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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

ROYAL IRRIGATION DEPARTMENT
MINISTRY OF AGRICULTURE AND COOPERATIVES
THE KINGDOM OF THAILAND

THE STUDY
ON
THE NORTHERN WATER DIVERSION PROJECT
IN
THE KINGDOM OF THAILAND

MAIN REPORT

(Feasibility Study)

NOVEMBER 1999

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ROYAL IRRIGATION DEPARTMENT
MINISTRY OF AGRICULTURE AND COOPERATIVES
THE KINGDOM OF THAILAND

THE STUDY
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PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Government of Japan decided to conduct a study on the Kok-Ing-Nan Water Diversion Project (Phase II) and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Shoichiro Higuchi of SANYU CONSULTANTS INC. and consisted of SANYU CONSULTANTS INC. and NIPPON KOEI Co., Ltd. to Thailand, 3 times between December, 1997 and October, 1999. In addition, JICA set up an advisory committee headed by Mr. Hidetomi Oi, Development Specialist, JICA between December, 1997 and October, 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.

November 1999

Kimio Fujita
President
Japan International Cooperation Agency

November 24, 1999

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

Letter of Transmittal

Dear Mr. Fujita,

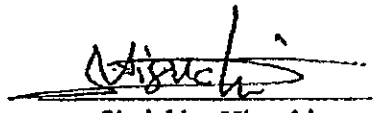
We are pleased to submit hereby the Final Report on the Feasibility Study and the Environmental Technical Assistance Study on the Kok-Ing-Nan Water Diversion Project (Phase II Study) in the Kingdom of Thailand. This report incorporates advice and suggestions of authorities concerned of the Government of Japan and your good agency as well as the comments made by the Royal Irrigation Department (RID) of the Ministry of Agriculture and Cooperatives and other responsible agencies of the Government of Thailand on the formulation of the project during technical discussions on the draft final report, which were held in Tokyo and Bangkok.

In the light of urgent importance of solving water shortage problems prevailing over the Chao Phraya basin, the Study is to supplement and strengthen the study initiated already by the Government of Thailand. Following the Conceptual Planning Study and the IEE as the Phase I Study, the Phase II Study was formulated and evaluated from both engineering and economic point of view for further implementation of the Project. The Environmental Technical Assistance Study was also conducted focusing mainly on the review of the EIA made by the Thai-side inclusive of some supplemental studies in the field of watershed management, etc.

In view of critical condition of balance between demand and supply of water and of need for sustainable development of the Chao Phraya basin as a whole, water diversion as studied can be considered as one of the effective measures. The Study aims to furnish full information regarding the demand and supply of water so that the Government of Thailand can make decision for further implementation of the Project under due consideration of not only technical aspects but also economic and other situation of the country. The magnitude of influence that might be caused by Project would also be considerable, and therefore public relation activities should be executed not only in the Kok, Ing and upper Nan basins but also in the direct beneficiary areas in the lower Nan and Chao Phraya delta.

We wish to take this opportunity to express our heartfelt gratitude to your Agency and other authority concerned of the Government of Japan as well as to the RID and other agencies of the Government of Thailand for close cooperation and assistance extended to us during the course of our investigations and studies.

Very truly yours,

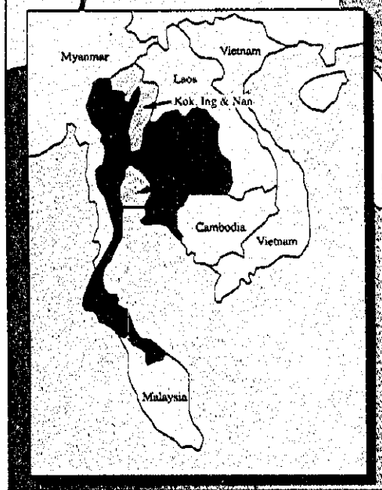


Shoichiro Higuchi
Leader of the Study Team

STUDY AREA LOCATION MAP

THE KOK-ING-NAN WATER DIVERSION PROJECT
IN
THE KINGDOM OF THAILAND

MYANMAR
LAO PDR
Kok River
Kok River
Chiang Rai
Kok-Ing-Nan Diversion
Mekong River
Fang River
Kok Basin
Mae Lao Irrigation
Lao River
Ing River
Ing Basin
Mae Ngat Dam
Bhumibol Lake
Upper Nan Basin
Mae Kuang Dam
CHIANG MAI
NAN
Kio Kor Mo Dam
Kaeo Sua Ten Dam
Kiew Lom Dam
LAMPANG
PHRAE
Yom River
Srikit Dam
Wang River
UTTARADIT
Nan River
Bhumibol Dam
SUKHOTHAI
Khaeo Noi Dam
TAK
PHITSANULOK
Lower Nan Basin
KAMPHAENGPHET
Ping River
Khlong Khlung Dam
Mae Wong Dam
NAKHON SAWAN
Bung Boraphet
Khlong Plio Dam
Thap Salao Dam
CHAINAT
Kraseo Dam
CHAO PHRAYA DELTA
Pasak Dam
Chao Phraya River
Tha Chin River
Pasak River
AYUTTHAYA
BANGKOK
Gulf of Thailand



