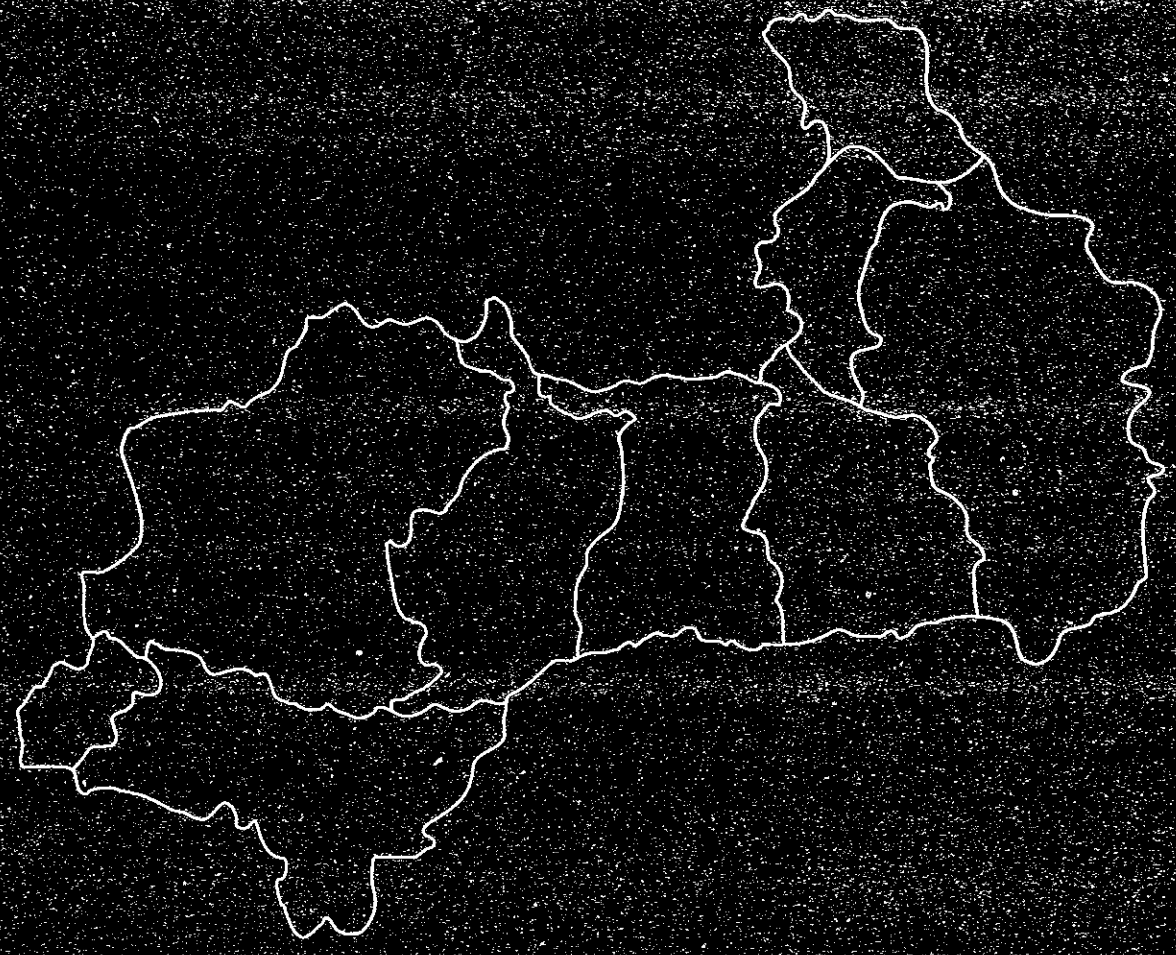
JAPAN INTERNATIONAL COOPERATION AGENCY

THE GOVERNMENT OF THE KINGDOM OF THAILAND
NATIONAL ECONOMIC AND SOCIAL DEVELOPMENT BOARD

THE STUDY ON THE REGIONAL DEVELOPMENT PLAN FOR THE LOWER NORTHEAST AND THE UPPER EAST REGIONS IN THE KINGDOM OF THAILAND

FINAL REPORT



6. Water Resources

September, 1993

NIPPON KOEI CO., LTD.

JAPAN INTERNATIONAL COOPERATION AGENCY

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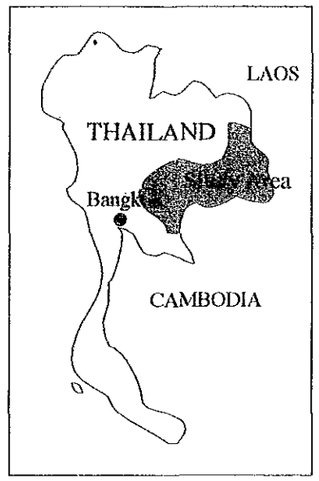

LEGEND

- International Boundary
- Provincial Boundary
- 202 National Highway (Number)
- Railway
- Airport
- National Park
- Major Tourism Attraction
- Major City (Population)
  - 100,000~500,000
  - 50,000~100,000
  - 25,000~ 50,000
  - 10,000~ 25,000

N

SCALE

0 6.5 32.5 65.0

km

Laos

Khon Kaen

Bua Yai

Nakhon Ratchasima (Khorat)

Sung Noen

Sikhiu

Dan Kwian

Pak Tong Chai

Pak Chong

Chok Chai

Khao Yai

Wang Takrai N.P.

Tha Plan

Phimai

Satuk

Buri Ram

Nang Rong

Prakhon Chai

Phanom Rung

Muang Tam

Surin

Prasat

Prasart Kamphaeng Yai

Si Sa Ket

Mukdahan

Huai Huat

Savannakhet

Yasothon

Amnat Charoen

Ubon Ratchatani

Pha Taem

Warin Chamrap

Phibun Mangsahan

Kaeng Tana

Chon Mek Border Point

Det Udom

Kantralak

Khao Phra Viharn

Phu Chong Nayoi

Nakhon Nayok

Prachin Buri

Kabin Buri

Sa Kaeo

Aranyaprathet

Bangkok Metropolitan Region

Eastern Seaboard

Phnom Penh

Cambodia

Note : Basic elements of this map composition were derived from the Geographic Information System (GIS) Database developed in the study.

Location Map of Study Area

The Study on the Regional Development Plan for the Lower Northeast and Upper East Regions in the Kingdom of Thailand

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Abbreviations

AAT	Airports Authority of Thailand [MOTC]
ADB	Asian Development Bank
AED	Agricultural Extension Department [MOAC]
BAAC	Bank for Agriculture and Agricultural Cooperatives [MOF]
BMA	Bangkok Metropolitan Area
BMR	Bangkok Metropolitan Region
BOB	Bureau of the Budget [OPM]
BOI	Board of Investment [OPM]
BOT	Bank of Thailand
CAO	Changwat Administration Organization [MOIT]
CAT	Communication Authority of Thailand [MOTC]
CDD	Community Development Department [MOIT]
CPD	Cooperatives Promotion Department [MOAC]
CRDP	Coordinating Committee for the Royal Development Projects
DFPOT	Dairy Farming Promotion Organization of Thailand [MOAC]
DOA	Department of Aviation [MOTC]
DOH	Department of Highways [MOTC]
DOLA	Department of Local Administration [MOIT]
DRDC	District Rural (or Regional) Development Committee
DTEC	Department of Technical and Economic Cooperation [OPM]
EGAT	Electricity Generating Authority of Thailand [OPM]
ESBC	Eastern Seaboard Committee [NESDB]
ERTAT	Expressway and Rapid Transit Authority of Thailand [MOIT]
ETOT	Express Transportation Organization of Thailand [MOTC]
FIO	Forest Industry Organization [MOAC]
GCST	Government Cold Storage Organization [MOAC]
IEAT	Industrial Estate Authority of Thailand [MOID]
IFCT	Industrial Finance Corporation of Thailand
IPD	Industry Promotion Department [MOID]
ITD	Internal Trade Department [MOC]
JICA	Japan International Cooperation Agency
JPPCC	Joint Public / Private Consultative Committee [BOI]
LDD	Livestock Development Department [MOAC]
LNE-UE	Lower Northeast - Upper East
LTD	Land Transport Department [MOTC]
MOAC	Ministry of Agriculture and Cooperatives
MO	Marketing Organization [MOIT]
MOC	Ministry of Commerce
MOD	Ministry of Defence
MOE	Ministry of Education
MOF	Ministry of Finance
MOFF	Marketing Organization for Farmers [MOAC]
MOID	Ministry of Industry
MOIT	Ministry of Interior
MOPH	Ministry of Public Health
MOTC	Ministry of Transport and Communications
MOUA	Ministry of University Affairs
MSTE	Ministry of Science, Technology and Environment
NEB	National Environment Board [MSTE]
NESDB	National Economic and Social Development Board [OPM]

NESDC	National Economic and Social Development Committee
NHA	National Housing Authority [MOIT]
NRDC	National Rural (or Regional) Development Committee
OARD	Office of Accelerated Rural Development [MOIT]
OCSC	Office of the Civil Service Commission [OPM]
OECF	Overseas Economic Cooperation Fund (Japan)
OPM	Office of Prime Minister
OPP	Office of Policy and Planning [MOIT]
PDA	Provincial Development Committee
PEA	Provincial Electricity Authority [MOIT]
PRDC	Provincial Regional Development Committee
PRDCC	Provincial Rural (or Regional) Development Coordination Center
PWA	Provincial Waterworks Authority [MOIT]
PWD	Public Works Department [MOIT]
PWO	Public Warehouse Organization [MOC]
RFD	Royal Forest Department [MOAC]
RID	Royal Irrigation Department [MOAC]
SNRDC	Office of the Secretary to the National Rural (or Regional) Development Committee
SRT	State Railway of Thailand [MOTC]
TAT	Tourism Authority of Thailand [OPM]
TCPD	Town and Country Planning Department [MOIT]
TOT	Telephone Organization of Thailand [MOTC]
TRDC	Tambon Rural Development Committee
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Organization
USAID	United State Agency for International Development

Abbreviation of Measures

Length

mm	=	millimeter
m	=	meter
km	=	kilometer

Area

ha	=	hectare
km^2	=	square kilometer

Volume

l	=	lit = litre
m^3	=	cubic meter
MCM	=	million cubic meter

Weight

mg	=	milligram
g	=	gram
kg	=	kilogram
t	=	ton = MT = metric ton

Time

sec	=	second
hr	=	hour
d	=	day
yr	=	year

Money

US$	=	U.S. dollar
B	=	Baht

Energy

kcal	=	kilocaloric
J	=	joule
MJ	=	megajoule
HP	=	horsepower
TOE	=	tons of oil equivalent
kW	=	kilowatt
MW	=	megawatt
kWh	=	kilowatt-hour
GWh	=	gigawatt-hour

Others

%	=	percent
°	=	degree
'	=	minute
°C	=	degree Celsius
cap.	=	capita
md	=	man-day
mil.	=	million
no.	=	number
pers.	=	person
PCU	=	passenger car unit
ppb	=	parts per billion

Unit Conversions

1 rai	=	0.16 hectare

CHAPTER 1

WATER RESOURCES POLICIES AND INSTITUTIONS

1.1 Evolution of Water Resources Policies in Thailand

For many years, the government efforts for water resources development and management have been made by a large number of agencies, of which each is in charge of only limited aspect of the nation's water resources. Those agencies may be broadly categorized in a few sub-sectors. Agencies involved in each sub-sector include the Royal Irrigation Department (RID) for irrigation, the Electricity Generaling Authority of Thailand (EGAT), the National Energy Administration (NEA) and the Provincial Electricity Authority (PEA) for hydropower, the Department of Mineral Resources (DMR) for groundwater exploration, and the Metropolitan Waterworks Authority (MWA) and the Provincial Waterworks Authority (PWA) for domestic water supply.

