	:	Flood Forecasting Center

Japanese Government and International Organizations

GOJ	:	Government of Japan
JICA	:	Japan International Cooperation Agency
MAFF	:	Ministry of Agriculture, Forestry and Fisheries, Japan
MOC	:	Ministry of Construction, GOJ
ADB	:	Asian Development Bank
IBRD	:	International Bank for Reconstruction and Development (World Bank)

Units of Measurement

(Length)

mm	:	millimeter(s)
cm	:	centimeter(s)
m	:	meter(s)
km	:	kilometer(s)

(Weight)

g, gr.	:	gram(s)
kg	:	kilogram(s)
ton	:	ton(s)

(Area)

mm^2	:	square millimeter(s)
cm^2	:	square centimeter(s)
m^2	:	square meter(s)
km^2	:	square kilometer(s)
ha	:	hectare(s)
rai	:	0.16 ha

(Time)

s, sec	:	second(s)
min	:	minute(s)
h (hrs)	:	hour(s)
d (dys)	:	day(s)
y, yr (yrs)	:	year(s)

(Volume)

cm^3	:	cubic centimeter(s)
m^3	:	cubic meter(s)
l	:	liter(s)
mcm or MCM	:	million cubic meter(s)

(Electrical Units)

W	:	watt(s)
kW	:	kilowatt(s)
MW	:	megawatt(s)
kWh	:	kilowatt-hour
MWh		megawatt-hour
GWh	:	gigawatt-hour
V	:	volt(s)
kV	:	kilovolt(s)

(Speed/Velocity)

cm/sec, cm/s	:	centimeter per second
m/sec, m/s	:	meter per second
km/hr, km/h	:	kilometer per hour

(Stress)

kgf/cm^2	:	kilogram per square centimeter
$tonf/m^2$	:	ton per square meter

(Discharge)

l/sec, *l*/s	:	liter per second
m^3/sec, m^3/s	:	cubic meter per second
m^3/yr, m^3/y	:	cubic meter per year

(Note : Other combined units may be constructed similarly as above)

Monetary Terms

¥, YEN	:	Japanese Yen
Bht, Baht	:	Thai Baht
US$	:	United States Dollar

Other Measurements

HWL	:	High Water Level
MSL	:	Mean Sea Level
°	:	degree
'	:	minute

"	:	second
%	:	percent
°C	:	degree centigrade
KB	:	kilobyte
MB	:	megabyte
RAD	:	radian
bps	:	bit per second
BPI	:	bit per inch
AH	:	Ampere Hour

SUMMARY

1. INTRODUCTION

1.1 Objectives of the Study

The objectives of this Study on Integrated Plan for Flood Mitigation in Chao Phraya River Basin are:

(1) To formulate an integrated master plan of flood mitigation in the Chao Phraya River Basin, taking flood damage, agricultural land conservation, water use, land use management, and so on into consideration;

(2) To conduct a feasibility study on the urgent and/or priority project(s) identified through the master plan study; and

(3) To carry out technology transfer to the Thai counterpart personnel in the course of the Study.

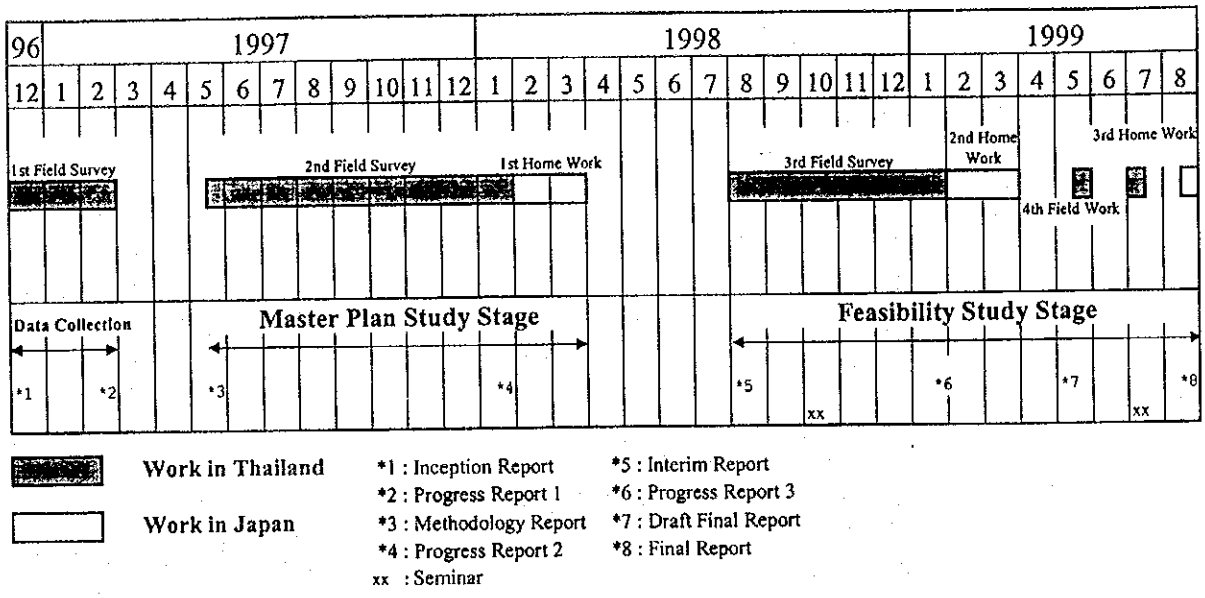
1.2 Study Area

The study area is the whole Chao Phraya River Basin of 163,000 km^2 (see General Map). The Chao Phraya Delta and the lower reaches of the Nan and Yom rivers are the target areas for flood mitigation, giving high priority to the Chao Phraya Delta, and including the Bangkok metropolitan area because of its social and economic significance.

1.3 Study Schedule

The study schedule is as shown in the chart below. The primary objective of the master plan study from the end of December 1996 to the end of March 1998 was to formulate the Master Plan through a comparison study among the conceivable alternatives based on the results of several kinds of surveys and analyses. Priority projects for the Feasibility Study were selected from among the project components of the Master Plan. The Feasibility Study was conducted from the beginning of August 1998 to the end of March 1999, followed by the presentation of the Draft Final Report, the holding of a seminar in July 1999, and the presentation of the Final Report.

STUDY SCHEDULE



2. RIVER BASIN CONDITIONS

2.1 Present River Basin Condition

2.1.1 Major Flood Events

The Chao Phraya river basin has experienced so many floods, and the 1983 and 1995 floods were the most serious. As seen in Fig. 2.1, the flood had inundated a wide area that has a natural retarding function along the river course.

2.1.2 Features of Flood

The features of flooding in the Chao Phraya river basin are as described below and summarized in Table 2.1. The flood area was divided into four (4), namely, Upper Central Plain, Nakhon Sawan Area, Higher Delta and Lower Delta in Lower Central Plain (refer to Fig. 2.1).

(1) Extensive Inundation and Retarding Effect

The 1995 flood was the recent biggest, followed by the 1983 flood in terms of inundation volume. The inundation volume in 1995 was 5.1 billion m^3 in the Upper Central Plain, 1.3 billion m^3 in the Nakhon Sawan Area, 7.0 billion m^3 in the Higher Delta and 2.5 billion m^3 in the Lower Delta in Lower Central Plain.

The total inundation volume nearly exceeded 16 billion m^3, which almost corresponds to the total active capacity of the Bhumibol and Sirikit dams (refer to Fig. 2.2). Assuming that the inundation volume was confined in the river channel, the water level at Bangkok would have risen from 2.3 (M.S.L+m) at present to about 3.9 (M.S.L+m). This extensive inundation,

on the other hand, had considerably relieved urban areas located downstream like Bangkok from a catastrophic disaster.

(2) River Flood

The main causes of flooding are the low flow capacities of river channels. In the 1995 flood, dike breaching and overtopping occurred at almost every reach of the Chao Phraya River, its tributaries and distributaries.

Fig. 2.3 shows the flow capacities estimated by dynamic flow calculation along the Chao Phraya River, the tributaries and the distributaries. The present river channel capacities are broadly summarized as follows:

- Between 3,000 and 4,000m^3/s in the stretch near Nakhon Sawan.
- About 1,300m^3/s in upstream near Ayuthaya.
- About 2,900m^3/s in downstream near Ayuthaya.
- About 3,600m^3/s at Bangkok.

