社会開発調査部報告書

No. 2

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

(Conceptual Planning Study and Initial Environmental Examination)

MARCH 1997

YACHIYO ENGINEERING 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

(Conceptual Planning Study and Initial Environmental Examination)

MARCH 1997

SANYU CONSULTANTS INC.
NIPPON KOEI CO., LTD.

March 26, 1997

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

Letter of Transmittal

Dear Mr. Fujita,

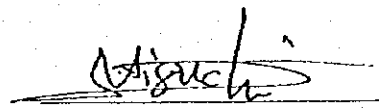
We are pleased to submit hereby the final report on the Conceptual Planning and Initial Environmental Examination on the Kok-Ing-Nan Water Diversion Project in the northern and central regions of the Kingdom of Thailand. This report incorporates the advice and suggestions of the authorities concerned of the Government of Japan and your good Agency and the conceptual formulation of the above mentioned project. Also included are comments made by the Royal Irrigation Department of the Ministry of Agriculture and Cooperatives of the Government of Thailand during technical discussions on the draft report which were held in Bangkok.

The conceptual plan was formulated and evaluated in order to confirm the necessity and viability of the proposed project for further implementation of the feasibility study. The proposed project will make a large contribution to the sustainable socio-economic development of the Chao Phraya basin toward 21 century and hence it was judged from this conceptual planning study that this project is necessary and viable. There exist, however, impacts on the natural environment on the diversion routes or at any local places where environmental mitigation measures should be carefully planned and implemented taking into account the watershed management rules provided in Thailand.

In view of the urgency of solving water shortage problems and of need for sustainable socio-economic development of the Chao Phraya river basin as a whole, it is recommended to proceed to the feasibility study. It is however necessary prior to the commencement of the feasibility study that agencies concerned arrive at a general consensus on the conceptual planning of the proposed project in connection with watershed management rules.

We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, the Ministry of Construction and the Ministry of Agriculture, Forestry and Fishery. We also wish to express our deep gratitude to the RID and other authorities concerned of the Government of Thailand for the close cooperation and assistance extended to us during our investigations and study.

Very truly yours,



Shoichiro Higuchi
Leader of the Study Team

PREFACE

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

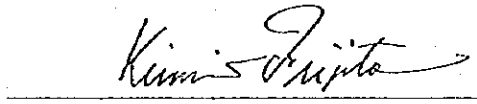
JICA sent to the Kingdom of Thailand a study team headed by Mr. Shoichiro Higuchi, Sanyu Consultants Inc., and composed of staff members from Sanyu Consultants Inc. and Nippon Koei Co., Ltd., for the period of 3.5 months from August to November, 1996 in order to conduct the conceptual planning study and the initial environmental examination.

The team held discussions with the officials concerned of the Government of the Kingdom of Thailand and conducted field investigations and surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

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

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

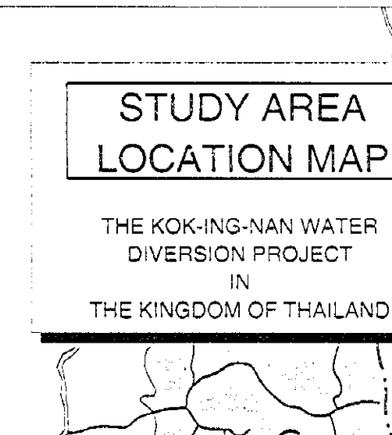
March, 1997

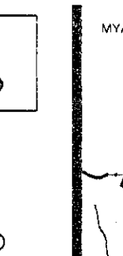


Kimio Fujita
President
Japan International Cooperation Agency

STUDY AREA LOCATION MAP

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

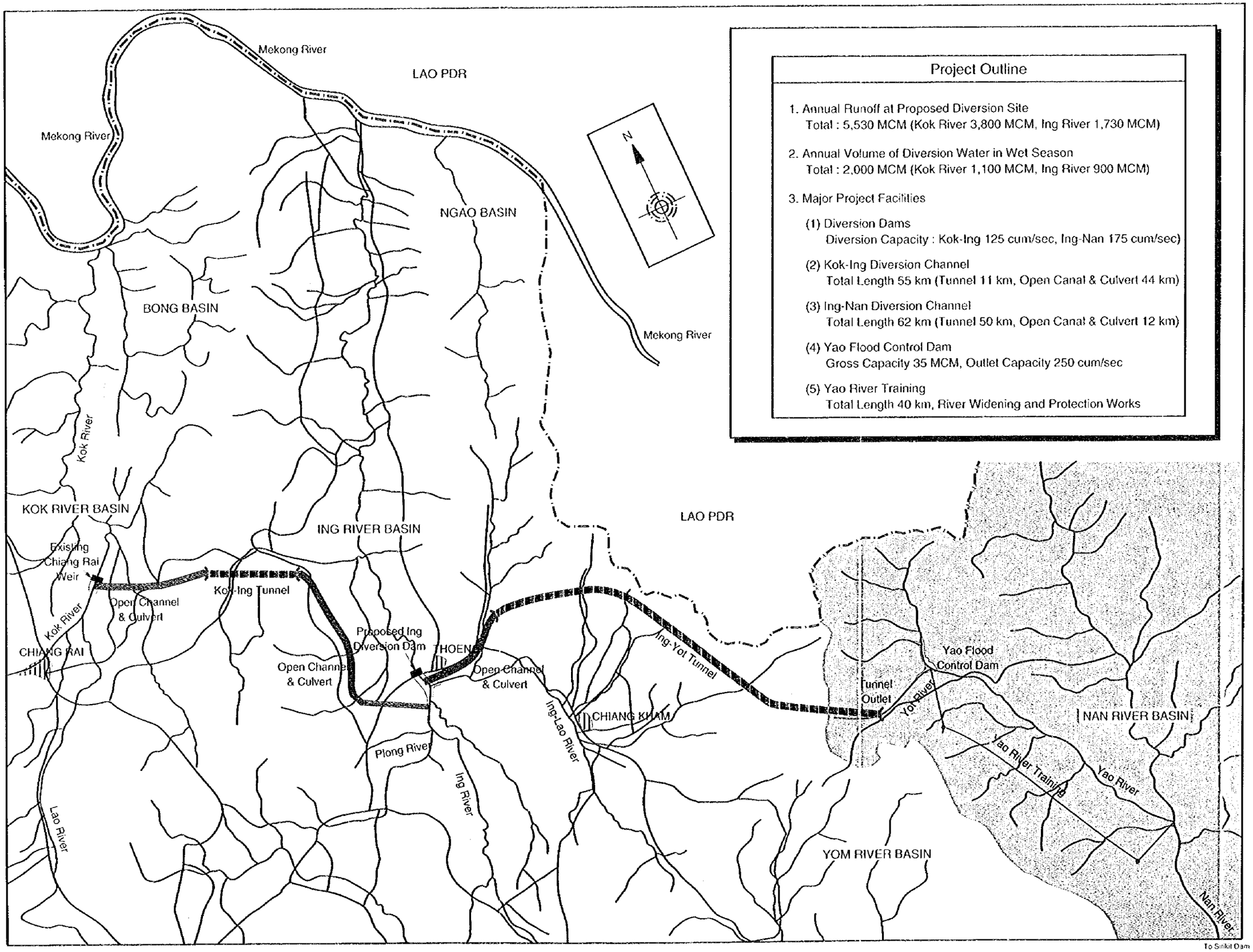




LEGEND

- Existing Dam/Reservoir
- Proposed Dam/Reservoir
- River Course
- Existing Irrigation Project Area

MYANMAR
LAO PDR
Kok River
Chiang Rai
Fang River
Mekong River
Mae Lao Irrigation
Lao River
Ing-Lao River
Ing River
Phayao
Mae Ngat Dam
Phayao Lake
Mae Kuang Dam
CHIANG MAI
NAN
Kiu Kor Ma Dam
Kaen Sua Ten Dam
Kiew Lom Dam
Ping River
LAMPANG
PHRAE
Yom River
Sirikit Dam
Wang River
UTTARADIT
Nan River
Bhumbol Dam
SUKHOTHAI
Khwae Noi Dam
TAK
PHITSANULOK
KAMPHAENGPHET
Ping River
Khlong Khlung Dam
Mae Wong Dam
NAKHON SAWAN
Bung Boraphet
Khlong Pho Dam
Thap Salao Dam
CHAINAT
Krasieo Dam
CHAO PHRAYA DELTA
Lam Takhong Dam
Pasak Dam
Chao Phraya River
Tha Chin River
Pasak River
Lam Phra Phloeng Dam
AYUTTHAYA
Mae Klong River
BANGKOK
Khlong Rabom Dam
Khlong Si Yat Dam
Gulf of Thailand



