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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

SUMMARY REPORT

(Executive Summary)

NOVEMBER 1999

SANYU CONSULTANTS INC.
NIPPON KOEI CO., LTD.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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

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

SUMMARY REPORT

(Feasibility Study)

NOVEMBER 1999

SANYU CONSULTANTS INC.
NIPPON KOEI CO., LTD.

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,

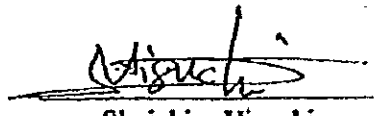
We are pleased to submit hereby the Final Report on the Feasibility Study and the Environmental Technical Assistance Study on the Kok-Ing-Nan Water Diversion Project (Phase II Study) in the Kingdom of Thailand. This report incorporates advice and suggestions of authorities concerned of the Government 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.

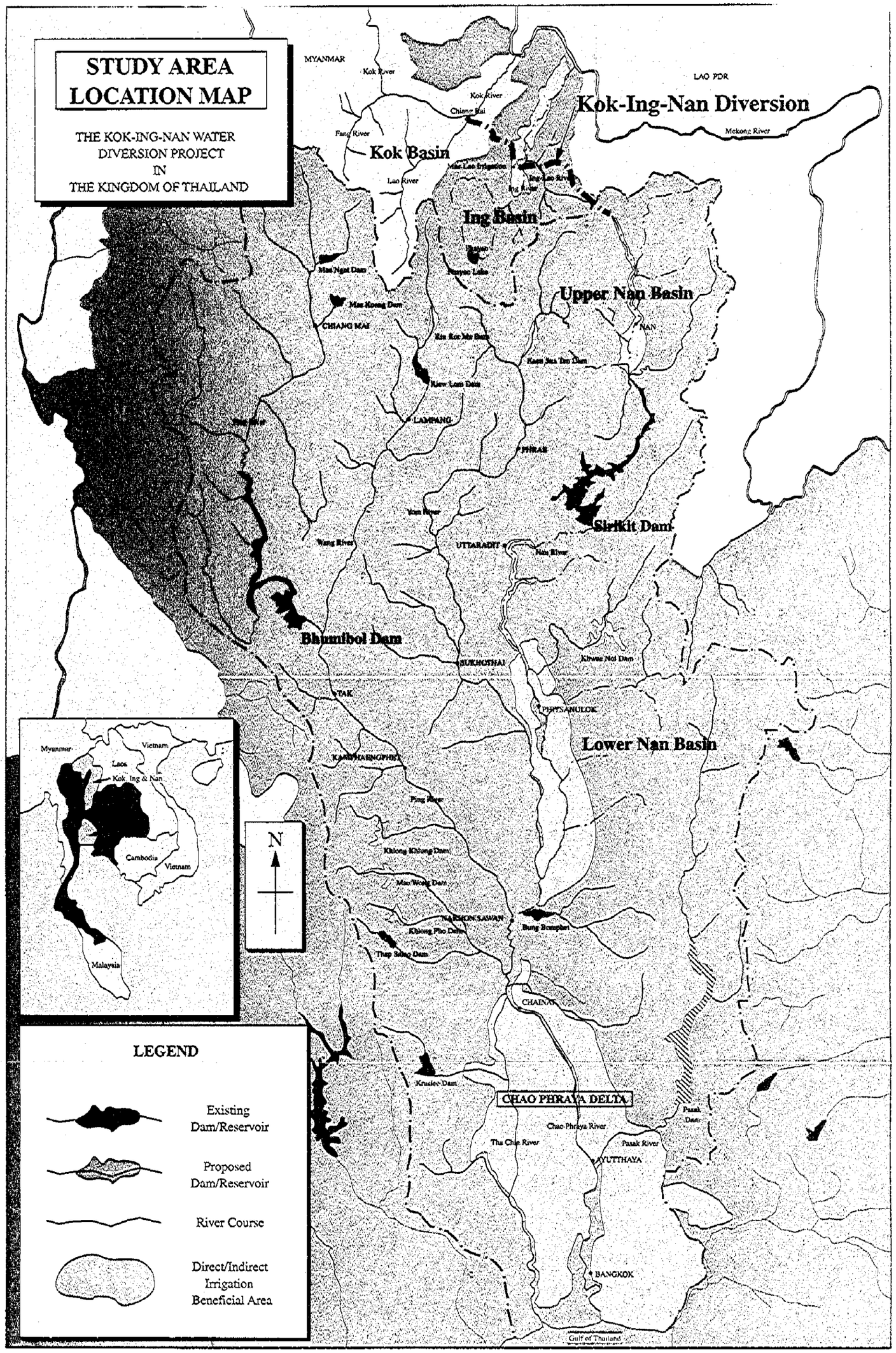
Very truly yours,



Shoichiro Higuchi
Leader of the Study Team

STUDY AREA LOCATION MAP

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

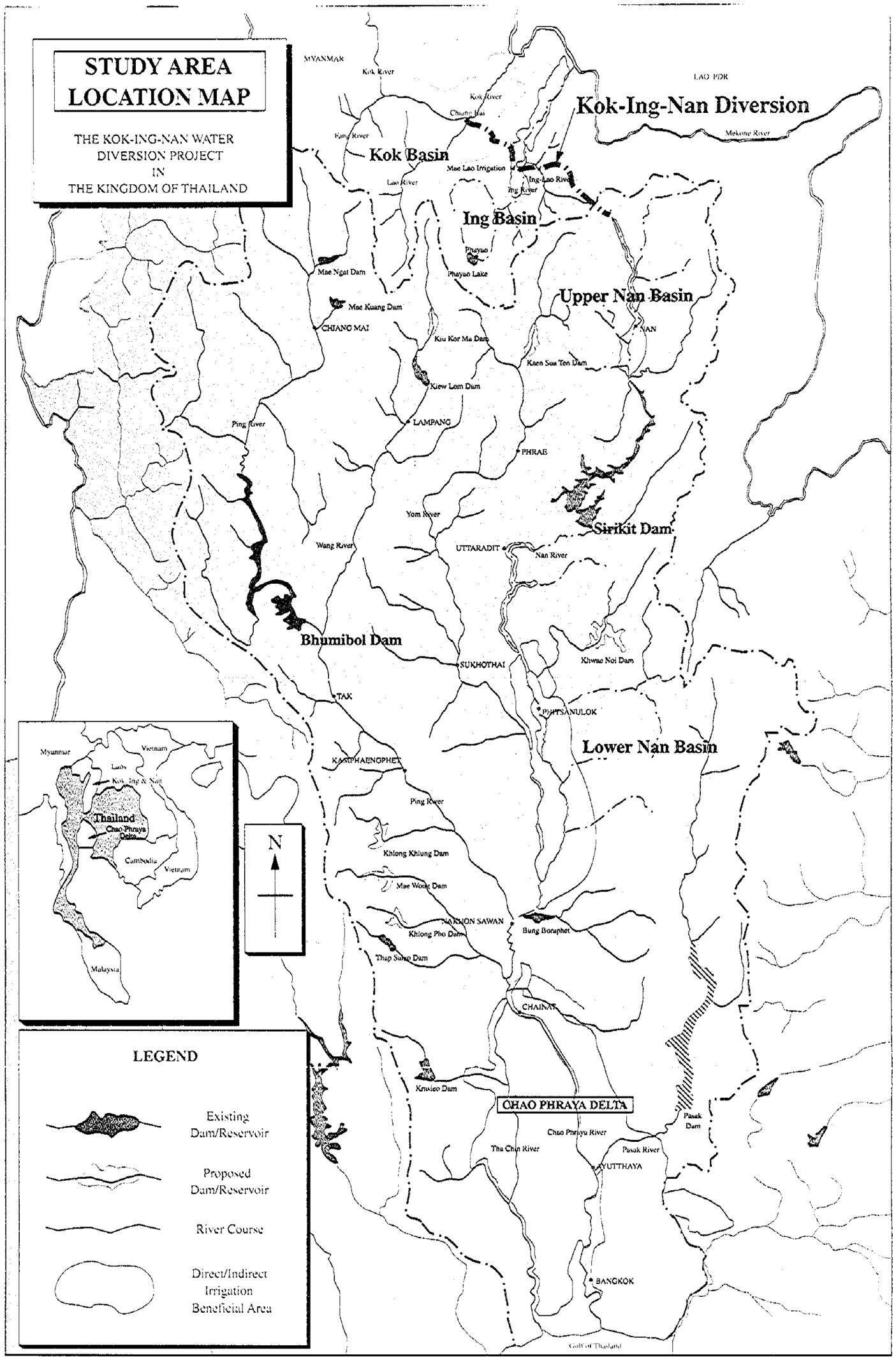


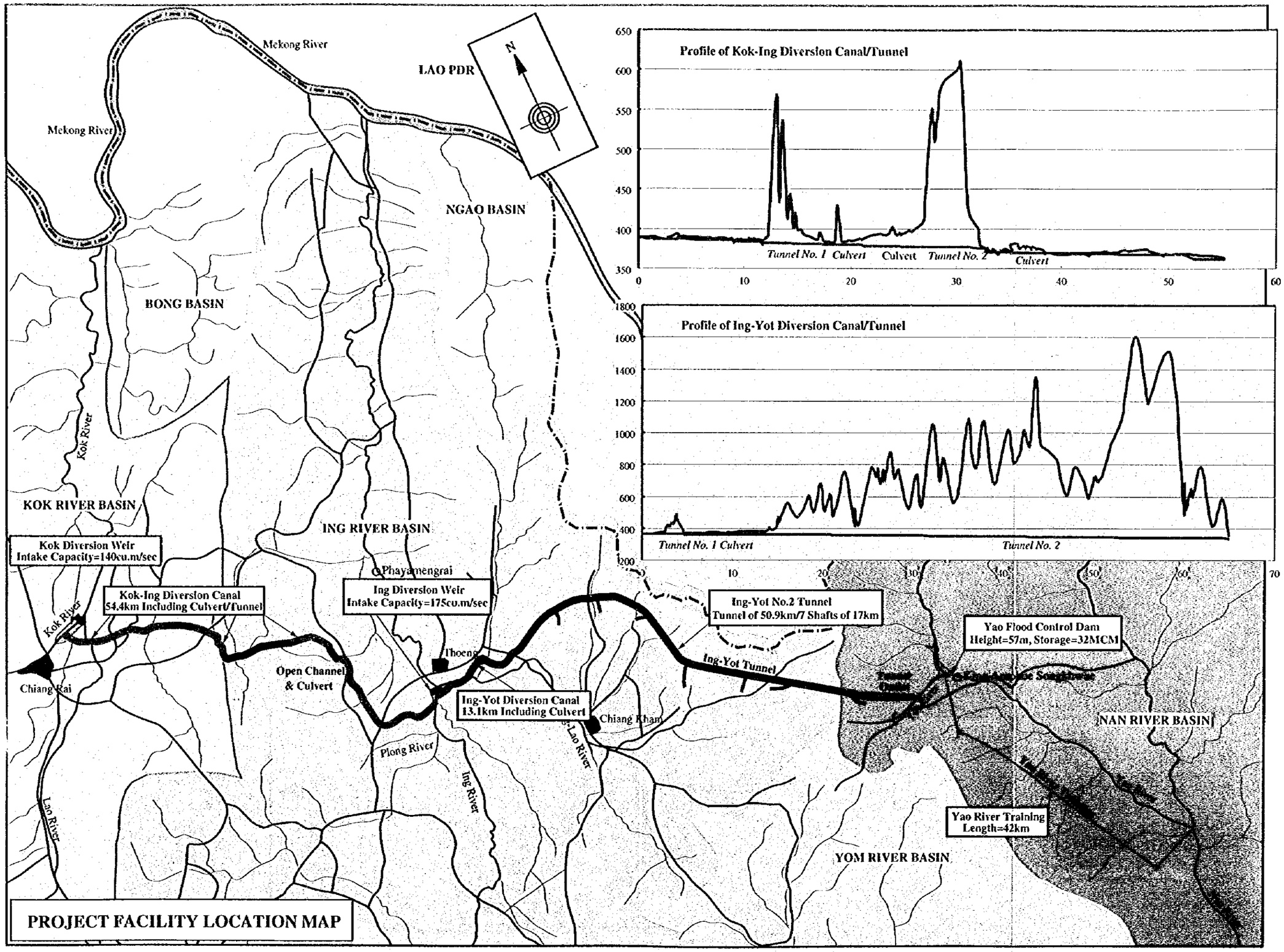
LEGEND

- 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




Mekong River
LAO PDR
N
Mekong River
NGAO BASIN
BONG BASIN
Kok River
KOK RIVER BASIN
ING RIVER BASIN
Kok Diversion Weir
Intake Capacity=140cu.m/sec
Kok-Ing Diversion Canal
54.4km Including Culvert/Tunnel
Ing Diversion Weir
Intake Capacity=175cu.m/sec
Phayamengrai
Kok River
Chiang Rai
Open Channel
& Culvert
Thoeng
Ing-Yot Diversion Canal
13.1km Including Culvert
Chiang Kham
Plong River
Ing River
Lao River
Ing-Yot No.2 Tunnel
Tunnel of 50.9km/7 Shafts of 17km
Ing-Yot Tunnel
Yao Flood Control Dam
Height=57m, Storage=32MCM
NAN RIVER BASIN
Yao River Training
Length=42km
YOM RIVER BASIN
To Sirikit Dam
PROJECT FACILITY LOCATION MAP
Profile of Kok-Ing Diversion Canal/Tunnel
650
600
550
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450
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Tunnel No. 1
Culvert
Culvert
Tunnel No. 2
Culvert
Profile of Ing-Yot Diversion Canal/Tunnel
1800
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1400
1200
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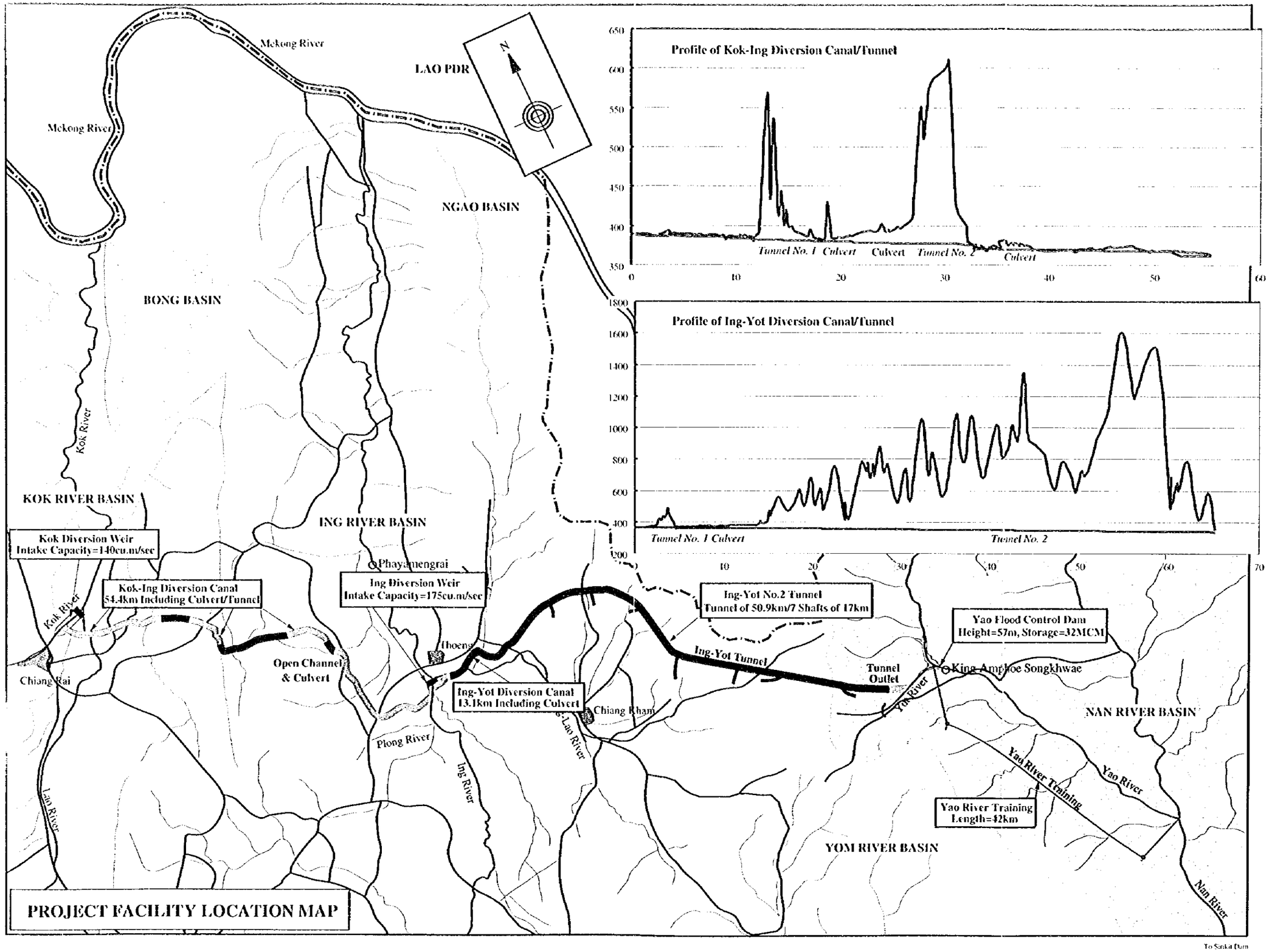
Tunnel No. 1
Culvert
Tunnel No. 2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Culvert
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Culvert
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60
70
Tunnel No. 1 Culvert
Tunnel No. 2

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		10^3km^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		10^9m^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%

Executive Summary

The Kok-Ing-Nan Water Diversion Project is the transbasin water resources development project that has been propelled by the Thai government as a National Project to cope with the chronic shortage of water prevailing in the Chao Phraya basin.

(1) Source of Water for the Diversion Plan

The sources of water for the diversion plan are the Kok and Ing rivers that traverse the northern-most part of Thailand from south to north, finally flowing into the Mekong river. Some 8,000 MCM of the annual renewable water resources in the basins has been utilized for irrigation, domestic water supply and other purposes and will be used for proposed and potential water resources developments in future. The area for future potential irrigation has been estimated at about 1.0 million rai which would consume water of some 2,000 MCM including water uses for non-agriculture sectors. About 6,000 MCM of water is still available for the proposed water diversion project. Available water resources of the Kok and Ing rivers at the proposed sites of intake are estimated at about 4,000 MCM.

(2) Method and Amount of Water Diversion

The proposed diversion plan intends to divert about 2,000 MCM in average of water during the wet season at the proposed sites of intake. Diverted water is then transferred through diversion canals and tunnels of about 120 km long to the head of the Yao river, a tributary of the Nan river, and through the Nan river into the Sirikit reservoir where water is once stored providing for necessary release during dry season.