These agencies worked more or less independent to one another for planning, development and management of respective facilities, although NESDB coordinated their activities to some extent. As the water demand for various purposes expands rapidly and the conflicts between different purposes become serious, the need has been recognized for better coordination among the agencies and integrated approach to planning, developing and managing the nation's limited water resources. The National Water Resources Board was formed under NESDB in 1983 for planning and implementing water resources development effectively on a national scale.

Although the coordination and integration of activities by various water-related agencies need to be pursued further, the water management in Thailand is entering an advanced stage characterized by demand-side management as well as supply-side expansion. This may involve the allocation of water resources to different uses from a viewpoint of entire localities or river basins for overall efficiency, control and regulation of wastewater, measures to conserve water including pricing, and information system for water resources management.

1.2 Water Related Agencies

(1) Irrigation

The government through RID and other agencies has been undertaking not only the construction of new irrigation schemes and operation and management of existing ones, but also activities to improve the efficiency in the use of water resources in existing projects. Throughout the Fourth and the Fifth Plan periods, the emphasis of water resources development by RID shifted towards small-scale projects to spread the benefit with the priority given to low income areas. This resulted in considerable improvements of water situations in the Northeast.

For some traditional irrigation schemes, irrigation management is done by farmers who pay for their operation and maintenance by contributing labour and rice for the salary of operators. Fines are also effectively imposed. However, there is little

national efforts to charge farmers for water use in agriculture, and inefficient water use is often the result along with low irrigation efficiency.

(2) Groundwater exploration

The Department of Mineral Resources started a groundwater investigation program in 1962 with the help of the U.S. Geological Survey. The goal was originally to provide groundwater for domestic water supply and sanitation for the Northeast. The program was expanded subsequently to cover all the regions. This resulted in hydrogeological maps covering the entire kingdom.

(3) Hydropower

EGAT became in 1969 responsible for nearly all the hydropower development in the country. In addition, NEA and PEA have been active in carrying out mini-hydropower and micro-hydroprower projects having the generating capacity smaller than 6 MW. In most cases, beneficiary communities participate in the construction and maintenance of such projects.

1.3 Seventh Plan Guidelines

The Seventh Plan notes that the development of raw water resources is dispersed in various public agencies without a core agency to formulate administrative and management policies. The following are stipulated in the Plan:

1) To organize an integrated coordinating mechanism to function through all the phases of water resources planning, development and management,

2) To designate the scope of responsibilities of each water-related agency, while encouraging a greater private sector role, and

3) To formulate criteria for investment cost sharing and user charges reflecting production costs.

To improve the water supply, the Plan further stipulates as follows:

1) To improve efficiency of existing water supply and construct new plants to meet increasing demand particularly in areas with high development potential,

2) To determine water rates to reflect production costs in each locality, while ensuring fairness to producers and users of services, and

3) To formulate guidelines for promoting and attracting private investments in the development of water service system.

CHAPTER 2

EXISTING CONDITIONS OF WATER RESOURCES IN LNE-UE

2.1 Rainfall Patterns

(1) Rainfall distribution

The Study Area (LNE-UE) is one of arid parts of the country with the average annual rainfall of 1,370 mm under savanna climate. This is substantially larger than the world average of 970 mm and only slightly smaller than the average of 1,420 mm in Thailand (Table 2.1). The seasonal and annual rainfall distribution, however, is highly biased in the Study Area (Table 2.2).

Rainfall patterns in the Study Area are heavily influenced by the southeast monsoons. As a result, there are distinct rainy season and dry season. In seven provinces in the Northeast within the Study Area, more or less 90% of the total annual precipitation concentrates in the rainy season of May through October. Extended droughts are common during the dry months.

The provinces of Nakhon Ratchasima and Buri Ram on the Khorat plateau have the lowest average precipitation at 1,086 mm and 1,165 mm per annum respectively. In the two provinces in the East, Prachin Buri and Nakhon Nayok, the average precipitation is higher at 1,626 mm and 1,677 mm per annum respectively. Distribution of annual average rainfall in the Study Area is shown in Figure 2.1.

(2) Rainfall and vegetation

The amount of rainfall in general is a decisive factor to affect the land productivity. The relationship between rainfall and land productivity may be examined for the Study Area. In Figure 2.2, the total of forest area and the area of paddy fields as a proxy of land productivity is plotted against the annual precipitation for each province. Fairly high correlation is observed between these indices.

2.2 Basin System

(1) Basin system

The basin system in the Study Area is illustrated in Figure 2.3, where the division of river basins and sub-basins is shown. The Study Area is broadly divided into the catchment area of the Mekong river which largely coincides with the seven provinces in the Northeast and that of the Bang Pakong river which drains the most part of the two provinces in the East. The Mekong catchment area can be devided in the Mun river basin, the Chi river basin, river basins flowing into the downstream reach of the Mun river, and basins of small rivers draining directly into the Mekong.

(2) Major rivers

Major basins in the Study Area are:

- Mun River basin,

- Chi River basin,
- Prachin Buri River basin,
- Nakhon Nayok River basin, and
- Mekong River basin.

Hydrological data of these and other rivers are summarized in Table 2.3.

2.3 Existing Water Use and Facilities

(1) Irrigation

Existing irrigation facilities consist of small, medium and large dams and public wells. Supply capacity is summarized by province.

Existing Irrigation Water Supply Capacity in LNE-UE

Province	Irrigation Storage Capacity			Total	Irrigation Area [ha]	Unit Water Supply
	Public Ponds	Large/Medium Scale Dams	Small Scale Dams	(10^6 m^3/year)		(m^3/m^2/year)
Prachin Buri	16.4	249.3	77.4	343.1	68,703	0.50
Nakhon Nayok	21.4	325.3	101.0	447.7	89,671	0.50
N. Ratchasima	14.3	770.0	45.6	830.0	117,713	0.71
Buri Ram	9.6	238.9	57.0	305.4	30,622	1.00
Surin	8.3	95.6	45.6	149.5	29,321	0.51
Si Sa Ket	6.7	81.7	46.3	134.7	25,588	0.52
U. Ratchathani	10.1	100.8	44.8	145.6	41,772	0.35
Yasothon	3.2	17.5	34.9	55.6	7,541	0.70
Mukdahan	2.4	54.6	13.3	70.3	9,997	0.70

(2) Drinking water

Piped water supply

Piped water supply is very limited in the Study Area. The number of customers served and the amount of water supplied by piped water under the Provincial Water Authority (PWA) in the Study Area are summarized.

Water Supply Under PWA in the Study Area, 1990

Province *	No. of Customers	Service Ratio in Municipalities* (%)	Amount of Water Supplied (10^3 m^3)	Average Per Capita Supply (ℓ/day)
Prachin Buri	8,132	83	5,481	284
Nakhon Nayok	4,506	100	2,131	199
N. Ratchasima	13,754	20	4,595	141
Buri Ram	8,473	59	3,254	162
Surin	7,736	79	4,039	220
Si Sa Ket	5,389	63	2,281	178
U. Ratchathani	18,642	54	7,861	178
Yasothon	5,387	98	1,649	129
Mukdahan	2,472	38	1,154	197
Study Area	74,491	45	32,445	184

* calculated assuming 4.5 persons are served per customer
Source: PWA

The service ratio of piped water supply tends to be higher in provinces with large shares of urban population. A notable exception is Nakhon Ratchasima, where the share of urban population is the highest at 12.2% in 1990 but the water supply service ratio is low. This is due to the rapid increase in urban population particularly in the capital city of Nakhon Ratchasima and the large area of the province.

Conventional water supply

As a result of extensive efforts under the "Water Jar" program, collection of rainwater with large ceramic containers is an important mode of water supply mainly in rural areas in the Study Area. The number of water jars in the Study Area is summarized.

Water Jars in the Study Area

Region	No.of jars	No.of jars per household
Northeast (7 provinces)	2,000,000 (approximate)	1.79
East (2 provinces)	400,000	1.21

As seen, comparatively large number of water jars are used by households in the drier Northeast. Each water jar has typically about 2.0 m^3 capacity.

Drinking water shortage is particularly acute in the Northeastern provinces as follows.

Province	No.of households suffering from serious shortage	Ratio of suffering households to total(%)
Nakhon Ratchasima	34,689	11.8
Buri Ram	83,281	45.5
Surin	108,928	61.2
Si Sa Ket	104,423	55.4
Ubon Ratchathani	121,768	49.0
Yasothon	34,691	46.1
Mukdahan	24,350	63.0

In addition, large number of wells and shallow ponds exist for various water supply purposes. In the Northeast, there exist 268,493 wells, consisting of 55,288 public and 213,205 private ones. The average number of wells per village is 10, which is slightly larger than the national average of 8. The number of shallow ponds in the Northeast consists of 64,082 public and 197,194 private ones for the total of 261,276. The average per village is 10, which is much lower than the national average of 33. There are a comparatively larger number of the public ponds in the Northeast than in other regions.

Existing capacity of conventional water supply systems mainly for rural areas has been estimated, covering water jars, shallow and sanitary wells and other conventional systems. Results are summarized by province.

Existing Capacity of Conventional Water Supply Systems in LNE-UE

(Unit: 10^6 m^3)

Province	Large Artesian Wells	Small Artesian Wells	Water Jars	Shallow Wells	Sanitary Wells	Other Conventional Systems	Total
Prachin Buri	0.5	0.1	0.1	1.0	0.1	8.4	10.2
Nakhon Nayok	0.2	0.0	0.0	0.4	0.0	3.2	3.8
N. Ratchasima	1.1	0.1	0.9	0.5	0.1	23.4	26.1
Buri Ram	1.0	0.2	0.4	1.0	0.1	4.8	7.5
Surin	0.9	0.2	0.2	1.3	0.0	9.1	11.7
Si Sa Ket	1.0	0.2	0.2	3.1	0.2	2.7	7.4
U. Ratchathani	1.5	0.3	0.2	3.2	0.2	14.1	19.5
Yasothon	0.7	0.1	0.1	1.5	0.1	2.5	5.0
Mukdahan	0.4	0.0	0.1	0.8	0.1	2.4	3.8
Study Area	7.3	1.2	2.2	12.8	0.9	70.6	95.0

(3) Hydro-electric power

As of the end of the fiscal year 1988, EGAT has 21 hydro-electric power plants throughout the country with combined installed capacity of 2,250 MW to yield 5,410 GWh for the supply to the country's grid system. EGAT's hydropower plants account for 33% of the total installed capacity. Of all the hydropower plants, 14 are medium to large with the installed capacity ranging from 6.0 MW to 540 MW.

Distribution of hydropower plants in the four regions is summarized below.

Region	No.of dam reservoirs	Total installed capacity (MW)	Annual energy (GWh)	Reservoir storage capacity(10^6m^3)
Central	7	909.3	2,170	27,446
Northeast	5	108.5	254	4,605
South	3	313.3	756	7,042
North	6	919.3	2,230	23,237

In the Study Area, only one hydropower plant exists : Sirindhorn dam and hydropower plant in Ubon Ratchathani. This plant has the installed capacity of 36 MW with the reservoir of 1,966 million m^3 storage capacity to generate 86 GWh annual energy and command the irrigation area of 150,000 rai.