A bottleneck with the lowest flow capacity of 1,300 m^3/s, which causes habitual and extensive inundation, is found near Ayuthaya in the Upper Delta. The flow capacity near Bangkok is estimated at about 3,600 m^3/s, which corresponds to about a 3-year return period discharge, if flood water from Chainat is confined in the river channel without inundation.

(3) Inland Flood

In addition to river floods, inland floods caused by intensive local rainfall are also serious. Inland flood areas are usually small and localized, but the flood situation could become terrible if river flood and inland flood are combined. The 1983 flood was the worst case when both the river flood and the inland flood took place in the Higher and Lower deltas simultaneously.

(4) Influence of Tide

The Lower Delta is threatened with a combination of high tide and flood runoff discharge flowing from the upstream. When flood discharge meets high tide, water level is raised by the backwater effect of the high tide, and may spill over banks. A flood of the Chao Phraya River usually starts at the end of September and lasts for about two months. Unluckily, the higher sea level season of the Gulf of Thailand often coincide with this long-term flood.

(5) Influence of Land Development and Embankment in Flood Plain

In general, land development in flood prone area is also a cause of flood damage. Besides, some embankments including roads, railways and irrigation canal dikes seem to influence the flooding condition. Satellite images reveal that some embankments including National Highway Route 32, the Chainat-Pasak Canal embankment, and the Klong Raphipat Yaek Tak have been preventing floodwaters from expanding over the lower vast flood plains.

Such an embankment may result in the increase of flood damage in areas impounded with floodwater and the decrease of retarding effect.

(6) Influence of Operation of Flow Control Structures

In the basin, there are several large-scale flow control structures such as the Bhumibol, Sirikit and Chao Phraya dams. These structures are operated for the primary purpose of water resources management and also for flood mitigation. The operation of these structures for water resources management sometimes causes an adverse influence on flood mitigation. In the case of Sirikit Dam, it experienced spill of the reservoir in the 1995 flood through operation under the present rule curve, resulting in increase of flood damage in the downstream.

2.1.3 Flood Damage

Under such circumstances, flood damage is very severe in the whole basin. According to the flood damage analysis, the flood damage in the 1995 flood amounted to about 72 billion baht in the four areas. The damage was composed of damage to houses as well as commercial, industrial, agricultural and public facilities. The share of each kind of damage was 14%, 27%, 50%, 5% and 3%, respectively (refer to Table 2.2).

2.2 Expected Future Condition

2.2.1 Future Development in the Basin and Future Flood Damage

In connection with the present condition, the Chao Phraya river basin is going to be developed mainly in the following manner: expansion of urban area, change of cropping pattern and diversification of crops, and development of unused land such as swampy area and natural ponds.

Land use in 2018, as shown in Fig. 2.4, is assumed in this Study based on the recent trend of land use and the urban development plans proposed by DTCP and PWD.

Under the future land use, flood damage in the 1995 flooding condition is expected to increase to 164 billion baht from 72 billion baht under the present land use condition, as shown in Fig. 2.5.

2.2.2 Flood Mitigation and Protection Works by Agencies Concerned

To cope with floods, the agencies concerned have been undertaking flood mitigation and protection works, as mentioned below (refer to Fig. 2.6).

- Heightening of the flood barrier to cope with a 100-year return period flood by BMA.
- Provision of flood protection works for major urban areas to cope with a flood of up to 100-year return period by PWD.
- River improvement works for the protection of agricultural areas (implemented) and drainage system improvement in the lower delta area called the "Monkey Cheek Project" by RID.

- Loop-cut near Bangkok Port, and construction of several new dams for purposes of irrigation and flood control by RID.

2.2.3 Future Flooding Condition

With the future development and flood mitigation works, the flooding condition will change. Such changes in flooding condition have been evaluated using a simulation model with the following specific simulation results (refer to Table 2.3 and Fig. 2.5):

- In general, flood damage will increase due to changes in land use, as discussed in Subsection 2.2.1. Furthermore, such changes in land use could reduce the present natural retarding effect resulting in the increase of flood discharge to the downstream. According to the simulation results, the influence is about 1 cm rise of water level at Bangkok.
- The flood mitigation and protection works will enhance the safety level of urban areas. Fig. 2.5 shows that the flood damage in the three areas except the Lower Delta could be reduced dramatically by the protection works for the urban areas, although the safety level in the agricultural areas under the present condition will not change.
- Flood mitigation and protection works in the upstream sometimes bring about an adverse influence to the downstream, but in the case of Chao Phraya River, such influence to the downstream is minimal up to the Bang Sai point.
- However, protection works for Pathum Thani and Nonthaburi could bring about an adverse influence to the Bangkok metropolitan area. The protection works will raise the water level at the area, resulting in the decrease of safety level from 100-year return period to about 10-year return period and increase of flood damage in the lower area, as shown in Figs. 2.7 and 2.8.

3. MASTER PLAN STUDY

3.1 Strategy of the Master Plan Study

3.1.1 Major Issues Considered

The major issues considering the above basin conditions are the following:

- Increase of future flood damage due to basin development.
- Reduction of safety level against floods at Bangkok due to protection works for Pathum Thani and Nonthaburi.
- Continuation of low safety level against floods in agricultural areas.

3.1.2 Basic Concepts

Considering the major issues on flood mitigation in the Chao Phraya river basin, the basic concepts are as follows:

- Preservation of present natural retarding effect to minimize the increase of future flood damage through control and guidance on basin development in the area

where flood damage is expected. (This concept is the current global concept for flood mitigation, and is the "Monkey Cheek" concept that is being practiced in Thailand.)

- Introduction of suitable measures to assure the safety level against floods at Bangkok and other urban areas, and to enhance the safety level in agricultural areas.

3.2 Measures of the Master Plan

The Master Plan is formulated with 2018 as the target year. In general, several measures consisting of structural and nonstructural ones are considered to cope with the flooding problems, as shown in Fig. 3.1, and the applicability of these measures were examined as summarized in Table 3.1. Among them, the following are specified to deal with the above-said issues in the Chao Phraya river basin.

3.2.1 Preservation of Present Natural Retarding Effect and Minimization of Increase of Flood Damage

To maintain the present natural retarding effect and to minimize the increase of flood damage, nonstructural measures are essential, especially land use control and guidance, although these may require strengthening of the present institutional arrangement. For the realization of land use control and guidance, flood risk maps are provided, so that the agencies concerned can prepare their development plans based on these maps considering the influence of development. Also, people who are going to develop the land are forewarned through publication of the flood risk maps.

3.2.2 Assurance of Safety Level for Urban Areas

To assure the safety level against floods for urban areas, nonstructural measures such as the modification of reservoir operation rule, flood forecasting, flood fighting and land use control and guidance are considered. Ring levee with drainage system improvement is applied as the structural measure.

As the adverse influence of the protection works for Pathum Thani and Nonthaburi to the Bangkok metropolitan area, the safety level of 100-year return period at the area will decrease to a 10-year return period (refer to Fig. 2.8). To cope with this situation, some options are considered, as follows (refer to Fig. 3.2):

- Option 1: To maintain the present condition at Pathum Thani and Nonthaburi (i.e., not to implement protection works).
- Option 2: To enhance the safety level only up to the level where adverse influence to Bangkok is not so much expected.
- Option 3: To lower the safety level of 100-year return period at Bangkok to a certain level, i.e., 50-year return period, and to slightly enhance the safety level for Pathum Thani and Nonthaburi.
- Option 4: To narrow down the protection area for Pathum Thani and Nonthaburi to minimize the adverse influence.

- Option 5: To heighten the flood barrier to cope with the increase of water level at Bangkok.
- Option 6: To provide a diversion channel to cope with the increase of water level at Bangkok.

The relation of safety level between protection works for Pathum Thani and Nonthaburi and those for Bangkok is shown in Fig. 3.3. The advantages and disadvantages of these options are summarized in Table 3.2.