Project Outline

1. Annual Runoff at Proposed Diversion Site
   Total : 5,530 MCM (Kok River 3,800 MCM, Ing River 1,730 MCM)

2. Annual Volume of Diversion Water in Wet Season
   Total : 2,000 MCM (Kok River 1,100 MCM, Ing River 900 MCM)

3. Major Project Facilities

   (1) Diversion Dams
   Diversion Capacity : Kok-Ing 125 cum/sec, Ing-Nan 175 cum/sec)

   (2) Kok-Ing Diversion Channel
   Total Length 55 km (Tunnel 11 km, Open Canal & Culvert 44 km)

   (3) Ing-Nan Diversion Channel
   Total Length 62 km (Tunnel 50 km, Open Canal & Culvert 12 km)

   (4) Yao Flood Control Dam
   Gross Capacity 35 MCM, Outlet Capacity 250 cum/sec

   (5) Yao River Training
   Total Length 40 km, River Widening and Protection Works

Key Indicators Involved in the Kok-Ing-Nan Water Diversion Project

1. Chao Phraya Basin In Need of Water by Transbasin Water Diversion

Drainage Area	158,000 sq km
Potential Farmland Area	5,900,000 ha
Available Water Resources	33,000 MCM/year
Specific Runoff Yield	210 mm
Water Demand	25,300 MCM (1993), 33,330 MCM (2016)
Population	22.6 million (1993), 26.7 million (2016)
GDP	1,750 billion Baht (US$ 70 billion) in 1994
GDP per Capita	79,000 Baht (US$ 3,200) in 1994

2. Water Resources In Kok and Ing Basins

Item	Kok	Ing	Total
Drainage Area at River Mouth (sq.km)	10,875	7,120	17,995
Average Annual Runoff at River Mouth (MCM)	5,300	2,300	7,600
Average Annual Runoff at Diversion Site (MCM)	3,800	1,700	5,500
Planned Diversion Water in Wet Season (MCM)	1,100	900	2,000
Planned Diversion Water in Dry Season (MCM)	200	-	200

3. Irrigation Beneficial Area by Alternative Water Use Plans

Beneficial Area	Plan A	Plan B	Plan C
Existing Phitsanulok Area	23,100	17,000	13,000
New Phitsanulok Stage II Area	-	-	147,000
Existing Delta Area	246,900	207,000	175,000
Kok & Ing New Developed Area	32,000	32,000	32,000
Total	302,000	256,000	367,000

4. Increasing Municipal and Industrial Water in Lower Nan and Delta Area

Increasing Amount from 1993 to 2016 = 1,240 MCM/year (620 MCM in dry season)

5. Project Facility

(1)	Kok Diversion Dam	Intake Capacity 125 cu.m/sec
(2)	Kok-Ing Diversion Channel	55 km including open canal, culvert and tunnel
(3)	Ing Diversion Dam	Intake capacity 175 cu.m/sec
(4)	Lao Diversion Canal	12.4 km consisting of culvert and tunnel
(5)	Ing-Yot Diversion Tunnel	Tunnel of 50 km and shafts of 17 km
(6)	Yao Flood Control Dam	Dam Height of 37 m, storage of 35 MCM
(7)	Yao River Training	Length of 40 km

6. Project Cost

47,600 million Baht for water use plans A and B
55,600 million Baht for water use plan C

7. Project Evaluation

Item	Plan A	Plan B	Plan C
(1) Incremental Benefit (10^6 Baht)			
Irrigated Agriculture	6,261	4,312	5,435
Municipal & Industrial Water of 1,240 MCM/year	4,024	4,024	4,024
Hydro-power Generation	328	328	328
Total	10,613	8,664	9,787
(2) EIRR (%)	15.1	13.2	12.7

PART I

CONCEPTUAL PLANNING STUDY

EXECUTIVE SUMMARY

Executive Summary

1. Necessity of Additional Supply of Water in the Chao Phraya Basin

1.1 Agricultural and Socio-Economic Background

The Chao Phraya river basin covers a large watershed area of 158,000 sq.km (31% of the country land area) with the population of 22 million (40% of the national population), being recognized as the most important area in the country in view of the national economy.

- The basin has a bulk and fertile farmland of 5.9 million ha yielding 40% to 50% of the national agricultural products. The basin has long been the most important base in the country to support the national food security as well as to contribute for export of agricultural product, and this tendency will further continue toward 21 century.
- The economy of the Chao Phraya delta involving the Bangkok Metropolis, satellite cities and industrial zones has been remarkably levelled up as indicated by its GDP of 1,520 billion Baht (US$ 60 billion) or per capita GDP of 121,000 Baht (US$ 4,800) covering 87% of the whole GDP in the basin. This trend of economic growth in the delta area is expected to continue toward 21 century with a projection of over US$ 10,000 of per capita GDP in the year of 2006 and US$ 20,000 in 2016.

1.2 Status of Water Shortage

(1) Water Demand

With the advance of agriculture and socio-economy in the Chao Phraya basin, demand of water has also been increasing. The present water demand of 25,300 MCM including 20,300 MCM for irrigation and 4,900 MCM for domestic and industrial water supply in the whole Chao Phraya basin is projected to increase to 33,300 MCM, of which 27,400 MCM is for irrigation and 5,900 MCM for other uses, in the project target year of 2016.

(2) Water Resources and Water Balance

Water resources in the basin and the balance of water supply and demand is summarized as follows;

Present and Future Water Balance

Unit = 1,000MCM	Present (1993)				Future (2016)			
	Available Water Resources	Water Demand	Rate of Use	Surplus Water	Available Water Resources	Water Demand	Rate of Use	Surplus Water
Upper Basin	30.6	8.1	26%	22.5	30.6	13.2	43%	17.4
Lower Basin	26.4	17.2	65%	9.2	21.3	20.2	95%	1.1

Note: Available water resources in the lower basin comprises surplus water from the upper basin and runoff from the Pasak river.

1.3 Water Resources Development and Transbasin Water Diversion Projects

(1) Water Resources Development Projects

Numbers of large/medium scale storage dams have been constructed or studied for future implementation

in the basin. Implementation of proposed dams has however faced various difficulties such as social /environmental constraints including resettlement problem in reservoir areas. Moreover, developed water of some 4,000 MCM by these proposed dams would be utilized for supplemental irrigation and other purposes within tributary basins, and therefore no contribution to solution of water shortage problem in the delta area would be expected.

(2) Transbasin Water Diversion Plans

To guarantee stable water supply for socio-economic and agricultural development in the Chao Phraya basin toward 21 century, the Thai Government has studied various transbasin water diversion plans mainly from the Salawin and Mekong rivers. In total 18 alternative water diversion plans were studied since early 1980s, however, all plans except the Kok-Ing-Nan diversion plan were evaluated to be not or less feasible due to constraints to be caused by difficulty of diversion from international rivers, construction of large scale storage dams/reservoirs which would bring peoples resettlement problem and large construction and O/M costs for pumping diversion with high water head, etc.

(3) Advantage of Kok-Ing-Nan Water Diversion Plan

The Kok-Ing-Nan diversion plan would be the only project which could be implemented in near future to solve the water shortage problem in the Chao Phraya basin. The proposed project would be the most advantageous as compared with other alternative plans since waters could be diverted from tributaries located within Thai territory, the existing Sirikit dam could be effectively used without requiring construction of new storage dam/reservoir, waters could be distributed under gravity system, etc.

2 Water Diversion Plan

2.1 Basic Concept of Water Diversion Plan

The proposed Kok-Ing-Nan water diversion plan intends to divert in wet season about 2,000 MCM of surplus water from Kok and Ing rivers through a series of open canals, culverts and tunnels into the existing Sirikit reservoir where empty space of storage of 2,000 MCM to 3,000 MCM is available at the end of wet season. Accompanied by improvement of the Sirikit reservoir operation, the proposed project would supply in dry season additional water of 2,400 MCM in response to the requirement in the lower Nan basin as well as in the Chao Phraya delta area after once stored and regulated in the reservoir.