(3) Increased Water Demand and Decreased Resources in the Upper Chao Phraya Basin

The upper Chao Phraya basin having 124,000 sq.km of catchment area has contributed toward providing the source of water to the lower Chao Phraya basin. A vast farmland of exceeding 24.0 million rai (4 million ha) extends in the basin populated with 9.5 million farmers and consuming irrigation water which has been increasing year by year. Currently, irrigable area in the basin amounts to 6.6 million rai covering 28% of the total farmland area and water demand for irrigation is estimated at 10,500 MCM. Irrigation projects will be expanded more and more in future to meet demand from the increasing population which is projected at 12.7 million, and irrigable area and water demand for irrigation are estimated respectively at 12.0 million rai and 20,000 MCM, both are twice as much as the present figures.

The lower Chao Phraya basin, especially the delta, has received a great contribution of water supply from the upper basin. Available runoff of the Chao Phraya river has, however, been decreasing year by year because of increasing water demand within the upper basin indicating 26,500 MCM as an average from 1974 to 1984 and 20,000 MCM from 1985 to 1996. It is estimated that the Chao Phraya flow will decrease further to 11,000 MCM in future in the year 2016. Accordingly, available flow of the Chao Phraya river at Chainat, which is most important to maintain dry season cropping in the delta, will decrease by 1,900 MCM from 5,800 MCM at present to 3,900 MCM in future.

(4) Increasing Water Demand in the Chao Phraya Delta

Holding the Bangkok Metropolis and a large expansion of industrial zone as well as irrigated agricultural systems of exceeding 7.3 million rai (1.2 million ha), the Chao Phraya delta stands first in the economic development and food security of the country. The population amounts to 12.5 million at present, which will increase to 14.0 million in the year 2016, with consumption of water being greatest in Thailand. At present under the normal year conditions, of the 6,000 MCM of Chao Phraya flow during dry season at Chainat, 2,000 MCM is released downstream to cover demands for domestic and industrial water supply, navigation and river maintenance. The remaining 4,000 MCM is allocated to irrigated agriculture. Accompanied by the increasing population and commercial/industrial development in the delta, future demand of water for domestic and industrial supply from the surface water source will increase by 830 MCM. In order to protect the area from salinity intrusion, sufficient and stable supply of water throughout a year is needed on the paddy fields and fish ponds in the lower delta and on the farmland to be planted to diversified crops in the upper delta. Such an increase of irrigation water in dry season would reach 1,220 MCM in future, amounting to 2,050 MCM of additional demand of water in total.

(5) Necessity of Transbasin Water Diversion Plan

Additional demands of water in dry season will come up to 1,900 MCM and 2,050 MCM respectively in the upper and lower Chao Phraya basins, totaling up to 4,000 MCM in 2016. It is difficult to generate this order of dry season water within the Chao Phraya basin by developing new water resources and by achieving water saving in terms of water management, providing major reasons why the government has investigated and studied various water diversion plans transbasin from the Mekong and Salawin tributaries since 1980s. It was judged from the preliminary study made by RID that the Kok-Ing-Nan diversion would be technically and economically feasible with less environmental impacts as compared with other projects, and the government commenced its feasibility study in 1996. The proposed Kok-Ing-Nan Project could produce about 2,800 MCM of dry season water when 2,000 MCM of water diverted from the Kok and Ing rivers is combined with improvement of the Sirikit reservoir operation. To meet additional requirement of 4,000 MCM of water, however, another water diversion plan probably from the Salawin tributary would be required in the next stage.