To select the suitable option, it is necessary to thoroughly discuss it with the agencies concerned. In this study, the following alternatives are proposed:

- Alternative 1: Option 4 (Partial Protection of Pathum Thani and Nonthaburi)
- Alternative 2-1: Option 5 (Heightening of Flood Barrier)
- Alternative 2-2: Option 6 (Diversion Channel)

3.2.3 Mitigation of Flood Damage in Agricultural Areas

For the mitigation of flood damage in agricultural areas, nonstructural measures such as the modification of reservoir operation rule, flood forecasting, flood fighting and land use control and guidance, and structural measures based on river improvement are proposed.

Also it is proposed to preserve the present natural retarding effect mainly in the agricultural areas. In this connection, it is necessary to mitigate the flood damage in the agricultural areas. For that purpose, the distribution and drainage system improvements are proposed.

By these measures, the following effectiveness are expected:

- By the combination of distribution and drainage system improvements, river channel improvement and modification of reservoir operation rule, the protection level for agricultural areas in the downstream of Chainat will be enhanced to a 10-year return period.
- The protection level can be further enhanced to a 25-year return period when Alternative 2-2 is applied (in case the flow capacity of diversion channel is increased to absorb the increased flood discharge to the downstream caused by river improvement works).

For the distribution system improvement, it is necessary to provide compensation measures for the area where flood damage will increase resulting from the mitigation of flood damage in the other areas.

3.3 Master Plan

3.3.1 Measures Selected for the Master Plan

In this Study, the Master Plan is formulated with structural and nonstructural measures, as shown in Figs. 3.4, 3.5, 3.6 and 3.7. For flood mitigation in the urban areas of Pathum Thani, Nonthaburi and Bangkok, three (3) alternative measures are

provided; namely, Alternative 1, Partial Protection of Pathum Thani and Nonthaburi; Alternative 2-1, Heightening of Flood Barrier at Bangkok; and Alternative 2-2, Construction of Diversion Channel. The difference among the measures adopted in these options is only in the way of flood mitigation in these urban areas. The other measures are commonly applied to these three options (refer to Table 3.3).

3.3.2 Major Issues on Alternative Measures

The alternative measures have individual advantages and disadvantages. The major issues are mainly the following:

(1) Alternative 1 (Partial Protection of Pathum Thani and Nonthaburi)

From the technical point of view, this is slightly better than "do nothing", because it limits the protection area and it is not effective to mitigate flood damage in a wide area. From the economical and environmental points of view, the implementation of this alternative may not cause serious issues. However, from the social point of view, inhabitants will not accept the delineation of protected and not protected areas within the same administrative area.

(2) Alternative 2-1 (Heightening of Flood Barrier at Bangkok)

From the technical point of view, this measure is to absorb the increase of flood discharge at Bangkok due to protection works for Pathum Thani and Nonthaburi. This alternative may enhance the protection level in the upstream area to a certain extent. From the economical point of view, this alternative may not require a huge cost. However, from the social and environmental points of view, it will cause serious issues due to the construction of a barrier between inside and outside of the riparian area. This barrier may affect the daily activities of many people concerned who use the infrastructures and facilities along the river course.

(3) Alternative 2-2 (Construction of Diversion Channel)

From the technical point of view, this is the only alternative that can provide opportunity for the enhancement of protection level in the upstream area while satisfactorily protecting the downstream area. From the economical and social points of view, this alternative will require an enormous investment as well as a number of house evacuation and land acquisition. On the other hand, this alternative can be multipurposely used as large-scale infrastructure for regional development such as transportation, land and town planning, etc.

3.3.3 Institutional Arrangement for Implementation of Measures

In principle, the existing agencies concerned will handle these measures under their own responsibilities. To smoothly implement these measures, however, it is necessary to set up a new organization, the River Basin Committee, as the coordination agency among the agencies concerned, because such an organization does not exist at present in the Thai government.

3.3.4 Economic Evaluation of the Master Plan

The cost, benefit and economic viability of the three alternatives mentioned above are as shown below.

Alter-native	Project Component	Cost (mil. Baht)		Benefit (mil. Baht)	Economic Viability		
		Initial	O&M		EIRR*	B-C	B/C
Alt. 1	Modification of Dam Operation Rule	40	394	3,268 /year	21.1%	5,875 (mil.B)	2.4
	Distribution and drainage system improvement	5,633	39				
	River Improvement	1,234	31				
	Total Cost	6,907	464				
Alt. 2-1	Modification of Dam Operation Rule	40	394	4,838 /year	24.0	9,014	2.9
	Distribution and drainage system improvement	5,633	39				
	Heightening of Flood Barrier	1,493	12				
	River Improvement	1,234	31				
	Total Cost	8,400	476				
Alt. 2-2	Modification of Dam Operation Rule	40	394	6,300 /year	12.0	1,427	1.1
	Distribution and drainage system improvement	5,633	39				
	Diversion Channel	31,402	167				
	River Improvement	2,821	71				
	Total Cost	39,896	671				

* Component of reservoir operation rule is not included.

From the financial point of view, the source of the cost is assumed to be the government budget, which roughly amounts to the total annual budget of 96.5 billion baht; i.e., 44.4 billion baht for RID, 39.8 billion baht for PWD and 12.3 billion baht for BMA (Bangkok Metropolitan Authority). The annual cost assuming repayment period of 20 years roughly corresponds to between 0.5 and 3.1% of the annual budget. The government budget will be fulfilled by increase of government income resulting from the increase of productivity in the river basin due to flood damage mitigation.

3.4 Selection of Project Components for the Feasibility Study

Priority projects have been selected for the Feasibility Study. As shown in the implementation schedule in Fig. 3.7, it was proposed to implement or adopt most of the project components of the Master Plan. However, according to time constraint and difficulty of selecting the optimum solution, the measures proposed in each alternative (Alternative 2-1, Heightening of Flood Barrier, and Alternative 2-2, Diversion Channel (Stage 1 and 2) and River Improvement (Stage 2)) were excluded.

Among the project components which should be promptly implemented, some are not necessary to conduct a feasibility study because they are now under the preparation stage for implementation by the Government or are recommended to be studied in other projects according to the project features. Under such considerations, the following project components were selected for the Feasibility Study:

- Nonstructural Measures: Land use control and guidance based on flood risk map, modification of reservoir operation rule, and institutional and organizational arrangement.
- Structural Measures: River Improvement (Stage 1)

Here, the necessity of the feasibility study on river improvement is emphasized with the following points.

- To promptly realize flood mitigation, river improvement is one of the essential measures.
- However, river improvement in the upstream may cause adverse influence to the downstream.
- In this connection, it is necessary to identify the allowable extent of river improvement as early as possible and to implement river improvement within such an extent.

Regarding the partial protection of Pathum Thani and Nonthaburi, it is proposed that a study be conducted by PWD in the context of the currently ongoing study.

3.5 Consideration on the Possibility of Water Resources Development Using Measures Proposed for Flood Mitigation

In this Study, several measures are proposed for flood damage mitigation and some of them have the possibility for water resources development, especially irrigation. Among the proposed measures, considered are the preservation of natural retarding area with the capacity of about 16 billion m^3 and construction of a diversion channel in case of Alternative 2-2.

However, in case of the former measure, the situation of inundation water storage will not change between before and after the measure is introduced, since the natural retarding area currently stores inundation water for irrigation purposes of the next cultivation period. On the other hand, the diversion channel can be used as a new water storage facility for irrigation purposes.

The possible storage capacity of the diversion channel is about 55 million m^3, which is sufficient to supply irrigation water for an area of 2,600 ha. From the irrigated area, the production value of rice is expected to increase to 15.3 million baht, assuming that the current production value of rice is 5,900 baht/ha. This measure, however, would require the installation of pump with the capacity of about 10 m^3/s, as an additional facility.

3.6 Farmland Drainage System Improvement

Discussed in this section is the drainage system improvement for farmland in the Chao Phraya Delta.

(1) Objective Study Area

Inland drainage problems spread over wide areas of the Chao Phraya river basin. However, only the drainage improvement study in areas located in the

Chao Phraya River delta in the downstream is discussed here, because covering all areas may not be realistic to reach a reasonable conclusion. Drainage improvement problems in the downstream seem to be more of economic impact, judging from the size of areas affected (refer to Fig. 3.8).