2.2 Capacity and Volume of Water Diversion

The design capacities are preliminarily taken at 175 cu.m/sec for the Ing-Yot tunnel and 125 cu.m/sec for the Kok-Ing diversion channel in order to convey about 2,000 MCM of wet season water to the Sirikit reservoir.

2.3 Water Use Plan

Out of the additional water of 2,400 MCM to be released in dry season from the Sirikit reservoir, 620 MCM is allocated first to the increasing dry season demand of municipal and industrial water supply in the lower Nan basin and the Chao Phraya delta area. The remaining 1,780 MCM will be allocated for irrigated agricultural areas of either existing or newly developed in the lower Nan basin and Chao Phraya delta area aiming at expansion of 250,000 to 300,000 ha of cultivation area mainly for dry season second crops. The increase in agricultural production would accelerate the crop diversification program and would contribute to agricultural and agro-industrial development of the region to a great extent.

In addition, there still remains considerable amount of water in the Kok river even in dry season. Judging from

the availability of the Kok river water, about 30,000 ha of second crop area mainly in the middle/lower Ing river basin will be irrigated in dry season by the water diverted from the Kok river and conveyed through the Kok-Ing diversion channel.

2.4 Water Diversion Facility Plan

The project facility to be proposed by the Kok-Ing-Nan water diversion plan is outlined as follows;

(1) Kok Diversion Dam: Water intake capacity of 125 cu.m/sec at either existing Chiang Rai weir or new diversion damsite.

(2) Kok-Ing Diversion Channel: To connect Kok and Ing diversion dams with 125 cu.m/sec capacity and a length of 50 km consisting of open canal, culvert and tunnel.

(3) Ing Diversion Dam: To divert Ing water and to regulate both Kok and Ing waters.

(4) Lao Diversion Canal: To connect Ing diversion dam and Ing-Yot tunnel with a capacity of 175 cu.m/sec and a length of 12.4 km.

(5) Ing-Yot Tunnel: Diversion tunnel to link Ing river to Yot river with a capacity 175 cu.m/sec and a length of 50 km excluding 7 inclined shafts of 17 km.

(6) Yao Flood Control Dam: To control floods from upper Yao basin to mitigate flood damage along Yao river with a storage capacity of 35 MCM.

(7) Yao River Training Works: Improve Yao river to let flow design discharge of 200 cu.m/sec in upper and 400 cu.m/sec in lower reaches.

2.5 Project Cost and Project Evaluation

The project cost is estimated at 47,600 million Baht for the water diversion plan and 55,600 million Baht if the cost for consolidation of irrigation system in the Phitsanulok left bank area (Stage II area) is included. The project benefit including incremental benefits from irrigated agriculture, municipal and industrial water supply and hydro-power generation accounts for 8,700 to 10,600 million Baht per annum according as water use plans. The project economy shows the EIRR value of exceeding 13%.

3 Necessity and Viability of Kok-Ing-Nan Water Diversion Project

Economic activities in the Chao Phraya basin, especially in the delta area, will be largely restricted by the water shortage problems and as a result the socio-economic growth in Thailand will be stagnant in future. It is judged at the present phase that the Kok-Ing-Nan water diversion project among various transbasin water diversion projects ever studied will have every possibility of realization for its implementation. Under this situation, Thai Government issued the Official Notice to commence the feasibility study on the Kok-Ing-Nan water diversion project to the Mekong Joint Committee and provided the large scale budget of 150 million Baht for the conceptual planning and feasibility studies of the proposed project in 1993, being carried out at present by RID.

The proposed project is judged to be economically feasible with the EIRR value of exceeding 13% and RID is, with its budget size, considered to be the proper agency for smooth and successful implementation of the proposed project. Construction of the long distance tunnel, the most difficult work among the proposed project facilities, could be implemented by international competent contractors.

Since there exist impacts on the natural environment on the diversion routes or at any local places, environmental mitigation measures should be carefully planned and implemented taking into account the watershed management rules provided in Thailand. On the other hand, the irrigation development projects to be implemented in association with the proposed water diversion project will contribute to a great extent to the economic growth of the Kok and Ing river basins, and therefore it is necessary to make every effort to obtain the consent and participation of the rural inhabitant in the project area.

The Study on the Kok-Ing-Nan Water Diversion Project
Summary.....Conceptual Planning Study

Table of Contents

CONCEPTUAL PLANNING STUDY

CHAPTER 1 NECESSITY OF KOK-ING-NAN WATER DIVERSION PROJECT

1.1 Necessity of Additional Water in Chao Phraya Basin

(1) Background of Agriculture and Socio-Economy

The Chao Phraya river basin covers most of the northern and central regions of Thailand having a large watershed area of 158,000 sq.km (31% of the country land area) and the population of 22 million (40% of the national population). The basin is generally recognized as the most important area in the country in view of the national economy since it has achieved the successful agricultural and socio-economic development as briefed below, as derived from proper utilization of land resources extending over the central plateau and the lower delta area and of water resources of the Chao Phraya river.

(a) Agriculture in the Basin

The basin has a bulk and fertile farm land of 5.9 million ha (25% of national farm land area) yielding a high agricultural productivity as shown in the following table, and has long been the most important base in the country to support the national food security as well as to contribute for export of agricultural product.

Item	Production (10^3ton)	% in National Production
Rice	9,500	45
Maize	2,100	55
Sugarcane	2,200	44
Soybean	400	75
Milk & Meat Cow	2,300	40
Swine	2,300	40
Inland Fish	83	75

In particular in the whole basin, the lower Nan basin and the Chao Phraya delta area, which are the beneficial areas to receive waters to be diverted through the proposed project, occupy a large potential farmland and considered as a core of agricultural production.

The production of inland fishery in the delta area reaches as high as 58,000 tons which corresponds to 70% of the total production in the whole Chao Phraya basin.

(b) Socio-Economy

The urban and industrial areas in the Chao Phraya basin have shown a rapid development in recent years, as a result GDP in the basin has reached a high value of 1,750 billion Baht (US$ 70 billion) which is equivalent to the per capita value of 79,000 Baht or US$ 3,200, taking up its position to a higher level not only in Thailand but also among the southeastern Asian countries. The economy of the Chao Phraya delta involving the Bangkok Metropolis, satellite cities and industrial zones, in particular, has been remarkably levelled up as indicated by its GDP of 1,520 billion Baht (US$ 60 billion) or per capita GDP of 121,000 Baht (US$ 4,800), which cover 87% of the whole GDP in the basin. This trend economic growth is expected to continue toward 21' st century with a projection of over US$ 10,000 of per capita GDP in the delta area in the year of 2006 and US$ 20,000 in 2016.

(2) Limited Water Resources

Water resources in the Chao Phraya river system are summarized based on available river runoff records in the past 20 years, as shown in Table-1. The average annual amount of water resources in the basin is estimated at about 33,000 MCM in the entire basin, which is further divided into 22,000 MCM in the basin upstream of the Chainat barrage (upper basin) and 11,000 MCM in the lower basin downstream of the barrage (delta area). The annual amount of 33,000 MCM is equivalent to 210 mm in terms of the specific runoff yield, 1,500 cu.m of per capita amount or 5,600 cu.m per ha of agricultural land, showing the lowest value as compared with those either in other basins in Thailand or in other regions in southeast Asian countries. Furthermore, 80% to 85% of annual runoff concentrates only in wet season and therefore river water in dry season is very scarce.

Runoff characteristics of the river system observed at major control points in the Chao Phraya basin is given in Table-2 and schematic flow diagrams of river system in normal and dry years are illustrated in Figures 1 and 2. As is clear in these figures, the

average dry season runoff of 6,390 MCM of the Chao Phraya river at the Chainat barrage decreases to 3,390 MCM in dry years causing serious constraints in water use especially in the delta area.

In the Chao Phraya delta, the most important area for economic development in Thailand, volume of available water resources is as small as 610 cu.m/capita or 3,600 cu.m/ha. Accordingly water supply for irrigation, domestic, municipal and industrial uses in the delta area depends on runoff contribution from the upper basin, especially from the Nan and Ping river basins. The Sirikit dam on the Nan river and Bhumibol dam on the Ping river have been so operated as to cover the water demand in the delta area. Contribution of both dams to the delta area is, however, quite insufficient because of lack of inflow into reservoir as explained below.