Water Supply under PWA in the Study Area, 1990

Province	No.of customers	Service ratio*(%)	Amount of water supplied (10^3m^3)	Average per capita supply* l/day)
Prachin Buri	8,132	11.7	5,481	284
Nakhon Nayok	4,506	13.2	2,131	199
Nakhon Ratchasima	13,754	3.8	4,595	141
Buri Ram	8,473	4.1	3,254	162
Surin	7,736	4.1	4,039	220
Si Sa Ket	5,389	2.7	2,281	178
Ubon Ratchathani	18,642	6.5	7,861	178
Yasothon	5,387	6.6	1,649	129
Mukdahan	2,472	6.1	1,154	197
Study Area	74,491	4.9	32,445	184

* calculated assuming 6.5 persons are served per customer
Source : PWA

2.4 Options and Priority for Water Resources Development in LNE-UE

(1) Perception of problems

The water situations in the Study Area (LNE-UE) as outlined above seem almost dismal. Access to improved water supply is assured for only 5% of the people in the Study Area as far as PWA facilities are concerned, while this ratio is over 15% nation-wide. Of the total households in the seven Study Area provinces in the Northeast, 40% are suffering from acute shortage of drinking water. The severe drought in this year, reported by the media, further emphasizes these situations.

Solving these problems would be by no means an easy task, given the natural conditions in the Study Area. Distribution of rainfalls is uneven, value of run-off coefficient is very low, and groundwater is often salty in the Study Area. Options and priority for the water resources development in the Study Area under these conditions are described below for storage reservoirs, water jars, groundwater exploration, and multi-purpose water resources development.

(2) Storage reservoirs

Given the perception of problems outlined above, an obvious option is to store rain water when available. The water jar option is discussed later. Storage of rain water in lowland area is not generally an efficient option, especially when it is in the form of unconnected irrigation ditches and ponds, as widely practiced in the Study Area. This is because water surface area tends to be large with small depth to increase evaporation, and water would have to be pumped up to serve an extensive area. When water is stored in unconnected existing rivers and irrigation canals or so, surface water run-offs are reduced to make less water available for further downstream.

In order to rectify the situation, water storage and regulating facilities, small and large, should be inter-connected as much as possible. This would call for two conditions to be satisfied. First, better planning of those facilities would be necessary to begin with from a viewpoint of larger areas, ideally entire river basins or sub-basins. Second, proper arrangements would have to be worked out for the management of the integrated facilities.

CHAPTER 3

WATER RESOURCES POTENTIALS

3.1 Surface Water Potential

(1) Total run-offs

The Study Area has been divided into sub-basins, and the surface water run-off has been estimated by sub-basin based on the drainage area, average annual rainfall and run-off coefficient. The river basin division has been adapted to provincial administrative division, and estimates have been compiled by "adapted province".

Estimated Surface Water Runoff by "Adapted Province"

Province	Estimated Drainage Ares (km^2)	Annual Rainfall (mm)	Runoff Coefficient	Estimated Runoff (Unit: 10^6 m^3)
Prachin Buri	11,108	1,626	0.225	4,064
Nakhon Nayok	488	1,677	0.424	347
N. Ratchasima	15,965	1,086	0.135	2,341
Buri Ram	9,835	1,165	0.270	3,094
Surin	10,739	1,224	0.186	2,445
Si Sa Ket	7,723	1,226	0.083	786
U. Ratchathani	19,309	1,520	0.126	3,698
Yasothon	2095	1,369	0.186	533
Mukdahan	3,498	1,467	0.177	908
Total	80,760	-	-	18,216

(2) Dependable run-offs

The total estimated run-off in the Study Area is 18.2 billion m^3. This total can not be fully utilized effectively due to river flow variation. According to flow duration curves of some rivers in the Study Area, low stream flow constitutes about 25% of the total flow. Thus the total dependable run-off in the Study Area is estimated to be 4.60 billion m^3.

The Study Area has another major problem: the presence of subsurface salt beds which tend to make water and soil salty. Surface run-offs on salty soil can not be easily used for irrigation nor drinking purpose, even if the run-off volume is regulated. Distribution of salty soil is found out from hydrological maps of the Department of Mineral Resources, Ministry of Industry (1977).

Based on these maps, the ratio of river basin area not affected by the salt problem has been determined by "adapted province". The amount of water that can be relied on for irrigation and drinking purpose has been estimated as below.

Estimated Amount of Reliable Water by "Adapted Province"

Province	Estimated Dependable Runoff (10^6 m^3)	Ratio of Land not Affected by Salt (%)	Estimated Amount of Reliable Water (10^6 m^3)
Prachin Buri	1,016	25	254
Nakhon Nayok	87	50	44
N. Ratchasima	585	50	293
Buri Ram	773	80	618
Surin	612	50	306
Si Sa Ket	197	70	138
U. Ratchathani	924	80	739
Yasothon	133	80	106
Mukdahan	227	40	91
Total	4,604	-	2,589

The total amount of water that can be relied upon even in the driest year has been estimated at about 2.60 billion m^3. This is only an indicative number, and the estimate is probably conservative.

3.2 Groundwater Potential

(1) Groundwater distribution

Distribution of groundwater in the Study Area has been examined based on the Hydrogeological Map of the Northeastern Thailand prepared by the Department of Mineral Resources, Ministry of Industry. The groundwater potential is classified as follows.

Class	Yield	Water quality	Characteristics
I	Highest	Over 90% good quality	Gravelly and sandy deposit
II	High	Over 95% good quality	Medium high terraces; depth less than 60 m
Il	Medium	Over 80% good quality	Mound and depression type topography
IV	Low	Over 90% good quality	Decomposed zone or fractures of intrusive rocks
V	-	50% good quality, 50% salty	Flat land
VI	-	Over 90% salty	
VII	unproductive		Yellow wish gray to grayish pink massive sand stone and conglomerate

Distribution of these classes of land in the Study Area is shown in Figure 3.1. More promising areas under classes I through IV have been found out by province.

Distribution of Groundwater Potential Area in the Study Area

(Unit: km^2)

Province	Groundwater Potential Area by Class I	II	III	IV	Total I ~ IV
Prachin Buri	491	-	3,200	-	3,691
Nakhon Nayok	877	-	130	-	1,007
N. Ratchasima	591	-	3,167	3,392	7,150
Buri Ram	-	-	2,073	5,673	7,746
Surin	-	-	1,690	2,271	3,961
Si Sa Ket	-	202	5,056	617	5,875
U. Ratchathani	217	1,893	8,082	3,251	13,443
Yasothon	-	147	2,460	-	2,607
Mukdahan	-	-	449	1,246	1,695
Total	2,176	2,242	26,307	16,450	47,175

Groundwater potential

To estimate the groundwater potential in the Study Area, it is assumed that large artesian wells are located at nodes of 1.0 km grid to avoid excessive drawdowns due to interference with neighboring wells. A pumping rate is assumed for each class of groundwater potential area. Based on 10-hour pumping per day for 300 days per year, number of wells that can be located in the groundwater potential area summarized above, and ratios of successful wells, the groundwater potential is estimated by province as summarized below.

Groundwater Potential in the Study Area

Province	No. of Large Artesian Wells by Groundwater Potential Class I	II	III	IV	Total Groundwater Potential (10^6 m^3/year)
Prachin Buri	1,964	-	12,800	-	12.6
Nakhon Nayok	3,508	-	520	-	9.7
N. Ratchasima	2,364	-	12,668	13,568	18.0
Buri Ram	-	-	8,292	22,692	12.2
Surin	-	-	6,760	9,084	6.9
Si Sa Ket	-	808	20,224	2,468	13.6
U. Ratchathani	868	7,572	32,328	13,004	35.8
Yasothon	-	588	9,840	-	2.7
Mukdahan	-	-	1.7%	4,984	6.5
Total	8,704	8,968	105,228	65,800	118.0

The total amount of groundwater that may be safely extracted has been estimated at 118 million m^3 in the Study Area. The estimate is crude, but it is clear that the groundwater availability is smaller than the surface water availability.

CHAPTER 4

WATER RESOURCES DEVELOPMENT PLAN

4.1 Water Supply-Demand Balance

Water resources potentials have been estimated for both surface water and groundwater as reported in the previous chapter. Water demand is projected in this sector for drinking and other domestic uses and also for domestic animals. Future supply-demand balance is examined to set a framework for formulating a water resources Development plan.

4.1.1 Water demand projection

The water demand projection follows the population growth and increase in domestic animals for the balanced Development alternative of the LNE-UE regional Development. The projection is made to the year 2010 and also to an intermediate year of 2000.

(1) Unit water use

Unit water use for various purposes in rural areas has been set as follows.

Unit Water Use for Water Demand Projection in Rural Areas

Use		Unit Water Use (l/day/head)
Human use:	Drinking	5
	Domestic	45
Domestic animals:	Buffalo	50
	Cattle	50
	Swine	20
	Chicken	0.15
	Duck	0.15

Source: Office of Accelerated Rural Development, Ministry of Interior

No standard has been established for unit water use in urban areas. Usually it ranges within 150 - 250 l/day/capita. For the projection here, the unit water use in urban areas is set at 225 l/day/capita, including both drinking and other domestic uses.

(2) Growth rates of human and animal populations

Human population

Growth of population in the Study Area has been projected by province and also for urban and rural areas (Social Sector Report). Projected urban population is taken to

project municipal water demand, and projected rural population is used for the projection of non-municipal water demand. The projection of both municipal and non-municipal water demand is made by province. Projected urban and rural populations are summarized in Table 4.1.

Animal populations

Growth rates of animal population are assumed separately for buffalo, cattle, swine, duck and chicken. Buffalo population is assumed to grow only at 1% per annum for all the provinces. The annual average growth rates of cattle population are assumed at 7% in Ubon Ratchathani, Yasothon and Mukdahan, 3% in Nakhon Nayok and Nakhon Ratchasima, and 5% in other provinces. Swine population is assumed to grow annually at 2% in Nakhon Nayok, Nakhon Ratchasima and Buri Ram, and at 4% in other provinces. Duck population is assumed to grow at 3% per annum, and chicken population at 6% per annum respectively in all the provinces. Projected animal populations are summarized in Table 4.2.

(3) Projected water demand

Results of the water demand projection are given in Table 4.3 for human use and in Table 4.4 for animal use. They are summarized below.

Projected Water Demand for Human and Animal Consumption

(10^6 m^3/year)

Province	2000			2010		
	Human Use	Domestic Animals	Total	Human Use	Domestic Animals	Total
Nakhon Nayok	5.7	0.5	6.2	6.5	0.7	7.2
Prachin Buri	20.7	5.0	25.7	27.2	6.9	34.1
N. Ratchasima	82.9	14.0	96.9	131.6	17.6	149.2
Buri Ram	35.2	10.0	45.2	44.5	12.5	57.0
Surin	29.9	11.2	41.1	36.5	14.6	51.1
Si Sa Ket	30.7	10.4	41.1	37.2	13.6	50.8
U. Ratchathani	56.2	16.0	72.2	77.4	23.5	100.9
Mukdahan	9.3	4.5	13.8	16.9	6.2	23.1
Yasothon	13.5	4.1	17.6	14.1	6.7	20.7
Study Area	285.4	75.7	361.1	391.9	102.3	494.1

4.1.2 Future water balance

Future water balance is examined based the water potentials and the projected water demand presented above. The balance is checked for municipal and non-municipal water as well as the total demand for human and animal consumption, and prospects for irrigation water supply are also indicated.