(2) Division of the Study Area

In accordance with the river channel system and topographic conditions, the study area is broadly divided into two (2) areas, higher delta and lower delta, which are further divided into the following areas:

(a) Higher Delta

- The northern part of the area surrounded by the Thachin and Noi rivers
- The area surrounded by the Noi and Chao Phraya rivers
- The area surrounded by the Chao Phraya and Lop Buri rivers
- The area surrounded by the Lop Buri and Pasak rivers

(b) Lower Delta

- The east bank areas of the Chao Phraya River
- The west bank areas of the Chao Phraya River

These areas are further divided into several RID Project areas, as shown in Fig. 3.8.

(3) Features of the Divided Areas

The divided areas have been examined from the drainage point of view; i.e., catchment area, general slope of the area, main drainage outlet, land use condition, etc. The features of the divided areas are summarized in Table 3.4.

(4) Identification of Main Issues on Drainage

In the divided areas, the main issues on drainage from the aspects of main causes and drainage conditions have been identified (refer to Table 3.5).

(5) Measures to Mitigate Flood Damage

After the identification of main issues, the measures to cope with the flood damage have been examined. The conceivable measures are as follows (refer to Fig. 3.9):

- Improvement of drainage channel
- Installation of drainage pump
- Provision of retarding basin
- Construction of new drainage channel

- Drainage to the area in the downstream
- Heightening of dike to prevent overflow from the river channel

(6) Prioritization of Implementation of Drainage System Improvement

In general, prioritization was made considering the significance of the issue, the economic efficiency, etc. However, the area covered in this Study is so large that the optimum measures as well as the construction cost and economic benefit were been identified. In this study, prioritization of implementation of drainage system improvement was examined considering the drainage issues (refer to Table 3.6.), and the implementation schedule according to the priority was prepared as shown in Fig. 3.10.

4. FEASIBILITY STUDY

The Feasibility Study for the selected measures was, in principle, conducted assuming that the target year is the year 2005, which was set considering the work volume of the river improvement works as a key project component to decide the implementation.

4.1 Nonstructural Measures

4.1.1 Study on the Modification of Reservoir Operation Rule

(1) General

In the feasibility study, the objective dams were narrowed down to Bhumibol, Sirikit and Pasak under the condition that Kok-Inn-Nan diversion project will not yet be in operation. This is because the completion year of the project is assumed to be 2012, while the target year of the Feasibility Study is 2005. The study on modification of the reservoir operation of these three dams was made putting more emphasis on the point of minimization of flood damage due to discharge from the reservoirs during flood time.

(2) Strategy for the Study

The Bhumibol and Sirikit reservoirs contribute to the flood mitigation in downstream areas to a great extent through their reservoir operation; however, spillage and large discharge release during flood period were observed resulting in increase of flood damage in the downstream. These issues are caused by shortage of flood control volume of the reservoirs.

In the case of Pasak reservoir, there is no limitation on stored water level because of small storage capacity and exclusive use for irrigation. The reservoir is filled at the early stage of flood period; therefore, sufficient flood mitigation effects are not expected when flood peak emerges.

Considering the issues mentioned above, the study on the modification of reservoir operation rule was carried out in accordance with the following principles:

- While downstream areas are inundated, no discharge is released from the reservoirs.
- Upper rule curves are modified to secure a vacant capacity for flood mitigation.
- In the case of Pasak reservoir, the upper rule curve is set up to secure a flood control function by maintaining a vacant capacity during flood period.

(3) Effectiveness and Influence of Modification of Operation Rule

Through the simulation, the most effective operation rule has been finally selected from the viewpoint of flood mitigation (refer to Fig. 4.1). The reduction of inundation volume and the influence on irrigation water supply and power generation obtained from the operation with the new rule curves are summarized in Table 4.1 and explained as follows:

(a) Flood Mitigation Effect

The average flood mitigation effect on five major floods (1975, 1981, 1983, 1995 and 1996) is the reduction of approximately 800 million m^3 of inundation volume. As for the effect on the 1995 flood, the maximum flood in the past 45 years, approximately 1,600 million m^3 of inundation volume, is totally reduced through the proposed operation of the three reservoirs. This volume is approximately equivalent to 10% of the total inundation volume.

(b) Influence on Irrigation Water Supply and Power Generation

The influence on irrigation water supply and power generation derived from the proposed operation is as described below:

(i) Reduction of Irrigation Areas during Dry Season

The average annual reduction of irrigation areas is about 4,400 ha (1.3%), but there is no reduction in drought years.

(ii) Reduction of Power Generation

The average reduction of power generation is about 27 Gwh (1.3%).

Effectiveness and Influence of Proposed Operation Rule

Name of Dam	Effectiveness for Flood Mitigation (Average for 5 floods)		Influence to Irrigation and Hydropower			
	Reduction of Inundation Volume (MCM)*		Reduction of Irrigation Volume (ha)		Hydropower Generation (Gwh)	
	Total reduction	Reduction from without	Total reduction	Reduction from without	Total reduction	Reduction from without
Bhumibol	2,232	234 (12%)	171	-	1,195	13 (1.1%)
Sirikit	1,458	255 (17%)	126	2,300 (2%)	899	14 (1.5%)
Pasak	252	252 (100%)	48	2,100 (4 %)	-	-
Total	3,942	756 (19%)	345	4,400 (1.3%)	2,094	27 (1.3%)

* Volume corresponds to that stored in the reservoir while floodwater overflows at the reference point.

(4) Evaluation of Proposed Operation Rule

The benefit from the annual average mitigation exceeds the annual compensation cost to a great extent and the proposed operation rule curves are recommended even from the economic viewpoint.

Item	Average Annual Economic Benefit (million Baht)	Annual Maintenance Cost (million Baht)
Total for three dams	1,038	80

Besides, an initial cost of 34 million baht is required for the study.

4.1.2 Study on Land Use Control and Guidance

(1) General

Effective land use control and guidance are essential for flood mitigation, as pointed out in the master plan study. In this connection, the area where land use control and guidance should be considered was identified based on the flood risk map incorporating the future land use and expected flood damage.

(2) Identification of Areas for Land Use Control and Guidance

To identify such areas, the following approaches were taken:

(a) Historical Approach

As one of the general approaches, the flood risk map based on previous floods, 1983, 1995 and 1996, was prepared using the satellite image (refer to Fig. 4.2 and 4.3).

(b) Hydrological-Hydraulic Approach

A map showing the potential flood risk area in case of 5-year return period was prepared based on the flood inundation area by simulation results (refer to Fig. 4.4).

(c) Damage Approach

A map showing the magnitude of flood damage increase in the future was prepared based on the flood damage calculation results that were obtained in combination with inundation water depth by flood simulation and the relation between inundation water depth and flood damage (refer to Fig. 4.5).

(3) Realization of Land Use Control and Guidance

Based on the above study results, the extents of loss of natural retarding volume and flood damage expected by land development of the inundation area were roughly identified. Considering such conditions, it is desirable that the land use control and guidance is realized through the following:

- Recognition of the flood risk map by agencies concerned, and publication of the flood risk map to caution on land use in the flood risk area.
- Preparation of land use plan based on the flood risk map so as to minimize increase of flood damage in the future and to preserve the natural retarding effect.
- Advice and coordination on the provision of public facilities such as roads and airports for the preservation of the present retarding effect, when such public facilities are provided in the flood risk area.

4.1.3 Study on Institutional Arrangement

(1) General

In the Master Plan study, several measures for flood mitigation have been proposed and the possibility of realization of these measures within the present institutional framework has been examined. To solve the present issues, additional institutional arrangement has also been examined.

(2) Possibility of Realization within the Present Framework

The agencies responsible for implementation or realization of the measures proposed in the Master Plan have been assumed, as shown in Table 4.2, considering the features of the proposed measures. Judging from the table, most of the measures can be handled by the agencies concerned in the present institutional framework, although strengthening or enforcement may be required. Among these measures, however, the additional institutional arrangement for coordination of implementation of some measures requires the setup of the River Basin Committee.