(3) Water Shortage Condition

(a) Water Shortage at Sirikit and Bhumibol Dams

Current status of operation based on the actual result during the past 20 years since 1974 for the Sirikit reservoir with the active storage capacity of 6,660 MCM and the Bhumibol reservoir with 9,660 MCM is summarized as shown in Tables 3 and 4. Reservoir storages at the end of each month are also visualized together with existing operation rule curves as given in Figures 3 and 4. As is clear in the said tables and figures, both reservoirs have not been filled with water up to the designed full level during the past 20 years due to short of inflow, except two flood years occurred in 1975 and 1995. As a consequence, reservoirs usually present large empty space for storage at the end of wet season that in turn reduces volume of water to be released from reservoir in the successive dry season. Such dry season outflows from reservoirs are considerably small as compared with their storage capacities as explained below;

(Unit: MCM)

Item	Sirikit Reservoir		Bhumibol Reservoir	
	Normal Year	Dry Year	Normal Year	Dry Year
Reservoir Inflow	5,120	3,240	5,250	3,700
Empty Volume at End of November	2,700	5,000	4,300	7,100
Dry Season Outflow	2,720	1,640	3,020	2,180

Influenced by these small outflows from both reservoirs, the flow of Chao Phraya river at the Chainat barrage located at the entrance to the delta area is also as small as 6,000 MCM in normal years and 3,400 MCM in dry years which are equivalent respectively to 30% and 15% of the average annual runoff of 22,000 MCM at this point. In order to fill both reservoirs with water at the end of wet season and as a result to increase dry season outflow for downstream uses, the Thai Government has studied since 1980s a number of alternative water diversion plans to import excess water from river basins where water is abundant into both reservoirs.

(b) Water Shortage in Existing Phitsanulok Project Area

The Sirikit reservoir was so proposed originally as to cover not only the existing Phitsanulok irrigation project area lying on the right bank of the Nan river and the Chao Phraya delta area but also the Uttaradit irrigation area and the Phitsanulok left bank area. However, development of the Uttaradit and Phitsanulok left bank area has been suspended due mainly to lack of inflow into the Sirikit reservoir.

The existing Phitsanulok irrigation area has been receiving sufficient water in wet season from the Sirikit reservoir and wet season paddy is cultivated there showing the irrigation intensity of 90%. On the contrary in dry season, irrigation intensities are as low as 35% in normal years and 15% to 20% in dry years because of limited outflow from the Sirikit reservoir. As a result farmers in the area are placed under insecure farming conditions in dry season.

Correlation among the Sirikit storage at the end of wet season, volume of water diversion at the Naresuan barrage and wet and dry season cropping areas are as shown in Figure-5. In the large flood year of 1995 when the Sirikit reservoir was restored to its full level and released rich dry season outflow downstream, as a result, the dry season irrigation intensity in the area reached the highest value of 90% ever recorded.

(c) Dry Season Water Shortage in Delta Area

The existing irrigation area in the Chao Phraya delta is about 1.2 million ha consisting of paddy area of 900,000 ha and other areas of 300,000 ha for upland crops, orchard, vegetable and fish ponds. As shown in Figure-6, irrigable area in the delta has been utilized for paddy cultivation with irrigation intensity of 90% to 95% in wet season receiving sufficient water from the Chao Phraya river at Chainat barrage, however in dry season irrigation intensities are as small as 35% in normal years and 20% in dry years due to lack of water.

The increase of various food demands in the Bangkok Metropolis, satellite cities, industrial estates and semi-urban areas in the delta has caused expansion of plantation for various upland crops, orchard and vegetables, and this tendency would continue from now on indicating that the dry season water will be required more and more in future.

(d) Shortage of Municipal and Industrial Water

Water demand for municipal and industrial uses in Bangkok Metropolis and surrounding urban and industrial areas has increased year by year resulting the following problems caused by the shortage of water;

- Ground subsidence in the Bangkok Metropolitan area caused by overpumping of groundwater
- Downstream release of Chao Phraya river water at the Chainat barrage, which is designed to be at least 100 cu.m/sec, has decreased to 70 to 90 cu.m/sec in dry months from January to April, as shown in Figure-7, due to shortage of dry season flow at the barrage. Saline problem caused by sea water intrusion during high tide period and water pollution due to sewage from cities and industrial zones have taken place in recent years.

It is therefore necessary to release designed amount of water downstream at the barrage in dry season in order to mitigate negative environmental impact in and around the river system.

(4) Agricultural Development Policy

The most important agricultural development policy of Thai Government is to promote the crop diversification program. This development policy was first set up in the Sixth National Economic and Social Development Plan (1987-1991), emphasized in the Seventh Plan (1992-1996) and further progress will take place in the Eighth Plan. The crop diversification program in Thailand will be strongly promoted in the future supported by the following background and reasons;

(a) Effective Use of Farmland

Farmland area in Thailand has expanded by means of clearing forest area and converting it to farmland with a rapid increase from 18 million ha in 1970s to about 21 million ha at present, while the forest area has decreased remarkably to 13.5 million ha at present from 21 million ha in 1970s. Expansion of farmland in this manner is now prohibited by the Government for the purpose of preserving the forest area as well as watershed environment. Accordingly, the Thai Government intends to expand the second crop cultivation in dry season in addition to wet season paddy plantation aiming at effective utilization of existing farmland and also increased agricultural productivity.

(b) Lack of Water Resources in Dry Season

As mentioned previously in paragraphs (2) and (3), water resources in dry season is quite limited. It is therefore necessary to convert dry season paddy plantation which consumes large amount of water to diversified upland crops such as maize, soybean, orchard, vegetable, etc in order to use effectively the limited irrigation water in dry season.

(c) Job Creation and Farmers' Income Generation

It is necessary, instead of mono-culture of paddy plantation, to introduce diversified crops as the second crops after wet season paddy also from standpoint of farmers' job creation and income generation in dry season.

(d) Increasing Food Demand

Various food demands have increased largely in not only urban and semi-urban area but also rural area induced by successful urban and industrial development and increasing income in both urban and rural areas. Accordingly, various demands for agricultural product including upland crops, orchard, vegetable, livestock and fishery have been increasing rapidly and widely in the country. Demand and supply of these product will further expand in future by means of development of agricultural industries including food processing and storage in Thailand.

Under the promotion policy of crop diversification, cropped area in 10 year period has changed as given in the following table. In the Chao Phraya basin and in particular in the delta area, the paddy area has largely decreased while the area for other crops increased.

(Unit: 10^3 ha)

Crops	Whole Country			Chao Phraya Basin			Delta Area		
	1981	1992	Rate 92/81 (%)	1981	1992	Rate 92/81 (%)	1981	1992	Rate 92/81 (%)
Paddy	11,760	11,100	94	3,730	3,210	86	1,600	1,310	82
Upland Crops	4,380	5,250	120	1,610	1,920	119	480	490	102
Fruits	1,830	3,340	183	190	390	201	80	140	175
Vegetables	50	140	280	20	60	280	10	20	200
Others	1,390	1,300	94	280	310	111	90	110	122
Total	19,410	21,130	109	5,830	5,890	101	2,260	2,070	92

In order to accelerate the crop diversification program in the future, the key factor is to increase available water in dry season and to use it most effectively.

(5) Projected Water Demand

The NESDB prepared the report on the Water Resources Development for study of available water resources and water demand, classifying the whole country into 25 major river basins and 264 small sub-basins. The water demands in the Chao Phraya basin based on the said report are summarized as shown in Table-5. Water demand for the delta area is not

clearly described in the said report, and then analysis was made by JICA Team based on the actual volume of water diverted from the Chao Phraya river at Chainat barrage to the delta area, which includes not only irrigation water but also waters for domestic use in rural area, navigation, fishery and sea water intrusion prevention.