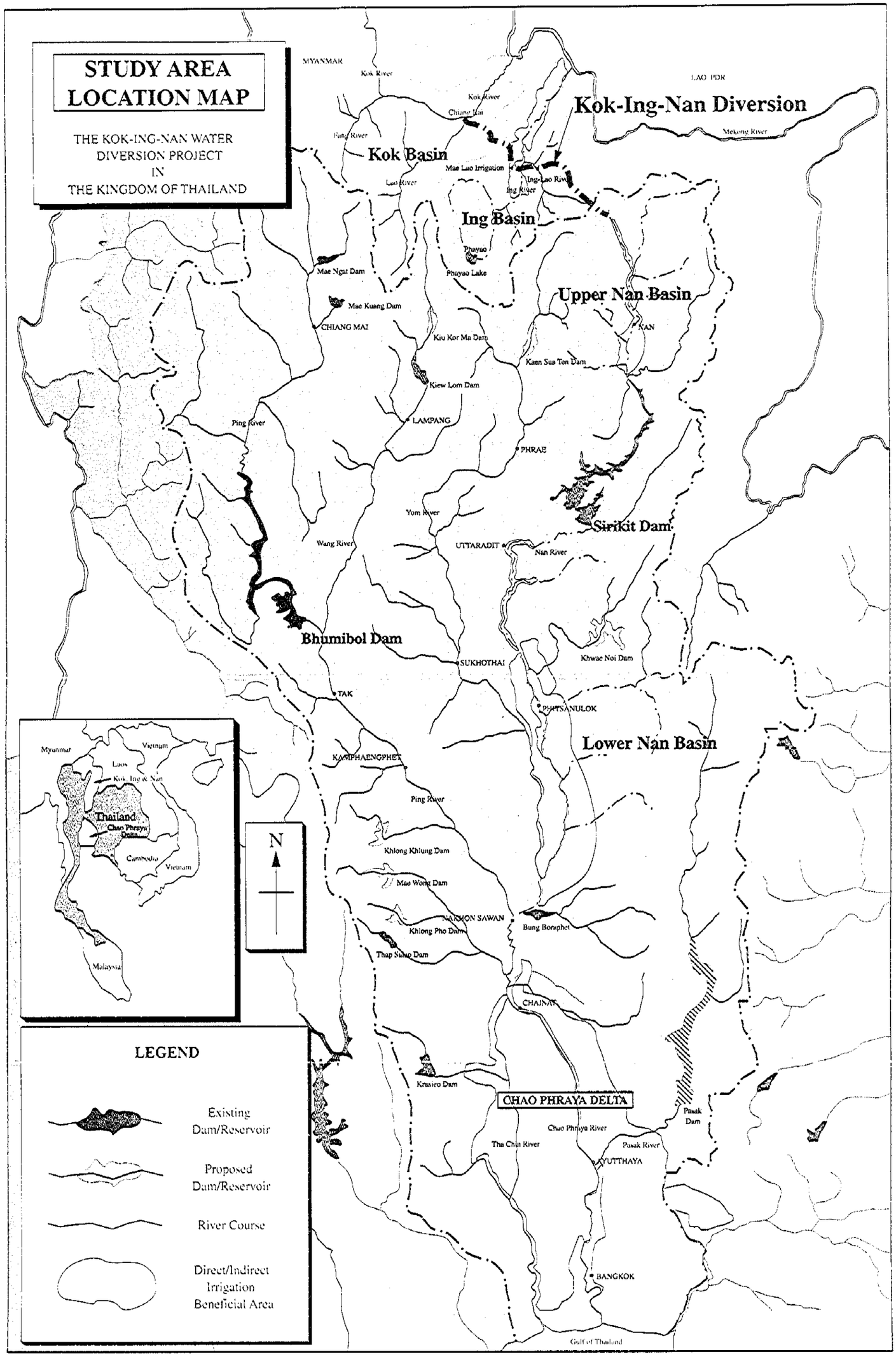
N

LEGEND

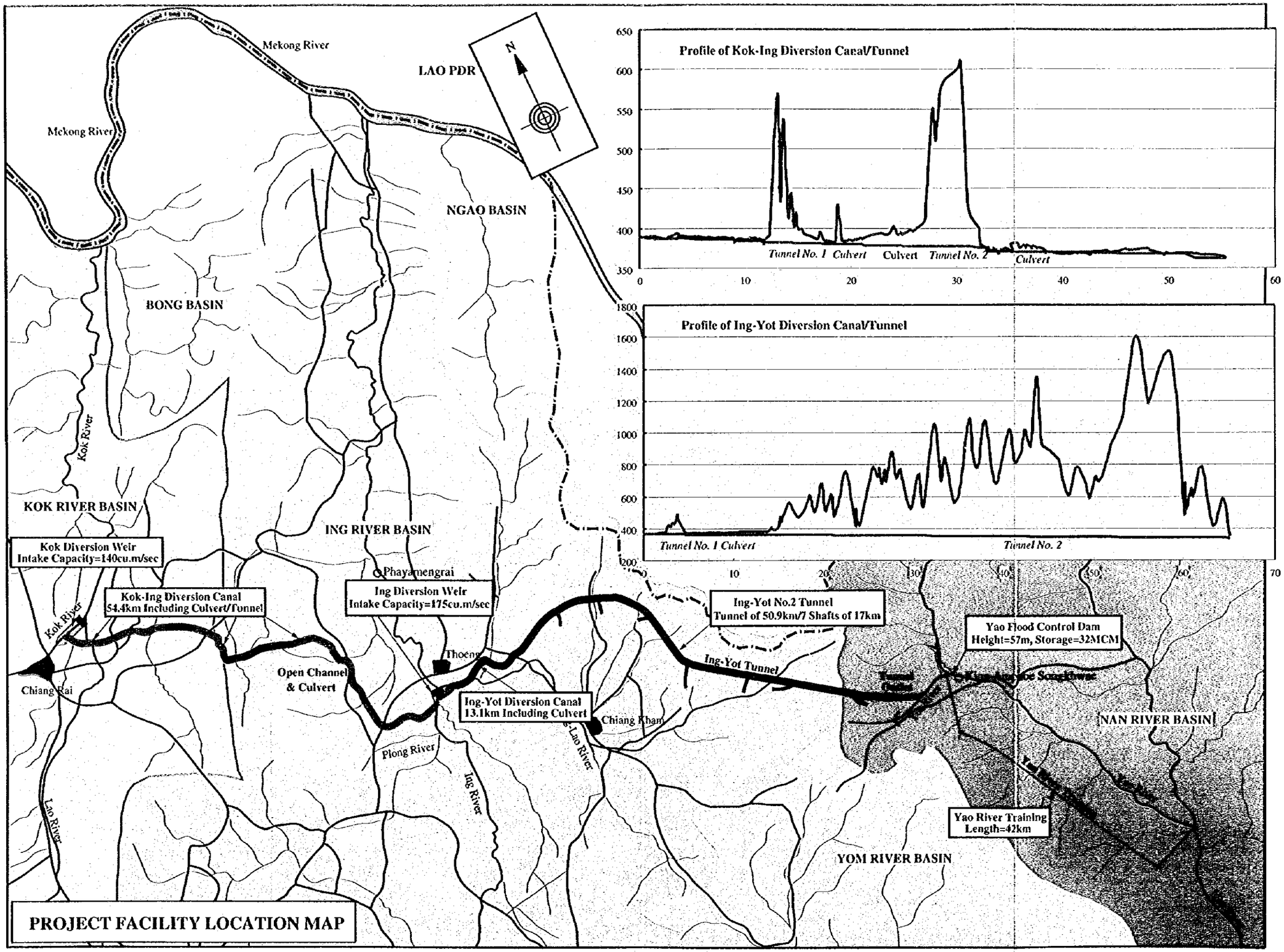
- Existing Dam/Reservoir
- Proposed Dam/Reservoir
- River Course
- Direct/Indirect Irrigation Beneficial Area