(1) Total water balance

The projected total water demand for human and animal consumption is compared with the estimated water potential by province .

Comparison between Water Demand and Potentials

(Unit: 10^6 m^3/year)

Province	Total Water Demand for Human and Animal Use		Water Potentials	
	2000	2010	Surface Water	Groundwater
Nakhon Nayok	6.2	7.2	44	9.7
Prachin Buri	25.7	34.1	268	12.6
N. Ratchasima	96.9	149.2	280	18.0
Buri Ram	45.2	57.0	534	12.2
Surin	41.1	51.1	285	6.9
Si Sa Ket	41.1	50.8	138	13.6
U. Ratchathani	72.2	100.9	662	35.8
Mukdahan	13.4	20.3	91	6.5
Yasothon	18.0	23.6	106	2.7
Total	361.1	494.1	2,408	118.0

For all the provinces in the Study Area, the estimated water potentials far exceed the water demand projected for the balanced development. Water potentials are particularly high in Ubon Ratchathani, Buri Ram and Prachin Buri.

(2) Municipal and non-municipal water

The total water demand is broken down into municipal and non-municipal water. The municipal water is expected to be supplied by PWA. The current PWA supply is compared with the projected municipal water demand by province.

PWA Water Supply and Projected Municipal Water Demand

(Unit: 10^6 m^3/year)

Province	Municipal Water Demand		PWA Water Supply in 1990
	2000	2010	
Nakhon Nayok	2.1	3.0	2.1
Prachin Buri	6.1	11.5	5.5
N. Ratchasima	47.4	98.7	4.6
Buri Ram	7.7	12.5	3.3
Surin	5.1	8.1	4.0
Si Sa Ket	4.5	7.1	2.3
U. Ratchathani	20.5	37.1	7.9
Mukdahan	4.0	7.5	1.2
Yasothon	2.9	4.8	1.6
Total	100.8	190.3	32.5

The supply capacity for municipal water will have to expand by 210% in the Study Area by the year 2000. In particular, Nakhon Ratchasima and Ubon Ratchathani would have to expand their supply capacity 10.3 times and 2.6 times, respectively by 2000, if the municipal water demand should be completely satisfied.

(3) Irrigation water

The present water supply capacity for irrigation is compared with the non-municipal water demand and the water potentials.

Irrigation Water Supply, Non-Municipal Water Demand and Water Potentials

(Unit: 10^6 m^3/year)

Province	Present Irrigation Water Supply *	Non-Municipal Water Demand		Water Potentials	
		2000	2010	Surface Water	Groundwater
Nakhon Nayok	-	3.6	3.5	44	9.7
Prachin Buri	-	146	15.7	268	12.6
N. Ratchasima	830.0	35.5	32.9	280	18.0
Buri Ram	305.4	27.5	32.0	534	12.2
Surin	141.2	24.8	28.4	285	6.9
Si Sa Ket	134.7	26.2	30.1	138	13.6
U. Ratchathani	145.6	35.7	40.3	662	35.8
Mukdahan	70.3	5.3	6.6	91	6.5
Yasothon	55.6	10.5	12.1	106	2.7
Total	1,682.8	184.6	201.6	2,408	118.0

* total water storage volume

The non-municipal water demand by 2000 in most provinces can be mostly satisfied by the groundwater alone distributed extensively in rural areas. Exceptions are Prachin Buri, Nakhon Ratchasima, Surin and Si Sa Ket. Substantial expansion of irrigation water supply is difficult for most provinces, even if the surface water potential is fully devoted to irrigation. The provinces of Ubon Ratchathani, Buri Ram, Prachin Buri and Surin are relatively better off with this respect. Future irrigation development should be directed to (1) effective utilization of existing irrigation facilities with consolidation/integration, (2) efficient development of surface water, (3) small scale development by groundwater, and (4) establishment of less water intensive crops and use of water saving irrigation technology (e.g. drip irrigation).

4.2 Objectives and Strategy for Water Resources Development and Management

(1) Characteristics of LNE-UE water situations

The water situations in the Study Area (LNE-UE) seem almost dismal. Access to improved water supply is assured for only 5% of the people in the Study Area as far

as PWA facilities area concerned, while this ratio is over 15% nation-wide. Of the total households in the seven Study Area provinces in the Northeast, 40% are suffering from acute shortage of drinking water.

Solving these problems would be no means be an easy task, given the natural conditions in the Study Area. Distribution of rainfalls is uneven especially in the Lower Northeast where more or less 90% of the total annual precipitation concentrates in the rainy season of May through October. Value of run-off coefficient is very low with the average of some 0.2. Groundwater is often salty in the northern part of the Study Area. Generally flat terrains and soil of low water retention capacity make water storage ineffective.

(2) Objectives

Water is critically important for the development of the Study Area as indicated by the characterization above. Objectives for water resources development, therefore, have direct bearings on the LNE-UE regional development objectives.

1) To expand substantially the supply of water to support industries and other urban activities and to develop appropriate sources of water to assure decent quality of rural life,

2) To develop water resources in selected localities where irrigation and/or tourism potentials are superior to enhance the quality of land and water environment, and

3) To promote people's participation in water resources development and management for efficient us of limited water resources.

(3) Strategy

Given the characteristics of water situations in the Study Area outlined above, the strategy for water resources development consists of a few components. One is to store rain water when available by storage reservoirs or water jars. Another is to explore more sources of water, typically groundwater. Still another is to formulate multipurpose water resources development projects to allow efficient use of these limited resources. These components are described below.

Storage reservoirs

Storage of rain water in lowland area is not generally an efficient option, especially when it is in the form of unconnected irrigation ditches and ponds, as widely practiced in the Study Area. This is because water surface area tends to be large with small depth to increase evaporation, and water would have to be pumped up to serve an extensive area. When water is stored in unconnected irrigation ditches, surface water run-offs are reduced to make less water available for further downstream.

In order to rectify the situation, water storage and regulating facilities, small and large, should be inter-connected as much as possible. This would call for two conditions to be satisfied. First, better planning of those facilities would be necessary to begin with from a viewpoint of larger areas, ideally entire river basins or sub-basins. Second, proper arrangements would have to be worked out for the management of the integrated facilities.

Storage reservoirs would better be located in the middle to the upper catchment area of any river basin/sub-basin for a few reasons. First, gravity flow can be used to distribute water to an extensive area. Second, storage efficiency would be generally better, if locations are properly selected. Third, even if the water storage on sandy soil results in more water lost by seepage, this may increase groundwater availability.

Water jars

Water jars provide effective means to store small amount of water for individual household use. For an average household with 4.0 family members, the storage of 10 m^3 would cover the water use for three months, if the minimum per capita use of 25 litre per day is assumed. This would help to bridge the water availability gap due to extended drought. Three to five water jars of larger size per household would satisfy this requirement, while the average number of water jars per household is less than two at present.

Groundwater exploration

Use of groundwater will continue to be important particularly for drinking water supply in rural areas not served by rivers or storage reservoirs. Groundwater exploration should be intensified in more promising areas identified by DMR. More promising areas in the Study Area may be found on the southern slope of the Mun river and in the middle to the upper catchment area of the Bang Pakong river in Prachin Buri.

Irrigation water management

Effective water management is essential for maximum utilization of limited water resources. Priority is the full utilization of existing facilities, but some facilities in the Study Area are not well planned for location and scale. An inventory of existing facilities should be reviewed and updated, and additional water storage should be planned in combination with rehabilitation/improvement of existing facilities by a river basin approach.

Water facilities planned by the river basin approach would call for an integrated operation and management. In particular, farmers need to be organized for on-farm water management. As a prerequisite, farmers should be involved in the planning and implementation of irrigation facilities.

Drip irrigation should be established as a water saving irrigation technology particularly for high value-added crops proposed by the Master Plan. Groundwater as well as surface water should be used as sources of water. Drip irrigation is the most efficient irrigation method with small losses of water in evaporation and percolation. Operation costs are low due to low pressure on pipes and low labour requirements.

Multi-purpose water resources development

To make an effective use of limited water resources, multi-purpose water resources development should be carried out from a viewpoint of river basins/sub-basins. Priority for multi-purpose reservoirs should in general be given to flood control and water supply, followed by irrigation and then hydropower. The public sector

initiative is essential for coordinated efforts by related agencies and also for public acceptance cultivation.

4.3 Small Pumping Reservoirs Development

Water resources development for multiple purposes is the key strategy for the Study Area . Several multipurpose development projects have been formulated by a river basin approach. They consist of the small pumping reservoirs development project and a few comprehensive river basin development and management projects. The latter are presented in the next section.

The Korat plateau is generally flat, and storage of water in large scale is difficult. Potential sites for dams in significant scale will be practically exhausted by the completion of the on-going Phanom Dong Rek water resources development project. Water storage in small scale is possible by utilizing natural depressions and excavating suitable sites. In the nine LNE-UE provinces, 30 sites have been identified,and development schemes formulated. These sites are by no means exhaustive. Many other sites may be identified through further studies. The sites identified at this time are used to illustrate the development concepts and possible development schemes of this project. They may be implemented first, while other sites are being examined.

4.3.1 Definition of the project

(1) Background

Water situations in Korat plateau

The Korat plateau coves most part of the provinces of Nakhon Ratchasima, Buri Ram and Surin, and small part of Si Sa Ket and Yasothon. The land is generally flat, and soil has low fertility and low water retention capacity. The northern part within the Study Area is extensively under-lain by rock salt layers to make groundwater salty. Annual precipitation ranges from 900 mm in the western plain of Nakhon Ratchasima to 1,300 mm in the central and eastern parts. This area is most problematic as for water. Some 40% of the households still suffer from acute shortage of drinking water.

Many water storage facilities have been developed in the area. Most potential dam sites have already been developed. Many small water impoundments have been created. There are many ceramic water jars use to store water for domestic purposes.

Water situation in Nakhon Nayok and Prachin Buri

The two provinces in the Upper East, Nakhon Nayok and Prachin Buri, coincide largely with the Bang Pakong river basin. The province of Prachin Buri is drained by the main stream of the Bang Pakong river, and the province of Nakhon Nayok by its main tributary of the Nakhon Nayok river.

Annual rainfall in these provinces are larger than in the Korat plateau, ranging from 1,200 mm up to over 2,000 mm with an average of 1,650 mm. Runoff coefficient is generally higher in these river basins than in the Mun river basin. Particularly, the runoff coefficient of the Nakhon Nayok river is typically 0.4.

Water resources are more developed in these river basins especially for irrigation. The total water storage capacity for irrigation by public ponds, large/medium dams, and small dams is 343 million m^3 in Prachin Buri and 448 million m^3 in Nakhon Nayok. In the Korat plateau, only Nakhon Ratchasima has a larger storage capacity at 830 million m^3. Potential storage sites by dams have been largely developed in these river basins as well.

Characteristics of surface water

A notable characteristic of rivers in the area is large seasonal variation of flow, reflecting the rainfall pattern. Typically the flow during the dry season s only one-fifth to one-third for most tributaries of the Mun river.