(a) Irrigation Water Demand

- Irrigation water demand in the whole Chao Phraya basin is estimated at about 20,300 MCM at present (1993) and 27,400 MCM in future (2016) occupying the largest portion or 80% of all water demand including domestic, municipal and industrial supply. In the delta area, irrigation demand reaches especially large amount of 11,600 MCM at present and 13,500 MCM in future.
- In the Nan and Ping basins, important source of water for the delta area, the present irrigation water demand is estimated at 5,300 MCM which will increase largely to 8,300 MCM in future. Accordingly, water use in the delta area in future will be influenced to a great extent by reduction of surplus water from both upstream basins.
- The unit water requirement for irrigation is evaluated as shown below;

Item	Nan	Yom	Wang	Ping	Sakae Krung	Pasak	Delta	Total
1. Present Irrigation (1993)								
(1) Area (1,000 ha)	278	132	68	260	92	121	1,281	2,232
(2) Total Irrigation Water (MCM)	2,871	859	487	2,428	1,161	835	11,620	20,261
(3) Unit Water Demand (cu.m/ha)	10,300	6,600	7,200	9,300	12,600	6,900	9,100	9,100
1. Present Irrigation (1993)								
(1) Area (1,000 ha)	437	285	138	482	126	179	1,315	2,962
(2) Total Irrigation Water (MCM)	4,360	2,066	813	4,344	1,161	1,114	13,500	27,358
(3) Unit Water Demand (cu.m/ha)	10,000	7,200	5,900	9,000	9,200	6,200	10,300	9,200

Note: The future water demand in the Nan basin does not include water requirements in the Uttaradit and Phitsanulok left bank areas.

- In the Yom, Wang and Pasak basins, supplemental irrigation for wet season paddy is the main water use in water resources development plans due to insufficient river runoff in the basin. As a result, the cropping intensity for second crops without dry season paddy is as small as 10% to 20%. In the basins, the unit irrigation requirement is assumed as;

Wet Season Paddy (6,500 cu.m/ha x 90%) + Dry Season Second Crops (6,000 cu.m/ha x 10 to 20%) = 6,500 to 7,100 cu.m/ha/year

- In the Nan, Ping and delta basins where there are relatively rich water at present, the cropping intensity of 100% for wet season paddy, 20 to 30% for dry season paddy and 15 to 20% for dry season upland crops are combined to assume the unit irrigation requirement as;

  Wet Season Paddy (6,500 cu.m/ha x 100%) + Dry Season Paddy (10,000 cu.m/ha x 20 to 30%) + Dry Season Upland Crops (7,000 cu.m/ha x 15 to 20%) = 9,600 to 10,900 cu.m/ha/year

(b) Other Water Demand

- Domestic water for towns and villages in rural area is supplied mainly from small tributaries in each basin.
- Municipal water for provincial capital cities such as Phitsanulok, Uttaradit and Phichit in the lower Nan basin and the Bangkok Metropolis and surrounding satellite cities in the Chao Phraya delta area is supplied from the mainstream of the Nan and Chao Phraya rivers. The population toward 21 century in the delta area is projected with a moderate growing rate, however, the per capita consumption of water will increase as the income of inhabitant increases and various activities in urban area expand. The municipal water demand in the delta area to be supplied from the Chao Phraya river is projected at 1,860 MCM in 2016 against the present demand of 1,200 MCM, according to the BMA's estimate.
- Water demand for industry and tourism in the delta area will also increase to 1,100 MCM in 2016 from the present demand of 550 MCM.

(6) Water Balance in Basins

(a) Upper Chao Phraya Basin

Available water resources in the upper Chao Phraya basin are presented in

Table-1. Water volumes in each river basin are such values that are estimated based on the observed river runoff data in the past 20 years. Accordingly they have already been reduced because of upstream water diversion for irrigation and other purposes. The potential water resources in basins after consideration of upstream water diversion are assumed as follows;

Present Condition (Unit: MCM)

	Nan	Yom	Wang	Ping	Sakae Krung	Total
River Runoff	9,160	2,960	1,100	7,970	1,300	22,490
Upstream Water Diversion	2,970	930	510	2,560	1,170	8,140
Potential Water Resources	12,130	3,890	1,610	10,530	2,470	30,630
Rate of Water Use (%)	24.5	23.9	31.7	24.3	47.4	26.6

Out of the total potential water resources of 30,630 MCM, annual amount of 8,140 MCM is utilized within the upper Chao Phraya basin, while remaining surplus of 22,490 MCM is released downstream forming the major source of water in the lower Chao Phraya basin. Water demand is projected to increase in each sub-basin in the project target year of 2016 as given in Table-5, and as a consequence available amount of water resources in the lower Chao Phraya basin will decrease as in the following table.

Future Condition (Unit: MCM)

	Nan	Yom	Wang	Ping	Sakae Krung	Total
Potential Water Resources	12,130	3,890	1,610	10,530	2,470	30,630
Water Demand	4,500	2,160	840	4,530	1,180	13,210
Surplus	7,630	1,730	770	6,000	1,290	17,420
Rate of Water Use (%)	37.1	55.5	52.2	43.0	47.8	43.1

The water using rate in the Yom, Wang and Sakae Krung basins reaches as high as 50%. It is rather difficult to achieve this order of water utilization without storage capacity of a large scale dam. Surplus water from these three basins in future will decrease to 3,800 MCM from the present surplus of 5,340 MCM if the projected water demands are used within basins.

Although the water using rates in the Nan and Ping basins are relatively high showing around 40%, a large surplus water of 13,600 MCM will be still available in future for utilization in the delta area.

(b) Lower Chao Phraya Basin

The surplus water from the upper Chao Phraya basin supplemented by the runoff from the Pasak basin is the potential water resources in the lower basin.

Water Balance in the Lower Chao Phraya Basin (Unit: MCM)

	Water Usable in Lower Basin			Water Demand in Lower Basin			Balance
	Surplus from Upper Basin	Pasak Runoff	Total	Lower Chao Phraya Basin	Pasak Basin	Total	
Present (1993)	22,490	3,910	26,400	16,230	930	17,160	9,240
Future (2016)	17,420	3,910	21,330	18,860	1,260	20,120	1,210

- The surplus water of 22,500 MCM is presently available at the Chainat barrage for water uses in the delta area as is shown in Figure-8. It will however decrease in future to 17,400 MCM due to increasing water use in the upstream river basins.
- Water demand in the lower basin also increases from 17,160 MCM at present to 20,120 MCM in future.
- In many basins, the future increasing water demand will take place in tributary sub-basin and it will be supplied from its own water resources within the basin. Accordingly only the areas requiring water from the mainstream of major river are the Phitsanulok irrigation project area and the Chao Phraya delta area.
- The water using rates of 65% at present and 94% in future are practically impossible to be achieved unless storage function is accompanied, since evaluation of water availability and demand is based on the annual volume of water which include flood runoff in wet season.
- In the NESDB's 25 River Basin Study, further development of the stage II and III of the Phitsanulok irrigation project is excluded from the proposed project in a long-term development plan, since the development of these areas would

include a negative influence on water utilization in the downstream delta area, unless the transbasin water diversion plan such as the proposed Kok-Ing-Nan project is accompanied.

(7) Assumption of Additional Water Demand in Lower Nan Basin and Delta

(a) Irrigation Water Demand

The water developed by the proposed diversion project can be possibly distributed under gravity system to either existing or newly developed areas along the lower Nan river and in the Chao Phraya delta area, where the following additional water will be required for dry season irrigation;

- For second crops in existing Uttaradit pump irrigation area
  7,000 cu.m/ha x 30,000 ha = 210 MCM
- For second crops in existing Phitsanulok project area
  7,000 cu.m/ha x 30,000 ha = 210 MCM
- For wet season paddy in newly developed Phitsanulok project area
  2,000 cu.m/ha x 120,000 ha = 240 MCM
- For second crops in newly developed Phitsanulok project area
  7,000 cu.m/ha x 50,000 ha = 350 MCM
- For second crops in delta area
  7,000 cu.m/ha x 250,000 ha = 1,750 MCM

Total 2,760 MCM

(b) Municipal and Industrial Water

Additional water demand for the municipal and industrial uses in future is presented in Table-5 or as summarized below;

- For provincial capitals in the lower Nan basin 26 MCM
- For Bangkok Metropolis and others in delta area 1,210 MCM

Total 1,236 MCM

Additional water supply in dry season (50%) 618 MCM

(c) Total Additional Water

The total volume of water to be additionally supplied in dry season for irrigation, municipal and industrial uses accounts for as large as 3,400 MCM, which is equivalent to more than 50% of presently available dry season runoff of 6,000 MCM in the Chao Phraya river at Chainat.