(6) Improvement of the Sirikit Reservoir Operation

Because of absolute lack of inflow into the reservoir, the Sirikit dam rarely restore its full storage at the end of wet season and 2,000 MCM to 3,000 MCM of empty space of storage is usually found except abnormal flood years like 1995. The proposed project could produce about 2,800 MCM of outflow in dry season from the Sirikit reservoir as a combined effect of water diversion of about 2,000 MCM from the Kok and Ing rivers and improvement of operation rule of the Sirikit reservoir. This order of increase of dry season water from the Sirikit reservoir, almost equivalent to the present outflow from the reservoir, would contribute to a great extent to the water use in the downstream beneficiary areas.

The water balance study shows that the average annual volume of water to be diverted from the

Kok and Ing rivers is 2,000 MCM or more, with variations between 2,500 MCM in ordinary or dry years when sufficient space of storage is available in the Sirikit reservoir and 1,000 MCM in flood years when the reservoir is filled with water from its own catchment.

The Sirikit reservoir has been operated maintaining a carry-over storage of 2,000 to 3,000 MCM at the end of dry season providing for unforeseen drought during the initial stage of wet season, resulting that the reservoir capacity to control flood during wet season is limited only to 3,500 MCM to 4,000 MCM. By means of introducing the water diverted from the Kok and Ing rivers, it becomes not necessary to keep this magnitude of carry-over capacity, and 6,000 MCM to 6,500 MCM of flood control capacity can be expected. Accordingly, the proposed plan would be effective to mitigate floods even in a critical flood year like 1995.

(7) Allocation of Dry Season Release of Water from the Sirikit Reservoir

About 2,800 MCM of water to be released additionally in dry season from the Sirikit reservoir can be usable for irrigation and domestic and industrial water supply in the beneficiary areas located downstream of the reservoir such as the lower Nan basin and the Chao Phraya delta. Among various plans of water allocation, it appears most recommendable to allocate 825 MCM to the domestic/industrial water in the delta and 1,985 MCM to irrigation.

(8) Irrigated Agriculture in the Kok, Ing and Upper Nan Basins

In association with the proposed water diversion plan aiming at upgrading socio-economy of the region, the following development plans of irrigated agriculture are taken into consideration for future implementation. In order to obtain and promote cooperation and participation of the people in the basins, it is required for these project to be implemented prior to or in parallel with the implementation of the proposed water diversion project.

- Implementation of new irrigation development projects which cover about 1.0 million rai of farmland in the Kok and Ing basins and about 300,000 rai in the upper Nan basin, consisting of a number of small-scale, medium-scale and pump irrigation projects.
- Associate Irrigation projects of about 200,000 rai in the middle/lower Kok and Ing basins and about 50,000 rai in the upper Nan basin are identified and proposed preliminarily by the JICA Study.

(9) Project Facility Plan

The diversion canals and tunnels of about 150 km long, consisting of the following facilities, are required by the Project.

- Kok Intake	At the intake structure to be constructed immediate upstream of the existing Chiang Rai weir, water is diverted from the Kok river with water levels raised by the Chiang Rai weir.
- Kok to Ing Diversion Canal	A series of open canal, siphon, tunnel and culvert with a total length

	of 54.4 km and a capacity of 140 cu.m/sec to link the Kok intake and the Ing diversion weir.
- Ing Diversion Weir	A rubber-type weir constructed on the Ing river near Amphoe Thoeng to divert 175 cu.m/sec of water from the Ing river together with the water diverted from the Kok river.
- Lao Diversion Canal	Diversion canal of 13.1 km long and 175 cu.m/sec capacity to connect the Ing diversion weir and the Ing to Yot tunnel, consisting of open canal, siphon, tunnel and culvert.
- Ing - Yot Tunnel	The diversion tunnel of 50.9 km long and 175 cu.m/sec capacity with 7 adits of 17.4 km long in total is planned to transport the water transbasin from the Ing basin to the Nan basin connecting the outlet of the Lao diversion canal and the Yot river, a tributary of the Yao river.
- Yao Flood Control Dam	This works to control flood runoffs during wet season from the upstream reaches of the Yao river and to provide in dry season irrigation water to the beneficiary areas situated along the Yao and Nan rivers.
- Yao River Training Works	Improvement works of Yao river channel extending over 41.9 km to let the 200 cu.m/sec at most of discharge flow smoothly.

(10) Construction Costs and Project Implementation Program

The Project cost for the water diversion works is 43,386 million Baht classifying into the foreign currency portion of 31,416 million Baht and the local portion of 11,970 million Baht. The Project cost including the other related costs such as associate irrigation project, environmental impact mitigation measures and development of the beneficial areas in the lower Nan and Delta is estimated at 59,563 million Baht for the Plan A with new irrigation project in the lower Nan basin.

Under the assumption that the EIA study and the Cabinet approval for the project implementation takes 2.5 years, the implementation of the Project will take 15 years starting the first year of the 9th 5-year plan (2002) up to the last year of the 11th 5-year plan (2016). The project facilities except the Ing-Yot tunnel would require construction period of 6 years including 2 years for detailed design, while the construction of the Ing-Yot tunnel will need 11 years including the detailed design works of 4 years, since the tunnel passes underneath the deep mountainous area of complex geology for a long distance of more than 50 km.

(11) Project Evaluation

Water Cost	The raw water cost at the Sirikit dam for the 2,000 MCM of water developed by the project is estimated at 1.3 Baht/cu.m after combining the project cost of 44,186 million Baht for the water diversion works and

environmental impact mitigation measures, repayment period of 50 years and annual interest of 5%.

Incremental Benefit — Among six alternative plans of water allocation, the incremental net economic value for the A-2 case is estimated at 14,090 million Baht consisting of 2,770 million Baht from domestic/industrial water supply, 10,920 million Baht from irrigated agriculture and 410 million Baht from hydro-power generation.

EIRR — The economic internal rate of return is estimated at 14.1%.

(12) Conclusion and Recommendation

(1) The irrigated agriculture in the upper Chao Phraya basin tends to expand, reducing the flow of the Chao Phraya river at Chainat from where water is diverted and distributed to the existing large-scale irrigation projects in the delta. Water demand in the delta also tends to increase because of agricultural, urban and industrial development. If these tendencies continue as they are, water resources especially in dry season will become short seriously in future. (Under the current water resources development policy as well as agricultural development policy including crop diversification program, about 4,000 MCM of water will be deficient in dry season in future.) Probable shortage of water in future would be far beyond of saving by means of effective operation and management of water, however, it is an urgent necessity to consider the comprehensive measures of water resources management aiming at sustainable development of limited water resources.

(2) In case that decision is made to take actions to mitigate the chronic shortage of water prevailing over the Chao Phraya basin during dry season, water diversion as studied by the F/S can be considered as one of effective measures from engineering point of view. Possible actions inclusive of improvement of operation rules of the existing storages, such as some 640 MCM of additional dry season release from the Sirikit reservoir proposed by the F/S, should however be taken to cope with the immediate needs of dry season water. A series of water balance scenarios within a possible range are shown in this report for further consideration of appropriate actions by the Thai side. About 8,000 MCM of the water resources in the Kok and Ing basins are very valuable for the peoples living in the basin, however most of them are released unused to the Mekong river at present. On the basis of the maximum development of the potential water resources in eventual future, the JICA Study estimated the volume of water to be reserved in the basins and in turn available water for diversion. However, to lead the implementation of the proposed project into success, it is necessary to continue the public relation activities with full information regarding the EIA and other studies including participatory rural appraisal etc, aiming to arrive at the common consent and understanding among the residents in the donor basins.

(3) In view of the magnitude of influence that might be caused by the water diversion, 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, and further at the national level. Water allocation and operation in the Chao Phraya seem to be done well making the use of its scale merit, however, the risk of water shortage even in wet season in future should be fully recognized by all concerned.

(4) In view of a critical condition of balance between demand and supply of water, "Water Resources Management" in the Chao Phraya basin is of quite importance. It is therefore necessary to establish a responsible organization to take charge of this (Strengthening of National Water Resources Committee, Establishment of Basin Authority, etc.).

(5) For the sustainable development of water resources and rationalization of water use, it is recommended to collect water charge from water users. In the case of the water diversion, it is desirable to allocate a part of the collected charge for development of the Kok and Ing basins.

(6) The JICA environmental technical assistance study was carried out focusing on review of RID's EIA study and supplemental study in due consideration of watershed conservation and sustainable rural development. Regarding EIA as it ought to be, RID is recommended to refer the conclusion and recommendation of the JICA environmental technical assistance study for future consultation with OEPP.

KOK-ING-NAN WATER DIVERSION PROJECT
SUMMARY REPORT OF FEASIBILITY STUDY

Table of Contents

1. Introduction

The Chao Phraya river has played an essential role in the economic development of the country providing about 28,000 MCM of annual runoff for various water users such as water supply, industry and agriculture to support their economic activities. The river runoff has, however, been decreasing year by year due to increasing demand associated with development of the basin causing frequent water shortage problems, and this situation would give a major reason for stagnation of sustainable development in the basin.

To cope with water shortage problems mainly in dry season at present and even more crucial in future in the forthcoming 21 century, the RID of Thai government initiated in 1993 the transbasin water diversion plan which intends to divert excess water of the Kok and Ing rivers in wet season to the Chao Phraya basin through the Nan river and Sirikit reservoir. The feasibility study for this project was commenced in March, 1996.

The implementation of the proposed plan, however, requires highly modernized engineering technology mainly for construction of large-scale and long distance canals and tunnels and the Thai government requested technical cooperation of the Japanese government to support and supplement the conceptual planning and feasibility studies to be undertaken by the Thai-side. The JICA dispatched a Study Team in August 1996 to carry out the studies of the project which were conducted in two phases as follows;

1) Conceptual Planning Study — August, 1996 to March, 1997 and
2) Feasibility Study — December, 1997 to September, 1999

2. Study Area

2.1 General Features of the Study Area

The Study area is categorized into three basins; namely (1) the Upper Chao Phraya basin, (2) the Lower Chao Phraya basin and (3) the Kok and Ing basins, covering a vast catchment area of 173,000 sq.km. General features of these basins are summarized as follows;

Table 2.1 Basin

Item	Unit	Whole Country	Chao Phraya Basin			Kok-Ing Basin
			Upper	Lower	Total	
1. Basin Area	10^3km^2	513.1	124.1	33.8	157.9	14.3
2. Population (1996)	10^6	60.5	9.59	12.54	22.13	1.50
3. Land Use Total	10^6rai	320.7 (100)	77.7 (100)	21.1 (100)	98.8 (100)	9.4 (100)
Farm	//	131.3 (41)	23.8 (30)	12.3 (58)	36.1 (36)	2.4 (26)
Forest	//	83.5 (26)	31.0 (46)	2.1 (10)	33.1 (34)	3.8 (40)
Others	//	106.0 (33)	22.9 (29)	6.7 (32)	29.6 (30)	3.2 (34)
4. Farm Area per Capita	rai	2.2	2.5	1.0	1.6	1.6
5. Water Resources (1974 - 85 Average)						
Annual Runoff	MCM	212,000	27,800	4,500	32,300	8,000
Runoff Yield	mm	414	224	133	205	547
Water per Capita	m^3	3,500	2,900	400	1,300	5,330
Water per rai	m^3	1,610	1,170	370	890	3,300
6. Gross Basin Product (1996)						
Total GBP	10^9Baht	3,080	264	1,720	1,980	28
Per Capita GBP	10^3Baht	50.8	27.5	137.1	89.5	18.8

(1) Upper Chao Phraya Basin

Being located in the northern and northwestern mountainous areas of the country, there exists about 31 million rai (5 million ha) of forest forming the important catchment area of the entire Chao Phraya basin. Gentle and undulating hill and flat alluvial plains along the river courses are formulated in the central part of the basin where a large extension of farmland of 23.8 million rai (3.8 million ha) planted mostly to wet season paddy relying mainly on rainfall. Population in the basin accounts for 9.6 million and the key industry is agriculture engaged by a majority of population.