(3) Establishment of River Basin Committee

To set up a new organization for river basin management, it is desirable to refer to examples in other countries, considering the historical background of governmental organization, the flood mitigation activities and major current issues. In this Study, the examples of foreign countries are summarized in

Table 4.3. Although it has been difficult to pinpoint which Country's organization is suitable to the situation in Thailand, the outline of the necessary organization based on the present issues has been considered, as follows:

(a) Identification of Issues on the Current Institutional Setup

In Thailand, there exists no single organization to handle flood mitigation basin-widely and comprehensively, and the issues on current institution and organization in terms of flood mitigation have arisen from this situation. At present, RID handles the flood mitigation works in agricultural areas, while PWD is responsible for major urban areas except the Bangkok metropolitan area that is undertaken by the BMA.

To cope with such issues, it seems to be necessary to set up an organization, the River Basin Committee, which has functions for coordination among the agencies concerned and for undertaking activities to enhance the capability for flood mitigation.

(b) Present Status of Institutions and Organizations

So far the government has been making efforts to set up a suitable organization to handle the issues, as follows:

- Establishment of the National Water Resources Committee in 1996
- Preparation of Water Resources Act including designation of River Basin Committee
- Study on the establishment of the Chao Phraya Basin Organization (River Basin Committee)

(c) Recommendation of functions to be involved in the River Basin Committee in terms of flood mitigation

In this Study, functions to be involved in the River Basin Committee in terms of flood mitigation are recommended considering the responsibilities and duties, as shown in Fig. 4.6 and summarized below:

- Setting up of strategy of integrated flood mitigation.
- Nomination and coordination of agencies concerned in the implementation of flood mitigation projects.
- Flood disaster management in the following flooding stages: (1) pre-flood management and preparedness; (2) flood management during flood time; and (3) flood management as post-disaster action.
- Other functions to enhance the flood mitigation capability (flood information center, training, public awareness and research).

In case that the prompt setting up of the River Basin Committee is difficult under the current movement to restructure the existing organization, the set up of an ad-hoc committee by the existing agencies

concerned is recommended as a tentative solution, referring to their current functions.

4.2 Structural Measure (River Improvement)

4.2.1 Outline of the Study

In the feasibility study, the possibility of river improvement in the midstream of the Chao Phraya river system from the Chao Phraya Dam to Pathum Thani was further examined to clarify the possible improvement scales and stretches.

4.2.2 Strategy of River Improvement

The river improvement, for which dike heightening is the main work, would reduce spillage at the improvement section but increase discharge to the downstream at the same time. For planning the river improvement, therefore, special consideration should be made so as not to lower but maintain the safety level for the Bangkok metropolitan area as well as Pathum Thani and Nonthaburi.

4.2.3 Project Features

Through the hydraulic analysis and preliminary designing, major features of the river improvement are proposed, as follows:

(1) Project Scale

The project design scale was determined at the safety level of 3-year return period. The river improvement will then upgrade the safety level of all the problem areas in the midstream to the 3-year return period, at least, but will not increase flood damage in the Bangkok metropolitan area (refer to Fig. 4.7).

(2) Design Water and Dike Level

The probable discharge with a 3-year return period is applied as the design discharge of river improvement works. The design water level was determined, based on the relation between water level and discharge at every cross section obtained from the flood simulation analysis. The design dike level was determined by adding a freeboard of 30 cm to the design water level (refer to Fig. 4.8).

(3) Dike Alignment and Regulators

The proposed dike alignment for the entire improvement stretch of 67,000 m has been drawn, as shown in Fig. 4.9, following the existing dikes or roads. A total of 13 regulators are proposed at the intersections of the existing/proposed dikes and khlongs.

(4) Work Quantities and Cost

The work quantities and cost of the proposed river improvement are summarized as follows:

Item	Chao Phraya R.	Lop Buri R.	Noi R.	K. Bang Bal	K. Bang Phro Mo	Total
Total Length of Dike Heightening Stretch (km)	41.8	14.0	6.6	2.5	2.1	67.0
Regulators (places)	10	3	-	-	-	13
Land Acquisition (m^2)	12,600	12,200	-	-	-	24,800
House Relocation (houses)	3	1	-	-	-	4
Financial Cost (mil. Baht)	1,052	284	55	23	11	1,425

As the O&M cost of river improvement, 34 million baht is required.

(5) Project Benefit

The area where the river improvement is implemented will be relieved from flood damage of up to a 3-year return period. The annual benefit derived from the river improvement is estimated at 221 million baht/year.

4.3 Project Evaluation and Implementation

4.3.1 Economic Evaluation

The economic evaluation was made only for project components that can be evaluated in monetary term based on the economic cost and benefit discussed above. The evaluation was made in a manner of EIRR, B-C and B/C, and the results are as shown below:

Item	(1) River Improvement	(2) Modification of Reservoir Operation Rule
EIRR (%)	12.5	-
B-C (million Baht)	28	5,693
B/C	1.0	13.3

As identified from these figures, the economic viability of river improvement is not so high, but the EIRR value is over 12%, which is regarded as the minimum of project viability. In the case of modification of reservoir operation, EIRR is not a suitable index to identify the economic viability. This is because the project will bring about a constant benefit and cost from the beginning (Bn and Cn are constant), so that the EIRR shown in the following equation cannot be obtainable unless Bn = Cn.

$$\Sigma[Bn/(1+i)^n] / \Sigma[Cn/(1+i)^n] = 1$$

Where,

Bn : Annual benefit of n-th year from the beginning

Cn : Annual cost of n-th year from the beginning

i : EIRR

Σ : Accumulation of benefit and cost for whole years in project life

Therefore, only B-C and B/C were used to evaluate the economic viability of the project component. Judging from the figures, the modification of reservoir operation rule will bring about a high economic return.

Also, these project components will bring about many intangible benefits such as the stabilization of people's living condition, decrease of waterborne diseases, increase of work opportunities, and so on.

4.3.2 Financial Consideration

The financial cost for modification of reservoir operation rule and river improvement requires 1,459 million baht as the initial cost and 114 million baht per year as the O&M cost. The source of the cost is assumed to be the government budget, which will be fulfilled by increase of government income resulting from the increase of productivity in the river basin due to flood damage mitigation.

The river improvement works consisting of dike heightening and provision of regulators are proposed in several sections scattered along the river course and will be undertaken by RID sub-project areas. In this connection, it is considered that RID should assure the budget from the Government or from the external source depending on the conditions.

4.3.3 Environmental Impact Assessment

The environmental impact assessment (EIA) was done only for the river improvement. The EIA had concluded that the river improvement will not cause a serious environmental impact in the project area.

4.3.4 Implementation Schedule

It is expected that most of the project components of nonstructural measures will be in the operation stage after the further study for a certain period of between 0.5 and 1.5 years.

As for the river improvement, it will take about 5 years for implementation after a detailed study for a period of 1.5 years.

The implementation schedule for these project components is shown in Fig. 4.10.

4.3.5 Organization for Project Implementation

As mentioned in Subsection 4.1.3, most of the project components are to be undertaken by the existing agencies concerned, such as DTCP, LDD, EGAT, RID and ONWRC, within their own responsibilities.

Among the project components, however, it is necessary to set up a new organization for project implementation of river improvement under the project office inside RID. The organization shall be composed as shown in Fig. 4.11.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The Master Plan of integrated flood damage mitigation in the Chao Phraya river basin has been formulated in accordance with the "Monkey Cheek" concept for preservation of the present retarding effect and also with the introduction of suitable flood mitigation measures. Emphasis has been placed on flood mitigation in the lower central plain from Chainat with the target year of 2018 (refer to Fig. 5.1). To realize the Master Plan, several project components for urgent implementation have been selected. For some of the project components, their feasibility have been examined and confirmed and, for the others, further studies have been undertaken.

In this JICA Study, it s concluded that flood mitigation in the context of the Master Plan is essential for the development of the basin and the country as a whole, and the implementation of selected project components is the most effective to attain the objectives.

5.2 Recommendation

(1) Justification of the Master Plan

The Master Plan of integrated flood mitigation in the Chao Phraya river basin has been formulated, as outlined in Fig. 5.1. Since the realization of the Master Plan is essential for the future development of the basin and the whole country as well, it should be justified as a part of Thailand's National Development Plan.

(2) Strengthening of the Present Organization and Setup of the River Basin Committee

The Master Plan is composed of several project components, most of which are to be undertaken by the agencies concerned within their scopes of responsibility. For the realization of the Master Plan, however, it is recommended that the present organization be strengthened to successfully implement the project components.