1.2 Water Resources Development in Chao Phraya Basin

(1) Present Water Resources Development

The large, medium and small scale dams have been constructed and under operation mainly for irrigation purpose in Thailand. Table-6 summarizes outline of major large /medium dams including representative notable dams such as Bhumibol (effective storage capacity of 9,660 MCM), Sirikit (6,660 MCM), Mae Ngat (243 MCM) and Mae Kuang (249 MCM). The reservoir water of Bhumibol and Sirikit dams has been supplied to the Chao Phraya delta area mainly for irrigation, municipal and industrial uses, while the other for irrigation purpose in the tributary basins.

Total effective storage capacity of such dams is estimated at 17,200 MCM, of which 95% is occupied by capacities of Bhumibol and Sirikit reservoirs. The reservoir inflow of both dams, however, is about 10,000 MCM, providing the major reason why 7,000 MCM of large empty space of storage exist in both reservoirs at the end of wet season. As a consequence, river runoffs regulated by these existing dams in the Chao Phraya basin accounts for 11,000 MCM or 50% of the total runoff in the basin.

All dams except Bhumibol and Sirikit have no function or contribution to supply excess water in response to the demand in the delta area, being utilized for irrigation and other purposes in tributary basins. The available waters to be supplied in dry season to the delta area are therefore limited to 6,000 MCM in normal years and 3,400 MCM in dry years, all of which are supplied only from Bhumibol and Sirikit dams.

(2) Future Water Resources Development

RID and other governmental agencies in Thailand have set up the future water resources development plan in the Chao Phraya basin since 1980 with the intention of storing more water in wet season and utilizing it during dry season. Table-7 summarizes proposed large and medium scale dams to be implemented in future. Implementation of such large/medium scale dams is, however, being delayed due to social and environmental constraints such as resettlement problem in the reservoir area.

The notable large dams nominated for implementation are the Kaen Sua Ten dam with the effective storage capacity of 1,200 MCM and the Pasak dam with 800 MCM capacity, both of which are relatively small scale when compared with the Bhumibol and Sirikit dams. The total effective storage capacity of all of proposed dams is more or less 4,000 MCM, which would be much smaller to regulate sufficiently wet season runoff in the Chao Phraya basin. Furthermore, the reservoir water will be used mostly for supplemental irrigation of wet season paddy, not allocated to second crops because of large existence of rainfed area for wet season paddy, insufficient inflow into reservoirs and others. Such waters stored in the proposed reservoirs will thus be supplied to irrigable areas in tributary basins, and no contribution to the Chao Phraya delta area will be expected.

Hence the delta area will face the critical water shortage problem when proposed water resources development in the upper basin be progressed in future. For that reason the Thai Government intends to introduce additional water transbasin from river basins where water is left unused to the Chao Phraya delta where water is needed.

1.3 Alternative Transbasin Water Diversion Plan Ever Studied

In order to guarantee the stable water supply for socio-economic and agricultural development in the Chao Phraya basin toward 21 century, the Thai Government has studied various transbasin water diversion plans mainly from the Salawin and Mekong rivers as shown in Figure-9. In total 18 alternative diversion plans have been studied since the early 1980s, however, all plans except the Kok-Ing-Nan diversion plan have been evaluated not or less feasible for project implementation and further surveys and studies have been suspended with reasons as summarized below;

(1) Salawin to Bhumibol Diversion Plans

In total 10 alternative transbasin plans from the Salawin river, the international river flowing down along the national boundary with Myanmar, to the upper Ping basin have been studied aiming at filling the empty space of Bhumibol reservoir with water diverted. All of these alternative plans have been judged less feasible for implementation at the present stage. Major reasons are as follows;

- It is necessary to set up the water agreement between both countries to utilize the Salawin river water.
- The Salawin basin belongs to the area being controlled by the Shan mountain tribe so that particular countermeasures to promote the project will be necessary.
- All plans consist of long tunnels and pumping stations requiring high pumping head of more than 90 m, therefore requiring high construction costs and operation and maintenance costs.

(2) Mekong River to Sirikit and Upper Pasak Diversion

The transbasin diversion plans from the Mekong river to the Sirikit reservoir and the upper Pasak basin were studied in order to fill the empty volume of Sirikit reservoir or to convey Mekong water through the Pasak river to the delta area. All of these plans have been evaluated less feasible to be implemented because of the following reasons;

- Approval of riparian countries through the Mekong River Committee is necessary to utilize the Mekong mainstream water.
- Intake weir to divert transbasin water is needed to be constructed at sites belonging to the Lao PDR or crossing the Mekong river. This construction work should also be approved by the Lao PDR and other riparian countries, and moreover operation of those facilities would inevitably face many difficulties.
- The intake weirs will be influenced by the back water of hydro-power dams such as the Pamon dam at present under planning by the Mekong River Committee.
- Some plans need long tunnels of more than 60 km where construction of access tunnels are quite difficult requiring high construction costs.

(3) Ing-Yom-Nan and Kok-Ing-Yom-Nan Diversion Plan

The transbasin plan was so set up as to pump up the runoff of the Kok and Ing rivers and ultimately the Mekong river water, convey it to the border between the Ing and Yom basins through diversion canals, and release it in the head of the Yom river. The Kaen Sua Ten dam facilitated with a large reservoir capacity of more than 5,000 MCM is required for this plan in order to store the bulk water diverted from the Kok, Ing and Mekong rivers. This transbasin diversion plan was once judged possible to be implemented and feasibility studies were carried out. However the project was canceled already because of significant environmental impact to be caused mainly by construction of the Kaen Sua Ten dam, including resettlement of more than 1,000 households, encroachment of large farmland and forest. At present the Kaen Sua Ten dam has been separated from its original transbasin diversion plan, and shifted from a multi-purpose dam for hydro-power and irrigation to a single purpose for irrigation with reduced reservoir capacity of some 1,100 MCM to regulate the Yom runoff only.

(4) Other Alternative Plans

Although some transbasin water diversion plans from the Mekong basin to the upper Ping basin were studied on desk study level, all plans were already canceled.

1.4 Advantage of Kok-Ing-Nan Water Diversion Plan

The Kok-Ing-Nan transbasin water diversion plan was formulated initially in 1991 under the preliminary study carried out by RID, which concluded the project would be highly possible for implementation. Major advantages of the project are summarized as under;

- The Kok and Ing rivers are large tributaries of the Mekong river but they belong to Thailand territory. In accordance with the Agreement on the Cooperation for the Sustainable Development of the Mekong River, water resources in tributary basin could be easily developed by the sovereign country after notification of development to the Joint Committee organized by riparian countries.
- The Thai Government already notified of the commencement of feasibility study on the Kok-Ing-Nan water diversion plan to the Joint Committee, and the notification

was greatly appreciated by riparian countries.

- The Kok and Ing rivers have abundant runoff of about 7,000 MCM per annum, most of which is currently emptying unused into the Mekong river because only a limited farmland area exists especially in the lower Kok river basin. There is no constraints, therefore, to utilize surplus runoff of Kok and Ing rivers in wet season for the proposed diversion plan.
- The diverted waters are to be once stored in the Sirikit reservoir where some 2,500 MCM of empty space is available at the end of wet season, and released in dry season in response to the request in the lower Nan basin and Chao Phraya delta area.
- Water diversion facility, composed of diversion dams, open canals and tunnels but no storage type facility, would cause less environmental impact due to project implementation.
- The proposed water diversion plan would contribute not only to the water shortage problems in the lower Nan basin and Chao Phraya delta area but also to development of remote rural areas by means of providing the dry season Kok runoff to potential irrigable areas in the Kok, Ing and upper Nan basins.