The basin is, however, left undeveloped showing an irrigation rate of 28% and per capita GBP of 27,500 Baht (1996) which is considerably smaller than 137,000 Baht recorded in the lower Chao Phraya basin. The basin has been making a great contribution to the lower Chao Phraya basin providing a major source of water.

(2) Lower Chao Phraya Basin

The lower Chao Phraya basin consists of the delta area where water is diverted and distributed from the Chainat dam and the highland area which extends around the delta. The former is recognized as the most important economic zone of the country having 7.3 million rai (1.2 million ha) of irrigated farmland, Bangkok Metropolis and large-scaled industrial estates. On the other hand, large extension of rainfed farmland exists belonging to the Changwat Nakhon Sawan and Chainat with irrigated farmland accounting only for 0.8 million rai (0.13 million ha) in the latter.

The lower Chao Phraya basin forms a center of national economy producing 1,700 billion Baht of GBP which occupies 55% of the GDP. Prosperous development of municipal, commercial, industrial and irrigated agricultural activities with the per capita GBP of 137,000 Baht has been consuming a vast amount of water at the highest level in the country. The basin has been receiving a contribution of water supply from the upper Chao Phraya basin, and the increase of water demand in the upper basin would be the major source of anxiety to prevent the area from sustainable development in future.

(3) Kok and Ing Basins

The Kok and Ing basins locate in the northwestern-most part of the country forming a part of tributary sub-basins of the Mekong river, and have abundant water resources of about 8,000 MCM as an annual average. A considerable part of the basins is occupied by mountainous topography and farmland and population to utilize water resources are limited to 2.4 million rai (0.38 million ha) and 1.5 million persons respectively allowing a great portion of the water resources flowing unused into the Mekong river. Water is withdrawn from the Kok and Ing rivers and the facilities are constructed in the basins under the proposed water diversion plan, and therefore, the basins are called as the "Donor Basin". For the most of inhabitants in the basins, rainfed agriculture in wet season is the means of livelihood, and accordingly, per capita GBP is 19,000 Baht accounting for only 20% of the averaged GBP of 90,000 Baht in the whole Chao Phraya basin. To lead the implementation of the proposed water diversion project to success, it would be necessary to promote participation of the people to and common consent about the project. In order to achieve this, it is strongly recognized that, prior to the implementation of the proposed project,

development of the Donor Basin should be progressed especially focusing on the irrigated agriculture.

2.2 Decreasing Water Resources in the Upper Chao Phraya Basin

There used to be 33,000 MCM of potential water resources in the upper Chao Phraya basin, however, due to increased water demand resulted from water resources developments in the basin since the early 1970s, it has decreased to 28,000 MCM as an average from 1974 to 1984 and 25,000 MCM for the period from 1986 to 1996. Various water resources development projects mainly for irrigated agriculture are planned for future implementation in the basin, consuming more and more water within the basin. River runoffs observed at major gauging stations have been decreasing remarkably at all stations due to rapid expansion of the irrigated agriculture as shown in the following table which compares annual average runoffs between the periods from 1974 to 1984 (past years) and 1985 to 1996 (recent years).

Table 2.2 Water resources at Major Control Points

(Unit: MCM)

Major Stations	Past Year 1974 - 84			Recent Year 1985 - 96			Decreasing Rate (%)	
	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry
Sirikit Inflow	5,110	770	5,880	4,090	660	4,750	80	86
Sirikit Outflow	2,640	3,070	5,710	1,790	2,540	4,330	68	83
N7 at Phicit in Nan	7,230	3,600	10,830	5,240	2,820	8,060	72	78
Bhumibol Inflow	4,920	720	5,640	4,300	700	5,000	87	97
Bhumibol Outflow	2,390	3,140	5,530	1,400	3,040	4,440	59	97
P7A at Ping	4,660	3,320	7,980	3,060	3,060	6,120	66	92
Y17 at Yom	3,170	260	3,430	2,870	200	3,070	91	77
C2 at Nakhon Sawan	18,020	7,380	25,400	12,930	6,240	19,170	72	85
Chai Nat Inflow	19,310	7,200	26,510	14,160	5,840	20,000	73	81

- Due to water resources developments implemented in the upstream catchment basins, inflow into and outflow from the both Bhumibol and Sirikit reservoirs have been decreasing in recent years. To cope with water shortage in the downstream beneficial areas, possible efforts have been made in operating the reservoirs in order to reduce the outflow in wet season and, in turn, to increase the dry season release of water.
- Runoffs at major stations on the Nan, Ping, Yom and Wang rivers have been decreasing in recent years. Available water resources of the Chao Phraya river at Nakhon Sawan and Chainat have also decreased showing a reduction of 1,400 MCM in dry season from 7,200 MCM in the past years to 5,800 MCM in recent years. This considerable amount of decrease in dry season runoff has caused serious shortage of water resulted in scale-down of dry season cropping and subsidence of land and salinity intrusion due to over-pumping of the groundwater in the Chao Phraya delta area.

3. Socio-Economy and Agriculture

3.1 Socio-Economy

Population and per capita GBP (Gross Basin Products) of three basins are summarized as follows;

Table 3.1.1 Population and GBP in the Study

Basin	Population (10^3)			Per Capita GBP (10^3Baht)		
	1996	2016	Annual Growth Rate	1996	2016	Income below 10,000 Bhat (%)
1. Upper Chao Phraya						
Upper Nan	580	700	0.93	17.2	34.4	60.5
Lower Nan	1,790	2,380	1.42	20.7	37.5	38.4
Yom	2,000	2,330	0.75	20.0	41.3	41.9
Wang	670	820	1.01	30.7	73.7	50.2
Ping	2,430	3,870	2.36	33.0	78.8	40.1
Sakae Krang	440	540	1.01	24.8	71.8	31.9
Pasak	1,680	2,080	1.09	38.7	75.4	30.0
Total	9,590	12,720	1.37	27.5	60.6	40.9
2. Lower Chao Phraya						
Total	12,540	13,890	0.51	137.1	470.3	22.1
3. Kok/Ing						
Total	1,500	3,120	3.61	18.8	26.6	51.5

- Population in the lower Nan and Ping basins will strikingly increase in future resulting in expansion of the irrigated agriculture area and water demand to cope with the increasing population and food security.
- The lower Chao Phraya basin has a large number of urban population, however, an annual rate of population growth is as small as 0.5%. On the contrary, population has been rapidly growing in the Kok and Ing basins with the advance of development for tourism.
- In the upper Nan, lower Nan, Kok and Ing basins which are directly related to the Project, per capita GBP is less than 20,000 Baht in 1996 indicating necessity of improvement of regional economy by means of expansion of irrigated agriculture in future. Poor households with the per capita income less than 10,000 Baht account for 40.9% in the upper Chao Phraya basin and 51.5% in the Kok and Ing basins.

3.2 Outline of Agriculture

(1) Change of Farmland Use

Table 3.2.1 Change of Farmland Use in Three Basins

Crops	Unit	Chao Phraya						Kok/Ing	
		Upper		Lower		Total		1986	1993
		1986	1993	1986	1993	1986	1993		
Paddy	10^6rai	13.6	11.9	9.0	7.7	22.6	19.6	1.7	1.6
Field Crops	//	8.5	8.8	3.4	3.2	11.9	12.0	0.6	0.3
Fruit	//	0.9	1.6	0.7	0.8	1.6	2.4	0.1	0.2
Vegetable	//	0.1	0.2	0.1	0.1	0.2	0.3	-	-
Others	//	1.2	1.3	0.3	0.5	1.5	1.8	0.2	0.3
Total	//	24.2	23.8	13.5	12.3	37.7	36.1	2.6	2.4

- Farmland area has been slightly decreased during the period from 1986 to 1993 in all basins resulted from conversion of farmland into other land due to expansion of urban area and development of industry. The lower Chao Phraya basin, where the Bangkok Metropolitan area

extends and large-scale industrial estates operate, shows a relatively higher rate of farmland reduction than other basins.

- Supported by the government's agricultural policy to promote crop diversification program and also increasing market demand, cropped area with diversified crops tends to increase in exchange for paddy. This tendency will continue toward the 21st century.

(2) Outline of Production of Major Crops

- General situation of production of major crops in three basins in terms of an average from 1992 to 1996 is presented in Table 3.2.2. 6.43 million ton of wet season rice production in the Chao Phraya basin shares 35% of the national production explaining that the basin is the rice-bowl of the country. In addition, the delta area belonging to the lower Chao Phraya basin produces 1.53 million ton of dry season rice, or 65% of the national production, forming a base for rice export.
- Field crops are planted mainly in the upper Chao Phraya basin and the northern part of the delta where no inundation occurs in wet season, while fruit trees and vegetables are cultivated in the lower delta nearby Bangkok where irrigation systems are fully consolidated and strong demands for production are supported by the urban market, and in the upstream region of the Ping and Wang rivers near Chiangmai and Lamphun where different climatic zone dominates. Production of sugarcane and fruits have been rapidly increasing in recent years sustained by demand for domestic consumption and export.
- Except limited areas for maize and fruit tree cropping, farmland is not generally planted in dry season in the Kok and Ing basins. Basins are blessed with favorable climate, soil and geography for fruit tree cultivation and therefore production of fruits will make great strides in these basins in future.