STUDY AREA LOCATION MAP

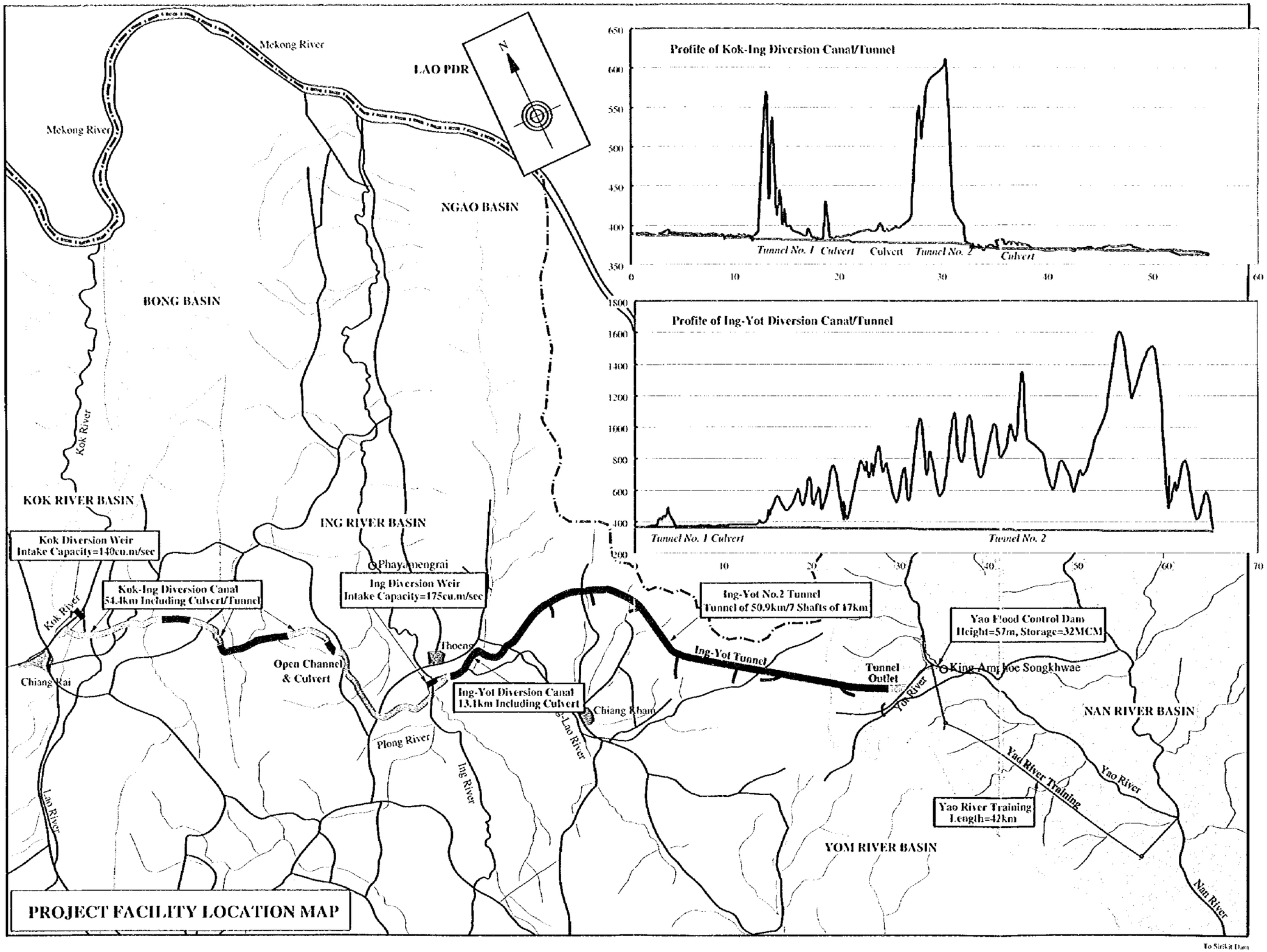
THE KOK-ING-NAN WATER DIVERSION PROJECT IN THE KINGDOM OF THAILAND



PROJECT FACILITY LOCATION MAP



PROJECT FACILITY LOCATION MAP



Key Indicators in Kok-Ing-Nan Water Diversion Project

1. General Features of Chao Phraya and Kok-Ing Basin

Item		Unit	Chao Phraya Basin			Kok-Ing Basin
			Upper	Lower	Total	
(1) Basin Area		$10^3 km^2$	124.1	33.8	157.9	14.3
(2) Population, 1996		10^6	9.6	12.5	22.1	1.5
(3) Farm Land Area		10^6rai	23.8	12.3	36.1	2.4
(4) Water Resources		$10^9 m^3$	27.8	4.5	32.3	8.0
(5) Irrigation Area,	Existing	10^6rai	6.6	8.0	14.6	1.0
	Future (2016)	10^6rai	12.1	8.0	20.1	1.8
(6) Irrigation Intensity	Existing	%	28	65	40	43
	Future	%	51	65	56	75
(7) G.B.P. Per capita 1996		10^3Baht	28	137	90	19
	2016	10^3Baht	61	470	275	27

2. Developed Water by Project

(1) Diversion Water by Project 2,000 MCM

(2) Dry Season Outflow at Sirikit Dam 2,810 MCM

3. Beneficial Area and Water Allocation

(1) Municipal and Industrial Water Supply in Delta 825 MCM

(2) Irrigation Water Supply in Delta and Lower Nan 1,985 MCM

Total 2,810 MCM

(3) Incremental Dry season Area in Delta 714,000 rai

(4) Incremental Dry season Area in Lower Nan 469,000 rai

Total 1,183,000 rai

4. Outline of Project Facility

(1) Kok Intake 140 cu.m/sec at Kok river

(2) Kok-Ing Diversion Canal 54.4km between Kok intake and Ing weir

(3) Ing Diversion Weir 175 cu.m/sec at Ing River

(4) Ing-Yot Diversion Canal 11.1km between Ing Weir and Ing-Yot Tunnel

(5) Ing-Yot Long Tunnel 52.9km with 7 Inclined Adits of 17.4km

(6) Yao Flood Control Dam Rockfill Type, Reservoir Capacity of 32 MCM

(7) Yao River Training River Length of 49km

5. Associate Irrigation Project Area in Kok-Ing and Upper Nan 237,500rai

6. Project Cost

Kok-Ing-Nan Water Diversion Project 43,386 Million Baht

Including Related Projects such as Associate, etc. 59,563 Million Baht

7. Incremental Project Benefit

Municipal and Industrial Water Supply 2,766 million Baht

Agriculture 10,918 million Baht

Hydropower Generation 406 million Baht

Total 14,090 million Baht

8. Economic Evaluation

Raw Water Cost 1.3 Baht/cu.m

EIRR 14.1%

ABBREVIATIONS AND LOCAL TERMS

A. ABBREVIATION OF MEASURES

(1)	Length	mm	=	millimeter
		cm	=	centimeter
		m	=	meter
		km	=	kilometer
(2)	Area	m^2	=	square meter
		ha	=	hectare = 10^4 m^2
		km^2	=	square kilometer = 10^6 m^2
		rai	=	0.16 ha
(3)	Volume	lit, l	=	liter = 1,000 cm^3
		cu.m	=	cubic meter = m^3
		MCM	=	million cubic meter = 1,000,000 m^3
(4)	Weight	mg	=	milligram
		g	=	gram
		kg	=	kilogram
		t	=	ton = 1,000 kg
(5)	Time	s	=	second
		min	=	minute
		h, hr	=	hour
		d	=	day
		yr	=	year
(6)	Currency	B	=	Baht
		US$	=	US Dollar
		¥	=	Japanese Yen
(7)	Electricity	kv	=	kilovolt
		kw	=	kilowatt
		MW	=	megawatt = 1,000 kw
		kwh	=	kilowatt hour
		MWh	=	megawatt hour = 1,000 kwh
		GWh	=	gigawatt hour = 1,000 Mwh
(8)	Discharge	cu.m/sec	=	cubic meter per second
(9)	Others	mmho	=	micromho = conductance
		ppm	=	parts per million

ppb	=	parts per billion
ppt	=	parts per thousand
%	=	percent
pH	=	scale of acidity
'	=	minute
"	=	second
°C	=	degree centigrade