For coordination to realize the Master Plan, it is indispensable to promptly set up the River Basin Committee as proposed in the Water Resources Act that is presently under consideration on the national level. Thus, it is also recommended that the setup of the River Basin Committee be expedited.

In case the prompt setting up of the River Basin Committee is difficult under the current movement to restructure the existing organization, it is suggested that an ad-hoc committee be set up by the agencies concerned, as a tentative solution, to cope with the flood mitigation issues caused by lack of coordination.

(3) Selection of Alternative Measures

In the Master Plan study, alternative measures (Alternative 1, 2-1 and 2-2) have been proposed to assure the safety level of protection for urban areas in

the downstream, especially Pathum Thani, Nonthaburi and Bangkok. Since it has been difficult to select the most suitable alternative due to significant issues involved, it is recommended that further discussions be made as early as possible to select the most acceptable for all concerned. In the discussion for realization of the study results, it is necessary for all concerned in the Thai side to recognize that further study shall be done before construction of diversion channel. Also, social and environmental assessment for the heightening of flood barrier in Bangkok shall be conducted in detail before construction.

(4) Implementation of Priority Projects

In the framework of the Master Plan, four (4) priority projects have been selected; namely, modification of reservoir operation rule, land use control and guidance, institutional and organizational arrangement, and river improvement. Since all of these priority projects are essential to promote the flood mitigation in the Chao Phraya river basin from the technical, social and environmental points of view, it is recommended that these projects be forwarded to the next stage of implementation as early as possible.

(5) Further Study on Flood Mitigation in Agricultural Areas

As the measures for flood mitigation in agricultural areas, river improvement works and drainage system and distribution system improvements have been proposed. The process of system improvement was introduced in the Master Plan study, and only the river improvement works were covered in the feasibility study. To mitigate the flood damage in agricultural areas, however, it is also necessary to promote the distribution and drainage system improvements in parallel with the implementation of river improvement works. Thus, it is recommended that a further study on these system improvement works should be undertaken as early as possible.

Tables

Table 2.1 SUMMARY OF FLOODING CONDITION

Area	Geographical Features	Land Use	Flooding Condition In 1995	Cause of Flooding	Flood Damage in 1995
Upper Central Plain (Upstream of Nakhon Sawan)	Valley plain between hilly areas with gentle slope in the east and west.	Main land use : Paddy (Traditional varieties are dominant, but HYV is applied in Phitsanulok Irrigation Area protected by dikes) Major urban area : Uttradit, Phitsanulok, Sukhothai, Phichit	Inundation Area : 5,000 km^2 Depth : 0.5 to 3 m Duration : 2 to 3 month (in some depression areas inundation continued more than 3 months up to January next year)	• Overtopping of Yom and Nan rivers • Inland flood • Overland flow from upstream • Flash flood from upper mountainous area	Agricultural Damage More than 50% of Phitsanulok project was protected. 180,000 ha of paddy field was damaged. Urban Area Damage Sukho Thai, Phitsanulok, Phichit are seriously damaged. Infrastructure Roads, bridges, irrigation facilities including regulators and canal embankment were damaged.
Nakhon Sawan Area (between Nakhon Sawan and Chainat)	Narrow valley plain with number of isolated mountains	Main land use : Paddy (Traditional varieties are dominant) Major urban area Nakhon Sawan, Uthai Thani	Inundation Area : 500 km^2 Depth : 0.5 to 3 m Duration : 1 to 2 month	• Overtopping of Chao Phraya River • Overtopping of Sakae Krang River caused by back water from Chao Phraya River • Inland flood • Overland flow from upstream	Agricultural Damage Paddy fields of 160,000 ha and 10,000 ha were damaged in Nakhon Sawan and Uthai Thani respectively. Urban Area Damage Nakhon Sawan and Uthai Thani were severely damaged. Infrastructure Damage Roads were damaged
Higher Delta in Lower Central Plain (between Chainat and Ayutthaya)	Natural levees and back marshes are well developed.	Main land use : Paddy (HYV is dominant but floating rice and deep water rice are dominant in habitually inundated area) Major urban area : Chainat, Sin Buri, Angthong, Ayutthaya, Supan Buri, Lop Buri	Inundation Area : 4,600 km^2 Depth : 0.5 to 4 m Duration : 2 to 3 month (in some depression areas inundation continued more than 3 months up to January next year)	• Overtopping and dike breaches along Chao Phraya, Nan, Lopburi, Tha Chin, Pasak rivers • Inland flood • Overland flow from upstream	Agricultural Damage Total 190,000 ha of paddy field including 50,000 ha in Maharat Project Area was damaged. Urban Area Damage Chainat, Sin Buri, Angthong, Ayutthaya and Suphan Buri are severely damaged. Infrastructure Damage Roads, bridges, irrigation facilities including regulators and canal embankments are damaged
Lower Delta in Lower Central Plain (downstream of Ayutthaya)	Very flat	Main land use : Paddy (HYV rice) is main but urban areas are expanding rapidly Major urban area : Bangkok, Pathum Thani, Nonthaburi Samut Prakan	Inundation Area : 4,700 km^2 Depth : 0.5 to 2 m Duration : 2 to 3 month	• Overtopping of Chao Phraya and Tha Chin rivers • Dike breach • Inland flood • Overland flow from upstream	Agricultural Damage 40,000 ha of paddy field and 10,000 ha of other crop fields were damaged. Urban Area Damage Pathum Thani, Nonthaburi, Samut Prakan are damaged. Infrastructure Damage Roads, irrigation facilities including regulators and canal embankments are damaged

Table 2.2 ESTIMATION FLOOD DAMAGE IN 1995 FLOOD

(mil. Baht)

RIGION	HOUSES	COMMERCIAL	INDUSTRIAL	AGRICULTURE	PUBULIC	OTHERS	TOTAL
UPPER CENTRAL PLAIN	1,903	4,050	5,439	959	670	295	13,316
NAKHON SAWAN	550	1,194	2,377	186	130	57	4,495
HIGHER DELTA	2,214	7,044	8,968	1,595	1,114	491	21,428
LOWER DELTA	5,524	7,279	19,234	721	504	222	33,484
TOTAL	10,192	19,567	36,018	3,461	2,418	1,066	72,723
TOTAL(%)	(14)	(27)	(50)	(5)	(3)	(1)	(100)

Table 2.3 SIMULATION CASE FOR IDENTIFICATION OF INFLUENCE BY FUTURE DEVELOPMENT

Case	Basin Condition							Simulation Results (1995 Flood)					Remarks
	Present Condition	Urban Development	Change of Agricultural Cultivation	Land Subsidence	Dam		Loop Cut	Flood Discharege at Nakon Sawan (m3/s)	Flood Discharge at Bang Sai (m3/s)	Water Level at Samsen (C.12) (MSL+m)	Water Level at Memorial Bridge (C.4) (MSL+m)	Total Inundation Volume (billion m3)	
					Existing	Planned							
Reappearance of Present Condition	○							4,600	4,150	2.32	2.20	15.9	
Influence by Urban Development (Providing Ring Levee with Drainage Pump)		○			○			4,430	4,070	2.80	2.57	16.0	
Influence by Change of Agricultural Cultivation (in combination with Urban Development)		○	○		○			4,430	4,070	2.81	2.57	16.1	
Influence by Land Subsidence (in combination with Urban Development and Change of Agricultutal Cultivation)		○	○	○	○			4,430	4,070	2.81	2.56	16.2	
Influence by Construction of Dam(in combination with Urban Development and Change of Agricultutal Cultivation)		○	○	○	◎	○		4,110	4,000	2.77	2.53	14.7	
Influence by Construction of Loop Cut (in combination with Urban Development, Change of Agricultural Cultivation and Construction of Dam)		○	○	○	◎	○	○	4,110	3,980	2.62	2.45	14.1	Future Basin Condition

◎ : Actual outflow is applied for Bhumipol Dam, but Sirikit Dam outflow is assumed to be regulated with a conduit newly added after the 1995 flood accrding to the current operation rulr, resulting in no spillage.