Table 3.2.2 Harvested Area and Production in Three Basins (1992~96 Average)

Crops		Unit	Chao Phraya			Kok/Ing
			Upper	Lower	Total	
1. Area	Wet Paddy	10^3rai	8,680	5,930	14,610	1,030
	Dry Paddy	//	930	2,070	3,000	20
	Maize	//	3,300	920	4,220	300
	Sugar Cane	//	1,240	1,180	2,420	-
	Fruit	//	1,600	770	2,370	160
2. Production	Wet Paddy	10^3ton	3,620	2,810	6,430	470
	Dry Paddy	//	650	1,530	2,210	10
	Maize	//	1,750	440	2,190	140
	Sugar Cane	//	9,920	9,980	1,990	-
	Fruit	//	1,095	1,970	3,065	790

(3) Livestock and Fresh Water Fish Culture

Livestock and fresh water fish culture are also the fields which have been extending in recent years and will expand more and more in future because of high marketability. Outline of existing progress of the livestock and fresh water fish culture are as summarized below;

Table 3.2.3 Profile of Livestock and Fishery in Three

Item	Unit	Chao Phraya						Kok/Ing	
		Upper		Lower		Total		1986	1995
		1986	1995	1986	1995	1986	1995		
1. Livestock									
Buffalo	10^3	816	417	213	107	1,029	524	160	80
Cattle	10^3	955	1,462	498	660	1,453	2,122	116	151
Swine	10^3	905	1,024	600	881	1,505	1,905	165	161
Chicken	10^3	15,952	24,694	7,840	20,336	23,792	45,030	2,748	4,426
2. Fresh Water Fish in 1996									
Household No	10^3	46.6		37.5		84.1		10.8	
Pond No	10^3	59.9		41.4		101.3		15.0	
Area	10^3 rai	58.8		309.7		368.5		11.0	
Production	ton	38,431		158,030		196,461		379.5	
Yield	kg/rai	654		510		530		282	

- Buffalo tends to decline due to extended use of farming machines while breeding of meat and dairy cattles has been increasing. Consumption of meat and dairy products has been growing recently in Thailand and this field will rise steadily in future. In parallel with this tendency, cultivation of fodder crops such as grass and maize has also been promoted. Swine breeding and chicken raising have also been expanding year by year showing an increased number of chicken more than two times during the period from 1986 to 1995 in the lower Chao Phraya, Kok and Ing basins.
- There are numbers of inundated lowlands and ponds where water is available in both wet and dry seasons, and so fish culture is prosperous in the lower Chao Phraya basin while fish breeding is not active in the upper basin. Fish culture is also popular in the Kok and Ing basins, however, productivity is rather low showing 280 kg/rai or 50% of that of the lower Chao Phraya basin because of lack of water in dry season.

(4) Rice Demand in Future

Rice demand of Thailand in future is estimated on the basis of population projection at 75.6 million in 2016 and making a premise that per capita consumption of rice would decrease from the present value of 190 kg/person to 150 kg/person in future; (125kg to 100kg/person in rice)

Paddy Consumption	150 kg/person×75.6 million =	11.3 million ton (100kg in rice)
Seed and Other Consumption	(same as present)	2.6 million ton
Export	(same as present)	8.5 million ton
Storage and Reserve	(same as present)	1.0 million ton
Total		23.4 million ton

This order of demand for paddy is almost similar to the present situation requiring about 3.0 million rai of cropped area for dry season rice. 70% of this area is planned to be allocated to the Chao Phraya delta area where 7.3 million rai of farmland is operated under irrigation.

(5) Diversified Agriculture

Thai government has promoted the crop diversification program starting from the 6th 5-Year Plan (1987-1991). Major strategies involved are;

- Development of urban and industrial districts has accelerated increasing demand for meat, vegetables, fruits, dairy products and fish other than rice, and expansion of production of diversified crops such as fruits, vegetables and fodder and promotion of breeding of livestock and fresh water fish became the important issue in the agricultural policy.
- There extends a vast farmland suitable for field crops, fruit and vegetable cultivation as well as grassland, however, the majority are left unused due to absolute lack of water in dry season. To reduce the area for rice cropping and to use the excess water to diversified crops in the existing irrigable area in dry season would contribute to a great extent to effective use of farmland throughout a year and in turn to increase of agricultural production as a whole.
- Upgrade of farm income and job opportunity can not be expected and stable rural living against the increasing population in future can not be guaranteed under the single-crop farming of rice. In order to activate the rural area and to create job opportunity, it is urgently needed to introduce agro-industry based on the promotion of crop diversification.
- Processed foods of fruits, vegetables and chicken are the most important items for export earnings and demand for export has been greatly increasing. On the other hand, it is the urgent need for the government to boost the production of livestock feed in order to save foreign currency since livestock and fish breeding depends largely on the imported fodder.

The above-mentioned agricultural policy for crop diversification has been placed in a key strategy during reviewing the 8th 5-Year Plan made after the economic crisis in 1997.

Rotational irrigation can be applicable for dry season paddy by means of adjusting the area to be cropped depending on the availability of water resources, as is done under the current Command and Control system. Stable supply of irrigation water is, however, to be guaranteed for the diversified crops, especially to perennial crops such as sugarcane, fruit trees and fish culture. In addition, policy backing in the fields of farming technology, agricultural extension, credit and market in order to lead the crop diversification program to success is indispensable. On the other hand, the program is required to be adopted in the order from the place where irrigation systems are already consolidated and irrigated agriculture is operated by skilled farmers, and where is located near the big market like Bangkok Metropolis. It seems to be quite difficult to spread the program in a agricultural area relying on rainfall.

4. Development and Management of Water Resources in the Upper Chao Phraya Basin

4.1 Water Resources Development

(1) Storage Capacity of Reservoirs

Numbers of storage dams/reservoirs of large, medium and small scales, inclusive of the Bhumibol and Sirikit, have been constructed and in operation mainly for irrigation in the basin. Various water resources development projects are also under study and design for future implementation by RID and other relevant governmental agencies. Potential water resources at present and existing and future storage capacities of such dams/reservoirs are summarized in Table 4.1.

Table 4.1 Storage Capacity of Reservoirs in the Upper Chao Phraya Basin

(Unit: MCM)

Item		Nan	Ping	Wang	Yom	Sakae Krang	Pasak	Total
(1) Storage Capacity	Present ①	85	644	196	73	163	879	2,040
	Future ②	2,493	1,351	634	1,724	481	1,093	7,776
	③=②−①	2,408	707	438	1,651	318	214	5,736
(2) Water Resources	④	7,850	6,380	890	3,260	1,300	2,530	22,210
(3) Rate	②/④%	31	21	71	53	37	43	35

Remark; Water resources are given as an average from 1985 to 1996 in the recent years.

Many water resources development projects are going to be implemented in the Nan basin where abundant water is still available.

(2) Irrigable Area

Starting from the 1970s, irrigable area in the upper Chao Phraya basin has increased to about 6.6 million rai (1.0 million ha) at present, as is visualized in Figure 4.1. This irrigable area is, however, still not large enough showing an irrigation rate of 28% when compared with the total potential farmland area of 23.8 million rai (3.8 million ha) in the basin. In parallel with implementation of water resources development projects, RID and relevant agencies have a number of plans to expand the irrigable area as summarized in Table 4.2.

Table 4.2 Present and Future Irrigable Area in the Upper ChaoPhraya Basin

(Unit: 10^3rai)

Item	Upper Nan	Lower Nan	Sub-total	Ping	Wang	Yom	Sakae Krang	Pasak	Total
1. Farm Area	1,120	5,720	6,840	4,140	950	4,800	1,630	5,450	23,810
2. Existing Irrigation									
Area in Wet	310	1,800	2,110	1,880	530	970	580	560	6,630
Area in Dry	50	660	710	420	80	190	80	60	1,540
Intensity in Wet (%)	28	31	31	45	56	20	36	10	28
Intensity in Dry (%)	4	12	10	10	8	4	50	1	6
3. Future Irrigation									
Area in Wet	620	3,530	4,150	3,190	880	1,870	840	1,180	12,110
Area in Dry	150	1,430	1,580	800	140	480	150	170	3,320
Intensity in Wet (%)	55	62	64	78	93	39	52	22	51
Intensity in Dry (%)	13	25	23	19	15	10	9	3	14

Out of 5.7 million rai and 4.1 million rai of a vast expansion of farmland existing respectively in the lower Nan and Ping basins, 3.5 million rai and 3.2 million rai will be irrigated in future. Although the existing rate of irrigation in the whole upper Chao Phraya basin is still low showing 28% in wet season and 6% in dry season, they will be increased to 51% and 14% in future.

(3) Irrigation Water Demand

Irrigation water demands are estimated on the basis of the above irrigable areas at present and in future as given in Table 4.3.

Table 4.3 Summary of Irrigation Water Demand

(Unit MCM)

	Nan			Ping			Wang	Yom	Sakae Krang	Total	Pasak	Grand Total
	Upper	Lower	Sub-total	Upper	Lower	Sub-total						
(1) Existing Project												
Wet Season	353	2,078	2,431	1,371	853	2,224	630	1,148	692	7,125	660	7,785
Dry Season	84	1,169	1,253	471	284	755	150	338	152	2,648	108	2,756
Total	437	3,247	3,684	1,842	1,137	2,979	780	1,486	844	9,773	768	10,541
(2) Future Project												
Wet Season	714	4,095	4,809	2,301	1,485	3,786	1,040	2,219	1,000	12,854	1,408	14,262
Dry Season	262	2,507	2,769	755	662	1,417	255	851	263	5,555	297	5,852
Total	976	6,602	7,578	3,056	2,147	5,203	1,295	3,070	1,263	18,409	1,705	20,114
(3) IncreasedDemand in Future, (2) - (1)												
Wet Season	361	2,017	2,378	930	632	1,562	410	1,071	308	5,729	748	6,477
Dry Season	178	1,338	1,516	284	378	662	105	513	111	2,907	189	3,096
Total	539	3,355	3,894	1,214	1,010	2,224	515	1,584	419	8,636	937	9,573

The increments of annual irrigation water demand will reach as large as 3,900 MCM in the Nan basin, consisting of 2,400 MCM and 1,500 MCM respectively for wet season and dry season. In the Ping and Yom basins also, such annual increments will reach 2,200 MCM and 1,600 MCM. The increase of irrigation water demand of 9,600 MCM in the entire upper Chao Phraya basin will cause a serious water shortage problems in future in the Chao Phraya basin as a whole.

(4) Domestic and Industrial Water Demand

The domestic and industrial water demands are summarized in Table 4.4.

Table 4.4 Summary of Other Water Demand by Surface Water

(Unit MCM)

	Nan	Ping	Wang	Yom	Sakae Krang	Pasak	Total
(1) Existing Demand, 1996	118	148	22	74	9	115	486
(2) Future Water Demand, 2006	139	190	26	92	16	148	611
(3) Future Water Demand, 2016	160	233	29	111	22	181	736
(4) Increased Demand, (3) – (1)	42	85	7	37	13	66	250

In the upper Chao Phraya basin, most of water for domestic and industrial uses is withdrawn from the groundwater aquifer, and hence increase of water demand depending on surface water resources is only 250 MCM showing much smaller volume than agriculture.

(5) Decreasing Water Resources

Due to increase of water demand for irrigation and other uses in future, available water resources in the upper Chao Phraya basin will decrease as estimated in Table 4.5.

Table 4.5 Decreasing Water Resources in the Upper Chao Phraya Basin

(Unit: MCM)

	Sirikit Outflow	Narasuan Inflow	Whole Nan Basin	Bhumibol Outflow	Whole Wang & Ping	Whole Yom	Chainat Inflow
(1) Existing Water Resources (Average 1985-96)							
Wet Season	1,790	2,570	5,510	1,400	3,340	3,050	14,160
Dry Season	2,540	2,390	2,340	3,040	3,040	210	5,840
Total	4,330	4,960	7,850	4,440	6,380	3,260	20,000
(2) Increased Water Use in Future							
Wet Season	390	780	2,460	880	1,360	1,450	6,930
Dry Season	160	580	930	370	220	180	1,900
Total	550	1,360	3,390	1,250	1,580	1,630	8,830
(3) Future Water Resources, (2) - (1)							
Wet Season	1,400	1,790	3,050	520	1,980	1,600	7,230
Dry Season	2,380	1,810	1,410	2,670	2,820	30	3,940
Total	3,780	3,600	4,460	3,190	4,800	1,630	11,170

The current 20,000 MCM of available water resources of the Chao Phraya river at Chainat, from where water is diverted and distributed to the Chao Phraya delta, is estimated to decrease to about 11,000 MCM in future as the water demand mainly for irrigation increases in the upstream sub-basins. These estimated values are for average year conditions, and in dry years such as 1991 to 1993 available water resources at Chainat will decrease from 114,000 MCM at present to only 2,550 MCM in future. Water use in the upstream sub-basin in these critically dry years may be restricted, however, water use in the Chao Phraya delta will be in panic.