B. OTHER ABBREVIATIONS

ASTM	=	American Society for Testing and Material
GDP	=	gross domestic product
GRP	=	gross regional product
GBP	=	gross basin product
El.	=	elevation
H.W.L.	=	high water level
L.W.L.	=	low water level
FOB	=	free on board
CIF	=	cost, insurance and freight
K-I-N	=	Kok-Ing-Nan
CPBWMS	=	Chao Phraya Basin Water Management Strategy

C. ABBREVIATION OF ORGANIZATIONS

AIT	Asian Institute of Technology
ALRO	Agricultural Land Reform Office
ARD	Accelerated Rural Development, MOI
ASDECON	ASDECON Corporation
BMA	Bangkok Metropolitan Administration
DCD	Department of Community Development
CPD	Cooperatives Promotion Department, MOAC
DEDP	Department of Energy Development and Promotion
DLD	Department of Land Development, MOAC
DMR	Department of Mineral Resources, Ministry of Industry
DOAE	Department of Agricultural Extension
DOF	Department of Fishery
DOH	Department of Health, Ministry of Public Health
DOLA	Department of Local Administration
DPW	Department of Public Works
DTEC	Department of Technical and Economic Cooperation
EGAT	Electricity Generating Authority of Thailand
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
IEAT	Industrial Estate Authority of Thailand
JICA	Japan International Cooperation Agency

MD	Meteorological Department, Ministry of Communications
MOAC	Ministry of Agriculture and Cooperatives
MOI	Ministry of Interior
MOSTE	Ministry of Science, Technology and Environment
MRC	Mekong River Committee
MWA	Metropolitan Waterworks Authority
NEA	National Energy Administration
NEB	National Environmental Board
NESDB	National Economic and Social Development Board of Thailand
NRDC	National Rural Development Committee
NSC	National Security Command
NSO	National Statistical Office
NWRC	National Water Resources Committee
NWRB	National Water Resources Board
OECF	Overseas Economic Cooperation Fund
OEPP	Office of Environmental Policy and Planning
PANYA	PANYA Consultants
PPD	Project Planning Division, RID
PWA	Provincial Waterworks Authority
PWD	Public Works Department, MOAC
RID	Royal Irrigation Department, MOAC
RFD	Royal Forestry Department
TDRI	Thailand Development Research Institute
TEAM	TEAM Consultants
SCT	Sanyu Consultants (Thailand) Inc.
WB	World Bank
WHO	World Health Organization
WMO	World Meteorological Organization

D. LOCAL TERMS

Changwat	Province
Amphoe	District
Tambon	Township
Muban	Village
Muang	Administrative Center of Province
King Amphoe	Sub-District
Mae Nam	River
Khwae	Main tributary of a river
Huai	stream, creek or small tributary
Khlong	canal
Khao	mountain

Kok-Ing-Nan Water Diversion Project
Feasibility Study of Phase II Study
Final Main Report

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CHAPTER 1.

INTRODUCTION

CHAPTER 1. INTRODUCTION

1.1 Background

The Chao Phraya river, which traverses the central plain of the Thailand, has played an essential role in the economic development of the country. Having a drainage area of 158,000 sq.km including major tributary sub-basins of Nan, Ping, Yom, Wang, Pasak and Sakae Krung, the river system drains off about 33,000 MCM of annual runoff providing the major source of water for various water users to support their economic activities. The river runoff is, however, concentrated mostly in the wet season, while during the dry months the river flow is insufficient causing frequent water shortage problems.

To cope with water shortage problems mainly in dry season, numbers of storage-type water resources development projects have been implemented in the upper sub-basins of the river. The Bhumibol and Sirikit dams with effective storage capacities of 9,660 MCM and 6,660 MCM respectively are the major examples. The result of such development is however still far from being sufficient against the potential demand of water in the basin. The growth of second crops in the lower basin is still limited to the minimum level and shortage of water for domestic and industrial uses becomes more crucial. Such a situation will become even more serious in the forthcoming years because water demand of the basin, particularly in the Chao Phraya Delta, will continue to increase.

On the other hand, development of new water resources to meet increasing demand has become more difficult due to lack of proper sites for dam/reservoir construction and more consideration of the environment conservation. In addition, the water resources development in sub-basins to use the developed water within their own beneficial area would bring another water shortage problem in the lower Chao Phraya delta area because that it receives major runoff contribution from the upstream sub-basins. In accordance with the RID's plan, the large and medium scale water resources development projects to be newly implemented in future in the upper Chao Phraya basin will produce about 5,700 MCM of additional water, of which available water resources in dry season are estimated at about 1,500 MCM only. To seek for additional water resources from the neighboring river basins through transbasin water diversion therefore, becomes one of the major options of the Government in the effort to solve water shortage problems in the Chao Phraya river basin.

Under this situation, in early 1990's the RID initiated the transbasin water diversion plan from the Kok and Ing rivers to the existing Sirikit dam by means of construction of long diversion channels and tunnels crossing the mountain ridge which divides the Ing and Nan watershed areas. The implementation of the proposed plan, however, requires highly modernized engineering technology mainly for a large-scale canal and tunnel construction and also requires a macroscopic issue of nation-wide development since the plan stands for the national strategy of water resources development.

The plan was considered to be viable at the preliminary stage of the study made by RID because of lesser environmental impact than the other trans-basin diversion plans and substantial volume of both excess amount of water to be diverted and available storage capacity of the Sirikit

reservoir. In order to support and strengthen the RID's Study which was being made to further ascertain feasibility, soundness and viability of the proposed project together with assessment of environmental impact to be induced by the project, the JICA dispatched a Study Team in August 1996 to carry out the study of the project which covers two aspects; namely the conceptual planning and initial environmental examination, with objectives (1) to investigate as the Phase I Study the necessity and viability of the Kok-Ing-Nan Water Diversion Project, which aims to contribute to agricultural and other development in Kok, Ing and Chao Phraya river basins, (2) to conduct as the Phase II Study a feasibility study for the Project in order to make the Project plan sound technically, economically, socially and environmentally, in case that the Project is confirmed to be necessary and viable through the Phase I Study, and (3) to review a study on the environmental impact of the implementation of the Project which will be carried out by the Thai side.

The Phase I Study was implemented during the period from August 1996 to March 1997 in order to investigate the necessity and viability of the Project through water demand projection, comparison of alternative water resources development plans and IEE. The Study recommended to proceed to the Feasibility Study since the proposed project was expected to make a great contribution to the sustainable socio-economic development of the Chao Phraya basin toward 21 century. The Draft Final Reports consisting of the Conceptual Planning Study Report and IEE were compiled in January 1997. They were submitted and explained to RID at the Steering Committee in February 1997. A seminar to transfer technical knowledge on the project study was also held in Bangkok at the same period. The final reports were submitted in April, 1997.

The Phase II Study was commenced in the early January, 1998 and its First Stage Field Survey was carried out covering the study period of about 2.5 months up to the end of March. The Second Stage Field Survey was carried out for the period of 5.5 months since the middle of October, 1998. The Interim Report of the project study to summarize the major findings of the survey and study conducted since then and also to conclude the basic plan of the proposed water diversion project was compiled and submitted in January 1999. Seminars on the project planning were held in parallel with the project study in Lampang in January and in Chiangrai in March 1999. The Progress Report (2) was compiled and submitted at the end of the Second Stage Field Survey at the end of March 1999. The Draft Final Reports for the Phase II Study were prepared in the home office work in Japan to comprehend all of the Study findings and results compiled in the Interim Reports and Progress Report (2) and submitted to RID in September 1999. The seminar on the Draft Final Report was held at the occasion of the report submission.