CHAPTER 2 PROJECT WATER DIVERSION PLAN

2.1 Improvement of Sirikit Reservoir Operation

As mentioned in 1.1 (3) (a), The Sirikit reservoir presents large empty volumes of 2,700 MCM in normal years and 5,000 MCM in dry years at the end of wet season due to lack of inflow into the reservoir, and as a result downstream release from the reservoir in dry season is as small as 2,700 and 1,600 MCM respectively in normal and dry years. To maximize the storage function of the Sirikit dam and in turn to increase reservoir outflow in dry season, the following improvement of reservoir operation will be required;

- The reservoir inflow during wet season in normal and dry years but except flood years should be stored as much as possible by means of reducing wet season outflow used mainly for power generation, in order to restore reservoir storage at the beginning of dry season.
- The Kok-Ing-Nan water diversion plan is to be set up so as to fill the empty volume of the Sirikit reservoir with water diverted from Kok and Ing rivers during wet season.
- The present carrying over volume of 2,000 to 3,000 MCM in the Sirikit reservoir, provided for unforeseen drought especially in early stage of wet season, should be reduced to some 1,000 MCM because the reservoir could receive wet season water diverted from the Kok and Ing rivers. As a consequence, usable storage capacity of 3,600 to 4,600 MCM at present actually achieved would increase to 5,660 MCM, which would in turn increase not only the dry season outflow but also the flood control capacity during wet season.

2.2 Water Diversion Plan from Kok and Ing Rivers

(1) Water Diversion Concept

The Kok and Ing rivers are blessed with rich runoff of 5,000 MCM and 2,000 MCM respectively at the river mouths and 3,800 MCM and 1,700 MCM at the proposed diversion damsites.The concept of water diversion from river runoff is set up as in the followings;

- The wet season runoff of the Kok and Ing rivers is diverted to the head of the Nan river which finally flows into the Sirikit reservoir in order to fill the existing empty volume of storage. Waters are conveyed under gravity throughout the diversion route.
- The Kok river runoff is taken at the Kok diversion dam and conveyed to the Ing river basin through the Kok-Ing diversion channel consisting of open canal, culvert and tunnel.
- The Kok water conveyed through the Kok-Ing diversion channel and the Ing river runoff are regulated at the Ing diversion dam and then conveyed to the Nan basin through the Ing-Yot long tunnel.
- The Ing-Yot tunnel passes through high mountainous area which forms the divide of the Ing and Nan basins and reaches the head of the Yot river, a tributary of the Yao river which finally flows into the Nan river.
- Diverted water flows down the Nan river and finally empties into the Sirikit reservoir.
- In order to minimize the project scale as well as cost between the Kok and Ing rivers, the plan intends to take primarily the Ing river runoff, and the deficit is compensated from the Kok river through the Kok-Ing diversion channel.

(2) Study on Optimum Water Diversion Capacity

The project facility with the following water diversion capacities will be required to fulfill the above objectives;

200 cu.m/sec x 183 days in wet season x 85% ≈ 2,690 MCM
175 cu.m/sec x 183 days in wet season x 85% ≈ 2,350 MCM
150 cu.m/sec x 183 days in wet season x 85% ≈ 2,020 MCM
where, 85% denotes the average rate of water diversion from rivers

Both Kok and Ing rivers keep abundant river flow of 200 to 500 cu.m/sec from the late July through September making possible to fill the above design capacities of 150 to 200 cu.m/sec. However the river discharges decrease to 50 to 150 cu.m/sec during the period from June to early half of July and October to November, providing some empty space of flow in the project facilities. The possible amount of annual water diversion is

simulated based on the daily observation record of river runoff for the past 20 years, combined with design capacities of 200, 175 and 150 cu.m/sec for the Ing-Yot tunnel and 150, 125 and 100 cu.m/sec for the Kok-Ing diversion channel.

The simulated result with various combination of design diversion capacities is given in Table-8, from which the optimum design capacities are taken at 175 cu.m/sec for the Ing-Yot tunnel and 125 cu.m/sec for the Kok-Ing diversion channel, supported by the following reasons;

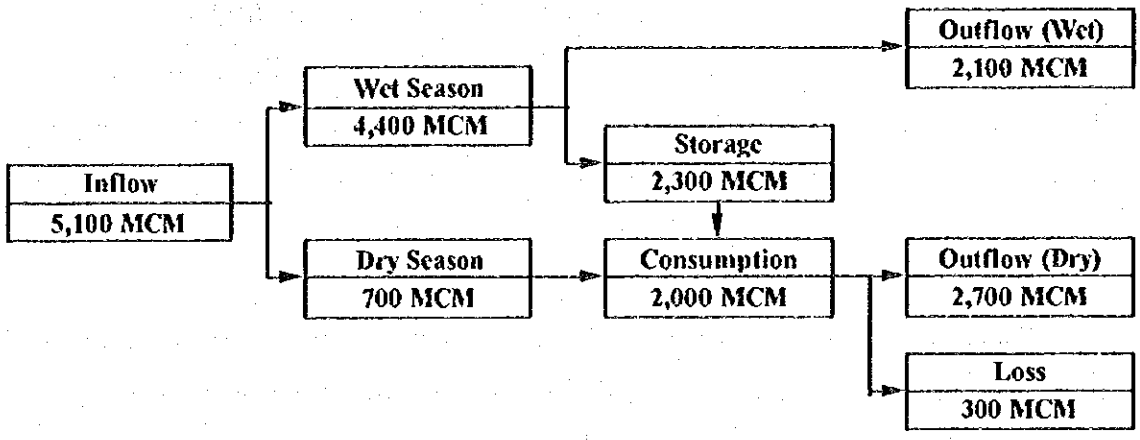
- In case that 150 cu.m/sec is given for the Ing-Yot tunnel capacity, annual effective amount of water diversion is more or less 1,870 MCM, which is slightly short to meet the existing empty space in the Sirikit reservoir.
- In case of 175 cu.m/sec, the volume of diversion reaches 2,000 MCM which is effective and reasonable to fill the Sirikit storage.
- In case of 200 cu.m/sec, the volume of diversion is simulated at 2,010 MCM which is also effective for recovery of reservoir capacity but incremental volume of diversion is not satisfactory as compared with that for 175 cu.m/sec case if increasing construction cost is taken into consideration.
- The comparison study showed that the lowest construction cost per unit volume of water diverted was for the 175 cu.m/sec case.

The operation of the Sirikit reservoir is also simulated employing the conditions given for the 175 cu.m/sec case and taking the carrying over capacity at 1,000 MCM. Consequently the dry season outflow from the Sirikit reservoir reaches as large as 5,100 MCM on an average. This increasing outflow of 2,400 MCM from existing achievement is equivalent to more than 50% of presently available water diversion of 4,180 MCM at the Chainat barrage, and is really very important and valuable to dissolve water shortage problem to be caused by the future socio-economic development in the Chao Phraya delta area.

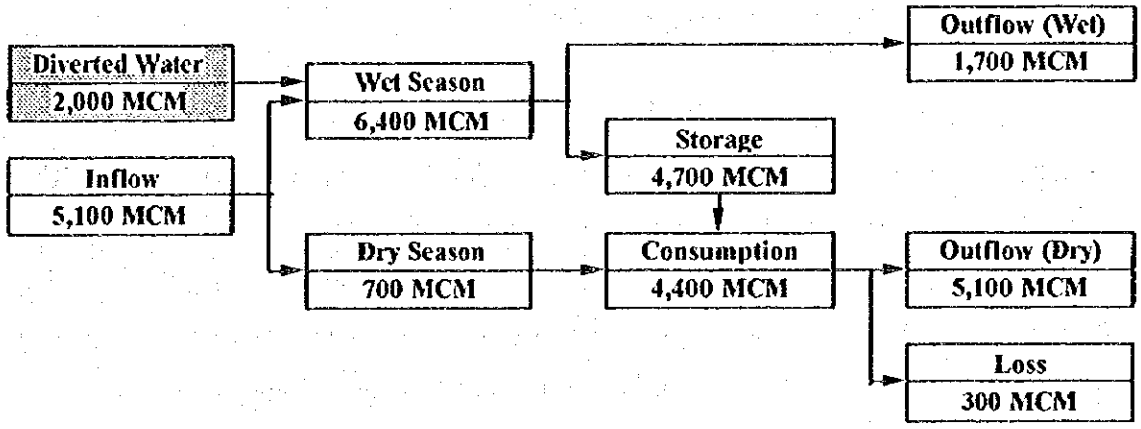
Dry Season Outflow of Sirikit Reservoir (Unit: MCM)

	Present Condition (1)	With Project (2)	Increase (3)	Rate (2)/(1)
Average	2,700	5,100	2,400	189%
Dry Year (1993)	1,120	3,840	2,720	343%

Existing Condition without Project



Proposed Condition with Project



2.3 Water Use Plan for Dry Season Irrigation in Lower Nan and Delta

The beneficial area which receives additional dry season water of 2,400 MCM from the Sirikit reservoir will be irrigated agricultural area of either existing or newly developed as well as urban and industrial area extending along the lower Nan river and over the Chao Phraya delta area, because the Sirikit outflow can't be distributed to other areas or basins unless pumping system is employed.