4.2 Water Resources Management

Regarding the water resources management in the Chao Phraya basin, problems are to be extracted and measures are to be taken which are categorized into 1) Watershed Management, 2) River Flow Management, 3) Water Source (Reservoir) Management, 4) Water Diversion and Distribution Management, 5) Water Use Management and 6) Other Water Management including Water Charge and Institution.

(1) Watershed Management

Dividing river basins such as Nan, Ping, Yom, etc. into medium and/or small tributary sub-basins, it is necessary to classify each tributary sub-basin based on the data related to the characteristics of catchment obtainable from the GIS analysis, involving;

- Topography and land use of catchment
- Status of slash-and-burn agriculture, devastation of forest and farmland, soil erosion and land slide, change and destruction of river channel

Potential water resources are to be always grasped through analysis on the specific runoff yield in each tributary sub-basins.

(2) River Flow Management

Flow in the river used to change from time to time in accordance with rainfall intensity in the catchment, river channel conditions and others. In case of the main stream of the river, flow

conditions are greatly influenced by the use of water in the irrigated and/or rainfed farmland which extends along the river. Accordingly river flow is to be managed by establishing a MEC system (Monitoring, Evaluation and Control System) through procedures as in the followings;

- Control points are to be established on the river at the existing gauging stations in order to monitor and classify the river flow depending on its magnitude.
- Control points are registered in the inventory and water level and discharge are observed continuously, as is done by RID.
- Change and fluctuation of river flow are analyzed and evaluated based on the monitored data. A proper rule of water allocation is then established within the river system as a whole, on the basis of potential water use observed between control points.
- Water uses at and between the control points are controlled by the above water allocation plan.

(3) Water Sources Management

Since most of river runoff concentrates during the wet season in Thailand, water use in the dry season depends mostly on the stored water in the reservoirs, and therefore, operation control of the reservoirs is the major target for water source management in the upper Chao Phraya basin. Operation rules to manage the storage in and outflow from the reservoir are, however, not established for majority of the dams excluding the Bhumibol and Sirikit dams. Even for the Bhumibol and Sirikit dams where operation rule curves exist, such rules are to be improved in time in response to the decreased inflow into the reservoir. Operation rules are to be established at all of the medium/large scale dams through "Reservoir Operation Study" after reviewing the decreasing inflow from the catchment and increasing water demand in the downstream beneficial area.

(4) Diversion and Distribution Water Management

Diversion water management takes charge of diversion and downstream release control at the Naresuan and Chainat diversion dams, while water control in the distribution system to achieve better allocation of water in the beneficial area is the target of the distribution water management. Currently problem is negligible in the wet season since there keeps a plenty of water in the distribution system, however, various difficulties are actually caused by shortage of water in the system in the dry season. A proper control of water diversion and distribution is to be made based on accurate estimation of water demand which will change as the "crop diversification program" progresses and diversion requirement at the intake and turn-out gates. Diversion requirement is to be reviewed on a weekly basis in accordance with the farming plan and cropping calendar at the diversion gates within the canal distribution systems.

(5) Water Use Management

There are many places in the irrigation system where losses of water can not be bypassed due to incomplete on-farm facilities. It is necessary for achievement of a better management of water use to consolidate on-farm irrigation facilities and to establish a rotational irrigation system by farmers' group. Adoption of sprinkler and drip irrigation method may be the important subject in future in order to achieve water saving in the diversified crops.

(6) Other Management

Collection of water charge has been placed high priority in the government policies ever since the government started investment in the state irrigation project. The State Irrigation Act of 1942 stated that land owners receiving benefit from irrigation works shall be subject to payment of irrigation service fees, however, collection of irrigation fees has not been implemented effectively because that the Thai farmers are considered as the lowest income group not bearable to impose any additional fees upon them. Collected fees which are deposited in a special revolving fund could be used as the source of investment for the future implementation of the water resources development as well as for future operation and maintenance. To set the standard of fees on the ability of beneficiary shall be given first consideration and amendment of the laws and regulations to enable such collection shall be conducted along with establishment of proper channel of implementation.

Water management in the Chao Phraya basin involves nine major items of activity such as irrigation and agriculture, hydro-power generation, domestic water supply, navigation, industrial water use, water quality control, fishery, flood alleviation and construction works. Altogether 25 government agencies belonged to 8 ministries/offices take charge of these activities, among which RID involves all 9 items excluding the hydro-power generation. Therefore, RID shall play the key role for effective water management in future, though it requires a single policy making agency at the cabinet level for guidance, coordination and supervision.

5. Water Demand Projection in the Beneficial Areas

The direct beneficial area denotes the area where dry season water can be directly served by the Kok-Ing-Nan Water Diversion Project for irrigation and other purposes under the gravity water conduction system. The area is hence situated along the main courses of the Nan and Chao Phraya rivers located downstream of the Sirikit reservoir, namely the lower Nan sub-basin and the lower Chao Phraya sub-basin (delta).

5.1 Irrigated Agriculture in the Beneficial Area

(1) Beneficial Area

The study covers the total irrigation service area of 8.4 million rai consisting of 7.3 million rai in the lower Chao Phraya basin and 1.8 million rai in the lower Nan basin as given in Table 5.1;

Table 5.1 Beneficial Areas in Chao Phraya Delta and Lower Nan B asin

(Unit: 10^3rai)

Chao Phraya Delta		Lower Nan Basin	
Irrigation Project	Area	Irrigation Project	Area
(1) Existing Upper West	2,299	(1) Existing Phitsanulok (1)	667
(2) Existing Upper East	1,657	(2) Existing DEDP Pump	486
Sub-total	3,956	Sub-total	1,153
(1) Existing Lower West	1,447	(3) New Phitsanulok (2)	500
(2) Existing Lower East	1,939	(4) New DEDP Pump	200
Sub-total	3,386	Sub-total	700
Total	7,342	Total	1,853

The Chao Phraya delta is consisting of 25 large-scale irrigation sub-projects under the Greater Chao Phraya Irrigation Project as shown in Figure 5.1.

(2) Outline of Diversified Agriculture in the Delta

After the completion of the Chainat dam in 1962 and the Bhumibol dam in 1964, about 7.3 million rai (1.2 million ha) of irrigation system was consolidated where irrigated agriculture mainly for wet season rice had been practiced in the delta. In 1974, the Sirikit dam commenced its operation to extend the dry season irrigation in the delta. Irrigation projects to support supplemental irrigation for wet season rice have also been implemented in the upper Chao Phraya basin since the beginning of 1980s, and the rice production has been extended year by year. Based on the projection of future demand and consumption of various foods in future, the Thai government adopted as the key strategy of agricultural development, the promotion of crop diversification program, and under this policy diversified agriculture was first applied to the delta where irrigation water can be obtained for diversified crops in the dry season and products of these crops have a high marketability. Harvested areas of diversified crops in the past and recent years are summarized in Table 5.2.

Table 5.2 Outline of Diversified Agriculture in the Delta (Dry Season)

(Unit : 10^3rai)

District	Perennial				Dry Season Crop				Total Area	Crop Intensity (%)
	Sugar Cane	Fruits	Fish Pond	Sub Total	Dry Paddy	Field Crop	Vegetable	Sub Total		
1. Upper West (A=2,299)										
1986 - 90	53.9	8.9	15.6	78.4	935.6	23.1	2.6	961.2	1,039.6	45.2
1991 - 96	161.9	39.8	12.8	214.4	712.7	22.8	4.5	740.1	954.4	41.5
2. Upper East (A=1,657)										
1986 - 90	0.2	11.3	1.2	12.8	259.5	42.6	2.4	304.5	317.3	19.1
1991 - 96	11.1	27.8	2.9	41.7	193.1	41.6	3.2	237.9	279.6	16.9
3. Lower West (A=1,447)										
1986 - 90	1.0	92.6	29.4	123.0	820.9	6.0	45.5	872.4	995.4	68.8
1991 - 96	2.3	93.5	30.4	126.1	758.4	2.2	33.5	794.1	920.1	63.6
4. Lower East (A=1,939)										
1986 - 90	0	135.4	145.3	280.7	671.9	1.6	1.4	675.0	955.7	49.3
1991 - 96	0	162.2	91.0	253.2	544.6	0.3	0.5	545.3	798.5	41.2
5. Total (A=7,342)										
1986 - 90	55.1	248.2	191.6	494.9	2,687.9	73.3	51.9	2,813.1	3,308.0	45.1
1991 - 96	175.2	323.2	136.9	635.3	2,208.7	66.9	41.7	2,317.3	2,952.6	40.2

- Harvested areas for diversified crops such as sugarcane, fruit, fish pond, etc. have increased between two periods, 1986 to 1990 and 1991 to 1996, while that for dry season rice has decreased accordingly.
- Sugarcane is cultivated mainly in the upper west zone of the delta where supply of water is rather sufficient and risk of flood inundation is rather small. A large extension of farmland exists in the upper east zone of the delta, however, sugarcane is not planted in a larger scale in this zone because of water shortage problem. Almost no farmland for sugarcane cultivation has been found in the lower west and east zones because of high groundwater level and frequent inundation in the wet season. Sugar mills and processing factories are distributed in both upper west and upper east zones where the areas planted to sugarcane will

continue to increase in future.

- Cropped area to fruit trees has been rapidly increasing and will increase more and more in future in the upper delta where a large expansion of suitable farmland for fruit tree cultivation exists. Although suitable area for fruit plantation is limited in the lower delta due to higher groundwater level and inundation, high ridges are provided to protect the area from inundation supported by sufficient supply of irrigation water and high market demand from the Bangkok Metropolitan area.
- Fish ponds had developed in the lower delta where water is available in both wet and dry seasons, showing a decreasing tendency in recent years due to lack of water especially in the dry season. In the upper delta, absolute lack of dry season water has prevented the promotion of fish culture in this area. Fish is quite important as the source of protein in the rural area and fish culture is a profitable industry, and therefore, fish culture will extended in the area if sufficient supply of water in the dry season can be expected.
- In the lower zones, cultivation of field crops in paddy fields is difficult due to soil texture and groundwater level unsuitable for field crops cultivation. Major field crops grown in the delta are soybean, mungbean and maize. At present harvested area of field crops is 67,000 rai on average consisting of 64,000 rai for the upper zones. On the contrary, rapid growth of field crop cultivation in recent years is found in the upper east delta. The field crop cultivation has not been accelerated enough until now in the delta because of no profitable crop due to low farm gate price and lack of irrigation water in the dry season. In future, pulses farming and fodder cultivation for livestock promotion are planned to be extended in the upper east delta.
- Cropped area for wet season rice has decreased as those for diversified crops increase. Cropped area for dry season rice has varied from year to year depending on water resources available, and generally tends to decrease because that rice cultivation requires much irrigation water. The current achievement of dry season rice cropping, 1.3 million rai as an average in 1991-96 period in the lower delta is considered to be the minimum in order to prevent the area from saline water intrusion. On the other hand in the upper delta where the supply of irrigation water is often restricted because of limitation of the water availability, 0.9 million rai of dry season rice has been cropped during the period from 1991 to 1996, while 1.2 million rai was achieved in the past period from 1986 to 1990. About 1.1 million rai of dry season rice cropping, equivalent to the average in 1986 to 1996, may be required in the upper delta including the production from the higher elevated area where the crop diversification will be highly promoted in future together with that from the lower elevated areas situated along the Chao Phraya river with soil conditions suitable only for rice cultivation. In total, the future cropped area in the dry season would be some 3.68 million rai consisting of 1.3 million rai and 1.1 million rai of the dry season rice and 0.44 million rai and 0.84 million rai of the diversified crops respectively in the lower and upper delta. The 40% of the present achievement of dry season cropping would be increased to 54% when the possible decrease of the irrigable area from 7.342 million rai to 6.8 million rai is taken into consideration. Detailed figures are explained in Table 5.3.