Another characteristic is extremely small run-off coefficient. The value of run-off coefficient is only 0.2 for the entire Mun river. The value is generally higher in the Bang Pakong river basin, but typically only slightly larger than 0.2 in the mainstream and 0.4 in the Nakhon Nayok river, a main tributary. Also the value has been decreasing. These characteristics are presumably due to the following factors :

1) increasing number of small and large reservoirs to reduce the discharges downstream,
2) deforestation in the upper catchment areas resulting in lower water retention capacity.
3) soil of low water retention capacity, and
4) climatic conditions with high evaporation.

Particularly, most small water impoundments are in the form of irrigation ditches and ponds located mostly in lowlands not linked with any river system. Such a form of storage makes water surface area large with small depth resulting in large evaporation and seepage losses. Also water stored is not available for use further downstream.

(2) Concepts and objectives

The basic concept of small pumping reservoirs proposed is to link them with river system. This will allow better utilization of excess river water during the rainy season to store in larger volume. Water quality would be better than the case of utilizing surface run-offs. It may also allow the release of water to the downstream when there is an excess.

Another concept is the storage in larger scale than usually practiced in the area. This would be more cost effective. Also, it would provide opportunities for such impoundments to be used for a wider range of objectives. The objectives may include recreation and fishery as well as water supply for domestic, industrial and irrigation purposes.

(3) Identification of sites

Sites suitable for small pumping reservoirs have been identified by the following procedure. First, the overall physiographic characteristics of the area were examined by maps of 1 to 250,000 scale. Second, field surveys were conducted to selected areas with the aid of maps of 1 to 50,000 scale. Third, the surveys were complemented by hearings from government officials and some local people.

The following sites have been identified.

Site No.	Province	Site
NR-1	Nakhon Ratchasima	(1) Chok Chai
NR-2		(2) Ban Dan Kata
NR-3		(3) Tha Chang
NR-4		(4) Ban Krathin
NR-5		(5) Ban Dan Yao Yai
BU-1	Buri Ram	(6) Ban Khok Yang
BU-2		(7) Huai Chorakhe Mak reservoir
BU-3		(8) Ban Yang
SU-1	Surin	(9) Ban Sawan Phatthana
SU-2		(10) Ban Sawai
SI-1	Si Sa Ket	(11) Ban Kran
SI-2		(12) Ban Khillek (*)
UR-1	Ubon Ratchathani	(13) Ban Rat Samran (*)
UR-2		(14) Ban Kud Kua Noi
UR-3		(15) Ban Nong Bo Baeng (*)
UR-4		(16) Ban Nong Chang Yai (*)
YT-1	Yasothon	(17) Nong Om Kaeo
YT-2		(18) Nong Wai (*)
YT-3		(19) Ban Kut Chum
MK-1	Mukdahan	(20) Wat Na Chan
MK-2		(21) Ban Na Tabaeng (*)
MK-3		(22) Ban Na Po Noi (*)
NN-1	Nakhon Nayok	(23) Ban Tak Caet
NN-2		(24) Ban Kut Rang Nai (*)
PB-1	Prachin Buri	(25) Ban Don Wai (*)
PB-2		(26) Ban Khao Chakan (*)
PB-3		(27) Ban Khlong Yai
PB-4		(28) Aranyaprathet
PB-5		(29) Ban Non Mek Mun
PB-6		(30) Ban Khok Thahan

Remarks: Site name with (*) marks are the locations having possibility of mini hydro electric power development.

A development scheme for each of these sites is described below, including physical features, expected effects and approximate costs.

4.3.2 Description of Chok Chai pumping reservoir

A typical small pumping reservoir scheme is described by using as an example the Chok Chai pumping reservoir. Descriptions of other schemes are contained in a separate volume (Preliminary Feasibility Analysis on Selected Priority Projects).

Site

The site is located 28 km south-southeast of Nakhon Ratchasima at north latitude 14°44'30" and east longitude 102°13' (Figure 4.1). It is 5.0 km east of Amphoe Chok Chai. To be immediate north is the route no.24.

The site is the lowland on the right bank of the Mun river. Land use around the site is paddy. Lack of water prohibits the paddy production during the dry season, and inundation by the overflow of the Mun river and limited access constrains the paddy cultivation during the rainy season.

Dimensions

Planned dimensions of the reservoir are 300 m wide, 500 m long and 6.0 m deep. Slope gradient is assumed to be 1 to 1.0. Total annual evaporation is assumed at 1,500 mm, and low water level is taken to be 1.0 m above the bottom (Figure 4.2). Effective storage volume, V, is calculated to be 600,000 m^3 as follows.

$$V = 290 \times 490 \times (5.0 - 1.5/2) = 603{,}925\ m^3$$

Available flow

Flow available in the Mun river for extraction into the reservoir has been estimated as follows. In the upstream of the proposed reservoir site, the followings dams exist mainly for irrigation.

Dam	Drainage Area (km^2)	Irrigation Area (ha)	Water Demand (m^3/sec)
Lam Phra Phleong	850	9,900	9.2
Upper Mun	500	6,600	6.1
Lam Sea	450	12,900	11.9

Excluding the catchment areas of these dams, and using flow records at two gauging stations listed below, the available flow has been estimated.

Station	River	Drainage Area (km^2)	Mean Discharge (m^3/sec) Wet Season	Dry Season
Khon Buri (M 50)	Mun	875	4.22	1.72
Satuk (M 6 A)	Mun	28,275	68.50	4.72
Proposed site	Mun	2,300	x_1	x_2

Discharge at the proposed site is roughly estimated by interpolating the observed discharges by using ratios of drainage areas. Wet season discharge x_1 and dry season discharge x_2 are respectively the following functions of the drainage area y :

$$y = 426.3 \quad x_1 - 923.8, \text{ and}$$
$$y = 9{,}133.3 \quad x_2 - 14{,}834.3.$$

Thus, the mean discharge during the wet and the dry season is calculated to be x_1 = 7.56 m^3/sec and x_2 = 1.88 m^3/sec. The discharge during the dry season is too small to depend on so that the discharge during the wet season is used to fill in the reservoir.

Intake rate

Different ratios of the available flow are assumed to be taken to fill in the reservoir to find out the number of days required until the reservoir is full. The following are obtained.

Intake water ratio (%)	Inflow (m^3/sec)	Days to be full
5	0.38	18.4
10	0.76	9.2
15	1.13	6.2
20	1.51	4.6
25	1.89	3.7
30	2.27	3.1

As shown, if 10% of the available flow in the Mun river is taken during the wet season, the reservoir can be completely filled in nine days. Thus any significant effects on the downstream are not likely to be involved. Capacity of the intake gate with two sluice gates is 1.4 m^3/sec, 2.6 m^3/sec and 4.8 m^3/sec with the flow depth respectively of 0.3 m, 0.5 m, and 0.8 m with the gate fully open.

Expected effects

The total amount of water in 600,000 m^3 will be available during the dry season. It can be used for domestic water supply, irrigation, fishery and recreation.

If the water is used exclusively for human consumption, the population of some 66,000 can be supported, assuming 50 l/day per capital consumption for six months. Irrigation water requirements for growing vegetables during the dry season are roughly estimated at 3 mm/day. If the growing period of vegetables is two months and two different vegetables can be grown successively during the dry season, the available water can irrigate some 170 ha.

The reservoir can be used to raise kelapia, carp of other fast growing fish species by using a floating net cage culture method (Figure 4.3). If the entire reservoir is used, the average yield could be as high as 10 ton/ha for a three month period.

Areas around the Nakhon Ratchasima city lack major recreational area with substantial water body. Considering the distance from the city, 28 km, the reservoir can be used as a recreational area. Swimming, boating, and fishing are among the activities to be possible.

Project costs

The site is located close to the national highway route no.24, and the access is easy. A new access road of only 500 m would be necessary. Project costs are estimated based on unit prices reported in the data base of the Price Survey Division, Department of Business Economics for the central Thailand. Considering the transportation costs to the site and difficulty in obtaining skilled labor, 20% increments are applied to the unit prices.

Estimated project costs are summarized in Table 4.5. The total costs would be approximately 59 million bahts. They do not include costs of appurtenant facilities for irrigation, water supply, recreation and other possible uses.

4.4 Comprehensive River Basin Development and Management

4.4.1 Definition of the project

(1) Background

As described in subsection 4.3.1, surface water availability in the Study Area is characterized by large seasonal variation of flow in any river, and extremely small runoff coefficient. The former makes the water storage in one way or another indispensable. The latter indicates the forms of storage critically important to avoid further reduction in runoff coefficient.

At present, most small water impoundments are in the form of irrigation ditches and ponds located mostly in lowlands and not linked with any river system. Some of these facilities need to be integrated one another, linked to river systems or abolished. Additional facilities can be formulated, possibly linked with existing ones, to augment the water availability without reducing much the surface runoffs. Small pumping reservoirs represent one way to realize this. Other projects should be formulated and implemented by a river basin approach. Also multi objective development is pursued as much as possible.

(2) Objectives

Objectives of the comprehensive river basin development and management are established as follows.

1) To expand the availability of water for domestic, agricultural and industrial uses by exploring the maximum potential and improving the use efficiency through formulation of development projects by a river basin approach including additional small pumping reservoirs and multipurpose dams; and

2) To establish a better practice for watershed management by realizing more rational land use for reforestation, field and tree crops cultivation and irrigated agriculture.

(3) Identification of projects

Comprehensive river basin development and management projects identified at this time are one each in the Upper East (Nakhon Nayok river basin), the central part (Lam Nam Chi/Lam Plai Mat river basins), the eastern part (Huai Thap Than/Lam Se Bai/Lam Se Bok river basins), and the northeastern part (Huai Bang Sai river basin) of the Lower Northeast. The Nakhon Nayok, Prachin Buri and Huai Bang Sai river basins would involve multipurpose dam schemes. For the Lam Nam Chi/Lam Plai Mat river basins, major dam schemes are unlikely to be involved, but several sites have been identified for the small pumping reservoirs development project. Watershed management is another purpose for these river basins characterized generally by vulnerable land and water environment.

4.4.2 Description of individual projects

(1) Lam Nam Chi/Lam Plai Mat multipurpose water resources development

The project will develop the Lam Nam Chi and the Lam Plai Mat river basins, main tributary basins of the Mun river, for multiple purposes. A comprehensive development and management plan needs to be prepared first. The plan should include a comprehensive water supply scheme for this dry area, irrigation development with groundwater and small water impoundments, and a plan for better watershed management through afforestation and improved land use. This project is essential for the development of the central part of the Lower Northeast around Surin and Buri Ram.

(2) Nakhon Nayok/Prachin Buri river basins multi-purpose water resources development

The project will develop the two tributaries of the Bang Pakong river for multiple purposes amining at the urban areas of Prachin Buri and Nakhon Nayok as well as upper watershed areas. Components include dams on the upper catchment areas and related works for flood control of the Nakhon Nayok and Prachin Buri cities, low flow augmentation to reduce salt water intrusion, and improvement of irrigated agriculture. A feasibility study should cover crop diversification under irrigation, tourism, and urban development, and reflect existing programs for the Bang Pakong river.

(3) Huai Bang Sai multipurpose water resources development

The project consists of three storage dams, two diversion dams, a hydroelectric power plant, and irrigation facilities in the Huai Bang Sai river basin occupying the northern part of Mukdahan. The project will be reformulated in the light of the Master Plan and cost-effectiveness of storage dams reviewed as well as environmental effects.