1.2 Objectives of the Study

The objectives of the Study are;

(1) To investigate and justify in Phase I study the necessity and viability of the project, which aims to contribute to agricultural and other development in the Kok, Ing and Chao Phraya river basins, through the study for the water resources potentiality, water demand projection, and the various alternative plans and projects ever studied/proposed within the Chao Phraya basin or transbasin projects from the other

river basins.

(2) In case that the project is justified to be necessary and viable through the Phase I study, to conduct as the Phase II study a feasibility study for the project in order to confirm the project plan sound technically, socially and environmentally.

(3) To review the study on the environmental impact assessment toward the implementation of the project, which will be performed by the Thai side.

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

1.3 Study Area

The Study area covers (1) Kok, Ing and the upper Nan (upstream of Sirikit dam) river basins for physical planning and environmental assessment of the Project, covering approximately 31,000 sq.km and (2) the direct beneficial areas being located downstream of the Sirikit dam inclusive of the lower Nan basin and the Chao Phraya delta for the study on potential benefit of the Project covering approximately 55,000 sq.km, amounting to 86,000 sq.km in total.

1.4 Scope of the Phase II Study

The RID has initiated the "Feasibility Study and Environmental Impact Study on Kok-Ing-Nan Development Project" for twenty four months period from March 1996. The JICA Study in the Phase II is to supplement and strengthen the RID study which comprises (1) the Feasibility Study and (2) the Environmental Impact Assessment. The "Scope of Works" undersigned by the both parties, RID and JICA, specifies the responsibility of the JICA Study Team to conduct (1) engineering works for water diversion including tunnels, canals, dams and culverts, and river training works, (2) water management plan involving irrigation development plan, method of overall water management and system of integrated water management and (3) geological survey such as time domain electro-magnetic prospecting survey and deep boring, of which geological survey works have already been completed during the course of the First Field Survey except data analysis to be carried out in the initial period of the Second Field Survey in Japan.

JICA Study also supports the Environmental Impact Assessment (EIA) to be made by RID, and then prepare a Comprehensive Report which includes (1) summary of the Phase I Study, (2) water utilization/management plan for irrigation and other water demands, (3) results of hydro-meteorological, topographical and geological studies, (4) comparison of alternative alignments of water diversion, (5) layout and preliminary design of facilities for the Project, (6) construction plan, (7) cost estimation, (8) financial and economic analysis, (9) operation and management plan of Sirikit dam and other related facilities, (10) monitoring system of water diversion, (11) reviewing result of EIA and impact mitigation measures, (12) procedures for public information and participation and (13) recommendation.

1.5 Personnel Engaged in the Study

Personnel engaged in the Study such as members of JICA Advisory Committee, RID Steering Committee and JICA Study Team are as shown in the Supporting Report attached to this report.

1.6 Items Supported and Strengthened by JICA

Study items supported and strengthened by the JICA Study Team for the results of the Thai side study are summarized in the Supporting Report.

CHAPTER 2.

RIVER BASINS

CHAPTER 2 RIVER BASINS

2.1 Outline of River Basins

The Study area covers three large river basins namely: the upper Chao Phraya with the large basin area of 124,100km^2, the lower Chao Phraya with 33,800km^2 and the Kok-Ing with 18,000km^2, including about 2,980km^2 in the Myanmar territory.

The upper Chao Phraya basin has a large farmland area of 23.8 million rai and population of 9.6 million (1996) and its socio-economy has been supported mainly by agriculture. Water resources in the basin however are quite limited indicating the runoff yield of 220mm, per capita water of 2,900m^3 and per rai water of 1,200m^3, and as a result a large area covering 72% of the total farmland is still cultivated under rainfed condition. Accordingly, GBP per capita in the basin is still as low as 27,500 Baht. The basin has been supplying the irrigation, domestic and industrial water also to the Chao Phraya Delta, which is the most important area in the country.

The lower Chao Phraya holds large irrigated agricultural area of 7.3 million rai, Bangkok metropolis and industrial area supporting the national economy and food security. The GBP in the basin reaches a large value of 1,720 billion Baht (1996) occupying about 60% of GNP (per capita GBP is 137,000 Baht). However water resources in the basin are very scarce and depending on the supply from the upper Chao Phraya basin.

The Kok-Ing basin has the water resources amount of 8,000 MCM which is quite abundant as compared with the farmland and population in the basin, and is emptying into the Mekong river without used. The Kok-Ing basin is defined as the Donor Basin to supply surplus water to the Chao Phraya. However, the basin has not been developed yet with its GBP of only 19,000 Baht per capita (1996) which is about 14% of that in the lower Chao Phraya. The regional development based on irrigated agriculture for diversified crops, accordingly, should be promoted together with the proposed Project. The outline of the above three basins is summarized as shown in Table 2.1.1

Table 2.1.1 Outline of Chao Phraya and Kok/Ing Basins

Item	Unit	Whole Country	Chao Phraya			Kok/Ing
			Upper	Lower	Total	
1. Basin Area	10^3km^2	513.1	124.1	33.8	157.9	14.3.#1
2. Population (1996)	10^6	60.5	9.59	12.54	22.13	1.50
3. Land Use (1993)						
Forest Area	10^6 rai	83.5 (26)	31.0 (40)	2.1 (10)	33.1 (34)	3.8 (40)
Farm Area	10^6 rai	131.3 (41)	23.8 (31)	12.3 (58)	36.1 (36)	2.4 (26)
Other Area	10^6 rai	106.0 (33)	22.9 (29)	6.7 (32)	29.6 (30)	3.2 (34)
Total	10^6 rai	320.7 (100)	77.7 (100)	21.1 (100)	98.8 (100)	9.4 (100)
4. Farm Area/Capita	Rai	2.2	2.5	1.0	1.6	1.6
5. Irrigation Intensity	%	25	28	63	39	43
6. Water Resources #2						
Annual runoff	MCM	212,000	27,800	4,500	32,300	8,000
Runoff Yield	mm	414	224	133	205	547
Water/ Capita	m^3	3,500	2,900	360	1,460	5,330
Water/ rai(farm)	m^3	1,610	1,170	370	890	3,300
7. G. B. P. (1996)						
Total G.B.P.	10^9 Baht	3,075	263.7	1,719.8	1,983.5	28.2
G.B.P./Capita	10^3 Baht	50.8	27.5	137.1	89.5	18.8

G.B.P.: Gross Basin Product. #1: Catchment within Thai territory. #2: mean over 1974-1996

2.1.1 Upper Chao Phraya Basin

The Upper Chao Phraya basin is consisting of six main sub-basins namely: the Nan, Ping, Wang, Yom, Sakae Krang and Pasak. Except for Sakae Krang, all of these rivers originate in the northern mountainous ranges. Except for Pasak and Sakae Krang, the other four rivers converge at Nakhon Sawan, forming the beginning point of the Chao Phraya river. The Sakae Krang empties directly into the Chao Phraya in the downstream of Nakhon Sawan, while the Pasak joins the Chao Phraya at Ayutthaya. The outlines of basin area, population, land use, surface water resources and GBP for the six main sub-basins are summarized in Table 2.1.2.