(3) Estimation of Diversified Crop Area in Future

Cropped area to diversified crops will increase greatly in the upper delta if stable supply of

irrigation water in the dry season can be expected. Rice cultivation will play a core role in the lower delta when soil and groundwater conditions are taken into consideration, and crop diversification will not be expanded more than present. Crop diversification has not been progressed in the Phitsanulok and pump irrigation areas in the lower Nan basin, however, diversified crop cultivation will be extended in future in the basin because of suitable farming conditions for diversified crops. Table 5.3 presents areas for diversified crops in future.

Table 5.3 Proposed Area of Crop Diversification in Future (Dry Season)

(Unit: 10^3rai)

Beneficial Area	Irrigable Area	Sugar Cane	Fruit	Fish Pond	Field Crop	Vegetable	Sub-total	Dry Paddy	Total	Crop Intensity (%)
1. Delta Area										
(1) Upper District	3,750	285	260	62	179	50	836	1,148	1,984	53
(2) Lower District	3,050	5	271	129	2	36	443	1,259	1,702	56
Total	6,800	290	531	191	181	86	1,279	2,407	3,686	54
2. Lower Nan										
(1) Existing Project	1,120	0	78	17	90	17	202	447	649	58
(2) New Project	700	0	49	10	56	10	125	224	349	50
Total	1,820	0	127	27	146	27	327	671	998	55

Remark; Irrigable area in Deta 6.8 million rai infuture, which decreases as compared with the existing area of 7.3 million rai due to area conversion from farm to urban and industrial area.

5.2 Projection of Water Demand for Irrigation

(1) Unit Irrigation Water Demand

More than 40 intake structures and regulators are installed in the Chao Phraya delta and flows to pass these facilities have been observed by the O/M Division of RID. Volume of water so collected together with information on the irrigated areas by use of this volume of water made it possible to estimate the water demand per unit area of irrigation as summarized below;

Table 5.4 Unit Irrigation Water Demand (Dry Season)

(Unit: m^3/rai)

District	Sugar Cane	Fruit	Fish Pond	Field Crop	Vegetable	Dry Paddy
Upper District	1,300	2,000	1,450	1,300	550	1,800
Lower District	875	1,250	925	900	400	1,000

The unit irrigation water demand in the lower delta showed a relatively smaller value as compared with that for the upper delta, because a part of irrigation requirement is supplemented in a form of return flow from the irrigated areas in the upper delta.

(2) Present Shortage of Irrigation Water in the Delta

As is seen in Table 5.5, harvested areas in the dry season in the delta have decreased in recent years.

Table 5.5 Change of Dry Season Cropping Intensity

(Unit: %)

Year	Upper West	Upper East	Lower West	Lower East	Mean
Past Year 1986~90	45.2	19.1	68.8	53.4	46.0
Recent Year 1991~96	41.5	16.9	63.6	44.6	41.0

Irrigation water is supplied to the conservation area of the lower west and east zones of the delta with a priority to conserve the areas. In these areas, irrigation water used to be supplied to cover more than 60% of irrigable area even in a critically dry year. A relatively lower values observed in the lower east delta is brought by the decrease of cropped area against irrigable area due to conversion from farmland to residential and industrial areas.

Distribution of the rate of harvested area against irrigable area is visualized in Figure 5.2. The upper east delta has faced serious shortage of water holding a number of irrigation sub-project areas of which cropping intensities are less than 20%.

Basic assumptions adopted in the estimation of dry season irrigation water demand are as follows;

- Areas given in Table 5.3 were used in the estimation of water demand for diversified crops.
- Minimum cropping intensity (50% for example) was applied for the irrigation sub-project area whose intensity in the past was less than the minimum intensity given.
- For the area with the cropping intensity in the past greater than the minimum given, past level of intensity was maintained.
- Area to be planted to the dry season rice is thus adjusted in accordance with the magnitude of the area for diversified crops.

Estimated results of irrigation water demand for various cases of the minimum intensities are summarized in Table 5.6.

Table 5.6 Additional Dry Season Water Demand for Irrigation in 2016

Minimum Cropping Intensity	Crop Diversification Program	Additional Water Demand (MCM)			Total
		Delta	Lower Nan Basin		
			Existing	New Expansion	
20%	High	-239	1	216	-22
	Normal	-194	11	223	40
	Moderate	-162	23	230	136
30%	High	40	1	345	386
	Normal	84	11	352	447
	Moderate	117	23	359	499
40%	High	528	1	475	1,004
	Normal	573	12	482	1,067
	Moderate	606	23	489	1,118
50%	High	1,117	40	604	1,761
	Normal	1,222	50	611	1,883
	Moderate	1,255	62	618	1,935
60%	High	1,963	176	734	2,873
	Normal	2,009	187	741	2,937
	Moderate	2,042	199	748	2,989
70%	High	2,841	331	863	4,035
	Normal	2,887	343	870	4,100
	Moderate	2,919	356	877	4,152
80%	High	3,800	506	992	5,298
	Normal	3,845	518	1,000	5,363
	Moderate	3,879	529	1,007	5,415
90%	High	4,798	704	1,122	6,624
	Normal	4,844	716	1,129	6,689
	Moderate	4,877	726	1,136	6,739

Total surface water abstraction for the normal case of water demand for non-irrigation sectors including domestic, industrial and livestock uses is summarized as follows;

Table 5.7 Non-Irrigation Water Demand in Zone (Normal Projection)

Zone	1996	2006	2016
Upper Chainat Area	5.94	1. 56	9.60
Upper West Bank	13.38	16.98	21.84
Lower West Bank	531.48	793.50	1,055.70
Upper East Bank	16.02	21.78	28.68
Lower East Bank	255.06	391.80	530.58
Total	821.88	1,231.62	1,646.40
Increase	0	409.74	824.52
Rate	100%	149.9%	200.3%

The above normal case of projection for non-irrigation sectors indicates 200% of water demand increase by the year 2016 mainly due to increase of population and per capita water consumption. Domestic and industrial sectors may have a priority to use water before irrigation, however, even so they have to aim to save water in order to cope with water shortage crisis that may occur more frequently in future.

The study intends to establish a further "low growth" variant to future water use not allowing a rapid increase of per capita water consumption as predicted in the normal forecast for water demand. Under the assumption that necessary countermeasure would be taken to keep per capita consumption of domestic water at the current level and also to save water for industrial use, the

future water demand for non-irrigation sector could be reduced to 85% of the normal forecast values. As a further "high growth" variant it is assumed that some of the current level of underground water abstraction in the Bangkok area would be shifted to surface water or additional surface water for artificial recharge of underground water would be required. To cope with this demand, the study concludes to add 278 MCM of water required for recharge of underground water for dry season use.

Table 5.7 High and Low Growth Variants of Non-Irrigation Water Demand

(MCM)

Variant	Equation	Dry Season Water Use in 2016	
		Water Demand	Additional
High Growth Forecast	Normal Forecast + 278 MCM	1,924.4	1,102.52
Normal Forecast	-	1,646.4	824.52
Low Growth Forecast	Normal Forecast x 85%	1,399.44	577.56

6. Necessity of the Kok-Ing-Nan Water Diversion Project

(1) Decreased Water Resources and Increased Water Demand

As shown in Table 4.5, 5,840 MCM of the existing dry season flow of the Chao Phraya river at Chainat will decrease to 3,940 MCM due to increase of water use of 1,900 MCM in the upper Chao Phraya basin. In parallel with this, water demand in the Chao Phraya delta will increase by 2,050 MCM, consisting of 1,220 MCM of irrigation water and 830 MCM for non-irrigation sectors. These increases of water demand in both upper and lower Chao Phraya basins will be combined to cause about 4,000 MCM of the shortage of water in the whole Chao Phraya basin in future. Flow of the Chao Phraya river during wet season will decrease from 14,200 MCM at present to 7,200 MCM, which is almost equivalent to the present wet season water demand of 7,400 MCM inclusive of 6,600 MCM for supplemental irrigation of 6.6 million rai of wet season paddy and 800 MCM of water use for non-irrigation sectors. This means that water would be in short even during wet season in future.

(2) Various Transbasin Water Diversion Plan

Under this situation, numbers of alternative transbasin water diversion plans, 18 plans in total, from the Mekong and its tributaries and from the Salawin and its tributaries to the Chao Phraya basin through existing Sirikit and Bhumibol reservoirs have been formulated at various study levels by the government. Most plans, however, have faced difficulties such that diversion of water from the main stream of the Mekong river requires water agreement among the riparian countries as well as with the Mekong Committee, withdrawal of dry season water is almost impossible, long distance tunnel and high pumping head require high construction and operation costs and that large environmental impact may be induced by the implementation of the project. Among those, the water diversion plans from the Salawin to the Bhumibol require agreement only with Myanmar, and the Thai government is going to resume further studies on these plans.

(3) Kok-Ing-Nan Water Diversion Project

The RID initiated in 1993 the transbasin water diversion plan from the Kok and Ing rivers to the existing Sirikit dam by means of constructing long diversion channels and tunnels crossing the

mountain ridge which divides the Ing and Nan watershed areas. The plan was considered to be viable at the preliminary stage of the study made by RID because of lesser environmental impact than other transbasin diversion plans and substantial volume of both excess amount of water to be diverted and available storage capacity of the Sirikit reservoir. Since then RID negotiated with the Mekong River Committee (MRC) to rectify Article 5 "Reasonable and Equitable Utilization in the Rights of Water Usage" in the Agreement on "Cooperation for the Sustainable Development of the Mekong River Basin" signed by four riparian countries in April 1995. The negotiations were successful and Article 5 was rectified allowing for every countries in the Mekong river basin to make use of the water in the basins of the Mekong river's tributaries in their own countries.

At the Joint Committee held on November 1995 in Vietnam, the head of the Thai Delegation, on the basis of Article 5 of the Agreement, notified the Joint Committee on two tributary projects being implemented by Thailand, namely, the Kok-Ing-Nan and Lamtakhong. The Joint Committee acknowledged the notification by Thailand with great appreciation.