(4) Lam Dom Yai/Huai Tha multipurpose water resources development

The project will develop the Lam Dom Yai and the Huai Tha river basins in the Ubon Ratchathani and the Si Sa Ket provinces. Additional sites for small pumping reservoirs will be identified through further studies. The existing plan for the Lam Don Yai dam will be reviewed. Multipurpose projects would be formulated for domestic water supply, irrigation and hydropower generation. Recreation and environmental management may also be incorporated for some projects. These projects will also support the conversion of agricultural land use, typically from paddy fields to managed pastures or field crops for lands of sandy soil.

4.5 Other Water Resources Projects

Multipurpose water resources development projects presented in Section 4.3 and Section 4.4 would contribute to expanding water availability in respective command areas. Additional projects need to be implemented for areas that may not be covered effectively by any project so far proposed. These areas are extensive rural areas and some part of Yasothon. Three projects have been defined : (1) Yasothon water network project, (2) revised water jar program, and (3) groundwater exploration. The groundwater exploration project would help also supplement the urban water supply.

(1) Yasothon water network development

The Chi river will be effectively connected with either the Se Bai river or the Mun river by a network of canals to improve water use efficiency for irrigation and other purposes and to control floods better. The first step is to study water demand for various purposes and potentials of these three rivers.

(2) Revised water jar program

As a result of extensive efforts under the original "water jar" program, collection of rain water in large ceramic containers is now an important mode of water supply mainly in rural areas of the Study Area. There are on an average 1.8 jars in the seven provinces in the Lower Northeast. A few more jars per household would help to bridge the water availability gap due to extended drought. Thus this program should be revised focusing on the most critical areas where no realistic alternative water supply is considered.

(3) Groundwater exploration

This is to expand the use of groundwater, an important source of water supply in rural areas in the Study Area. Existing data kept by the Department of Mineral Resources will be thoroughly reviewed to identify more promising areas particularly in the provinces of Nakhon Ratchasima, Buri Ram, Surin, Si Sa Ket and Yasothon. Boring and pumping test will be conducted before the development of production wells.

4.6 Purification Method of Intake of Pumping Reservoir

River management covers various issues such as shortage of water, quality of water and consideration of environmental aspects. Rivers in the Study Area irrespective of their length or size have problems in water quality due to siltation particularly during

the wet season. Resolving this problem at intake sites of pumping reservoirs by a simple low cost method is very important. In the present study, 30 sites for proposed pumping stations have been determined. A simple, low cost, and very effective method for purification of water at intake of pumping reservoirs is shown conceptually in Figure 4.4

Gravel, sand and charcoal are materials commonly used in filtration and water purification systems. The combination of these materials systems designed as shown would lead to water purification and treatment. A pilot scale system could be designed and tested before actual implementation. The characteristics of materials should be as follows:

A&E : gravel, particle size of less than 25 mm
B&D : sand, particle size of 0.3 mm to 2 mm
C : broken charcoal or chaff to be charcoal.

These materials need to be changed about once a year.

4.7 On-Going Water Resources Development Projects

4.7.1 General

Many water resources development projects of various scales have been carried out earnestly including completed one, on-going and newly started projects. To reserve the water is fundamental for every kind of activities such as human life, environmental preservation and industrial development, etc. Therefore, it is necessary to make plans of individual projects from the overall planning point of view to achieve effective results for water resources development. Some of ongoing water resources development projects are outlined below particularly in relation to the LNE-UE Master Plan.

4.7.2 Phanom Dongrek water resources development

The Phanom Dongrek mountain range forms the border between Thailand and Cambodia. The mountain range lasts from Nakhon Ratchasima, Buri Ram, Surin, Si Sa Ket to Ubon Ratchathani for 360 km approximately.

The project aims to develop the Phanom Dongrek mountain skirts areas by supplying sufficient irrigation water for the cultivation. Aiming at yield increase, large scale dam and weir construction have been highlighted for the storage of water covering the 5 provinces.

To give a glance of the project the location of the Phanom Dongrek Water Resources Development Project is shown in attached Figure 4.5. The project have the following four components. Namely,

1. First stage Development Program during 1990 to 1995 for 12 sites,
2. Second stage Development Program during 1994 to 1999 for 24 sites,
3. Cancelled project site due to the topographic and geological condition, and
4. Weir construction site during 1990 to 1995 for 30 sites.

4.7.3 Other projects

There exist a few relatively large dam projects on the Bang Pakong river, including the Bang Pakong conversion dam. Effective and integrated operation of these dams is essential for controlling floods in downstream areas of this huge river basins.

The Pakmoon dam is under construction on the Mun river near its confluence with the Mekong river for power generation and irrigation purposes. The Master Plan endorses its early completion provided that the use at the dam be reviewed to benefit local people better.

The Royal Irrigation Department has studied practically all the river basins and subbasins in the Study Area. While most studies are still valid, development plans for selected river basins should be reviewed by the river basin approach to identify more sites for small pumping reservoirs and formulate measures for watershed management. These river basins are those described in subsection 4.4.2.

Tables

Table 2.1 Rainfall in Selected Countries

Country	Population (10,000) (10,000)	Area (1,000 sq.km) (1,000 sq.km)	Annual rainfall (mm/year)	Gross annual rainfall (bln cubic meter/year)	Annual rainfall per capita (cubic meter/ year/person)
Canada	2,561	9,976	522	5,208	203,337
U.S.A	24,160	9,373	760	7,124	29,485
UK	5,615	244	1,064	260	4,624
France	5,539	552	750	441	7,474
Germany	6,105	249	803	200	3,275
Italy	5,722	301	1,000	301	5,260
Spain	3,867	505	600	303	7,836
Sweeden	837	441	700	309	36,882
Austria	757	84	1,191	100	13,216
Switzerland	650	41	1,470	60	9,272
U.S.S.R	28,014	22,402	502	11,246	40,144
Romania	2,317	238	700	167	7,190
Yugoslavia	2,327	256	975	250	10,726
Japan	12,105	378	1,749	661	5,458
China	107,222	9,597	660	6,334	5,907
Philippines	5,558	300	2,360	708	12,738
Indonesia	16,694	1,905	2,620	4,991	29,898
India	76,614	3,288	1,170	3,847	5,021
Iran	4,591	1,648	250	412	8,974
Saudi Arabia	1,201	2,150	100	215	17,902
Egypt	4,961	1,001	65	65	1,312
Kuwait	179	18	120	2	1,207
Australia	1,597	7,687	460	3,536	221,416
New Zealand	325	269	2,010	541	166,366
Thailand	5,209	513	1,420	729	13,985
World total	491,700	135,793	973	132,127	26,871

Source : UN Water Conference in 1977

Table 2.2 Monthly Rainfall in the Northeast Thailand (30 year average, 1951-1980)

(Unit : mm)

Province	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual
Nong Khai	5.9	8.6	2.9	97.2	247.2	294.5	248.8	333.1	301.1	51.2	8.2	3.5	1,602
Loei	5.8	16.4	47.2	87.6	195.3	174.7	159.0	193.0	247.0	94.8	11.7	3.7	1,236
Udon Thani	7.2	20.3	39.0	80.0	217.9	240.7	228.4	289.6	282.9	79.7	7.4	2.6	1,496
Nakhon Phanom	7.1	18.9	43.9	100.2	239.7	480.4	422.6	592.6	315.5	52.5	4.7	1.1	2,279
Sakhon Nakhon	7.0	15.6	41.7	84.9	229.6	260.8	208.1	319.2	260.4	62.2	5.7	2.5	1,498
Mukdahan	4.2	15.7	39.7	86.6	181.9	275.3	243.6	313.7	294.6	63.3	3.8	1.1	1,524
Khon Kaen	7.7	15.4	34.2	62.7	171.8	180.8	156.5	188.3	276.9	86.0	13.5	2.9	1,197
Roi Et	3.4	15.2	29.4	88.7	193.2	193.0	206.3	255.3	325.9	87.5	9.2	1.1	1,408
Ubon Ratchathani	0.7	8.5	43.3	78.7	206.3	252.7	282.5	322.3	279.0	91.5	20.3	1.8	1,588
Surin	2.5	9.2	28.1	88.2	182.2	160.2	189.3	200.5	282.0	131.9	22.4	1.7	1,298
Nakhon Ratchasima	3.5	22.9	55.2	70.0	157.6	116.2	181.0	126.9	263.3	157.7	30.0	3.1	1,187
Chaiyaphun	3.8	17.5	50.6	84.0	164.4	147.1	153.4	146.2	310.0	121.9	15.6	3.5	1,218
Kalasin	6.3	17.0	29.8	58.8	194.9	233.2	226.9	247.2	285.8	63.7	4.3	2.3	1,370
Maha Sarakham	4.8	13.6	39.6	69.1	188.8	189.8	179.2	211.6	292.5	70.1	6.4	2.5	1,268
Yasothon	5.1	14.7	26.9	66.3	196.2	194.2	223.6	262.7	312.5	83.7	11.7	0.4	1,398
Buri Ram	3.0	11.7	33.9	69.2	164.6	175.4	155.0	177.9	303.9	131.6	24.6	1.2	1,252
Si Sa Ket	0.2	7.2	23.9	73.6	180.8	270.1	217.7	263.6	285.8	159.9	23.1	0.8	1,457

Table 2.3 (1) Average Monthly Mean Discharge of Each Station of Mun River Basin

(unit : cu.m./s)