Table 2.1.2 Outline of 6 sub-basins in Upper Chao Phraya

Item	Unit	Nan			Ping	Wang	Yom	Sakae Krang	Pasak	Total
		Upper	Lower	Sub total						
1. Basin Area	10^3 km^2	13.0	21.3	34.3	33.9	10.8	23.6	5.2	16.3	124.1
2. Population (1996)	10^6	0.58	1.79	2.37	2.43	0.67	2.00	0.44	1.68	9.59
3. Land Use (1993)										
Forest Area	10^6 rai	3.36	3.04	6.40	12.70	4.45	5.22	0.75	1.44	30.96
Farm Area	10^6 rai	1.12	5.72	6.84	4.14	0.95	4.80	1.63	5.45	23.81
Other Area	10^6 rai	3.63	4.57	8.20	4.38	1.40	4.76	0.88	3.30	22.92
Total	10^6 rai	8.11	13.33	21.44	21.22	6.80	14.78	3.26	10.19	77.69
4. Farm Area/Capita	Rai	1.9	3.2	2.9	1.7	1.4	2.4	3.8	3.3	2.5
5. Irrigation Area	10^6 rai	0.31	1.80	2.11	1.88	0.53	0.97	0.58	0.55	6.62
6. Irrigation Intensity	%	28	31	31	45	56	20	36	10	28
7. Water Resources #1										
Annual Runoff	MCM	5,710	5,840	11,550	7,260	1,140	3,610	1,300	2,980	27,840
Runoff Yield	mm	439	274	336	214	105	153	250	183	224
Water/Capita	m^3	9,840	3,260	4,870	2,990	1,700	1,810	2,950	1,770	2,900
Water/rai	m^3	5,100	1,020	1,690	1,750	1,200	750	800	550	1,170
8. G. B. P.(1996)										
Total G.B.P.	10^9 Baht	10.0	37.0	47.0	80.2	20.6	39.9	10.9	65.1	263.7
G.B.P./Capita	10^3 Baht	17.2	20.7	19.8	33.0	30.7	20.0	34.8	38.7	27.5

Note: #1 mean over 1974-1985

(1) Nan Basin

The Nan basin is an important beneficial area related to the Project with the following background:

- The Sirikit dam, which will store and control the diversion water from the Kok and Ing basins, is located half way down the Nan river.
- Both the existing and proposed water resources development projects in the Nan basin will greatly affect agriculture, domestic and industrial water supply in the Delta.
- The beneficial area of about 1.8 million rai in the Phitsanulok large irrigation project and pumping irrigation projects by DEDP are located along the mainstream of the Nan river.

The Nan basin is primarily divided into two sub-basins after the construction of the Sirikit dam: the upper Nan (12,980km^2) and the lower Nan (21,350km^2) basin.

(a) Upper Nan Basin

The Nan river originates in the high mountains (1,000-1,500m) in the border area with Lao PDR. After converging with the Huai Yao river, it flows southwardly to pass Amphoe Muang Nan and empties into the Sirikit dam. The upper Nan basin is slender in shape, about 200km long and 60-70km wide, with many tributaries forming deep valleys. Of the many tributaries, the Huai Yao is vital to the Project and to fulfill the role to convey the diverted water by the Project to the Nan river. The Yao flood control dam and river training works are proposed in the Project.

The upper Nan basin is mainly mountainous area with steep slopes. About 41% (3.4 million rai or 540,000 ha) is covered with dense forest. Farmland distributes in the narrow strip of alluvial plain along the river and is scarce, only 1.1 million rai (180,000 ha) or 14% of the basin area.

Population in the upper Nan basin is about 580,000 (1996). The population density of 45 persons/km^2, is the lowest among the main sub-basins in the upper Chao Phraya basin. This also proves that mountainous terrain is one of the major limiting factors for commercial and industrial development.

Average runoff of the basin was 5,710 MCM at Sirikit dam in the past years (1974-1984) but decreased to 4,750 MCM in the recent years (1985-1996) due to less rainfall and water use for irrigation in the upper reaches. Seasonal runoff fluctuation is large: 4,090 MCM (86%) in the wet season as compared with 660 MCM (14%) in the dry season in the recent years.

Part of the upper Nan basin will also become the beneficial area of the Project. Together with the Huai Yao tributary, the Nan mainstream will function as the conveyance channel for the water diverted from the Kok and Ing basins. Farmland along these rivers could utilize some of the diversion water for irrigation. GBP per capita in the upper Nan is 17,000 Baht which is the lowest value in the upper Chao Phraya. In order to convey the diversion water of the Project through the Nan river, the flood control and irrigation projects for agricultural area along the Nan main stream will be required.

(b) Lower Nan Basin

The Lower Nan basin is extending on the alluvial plain downstream of the Sirikit dam. Except for the eastern side of the river, which is hilly and mountainous and rises up to over 1000m, most of the plain is about 100-30m in elevation. The Nan river joins with the Yom before converging with the Ping at Nakhon Sawan. The large farmland of 5.7 million rai is lying on the lower Nan basin and the farm area per capita reaches the high value of 3.2 rai. However agriculture in the basin depends mainly on the wet season paddy cultivation under rainfed condition. The irrigated agriculture has been developed only in the area along the main stream.

The famous Naresuan barrage, about 25 Km to the north of Amphoe Muang Phitsanulok, was constructed across the mainstream of the Nan river in 1983 to irrigate the Phitsanulok Irrigation Project (670,000 rai) and has been diverting water released from Sirikit dam. The Phitsanulok Irrigation Project, managed by RID, will require more water in the dry season which could be supplied by the Project. Other projects such as the pumping irrigation for the area of 392,000 rai developed by RID and DEDP have also faced the problems of water shortage in dry season. These projects will also need more water from the Project to mitigate water shortage problem.

The major tributaries, such as the Khwate Noi (4,689km^2) and Wang Thong (2,300km^2) have been feeding the Nan river with abundant side flow and floodwater in the wet season. Many large

and medium scale irrigation projects will be proposed in these tributary basins.

Although the lower Nan basin has large farmland area to be developed in future, the water resource in the basin is limited as shown in the runoff yield of 274 mm, water per capita of 3,260m^3 and water per rai of 1,020m^3 in the past years which are rather low compared with those in the upper Nan basin. Accordingly, the future irrigated agriculture in the area along the lower Nan mainstream will naturally require the additional water to be released from the Sirikit reservoir.

(2) Other Sub-Basins

The other sub-basins- the Ping, Wang, Yom, Pasak and Sakae Krang- in the upper Chao Phraya basin have no direct influence on the Project. All of these rivers supply water for irrigation and domestic consumption within the basins before flowing into the Chao Phraya. The surplus water of rivers has been used for irrigation, domestic and industrial purposes in the Delta. Except for the Ping, all other rivers have no sufficient surplus to cover the domestic and irrigation water demand in the Delta. The outlines of the basins are summarized as follows:

(a) Ping Basin

The Ping river (33,900km^2) originates in the high mountainous area (1,500-2,000m) in the Chiang Rai province, flows into the Bhumibol dam and finally into the Chao Phraya river at Nakhon Sawan.