The proposed Kok-Ing-Nan Water Diversion Project intends to divert about 2,000 MCM of water from the Kok and Ing rivers during the wet season. The diverted water is then transported through long-distance canal and tunnel to the head of the Nan river and stored once in the Sirikit reservoir for use in the dry season. Improvement of the Sirikit reservoir operation would produce additional 800 MCM of dry season water. The Study explains the significance of the project to cope with the present and future shortage of water in the dry season in the Chao Phraya basin, however, at the same time, explicated the fact that the proposed Kok-Ing-Nan Project alone is not sufficient to fulfill the entire water deficit in future when the progress of water resources development and increasing demand in the upper Chao Phraya basin are taken into consideration. Another water diversion project, transbasin from the Salawin river and its tributaries to the existing Bhumibol dam will be the next target.

7. Proposal for Improved Operation of Sirikit Reservoir

(1) Existing Operation of the Sirikit and Bhumibol Dams

The Sirikit and Bhumibol dams, constructed respectively on the Nan and Ping rivers, are being operated for multipurpose of irrigation, hydro-power generation, flood control and river maintenance, providing a great contribution to the Chao Phraya delta covering most of irrigation and other water uses especially in the dry season. Storage capacities of the reservoirs are as large as 6,660 MCM and 9,660 MCM, however, both reservoirs are seldom filled to their full storage levels at the end of the wet season because of absolutely insufficient inflows.

Table 7.1 Existing Operation of Sirikit and Bhumibol Dams

(Unit: MCM)

Item	Sirikit Dam			Bhumibol Dam		
	1974-84 Average	1985-96 Average	Increase & Decrease	1974-84 Average	1985-96 Average	Increase & Decrease
1. Inflow	5,850	4,750	-1,130	5,640	5,000	-640
2. Storage at the End of Wet Season	4,710	3,620	-1,090	6,230	4,880	-1,350
3. Empty Space at the End of Wet Season	1,950	3,040	+1,090	3,430	4,780	+1,350
4. Total Outflow	5,710	4,330	-1,380	5,530	4,430	-1,100
5. Wet Season Outflow	2,640	1,790	-850	2,390	1,400	-990
6. Dry Season Outflow	3,070	2,540	-530	3,140	3,040	-100

- Storages of water at the end of wet season in the reservoirs have decreased to 3,620 MCM and 4,880 MCM accounting for about 50% of the total effective storages.
- Possible efforts are made at both dams to reduce wet season outflow and in turn to increase dry season water release. The wet season outflow has been reduced to about 30% of the total outflow from the Bhumibol reservoir, however, at the Sirikit reservoir wet season water release occupies more than 40% of the annual outflow.
- Due to lack of inflow into reservoirs, both dams have faced various difficulties in operating reservoirs causing water shortage in the downstream beneficial areas as well as for power generation.

(2) Proposal for Improved Operation of the Sirikit Reservoir

Inflow into and in turn outflow from the reservoirs tend to decrease because of promotion of water resources development in the upstream catchment basins, and this would affect the water use in the Chao Phraya delta. There exists a considerable amount of side-flow from the residual catchment located downstream of the reservoirs in the wet season, however in the dry season such a flow becomes very small. It is hence necessary to store as much volume of inflow as possible in the reservoirs in the wet season in order to maximize the outflow in the dry season. To cope with this, the following measures are to be taken;

- The only practical way to generate additional release of water from reservoirs during dry season under the existing hydrological situation is to save the water released from the reservoirs and to promote restoration of storage during wet season, and to release the stored water during dry season, and this is none other than saving water required for wet season irrigation in the lower Chao Phraya basin. The degree of water saving for the wet season irrigation may be more or less 20% in a practical manner, and the concrete countermeasures are to be realized in order to achieve this order of water saving. Hence the target is;

  Water Saving for Wet Season Irrigation = 3,200 MCM x 20% = 640 MCM

- As is seen in Table 7.2, there remains in the dry season only 3,300 MCM of water resources in the Ping basin at the mouth of the Ping river including 1,400 MCM of outflow from the Bhumibol dam. This order of water resources should be reserved for future potential use within the basin, and therefore it would be difficult to reduce the outflow from the Bhumibol dam in wet season. On the contrary in the lower Nan basin, about 5,500 MCM of side-flow

is still available from the catchment downstream of the Sirikit dam in wet season, providing the major reason for reduction of 640 MCM from the wet season outflow from the Sirikit reservoir.

Table 7.2 Present Reservoir Outflow and Available Flow of Nan and Ping Rivers

Reservoir	Outflow from Reservoir (MCM)			River Flow (MCM)			River
	Wet	Dry	Total	Wet	Dry	Total	
Sirikit	1,790	2,540	4,330	5,510	2,340	7,850	Nan
Bhumibol	1,400	3,040	4,430	3,340	3,040	6,380	Ping

In order to achieve the above improvement of the Sirikit reservoir operation, rule curves were proposed by the study. This improvement of the Sirikit reservoir operation is preliminarily scheduled around 2006, in order to cope with the immediate requirement of water in the dry season.

8. Project Water Diversion Plan

8.1 Water Resources and Water Demand in the Kok and Ing Basins

(1) Potential Surface Water Resources

The potential surface water resources so estimated within the basins are as follows;

Table 8.1 Potential Surface Water Resources

Basin	Location	Catchment (km^2)	Potential Surface Water Resources (MCM)				Remarks
			Annual	Yield (mm)	Wet	Dry	
Kok	River Mouth	10,884	5,438	500	4,420	1,018	1974-96
Ing	River Mouth	7,120	2,465	346	2,255	210	1974-96

Note: Annual April to May, wet season June to November, dry season December to May.

(2) Potential Water Demand for Irrigated Agriculture

A preliminary study was conducted to find out the maximum potential water resources development in the basins. Because of limited water resources especially during dry season, the wet season water is to be stored in the reservoirs for uses in the dry season. The study is therefore to find out promising sites for reservoir construction. However, the purpose of this desk study made only on 1/50,000 maps without any field reconnaissance is not to recommend further implementation of additional project but to estimate the maximum potentials of water resources development in the basins, because that the maximum amount of water resources is to be reserved within the basins for possible development in future.

By means of constructing additional 13 reservoirs, 330,900 rai of agricultural land may possibly be irrigated inclusive of the Mae Lao Extension area where water is supplied from a number of storage reservoirs to be constructed in the Lao sub-basin through the extended Mae Lao irrigation canal. A comparison study of the existing, proposed and potential irrigation development in the Kok and Ing basins would result the followings;

Kok Basin

- Existing irrigation development covers 36% (464,000 rai) of the agricultural area when slash-and-burn cultivation areas are ignored and 45% of the practically irrigable area,
- Proposed development will cover 713,200 rai of irrigable or 55% of the agricultural area

excluding slash-and-burn area and 70% of the practically irrigable area, and
- Maximum potential development would cover 907,700 rai of irrigable area or 71% of the agricultural area and 89% of the practically irrigable area.

Ing Basin
- Existing irrigation development covers 41% (712,600 rai) of both the agricultural area when slash-and-burn cultivation areas are ignored and the practically irrigable area,
- Proposed development will cover 1,010,000 rai of irrigable area or 58% of both the agricultural area excluding slash-and-burn area and the practically irrigable area, and
- Maximum potential development would cover 1,187,300 rai of irrigable area or 68% of both the agricultural area and the practically irrigable area.

(3) Water Demand for Other Sectors than Agriculture

The study is summarized as follows;

Table 8.2 Water Demand for Others (Surface Water)

(Unit: MCM/year)

Sub-basin	Domestic Demand	Industrial Demand	Livestock Demand	Total Demand Non-Irrigation
Kok	75.09	16.01	1.75	92.85
Ing	87.90	2.97	2.28	93.15

(4) Surplus Water Available for Water Diversion

Discharges of the Kok and Ing rivers at the proposed sites of the proposed water diversion are used primarily to irrigate the existing, proposed and potential agricultural areas, to supply domestic and other purposes within the basins and to maintain downstream river courses. Residual river flows after such water diversions are the potential source of water for the proposed water diversion project. As an allowance, 5% of water is subtracted from the residual river flow for future unforeseen water resources development in the basins.

Table 8.3 Monthly Runoff of Kok River

(After Potential Development, Unit=MCM)

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Mean	61	91	131	296	568	605	373	277	183	126	91	83	2,884
Max.	97	174	215	557	1,076	1,005	578	513	355	177	170	91	3,978
Min.	34	43	57	152	303	314	196	132	110	79	61	44	1,725

Table 8.4 Monthly Runoff of Ing River

(After Potential Development, Unit=MCM)

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Mean	5	20	21	103	307	356	131	87	17	8	1	1	1,058
Max.	33	124	103	360	954	963	362	248	106	41	6	8	2,536
Min.	0	0	0	2	62	116	4	16	1	0	0	0	364

8.2 Optimum Diversion Capacity

Possible amount of water diversion from the Kok and Ing basins to the Sirikit reservoir largely

depends on the discharge capacity of diversion channel. A larger amount of water may be expected as the capacity enlarges, however the rate or incremental raise of amount may decrease when the capacity exceeds a certain limit. A greater construction cost will be required for a larger diversion channel and over-estimation of diversion discharge may cause needless control of diversion when the reservoir is filled with runoff from its own catchment, and therefore be uneconomic.

The following combinations of diversion capacities were put into the comparative study;

Capacity of Kok-Ing Diversion Canal/Tunnel	75, 100, 125, 140, 165 m^3/sec
Capacity of Ing-Yot Diversion Tunnel	110, 135, 160, 175, 200 m^3/sec

Various case-studies of water balance were made in order to know the amount of water which can be diverted from the Kok and Ing rivers and transferred to the Sirikit reservoir. The studies revealed the fact that (1) the potential total amount of diversion increases as the capacity of Kok-Ing channel enlarges, however a growth rate of increase turns negligible if the capacity of Kok-Ing channel exceeds 140 m^3/sec, and (2) it also turns to decrease when the capacity of the Ing-Yot tunnel exceeds 175 m^3/sec.

In order to evaluate the best suitable capacity of diversion canal and tunnel, the amount of water to be effectively and safely diverted from the Kok and Ing rivers without wasted in the Sirikit reservoir through spillage and cost to be required for construction were compared for various capacities of the Kok to Ing and Ing to Yot diversion canal/tunnel. A simple calculation was made for this purpose applying a value of the construction cost divided by the effective amount of diversion with a conclusion as given below;

Table 8.5 Proposed Diversion Capacity

Diversion Channel	Capacity
Ing - Nan	175 cum/sec
Kok - Ing	140 cum/sec

8.3 Proposed Water Diversion Plan

About 2,810 MCM of water could be released from the reservoir during the dry season in addition to the present 2,540 MCM amounting to a total release of 5,350 MCM. About 1,460 MCM of flood control capacity will also be added to the present capacity of 4,800 MCM for unforeseen flood during wet season meaning that the proposed project would contribute to a great extent to flood control in the Nan river system.

Table 8.6 Comparative Table of Water Balance at Sirikit Reservoir (MCM)

	Existing Situation	Improved Situation	Increase
Dry Season Outflow	2,540	5,350	2,810
Flood Control Capacity	4,800	6,260	1,460
Power Generated, GWh	820	1,170	350