Station & Province	Name of River	Location		D/A (sq.km.)	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Average
		Latitude	Longitude															
M2, NR	Lam Takong	15°00'03"	102°15'57"	4,800	0.86	3.40	3.04	6.42	25.48	36.72	76.99	37.31	9.75	1.75	0.91	0.82	203.46	16.93
M5, DK	Mun	15°20'16"	104°09'29"	44,275	3.18	10.52	66.00	140.05	222.42	535.20	739.92	390.31	103.78	43.76	8.05	4.21	2,267.38	188.95
M6A, BR	Mun	15°17'51"	103°17'51"	28,275	2.20	7.07	22.06	33.23	35.33	172.12	277.06	174.46	56.58	9.38	4.08	3.10	723.57	60.30
M7, UR	Mun	15°13'17"	104°51'39"	106,673	80.39	148.39	373.93	609.30	947.39	1,604.67	1,627.72	902.60	245.07	93.09	68.78	74.68	6,264.22	522.02
M9, SK	H. Samrang	15°07'00"	104°19'20"	3,026	0.19	0.33	7.36	14.99	16.22	65.78	75.56	36.48	3.12	0.59	0.27	0.18	185.53	15.46
M26, SR	Lam.Chi	14°54'03"	103°24'21"	2,927	0.24	0.67	5.69	16.21	19.33	79.46	80.57	21.44	2.84	0.45	0.31	0.19	227.39	18.95
M32, YT	H. Se Bai	15°50'20"	104°27'35"	1,654	0.04	1.16	18.11	35.42	71.05	96.69	44.48	2.30	0.60	0.61	0.87	0.07	271.41	22.62
M33, NR	Sam La	14°35'20"	101°50'30"	822	0.18	0.29	1.49	2.00	1.98	0.80	5.87	2.03	0.52	0.18	0.11	0.14	15.58	1.30
M38c, NR	Lam Takong	14°52'06"	101°33'53"	1,292	3.67	4.17	14.42	10.69	9.29	7.81	7.54	6.54	2.77	3.29	4.94	3.97	79.06	6.59
M42, SK	H. Thap Than	15°02'42"	104°01'29"	1,794	0.35	1.07	6.36	15.45	20.22	81.50	66.53	23.17	2.08	0.54	0.40	0.28	217.46	18.16
M43, NR	Lam Takong	14°31'40"	101°24'09"	235	0.38	1.35	3.78	4.92	7.91	9.80	8.10	2.53	1.10	0.65	0.46	0.32	41.28	3.44
M49, NR	Lam Sae	14°32'12"	102°10'07"	474	0.47	0.55	1.29	2.44	4.55	11.19	11.24	4.56	1.16	0.68	0.58	0.49	39.19	3.27
M50, NR	Lam Sae	14°31'08"	102°14'39"	875	5.15	4.67	6.67	10.59	13.05	22.07	21.92	11.99	7.95	6.65	5.93	5.65	121.82	10.15
M66, SK	M. Kanang	14°38'23"	104°39'45"	586	0.33	1.27	4.24	5.29	10.73	27.04	20.14	7.06	1.67	0.55	0.28	0.50	79.12	6.59
M69, UR	Lam Se Bok	15°30'19"	104°58'01"	2,132	0.62	8.95	40.43	54.11	128.17	137.78	54.96	18.89	2.62	0.41	0.31	0.41	447.66	37.30
M75, UR	H. Kwang	15°09'53"	105°17'01"	388	2.10	3.45	18.23	19.79	28.28	24.73	8.48	1.47	1.08	1.55	1.92	1.67	112.77	9.40
M80, UR	Lam Dom Yai	14°53'53"	106°05'08"	3,363	1.24	4.69	34.42	59.40	106.89	206.15	124.60	40.01	14.99	3.60	1.95	1.68	599.63	49.97
M81, NR	Lam Sae	14°23'51"	102°15'20"	482	0.33	2.34	6.05	8.08	13.62	14.28	15.64	3.73	1.31	0.75	0.42	0.20	66.75	5.56
M85, BR	Lam Chi	14°37'54"	103°14'03"	1,046	0.20	0.69	2.51	6.53	12.52	27.90	25.79	6.17	1.64	0.52	0.17	0.07	84.72	7.06
M89, NR	Lam Takong	14°41'46"	101°25'07"	673	2.24	3.64	5.04	6.41	8.64	16.66	18.98	6.69	3.55	2.50	2.05	1.91	78.05	6.50
M91, SK	H. Samran	14°29'48"	104°03'29"	128	0.15	0.32	0.66	0.89	2.58	6.97	5.57	1.49	0.42	0.15	0.06	0.18	19.42	1.62
M92, BR	Lam Phun Chu	15°32'57"	103°04'20"	1,094	0.14	1.20	11.55	10.99	11.66	24.93	13.46	3.27	0.85	0.31	0.13	0.06	28.50	6.54
M93, BR	H. Seo	14°28'24"	103°06'20"	329	0.02	0.09	0.54	1.47	1.92	5.04	8.28	2.12	0.50	0.28	0.12	0.05	20.43	1.70

Note : 1). These mean discharges are calculated by using the data of Hydrological Year Book from 1971 to 1989 published in R.I.D. Hydrological Division Bangkok.

2). Short term of provinces such as NR, BR, SU, SK, UR, YT etc. means as follows:

NR : Nakhon Ratchasima
BR : Buri Ram
SU : Surin
SK : Si Sa Ket
UR : Ubon Ratchathani
YT : Yasothon

Table 2.3 (2) Average Monthly Mean Discharge of Each Station of Mun River Basin

(unit : cu.m./s)

Station & Province	Name of River	Location		D/A (sq.km.)	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Average
		Latitude	Longitude															
M98, SK	H. Tha	14°52'39"	104°26'16"	1,092	0.12	0.47	4.00	6.09	11.51	31.69	34.01	12.12	2.07	0.47	0.17	0.15	102.86	8.57
M99, BR	H. Tha	14°36'22"	103°06'30"	88	0.00	0.05	0.40	0.87	1.19	3.16	3.53	1.45	0.15	0.03	0.02	0.01	10.86	0.91
M100, SR	H. Saneng	14°37'01"	103°28'44"	131	0.00	0.01	0.16	0.39	1.58	3.68	4.98	1.56	0.31	0.08	0.03	0.01	12.77	1.06
M101, SR	H. Thap Than	14°37'42"	103°42'12"	390	0.01	0.12	1.56	3.89	7.62	20.94	17.51	5.97	1.06	0.43	0.20	0.08	59.39	4.95
M102, SR	H. Sen	14°36'52"	103°53'24"	207	0.03	0.04	2.36	2.36	3.39	5.60	5.77	2.02	0.55	2.28	0.08	0.01	23.00	1.92
M105, NR	Nam Khen	15°00'42"	102°24'25"	1,291	0.01	0.00	0.00	0.00	4.04	12.64	32.20	3.70	0.67	0.46	0.27	0.08	54.07	4.51
M112, BR	H. Ta Khong	15°11'14"	103°12'22"	1,158	0.05	2.07	3.90	3.90	9.20	37.22	23.14	8.72	5.28	2.99	1.23	0.26	98.55	8.21
M121, NR	Lam Plai Mat	14°18'27"	102°26'22"	487	0.29	0.89	2.30	2.30	2.50	4.27	9.94	2.77	0.73	0.34	0.34	0.09	25.90	2.16
M123, SK		15°03'53"	104°20'56"	382	0.60	0.81	2.96	2.96	5.06	16.70	9.90	4.38	0.51	0.22	0.21	0.31	49.21	4.10
M127, UR	Lam Se Bok	15°34'27"	104°55'57"	414	0.04	0.26	7.46	7.46	15.76	19.09	6.13	0.47	0.10	0.03	0.00	0.02	53.65	7.55
M132, UR	H. Saphu	15°34'46"	105°04'00"	101	0.08	0.42	2.01	2.01	2.49	4.10	4.38	0.17	0.08	0.07	0.09	0.08	12.00	1.00
M137, SK	Sathing Sala	14°47'31"	104°10'40"	397	0.00	0.88	3.15	3.15	1.63	9.23	4.43	4.38	0.72	0.22	0.00	0.00	30.60	2.55
M138, SK	H. Samran	14°46'54"	104°07'32"	1,038	0.00	0.02	4.28	4.28	4.82	10.54	1.19	4.43	1.39	0.53	0.23	0.10	35.71	2.98
M141,UR		15°32'24"	104°58'46"	382	0.09	0.84	10.44	10.44	28.48	24.67	7.43	1.19	0.63	0.31	0.03	0.03	80.12	6.67

Table 2.3 (3) Average Monthly Mean Discharge of Each Station of Chi River Basin

(unit : cu.m./s)

Station & Province	Name of River	Location		D/A (sq.km.)	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Average
		Latitude	Longitude															
E2, YT	Nam Yang	15°47'06"	104°08'36"	47,391	67.23	90.20	169.51	337.39	438.24	598.83	598.50	279.30	74.48	41.48	43.39	46.35	2,784.86	232.07
E20A, YT	Chi	15°31'59"	104°15'24"	47,818	75.89	106.48	198.16	317.26	414.54	630.96	629.79	332.01	91.97	50.14	52.45	59.72	2,986.37	248.86

Table 2.3 (4) Average Monthly Mean Discharge of Thale Sap River Basin

(unit : cu.m./s)

Station & Province	Name of River	Location		D/A (sq.km.)	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Average
		Latitude	Longitude															
TL1, PB	Thale Sap	13°43'12"	102°28'06"	571	0.11	0.91	0.99	2.40	5.85	14.01	11.94	1.83	0.09	0.00	0.00	0.00	38.11	3.18

Note : 1). These mean discharges are calculated by using the data of Hydrological Year Book from 1971 to 1989 published in R.I.D. Hydrological Division Bangkok.
2). Short term of provinces such as NR, BR, SU, SK, UR, YT etc. means as follows:

NR : Nakhon Ratchasima
BR : Buri Ram
SR : Surin
SK : Si Sa Ket
UR : Ubon Ratchathani
YT : Yasothon

Table 2.3 (5) Average Monthly Mean Discharge of Each Station of Prachin Buri River Basin

(unit : cu.m./s)

Station & Province	Name of River	Location		D/A (sq.km.)	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Average
		Latitude	Longitude															
Kgt3, PB	Buri	13°59'05"	101°42'32"	7,502	4.41	19.53	72.52	135.64	251.14	352.20	283.41	76.25	20.59	6.16	3.26	3.12	1,228.22	102.35
Kgt6, PB		13°58'21"	101°30'57"	7,978	31.42	27.46	57.32	132.68	182.87	346.55	271.74	95.67	38.30	30.38	32.61	31.59	1,278.57	106.55
Kgt9, PB	K.Phra Sathung	13°40'10"	102°04'35"	2,279	3.98	8.77	12.40	19.58	47.64	82.37	70.57	19.87	5.38	3.61	2.76	3.30	280.22	23.35
Kgt10, PB	do	13°48'29"	102°03'35"	2,523	2.75	9.09	19.31	24.31	52.66	89.51	87.00	20.86	3.67	1.71	1.13	1.65	313.52	26.13
Kgt12, PB	K.Phra Prong	13°56'02"	101°58'41"	1,540	0.67	3.47	11.13	20.94	42.26	69.71	71.12	16.16	4.30	1.31	0.81	0.61	242.49	20.21
Kgt 13, PB	K.Phra Sathung	13°58'57"	101°42'46"	5,347	2.93	13.23	40.69	76.07	145.38	211.89	213.24	41.29	10.41	3.01	1.57	3.45	763.16	63.60
Kgt14, PB	H. Yang	14°09'30"	101°52'52"	366	0.20	1.32	3.07	5.46	10.39	14.22	11.12	1.99	0.56	0.29	0.21	0.42	49.25	4.10
Kgt15, PB	H. Seming	14°02'37"	101°47'30"	789	0.15	0.74	10.99	21.38	44.50	56.73	9.38	1.63	0.14	0.21	0.02	0.14	146.01	12.17
Kgt22, PB	Prachin Buri	13°59'45"	101°13'30"		122.61	115.79	121.71	195.7	260.20	378.45	373.45	216.75	143.49	130.05	136.18	135.21	2,329.94	194.16
Kgt24, PB	K. Pha Ka	14°10'34"	101°35'30"	121	0.19	0.75	5.28	13.43	17.18	12.96	7.95	1.54	0.39	0.15	0.10	0.09	60.02	5.00
Kgt27, NN	Nakhon Nayok	14°12'02"	101°27'05"	45	0.00	0.19	1.93	4.05	5.20	4.27	3.08	0.65	0.10	0.04	0.04	0.01	19.56	1.63

Table 2.3 (6) Average Monthly Mean Discharge of Each Station of Nakhon Nayok River Basin

(unit : cu.m./s)

Station & Province	Name of River	Location		D/A (sq.km.)	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Average
		Latitude	Longitude															
NY1, NN	Nakhon Nayok	14°14'22"	101°16'45"	520	0.15	1.40	34.15	67.35	53.15	60.05	30.65	12.85	4.25	1.85	0.22	0.31	226.38	22.20
NY1B, NN	do	14°14'45"	101°12'38"	519	0.43	3.96	26.29	50.78	67.40	55.14	31.09	13.16	5.48	1.71	0.84	0.52	256.80	21.40
NY3, NN	K.Ban Na	14°17'07"	100°04'26"	203	0.30	0.59	2.07	5.33	13.53	16.29	14.87	3.33	1.25	0.93	0.68	0.40	59.58	4.96
NY4, PB	Nakhon Nayok	14°17'23"	104°24'16"	128	0.00	1.61	11.58	17.72	20.44	19.94	12.17	1.89	0.34	0.68	0.05	0.03	86.47	7.21
NY5, NN	do	14°18'30"	101°20'60"	186	0.07	1.56	9.13	11.20	21.12	19.58	11.55	1.14	0.22	0.15	0.04	0.02	76.03	6.34