(1) Additional Water for Municipal and Industrial Use

As mentioned in 1.1 (7), additional water demand for municipal and industrial uses in the Nan and delta area is 1,240 MCM per annum involving dry season demand of 600 MCM (50%). Out of 1,700 MCM of outflow from the Sirikit reservoir during wet season,

600 MCM is allocated to municipal and industrial purposes after utilized for power generation. The remaining 1,100 MCM together with about 4,600 MCM of side flow from the catchment is used for supplemental irrigation as well as domestic purpose in the areas downstream of the reservoir. In this connection, it is preferable to control the Sirikit outflow in wet season by allocating more water in the early and late period while less water during August and September when side flows are abundant.

The priority is also to be given in dry season to allocate water demand of 600 MCM from additionally available water of 2,400 MCM taking into account the importance of urban and industrial development in the delta area.

(2) Additional Water for Irrigation Use

The remaining 1,800 MCM after subtraction of 600 MCM from additionally available water of 2,400 MCM could be allocated for irrigated agricultural purpose. Three alternative plans of irrigated agricultural development aiming at expansion of cultivation area and product mainly of second crops are proposed in accordance with the agricultural development policy to accelerate crop diversification program. This conceptual planning level study should however be upgraded during the course of the feasibility study.

(a) Second Cropping Plan Except Dry Season Paddy in the Existing Irrigated Agricultural Area (Plan A)

In the existing irrigation areas of 108,000 ha in the Phitsanulok project area and 1,190,000 ha consisting 26 large scale irrigation projects in the Chao Phraya delta area, wet season paddy has been cultivated with irrigation intensity of 90% to 100%. The intensity of dry season irrigation for dry paddy and other second crops is however limited to 30% to 35% due to insufficient irrigation water in dry season. This plan A aims to introduce dry season irrigation for second crops mainly composed of upland crops, orchard and vegetable but excepting dry season paddy, taking into account the followings;

- The agricultural development policy of Thailand intends to promote crop diversification program aiming at increasing second crop cultivation area and

production. The program accelerates conversion of farmland use and crops from dry season paddy to various upland crops for the purpose of effective use of limited farmland and water resources and in response to increase of various food demands including processed food in the country and expansion of export of agricultural products.

The complete irrigation systems up to on-farm level facilities have already been completed and operated by skillful farmers in both existing irrigation areas hence requiring no additional investment. Water users' groups and agricultural cooperatives have already been established in the area and therefore dry season water introduced will be used properly and effectively achieving the high agricultural productivity.

(b) Second Cropping Plan Including Dry Season Paddy in the Existing Irrigated Agricultural Area (Plan B)

The plan B is altered from the plan A with increase of irrigation for dry season paddy of 91,000 ha in the existing Phitsanulok and delta area. The extent of second crop area to be irrigated by additional water is estimated at 224,000 ha with reduction of 46,000 ha from the plan A, because of large consumption of irrigation water by dry season paddy.

(c) Second Cropping Plan Including New Phitsanulok Area (Plan C)

The Stage II of Phitsanulok project area lying over the left bank of the Nan river has been left undeveloped until now due to insufficient water from the Sirikit reservoir. In order to establish the balanced agricultural development and to promote income generation for both bank areas, the plan C is formulated to irrigate the left bank area of 120,000 ha in both wet and dry seasons in addition to irrigation in the existing Phitsanulok right bank area as well as in the Chao Phraya delta area. In the right bank area, 120,000 ha of farmland is presently cultivated in wet season under rainfed condition and could be improved if supplemental irrigation water is supplied by the proposed project in early stage of paddy growth in June and July, since there exists sufficient amount of water for irrigation during the period from August to October. The developed area in the plan C would reach 335,000 ha including the wet

season paddy area of 120,000 ha to be newly developed on the left bank of the Nan river.

The details of cropping plans A, B and C so formulated are given in Tables 9 and 10.

2.4 Water Use Plan for Dry Season Irrigation in Kok and Ing Basins

As shown in the following table, there still remains considerable amount of water in the Kok river even in dry season. On the contrary, water resources of Ing river especially during dry season are quite limited.

Runoff	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Normal Year (MCM)	241	179	118	97	86	130	851
Normal Year (cu.m/sec)	90	67	49	36	36	49	54
Dry Year (MCM)	90	60	35	20	20	25	255
Dry Year (cu.m/sec)	34	22	14	7	8	9	16

A large agricultural area of about 100,000 ha is lying on the flat alluvial plain along the Ing river and utilized for wet season paddy cultivation under rainfed condition. However the area is placed under severe dry situation without any vegetation because of no or less rainfall and stream flow in dry season. In parallel with the proposed Kok-Ing-Nan water diversion project, formulation and implementation of irrigated agricultural projects for dry season cultivation are strongly requested by the local inhabitant of the Ing basin. Judging from the availability of dry season water in the Kok river, about 30,000 ha of second crop area can be irrigated as evaluated in the following table;

Crops	Irrigable Area (ha)	Unit Water Demand (cu.m/ha)	Irrigation Water (MCM)
Maize	10,000	4,000	40
Soybean	6,000	5,000	30
Peanut	6,000	4,000	24
Fruits	6,000	11,000	66
Vegetable	2,000	6,000	12
Fishery	2,000	12,000	24
Total	32,000		196

2.5 Water Use for Hydro-Power Generation of Sirikit Dam

At the Sirikit dam, a hydro-power plant with the capacity of 500 MW (125 MW x 4 units) has been installed to generate the annual energy output of 1,200 GWh. However due to insufficient reservoir outflow and low water level in the reservoir, the average annual energy produced during the past 20 years was merely 820 GWh or 68% of the designed output. This situation of energy output will be highly improved to produce about 1,200 GWh brought by increased outflow from and water head in the reservoir.

2.6 Possibility of Supplying Additional Diversion Water

As explained in 1.1 (7), the increase of water demand in dry season in the lower Nan basin and Chao Phraya delta area in future is estimated at about 3,400 MCM, which can't be covered sufficiently by the proposed water of 2,400 MCM to be released from the Sirikit reservoir during wet season. The deficit amount of 1,000 MCM could however be supplied when the following countermeasures are taken into consideration;

(1) Kok Hydro-Power Dam Plan

Supported by the Ministry of Energy of Myanmar and DEDP of Thailand, a plan to construct the Kok hydro-power dam through BOT on the Kok river upstream in Myanmar territory is under going. The annual runoff at the proposed damsite is 2,100 MCM and the proposed effective storage capacity is 1,650 MCM. The above runoff of 2,100 MCM will be completely controlled by the dam, as a result, about 1,000 MCM of outflow will be released downstream the Kok river during dry season. This surplus dry season water can be diverted from the Kok river at the Kok diversion dam and conveyed finally to the Sirikit reservoir through the proposed diversion channel without requiring any additional investment. It is not necessary to store this dry season water in the reservoir, but immediately released downstream for use in the lower Nan basin and Chao Phraya delta area.

(2) Pumping Plan at Lower Ing River

Since the Ing river forms gentle river bed slope of less than 1 to 10,000 for a distance

between the proposed diversion dam and the river mouth, water head difference between these two points is 15 m during Mekong river's high water season and 25 m during low water season. With side flows from its lower tributary sub-basins, the Ing river maintains high river water levels under influence of back water from the Mekong river. Accordingly, the Ing river water can be diverted from somewhere in its lower reaches and conveyed to the Sirikit reservoir via proposed Ing diversion dam and through the Ing-Yot tunnel with a lift of 20 to 30 m by a pumping system.

If a pumping capacity of 50 cu.m/sec is installed, the water of about 300 MCM could be additionally supplied to the Sirikit reservoir during wet season by effectively utilizing empty capacity of the Ing-Yot tunnel which can't be filled with water diverted from the Kok and Ing rivers in June, July, October and November. Moreover, if dry season diversion of the Mekong river would be accepted by riparian countries, about 1,000 MCM of Mekong water could be diverted in dry season by this pumping system.