Table 3.1 APPLICABILITY OF MEASURES FOR FLOOD DAMAGE MITIGATION

Category	Measures		Effectiveness	Influence	Applicability
Structural Measure	River Training		Effective only for the protection area by river training	Affect to life for people living in riverline	Applicable
	Diversion Channel		Effective for down stream area from diversion point	Affect to people living in the area on the diversion route	Applicable, but further consultation is necessary.
	Retarding Basin	Natural Retarding Basin	Effective for damage mitigation in down stream	Agreement from agricultural people for use of natural retarding basin	Applicable but preservation of natural retarding function is practical.
		Artificial Retarding Basin	Effective for down stream area from retarding basin	Cause social problem for people engaged in the designated area as retarding basin	Not applicable
	Ring Levee		Effective for flood mitigation in specific area	May cause adverse influence to the downstream.	Regarded as given condition for study.
	Tidal Barrage with Pump		Effective for flood mitigation in downstream	Cause social and environmental problems due to clogging of river mouth.	Not applicable from economical reason as well as social and environmental aspect
	Heightening of Flood Barrier at Bangkok		Effective for Mitigation of Flood Damage in BMA	Cause social and environmental problems for people living along the River Course	Applicable but be considered in combination with Flood Insurance
Non-structural Measures	Modification of Reservoir Operation Rule		Effective to mitigate flood especially in the area of upstream	This affects to water supply resulting in reduction of agriculture production and hydro-power generation.	Applicable
	Strengthening of Control and Guidance	Control and Guidance for Land Development	Preservation of present retarding function.	May cause issues from economic and social view point	Applicable
		Control of Ground Water Suction	Reduction of inundation volume	May cause issues from economic view point	Applicable
	Flood Disaster Response	Flood Forecasting	Achievement of more precise flood forecasting	Not cause serious issue	Applicable
		Flood Fighting	Execution of more effective flood fighting	Not cause serious issue	Applicable
		Flood Recovery	Mitigation of secondary flood damage	Not cause serious issue	Applicable
	Financial Response	Subsidy	Stabilization of life for damaged people	Not cause serious issue	Applicable but be considered in combination with Flood Insurance
		Flood Insurance	Stabilization of life for damaged people	Not cause serious issue	Government is under study
	Watershed Management		Retarding of flood discharge and detention of low flow	Brings about favorable basin condition from environmental aspect	Government is practicing in a manner of reforestation
	Institution and Organization		Realization of more effective flood mitigation through coordination among agencies concerned.	Not cause serious issue	Government is under study

Table 3.2 COMPARISON OF OPTION TO MITIGATE FLOOD DAMAGE

Option	Safety Level		Description	Advantage and Disadvantage
	Bangkok	Pathum Thani and Nontha Buri		
(1)To maintain the present condition of Pathum Thani and Nontha Buri	125-year return period	2-3 year return period	Suspension of planned protection works by PWD	From technical, economical and environmental point of view, there may be no issues. From social point of view, inhabitants in urban areas, Pathum Thani and Nonthaburi, will not accept to maintain the present safety level in the future. The option can not cope with the situation to enhance the protection level of agricultural area in the upstream in the future.
(2) To enhance the safety level up to the allowable level	100	5	The safety level of Bangkok can be enhanced more than 100-year return period by loop cut at port. Therefore there is a room to enhance the safety level of Pathum Thani and Nontha Buri for that part.	From technical, economical and environmental point of view, there may be no issues. From social point of view, inhabitants in urban areas, Pathum Thani and Nonthaburi, will not accept to maintain the present safety level in the future. The option can not cope with the situation to enhance the protection level of agricultural area in the upstream in the future.
(3) To lower the safety level at Bangkok	50	7	The safety level of Bangkok will be reduced to 50-year return period for example, while those of Pathun Thani and Nontha Buri be enhanced to 7 year return period for example.	From technical, economical and environmental point of view, there may be no issues. From social point of view, inhabitants in urban areas, Pathum Thani and Nonthaburi, will not accept to maintain the present safety level in the future. The option can not cope with the situation to enhance the protection level of agricultural area in the upstream in the future.
(4) To narrow the protection area of Pathum Thani and Nontha Buri	100	100, and 2-3	The protection area of Pathum Thani and Nontha Buri is narrowed down to the extent, in which adverse influence to Bangkok is not severe.	From technical, economical and environmental point of view, there may be no issues. From social point of view, inhabitants in urban areas may oppose delineation of protected and not protected areas in the same municipality level in the future. The option can not cope with the situation to enhance the protection level of agricultural area in the upstream in the future.
(5) To heighten the flood barrier at Bangkok	100	100	To further heighten the flood barrier at Bangkok from ongoing project.	From the technical and economical point of view, the works will not involve serious issues. From environmental and social points of view, this option will cause serious issues. The option can not cope with the situation to enhance the protection level of agricultural area in the upstream in the future.
(6) To provide diversion channel	100	100	To provide diversion channel to absorb the adverse influence.	From the technical point of view, the works will not involve serious issues. From the environmental point of view, issues derived from the option will be solved. From economical point of view, this works will require a huge burden to the country. From social point of view, this option will cause issues for land acquisition and house evacuation. This option can be used for enhancement of the safety level of agricultural areas.

Table 3.3 MEASURES FOR MASTER PLAN

Area	Alternative-1		Alternative2-1		Alternative2-2	
	Non-structural Measures	Structural Measures	Non-structural Measures	Structural Measures	Non-structural Measures	Structural Measures
Upper Central Plain	Modification of Reservoir Operation Rule Land Use Control and guidance Flood Forecasting Warning System Flood Fighting Disaster Recovery Subsidy and Flood Insurance	Ring Levee for Urban Area by PWD	Same as Alternative-1	Same as Alternative-1	Same as Alternative-1	Same as Alternative-1
Nakon Sawan Area	Modification of Reservoir Operation Rule Land Use Control and guidance Flood Forecasting Warning System Flood Fighting Disaster Recovery Subsidy and Flood Insurance	Ring Levee for Urban Area by PWD	Same as Alternative-1	Same as Alternative-1	Same as Alternative-1	Same as Alternative-1
Higher Delta in Lower Central Plain	Modification of Reservoir Operation Rule Land Use Control and guidance Flood Forecasting Warning System Flood Fighting Disaster Recovery Subsidy and Flood Insurance	River Improvement Distribution System Improvement Ring Levee for Urban Area by PWD	Same as Alternative-1	Same as Alternative-1	Same as Alternative-1	Same as Alternative-1
Lower Delta in Lower Central Plain	Modification of Reservoir Operation Rule Land Use Control and guidance Control of Ground Water Extraction Flood Forecasting Warning System Flood Fighting Disaster Recovery Subsidy and Flood Insurance	Partial Protection of Pathum Thani and Nonthaburi Drainage System Improvement	Same as Alternative-1	Heightening of Flood Barrier at Bangkok Drainage System Improvement	Same as Alternative-1	Construction of Flood Diversion Drainage System Improvement

Table 3.4 FEATURES OF DRAINAGE AREA

Study Area	Division of Area	Name of Project Area	Features of the Drainage Area						
			Catchment Area (km2)	Slope Gradient	Main Drainage Outlet	Drainage Capacity of pump (m3/s)	Possibility to receive flood water from Rivers	Flood Damage Magnitude (based on Interview)	Main Land Use
Higer Delta	Norhtern Part surrounded by Thachin and Noi Rivers	Borommathad, Samdhuk, Chanasutr, Yamanee and Phak Hai, etc.	1,850	1/4,000	Thachin and Noi Rivers	24	Less Possibility	Not so serious	HYV
	Area surrounded by Noi and Chao Phraya Rivers	Borommathad, Yamanee and Phak Hai, Bang Bal	930	1/4,000	Noi and Chao Phraya Rivers	-	Chao Phraya River	Relatively Serious due to overflow from river	HYV, F/R and DWR
	Area surrounded by Chao Phraya and Lop Buri Rivers	Maharat and Khok Katiem	500	1/5,000	Chao Phraya and Lop Buri Rivers	-	Chao Phraya and Lop Buri Rivers	Relatively serious due tp overflow from rivers	F/R and DWR
	Area surrounded by Lop Buri and Pasak Rivers	Khok Katiem and Roeng Rang	530	1/5,000	Lop Buri and Pasak Rivers	-	Lop Buri and Pasak Rivers	Serious	F/R and HYV
Lower Delta	East Bank Area	Nakhon Luang, Pasak Tai, Rangsit Nua, Rangsit Tai, Khlong Dan and Phra Ong Chai Ya Nuchit	4,374	1/50,000	Choa Phraya, Nakhon Nayok and Bang Pakon Rivers and Sea	507.5	Chao Phraya and Pasak Rivers	Serious	HYV and Fruits Tree
	West Bank Area	Chao Ched Bang Yeehon, Phrayahantue, Phraypimol and Pashicharoen	2,385	1/60,000	Choa Phraya and Thachin Rivers and Sea	116	Chao Phraya and Tha Chin Rivers	Serious	HYV and Fruits Tree