Although the Ping basin has the large basin area of 33,900km^2 which is almost the same as that in the Nan basin and the largest forest area of 12.7 million rai occupying 40% of the total forest area in the upper Chao Phraya, but the farm area is only 4.1 million rai (650,000 ha) which is smaller than 6.8 million rai in the Nan basin. The farm area per capita is 1.7 rai which is the low value in the upper Chao Phraya basin. However, the irrigated agriculture not only for paddy but also for diversified crops has been developed in the upper Ping basin holding the provinces of Chiang Mai and Lamphun.

The Bhumibol dam is existing in the basin and has supplied the controlled reservoir water to the lower Ping basin and the Delta. The reservoir outflow however, has decreased from 5,500 MCM in the past years (1974-84) to 4,400 MCM in the recent years (1985-96) due to decreasing reservoir inflow caused by the large irrigation water use in the upper Ping.

Although the Ping basin had the annual runoff of 8,400 MCM at P7A in the past years, the runoff in the recent years is decreasing to about 6,400 MCM due to irrigation water use in the basin.

(b) Wang Basin

The Wang river (10,790km^2) is the largest tributary of the Ping river. Like the Ping, it originates in the mountainous and plateau area (1,000-1,300m) covered with dense forest in the Lampang province. The two rivers converge at the downstream of the Bhumibol dam.

The forest area occupies about 4.5 million rai (710,000 ha, or 65% of the basin area). Due to the scarcity of flat alluvial plain, farmland is small, only 950,000 rai (152,000 ha) or 14% of the basin area.

The population is also small (670,000), mostly engaged in agriculture. However, the irrigated agriculture for paddy and diversified crops has been practiced in the basin and irrigation intensity reaches the high value of 56%.

Average annual runoff at Tak (W4A 10,510km^2) in the recent years is 890 MCM, showing a small runoff yield of 85 mm due to the large irrigation water use in the basin. Surface water resources in the Wang have no allowance to supply dry season water to the Delta.

(c) Yom Basin

The Yom river (23,620km^2) originates in the lower mountains in the Phayao and Phrae province, flows down the plateau area in Sukhothai and joins the Nan river in Phichit province, at about 20 km upstream of Nakhon Sawan. Since the Yom flows through the plateau area with the high farmland occupancy, 4.8million rai (770,000 ha) or 32% of the basin area, much of the rainfall is either retained in the wet season paddy fields and/or lost to evapo-transpiration and percolation. Forest area is small, 5.2 million rai (830,000 ha) or 35% of the basin total, and is found mainly in the northern part of the basin.

Accordingly, the average runoff in recent years is small, 3,070 MCM at Y17 (21,415km^2 Si Satchanalai), showing a small runoff yield of 140 mm. The surface water resources of the Yom basin are utilized mostly by agriculture within the basin, and also has no surplus to supply dry season water to the Delta.

As a result of forest devastation in the upper Yom basin caused by slash-burn farming and tree cutting, peak flood discharge of about 5,000m^3/s had been recorded in 1995.

Kaeng Sue Ten dam has been proposed by RID to control flood discharge and to supply for irrigation water use. Water stored in the reservoir will be used in the beneficial area immediately downstream and will have no room to supply to the Delta.

(d) Sakae Krang Basin

The tributaries of the Sakae Krang (5,190km^2), the Mae Wong, Khlong Pho, Huai Tap Salao and the lower Sakae Krang originate in the western mountainous area and flow directly into the Chao Phraya.

About 1.6 million rai (260,000 ha) farmland, or 50% of the total basin area, had been developed in the lower reaches of these rivers to grow rainfed paddy in the wet season. Forest area, 750,000 rai (120,000 ha) or 23% of the total basin area, is rather small.

Population is also small, 440,000, mainly engaged in agriculture.

Since much of the rainfall is used by rainfed paddy in the lower part of the basin, the runoff is small, about 1,050 MCM in the recent year. This river has also no room to supply water to the Delta.

(e) Pasak Basin

The Pasak (16,290km^2) river originates in the mountains of Phetchabun province, flows parallel to the border with the northeast region, cutting through the east bank of the Delta and joins the Chao Phraya at Ayutthaya.

Large farmland, 5.5 million rai (870,000 ha) or 53% of the basin area, is located in the alluvial plain and hilly area along the river, while the forest area is as small as 1.4 million rai (230,000 ha) due to devastated forest area by slash-burn cultivation and tree-felling.

About 1.7 million people, mostly engaged in agriculture, live in the basin.

Although average runoff is fairly large, 2,350 MCM in the recent years, dry season runoff is scarce as only 190 MCM or 8%. This runoff will be used for irrigation in the flat alluvial plain along

the Pasak and the conservation area in the lower east bank of the Delta.

The Pasak reservoir, to be completed in 1999, has a capacity of 785 MCM. It will be used to control flood and supply irrigation water to the area along the Pasak river downstream of the reservoir and conservation area in the east bank of the Delta.

2.1.2 Lower Chao Phraya Basin

The lower Chao Phraya basin with the area of 33,800km^2 consists of Chao Phraya main basin of 20,100km^2 and its tributary basins of the Lopburi, Noi and Tha Chin. The lower Chao Phraya is formed with very flat area with ground elevation of 0 to 10 m and has a large farm land of 12.3 million rai (about 2 million ha). On the contrary, the forest area in the basin is very small as only 2.1 million rai (340,000 ha).

The basin has a large population of 12.5 million consisting of 6.7 million in the urban and 5.8 million in the rural areas.

The Delta being, located downstream of the Chai Nat barrage, is the most important and developed area in the country holding a large irrigated area of 7.3 million rai for paddy and diversified crops, Bangkok metropolitan area, industrial area surrounding Bangkok and 12 provincial areas. GBP per capita in the basin reaches the high value of 137,000 Baht which is about 5 times of that in the upper Chao Phraya.

The Delta is divided into four districts- the upper west and east bank districts and the lower west and east bank districts. The upper bank districts are the gravity irrigation area by the Chai Nat barrage, while the lower is the conservation area. The upper west district is irrigated by the Tha Chin and Noi canal system, and the upper east by the Chai Nat-Pasak canal.

The farmland of 7.3 million rai in the Delta has been irrigated fully in wet season except the inundation area in the conservation district but partially in dry season due to lack of irrigation water in dry season in the Chai Nat barrage site. The municipal water for Bangkok area and the city water in the provincial capitals have also been supplied by the Chao Phraya water controlled by the Chai Nat barrage.

The water resources in the Delta aside from those supplied from the Chai Nat barrage could be found in the Tha Chin river but very small in amount as only 2,500 MCM. All water demand for irrigation, domestic and industrial use in the Delta is mostly depending on the supply by the Chai Nat barrage which has controlled the inflow from the upper Chao Phraya basin.

Mean annual runoff at the Chai Nat is 20,000 MCM, including 14,200 MCM in the wet season and 5,800 MCM in the dry season in the recent years (1985-96), which has substantially decreased as compared with the past runoff of 26,500 MCM (1974-84). The decreasing trend of the water resources in the recent years is resulted by chronic water shortage in the Delta, especially in the dry season. This is mainly caused by increase of irrigation acreage and water resources development in the Upper Chao Phraya basin.

Since the Project had been planed to mitigate water shortage problem in the Delta, the Delta will be the most important beneficial area of the Project.

2.1.3 Kok and Ing Basins

The Kok and Ing basins, located in the northwest corner of the country, are the tributary basins of the Mekong. The catchment area of Kok basin is 10,880km^2, including 2,980km^2 in the Myanmar territory. The Ing basin is slightly smaller, about 7,120km^2.

The Kok and Ing basins have altogether about 2.4 million rai (400,000 ha or 25% of the basin area)

of farmland. Forest is about 3.8 million rai (600,000 ha or 40% of the basin area).

The majority of the populace, about 810,000 (1996) in the Kok and 690,000 (1996) in the Ing, are farmers. There are not much industrial establishments except for some tourism industry that has been developed by Chiang Rai province in recent years. Accordingly, GBP per capita in the basin is as low as 18,800 Baht.

The basins have relatively large water resources, 5,200 MCM in the Kok and 2,400 MCM in the Ing basins. This water resources are more than sufficient to meet the demand of local consumption. The surplus water could be diverted to the Chao Phraya basin by trans-basin schemes. In this perspective, the Kok and Ing basins are designated as the Donor Basins and will subject to high priority development.

Although the basin shows the high irrigation intensity of 43%, the irrigation is only supplemental to the wet season paddy. No irrigation area is existing in the dry season due to no rainfall and scarce runoff in the river.

(1) Kok Basin

The Kok river originates in the high mountains (>1,500m MSL) covered with dense forest in the territory of Myanmar. After joining the Fang river (470m MSL) at the border town of Ban Tha Don, it flows through deep valley and into the wide flood plain (380-420m MSL) at Amphoe Muang Chiang Rai. At the existing DEDP Chiang Rai weir, the Kok river joins the Kok-Lao river and empties into the Mekong river at Ban Sop Kok (360-380m, MSL), near Chiang Saen. After Chiang Rai, the meanders of river course are more prominent and the river slope is about 1/3,000. At the river mouth, the Kok river flow is subject to about 10m of fluctuation range of the Mekong flow, 350m MSL in the dry and 360m MSL in the wet seasons. The backwater of the Mekong in July to September reaches 30km upstream from the river mouth.

The upper reaches of the Fang and Kok-Lao sub-basins are also mountainous, about 1,000-1,300m in elevation and are covered with thick forest. Farmland is scarce, scattering in small spots in the narrow strips of alluvial land along the river course.

In the lower Kok basin, there is a little dry arable land. Most of the flat lands are constantly subjected to inundation and backwater effect of the Mekong in the wet season. The wetlands exist in the form of inundation areas, swamps and ponds. The Nong Luang Lake, the notable one, will be included in the development plan of the Project.

Forest area in the Kok basin is large, about 2.2 million rai (340,000 ha or 44% of the basin area). Farmland is about 1.2 million rai (200,000 ha or 25% of the basin area). Most of the farmland is found in the Fang tributary basin and the Kok-Lao basin which in the alluvial plain extending downstream of Amphoe Muang Chiang Rai.

The Mae Lao's large irrigation project with 127,000 rai is existing in the Kok-Lao river basin. The Chiang Rai weir to irrigate 78,000 rai of farmland and to supply municipal water to Amphoe Muang Chiang Rai was constructed by DEDP in 1994 which could be incorporated into the diversion water facilities of the Project.

(2) Ing Basin

The Ing river originates in the southern plateau (400-550m, MSL) of province Phayao, flows into the Phayao lake (380m, MSL) and joins with the Phung river (375m, MSL). In its northward course, the river collects water from the smaller tributaries. At Amphoe Thoeng it is joined by the Ing-

Lao (1,260km^2)-the largest tributary which originates in the eastern mountains (1,000-1,500m, MSL).

Large area of wetlands such as the Nong Leng Sai and the Phayao Lake are found in the alluvial plain. Most of the wetlands and swamps dry up during the dry season due to little rainfall and scarce runoff. The Phayao lake, located in the upper basin, is used for fish culture and irrigation. The flat alluvial plain, 6-8km wide and 70km long (350-450m, MSL) lying in the Ing middle basin, is used for rainfed paddy cultivation in the wet season.

At Amphoe Thoeng, the river slope is about 1/5,000. The river slope becomes more gentle further downstream, about 1/8,500, flowing through a series of meanders. At the river mouth, river flow is subjected to about 10m of fluctuation range of Mekong flow, 340m and 350m in the dry and wet season, respectively. The backwater of the Mekong in July to September reaches about 90km upstream from the river mouth.

Farmland is about 1.2 million rai (190,000 ha), extending mainly in the flat alluvial plain along the river. Forest is about 1.7 million rai (270,000 ha), existing mainly in the Ing-Lao basin and upper reaches of the tributaries.

In the recent years, average annual runoff is 1,840 MCM at Amphoe Thoeng (5,700km^2) and 2,400 MCM at the river mouth. Since most of the rain water is impounded in the paddy fields and thus does not appear in the river runoff, the runoff of the Ing river is smaller than that of the Kok river.

2.1.4 Provinces in Basins and their Area Rates

There are 35 provinces related to the three basins of upper and lower Chao Phraya and the Kok-Ing. The provincial area rate in the sub-basins is estimated as shown in Table 2.1.3. The provincial area rate will be used to estimate the socio-economical and agricultural conditions on the sub-basin level, because those data in the statistical book are shown on the provincial level and shall be converted to the basin level.

Table 2.1.3. Areal Rate of Basin in the Provinces

Unit: (%)

Upper Nan	Nan (94),Uttaradit (28)
Lower Nan	Uttaradit (72), Phitsanulok (88), Phichit (57),Phetchabun (17), Nakhon Sawan (15)
Yom	Nan (6), Phayao (42), Lampang (21), Phrae (100), Sukhothai (100), Phitsanulok (12), Phichit (43), Kamphaeng Phet (15)
Wang	Lampang (79),Tak (6)
Ping	Chiang Mai (77), Lamphun (100), Tak (46), Kamphaeng Phet (70), Nakhon Sawan (4)
Sakae Krang	Kamphaeng Phet (8), Nakhon Sawan (24), Uthai Thani (33)
Pasak	Loei (10), Phetchabun (72), Lopburi (50), Saraburi (77), Ayutthaya (7)
Lower Chao Phraya	Kamphaeng Phet (7), Nakhon Sawan (57), Chai Nat (100), Phetchabun (3), Lopburi (50), Saraburi (23), Uthai Thani (34), Singburi (100), Ang Thong (100), Ayutthaya (93), Pathum Thani (100), Nonthaburi (100), Bangkok (100), Suphanburi (89), Nakhon Pathom (92), Samut Prakan (100), Samut Sakhon (83), Kanchanaburi (10)
Kok	Chiang Mai (10),Chiang Rai (50)
Ing	Chiang Rai (30),Phayao (58)