Table 3.5 MAIN DRAINAGE ISSUES OF THE AREA (Yes* : Yes, but not so severe)

Study Area	Division of Area	Name of Project Area	Mian Cause of Flood			Drainage Condition			Main Issure
			Local Rainfall	Water from Upstream Area	Overflow From Rivers	Drainage System	Collection of Water to Outlet	Continuation of Higher Water Level at Outlet	
Higer Delta	Norhtern Part surrounded by Thachin and Noi Rivers	Borommathad	Yes *	No	No	Fair	Good	Not much	Drainage problem may not be severe in general, but due to water from upstream area, it is seriouse in the downstream project area.
		Samdhuk	〃	Yes *	〃	〃	〃	〃	
		Chanasut	〃	Yes	〃	〃	〃	〃	
		Phak Hai	〃	〃	〃	〃	〃	〃	
	Area surrounded by Noi and Chao Phraya Rivers	Borommathad	Yes *	no	Yes	Fair	Good	Yes	Drainage problem may not be severe in general, but it is very serious when overflow from rivers occurs
		Yamanee	〃	Yes	〃	〃	〃	〃	
		Phak Hai	〃	〃	〃	〃	〃	〃	
		Bang Bai	〃	no	〃	〃	〃	〃	
	Area surrounded by Chao Phraya and Lop Buri Rivers	Maharat	Yes *	no	Yes	Fair	Good	Yes	– do –
		Khok Katiem	〃	〃	〃	〃	〃	〃	
	Area surrounded by Lop Buri and Pasak Rivers	Khok Katiem	Yes *	no	Yes	Fair	Good	Yes	– do –
		Roeng Rang	〃	Yes	〃	〃	〃	〃	
Lower Delta	East Bank Area	Nakhon Luang	Yes *	No	Yes	Fair	Fair	Yes	Drainage issue is emphasized with the following points: difficulty of collection of inudation water, continuation of higher water level at outlet, overflow from rivers and water from upstream area
		Pasak Tai	〃	〃	No	〃	〃	〃	
		Rangsit Nua	〃	Yes*	〃	Good	Poor	〃	
		Rangsit Tai	〃	〃	〃	〃	〃	〃	
		Khlong Dan	〃	Yes	Yes	Poor	〃	〃	
		Phra Ong Chai Ya Nuchit	〃	〃	〃	〃	〃	〃	
	West Bank Area	Chao Ched Bang Yeehon	Yes *	no	Yes	Fair	Fair	Yes	– do –
		Phrayahantue	〃	Yes*	〃	Poor	Poor	〃	
		Phraypimol	〃	〃	〃	〃	〃	〃	
		Pashicharoen	〃	Yes	〃	〃	〃	〃	

Table 3.6 PRIORITY OF DRAINAGE SYSTEM IMPROVEMENT

Study Area	Priority	Division of Area	Priority	Name of Project Area	Priority
Higer Delta	2	Norhtern Part surrounded by Thachin and Noi Rivers	2-4	Borommathad	2-4-4
				Samdhuk	2-4-3
				Chanasut	2-4-2
				Phak Hai	2-4-1
		Area surrounded by Noi and Chao Phraya Rivers	2-3	Borommathad	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	2-1	Maharat	2-1-2
				Khok Katiem	2-1-2
		Area surrounded by Lop Buri and Pasak Rivers	2-2	Khok Katiem	2-2-2
				Roeng Rang	2-2-1
Lower Delta	1	East Bank Area	1-1	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	1-2	Chao Ched Bang Yeehon	1-2-4
				Phrayahantue	1-2-3
				Phraypimol	1-2-2
				Pashicharoen	1-2-1

Table 4.1 **FLOOD MITIGATION EFFECT FOR FIVE BIG FLOODS**

Name of dam	Operation Case	Reductin of inundation Volume (million m3)					
		1975 flood	1981 flood	1983 flood	1995 flood	1996 flood	Average
Bhumibol	Without(Present Operation)	3,436	342	1,615	3,681	918	1,998
	Proposed Operation	4,477	342	1,615	3,773	956	2,232
Sirikit	Without(KIN project proposed)	2,323	348	113	2,725	506	1,180
	Proposed Operation	2,813	348	113	3,510	506	1,458
Pasak	Without(without Operation)	0	0	0	0	0	0
	Proposed Operation(Case-1)	175	0	0	288	51	103
	Proposed Operation(Case-2)	370	0	0	587	109	213
	Proposed Operation(Case-3)	438	0	0	695	129	252

Table 4.2 RESPONSIBILITY FOR REALIZATION OF MEASURES

Measures		Agencies concerned	Present Situation	Issues	Remarks
Category	Measures				
Non-structural Measures	Land use control and Guidance	DTCP, Local Government, LDD	Currengly executing	Needs to strengthen	Additional Legal arrangement is necessary
	Modification of Operation Rule	EGAT, RID	Newly introduced	Coordination is necessary	-
	Control of Ground Water Sunction	DMR	Currengly executing	Need to strengthen	-
	Flood Forecasting	EGAT, RID, BMA, MED	Currengly executing	Need to improve	ONWRC is to establish a flood forecasting system.
	Flood Fighting	Civil Defence, BMA, RID and Provincial Gov.	Currengly executing	Coordination is necessary	-
	Disaster Recovery	RID, BMA, PWD, Provincial Gov. and Min. of Health	Currengly executing	Coordination is necessary	-
	Subsidy	MOAC, RID	Currengly executing	Need to strengthen	-
	Flood Insurance	MOAC, RID	Newly introduced	-	To be introduced in 8th Agricultural Development Plan
	Watershed Management	RFD	Currently Executing	Need to strengthen	-
Structural Measures	Preservation of Retarding Area with Flood Mitigation*	RID	Currently Executing	Need to improve	Establishment of new organization is necessary
	River Improvement	RID	Currently Executing	Need to improve	
	Heightening of Flood Barrier at Bangkok	BMA	Currently Executing	Need to improve	
	Construction of Diversion C	RID, BMA and PWD	Newly introduced	Coordination is necessary	

*: Distribution system and drainage system improvement in the agricultural area

Table 4.3 RIVER BASIN MANAGEMENT ORGANIZATION IN FOREIGN COUNTRIES

Countries	Governmental Frame Work		Existence of Special River Management Organization	Existence of River Management Law	Classificaiton of Rivers	Responsibility of Flood Mitigation		
	Centralization	Decentralization				Central Gov.	Local Gov.	Local Communities
Japan	Yes, but toward to decentraliza-tion	-	-	River Law	Class-A	Yes	-	-
					Class-B	-	Yes	-
					Equivalent Rivers	-	Yes	-
USA	-	Yes	Mississippi River Commission, Tennessee Valley Authority	Flood Control Act, Water Code	Large Scale Rivers	Provision of Flood Insurance	-	-
					Other Rivers	-	Yes	
UK	Yes	-	National River Authority	Water Act	Major River	Yes(NRA)	-	-
					Minor River	-	-	Yes (IDBs)
France	-	At present decetralization has settled down.	River Basin Committee	Civil Code	Six major basin	River Basin Committee		
					Other Rivers	Financial Support	Yes	
Germany	-	Yes	-	Federal Water Management Act	Federal Channel and Class-1	-	Yes	-
					Class-2 and 3	-	-	Yes
People's Republic of China	Yes	-	River Basin Authority	Water Law and Flood Protection Law	Seven Major Rivers	Yes	-	-
					Other Rivers	-	Yes	-
Kingdom of Thailand	Yes	-	No organization at present but river basin committee is under process	No law at present but Water Resources Act is under process	25 river basins	Yes (Agricultural Area and Major Urban areas)	Yes (BMA)	-