Table 2.3 (7) Average Monthly Mean Discharge of Each Station of Mekong River Basin

(unit : cu.m./s)

Station & Province	Name of River	Location		D/A (sq.km.)	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Average
		Latitude	Longitude															
KH84, MD	Ban Ian Dong	16°32'15"	104°24'20"	48	0.26	0.72	1.64	1.39	3.88	2.83	1.00	0.25	0.15	0.11	0.19	0.17	12.46	1.04
KH85, MD	Ban Kham Chai	16°31'12"	104°21'58"	28	0.16	0.35	0.68	0.84	3.29	4.01	1.02	0.34	0.21	0.16	0.20	0.34	11.58	0.97

Note : 1). These mean discharges are calculated by using the data of Hydrological Year Book from 1971 to 1989 published in R.I.D. Hydrological Division Bangkok.
2). Short term of provinces such as YT, PB, NN etc. means as follows:
YT : Yasothon
PB : Prachin Buri
NN : Nakhon Nayok
MD : Mukdahan

Table 4.1 Projected Urban and Rural Population in 2000 and 2010

(Unit : 1,000)

Province	Projected Population			
	2000		2010	
	Urban	Rural	Urban	Rural
Nakhon Nayok	18	204	36	191
Prachin Buri	39	746	140	862
Nakhon Ratchasima	278	2,097	1,202	1,804
Buri Ram	57	1,300	152	1,754
Surin	39	1,181	99	1,557
Si Sa Ket	34	1,252	87	1,650
Ubon Ratchathani	137	1,733	452	2,207
Yasothon	26	236	91	363
Mukdahan	22	507	58	664
Study Area	**650**	**9,259**	**2,318**	**11,042**

Table 4.2 Projected Animal Population in 2000 and 2010

(Unit : 1,000)

Province	Projected Animal Population									
	2000					2010				
	Buffalo	Cattle	Swine	Duck	Chicken	Buffalo	Cattle	Swine	Duck	Chicken
Nakhon Nayok	13.6	10.5	13.9	50.8	1,889	15.0	14.1	16.9	68.3	3,384
Prachin Buri	108.0	110.1	106.6	213.0	2,339	119.3	179.4	157.8	286.3	4,187
Nakhon Ratchasima	212.3	405.1	294.3	562.5	8,487	229.5	544.4	358.7	756.0	15,200
Buri Ram	338.6	119.2	173.9	356.6	6,162	374.0	194.2	212.3	479.2	11,036
Surin	339.1	194.2	134.7	621.8	5,122	374.6	316.3	199.4	835.7	9,172
Si Sa Ket	314.8	192.5	86.0	690.4	5,516	347.8	313.6	127.3	927.8	9,879
Ubon Ratchathani	395.0	369.8	102.9	748.2	12,054	436.3	727.5	152.3	1,005.5	21,587
Yasothon	116.7	107.8	23.2	200.4	2,102	128.9	212.1	34.4	269.3	3,765
Mukdahan	108.8	86.2	28.6	108.6	582	120.2	169.5	42.3	146.3	1,044
Study Area										

Table 4.3 Projected Water Demand for Human Use in 2000 and 2010

(Unit : 10^6 m^3/year)

Province	Projected Water Demand			
	2000		2010	
	Municipal	Non-municipal	Municipal	Non-municipal
Nakhon Nayok	2.1	3.6	3.0	3.5
Prachin Buri	6.4	14.6	11.5	15.7
Nakhon Ratchasima	47.4	35.5	98.7	32.9
Buri Ram	7.7	27.5	12.5	32.0
Surin	5.1	24.8	8.1	28.4
Si Sa Ket	4.5	26.2	7.1	30.1
Ubon Ratchathani	20.5	35.7	37.1	40.3
Yasothon	4.0	5.3	7.5	6.6
Mukdahan	2.9	10.6	4.8	12.1
Study Area	**100.8**	**184.6**	**190.3**	**201.6**

Table 4.4 Projected Water Demand for Animal Use in 2000 and 2010

(Unit : 10^6 m^3/year)

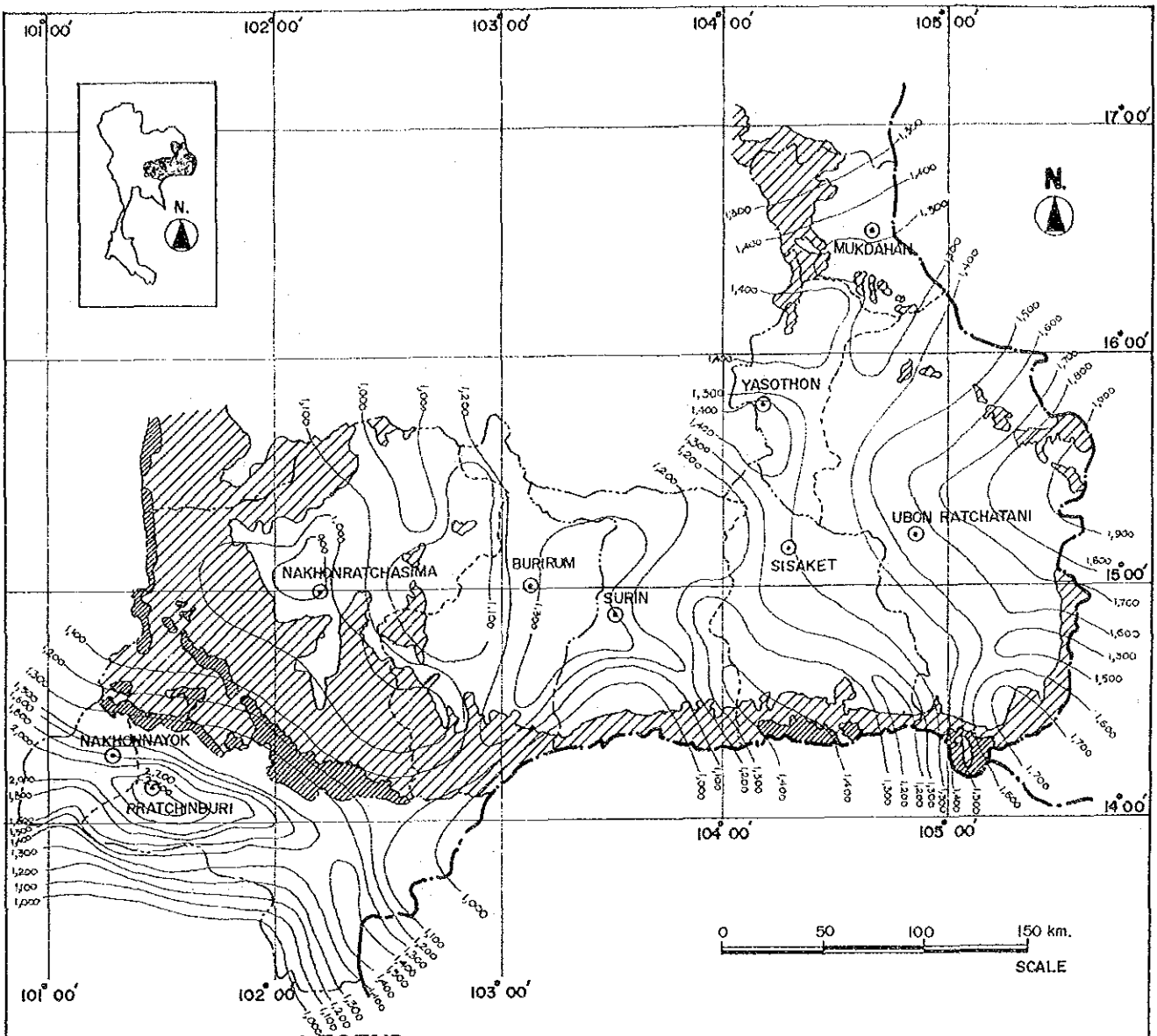
Province	Projected Water Demand					
	2000			2010		
	Buffalo & Cattle	Swine	Duck & Chicken	Buffalo Cattle	Swine	Duck Chicken
Nakhon Nayok	0.3	0.1	0.1	0.5	0.1	0.2
Prachin Buri	4.1	0.8	0.1	5.5	1.2	0.2
Nakhon Ratchasima	11.3	2.2	0.5	14.1	2.6	0.9
Buri Ram	8.5	1.2	0.3	10.4	1.5	0.6
Surin	9.9	1.0	0.3	12.6	1.5	0.5
Si Sa Ket	9.5	0.6	0.3	12.1	0.9	0.6
Ubon Ratchathani	14.6	0.7	0.7	21.2	1.1	1.2
Yasothon	4.2	0.2	0.1	6.2	0.3	0.2
Mukdahan	3.7	0.2	0.2	5.3	0.3	0.6

Table 4.5 Preliminary Construction Cost on Chok Chai Pumping Reservoir

Work Items		Unit	Quantity	Unit Prices (Baht)	Cost (x 10^6 Baht)	Remarks
1.	Direct cost					
1.1	Excavation	m^3	870,000	45.6	39.67	
1.2	Embankment	m^3	24,000	36.5	0.88	
1.3	Sod facing	m^2	19,000	60.0	1.14	
1.4	Macadam Pv.	m^2	10,000	96.0	0.96	
1.5	Intake conduit	L/S			0.21	
1.6	Access road	m	500	1,000	0.50	
1.7	Pump	Set	2	220,000	0.44	
1.8	Sluice gate	Set	2	10,000	0.02	
	Sub total				**43.82**	
2.	Overhead					
2.1	Project contingency (Direct cost x 4.3%)				1.88	
2.2	Benefit for contractor (Direct cost x 7.5%)				3.28	
2.3	Government tax (Direct cost x 7.96%)				3.48	
2.4	Engineering cost for government side (Direct cost x 3%)				1.31	
2.5	Engineering services for consultants (Direct cost x 6%)				2.63	
	Sub total				**12.58**	
3.	Land acquisition					
3.1	Proposed reservoir		18.4 ha	125,000	2.30	
3.2	Access road and others		1.0 ha	312,500	0.31	
	Sub total				**2.61**	
	Total			**59.01**	**≈ 59.00**	

Remarks: Overhead percentage is R.I.D.'s information.

Figures



LEGEND

——·——	INTERNATIONAL BOUNDARY
——··——	SUB - REGION BONDARY
- - - - - - -	PROVINCIAL BOUNDARY
⊙	NAME OF PROVINCIAL CAPITAL
	HEIGHT 1,500 - 2,000 METER
	HEIGHT 1,000 - 1,500 „
	HEIGHT 500 - 1,000 „
	HEIGHT 200 - 500 „
	HEIGHT 0 - 200 „
R 90.1 72.0 55.2	AVERGE HUMIDITY, MEANS, LOWEST
T 32.5 27.3 21.4	AVERGE TEMPERATURE , MEANS, LOWEST
	AVERGE RAINFALL / YEAR (mm.)

Figure 2.1 Annual Normal Rainfall Distribution in the Study Area

The Study on the Regional Development Plan
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in the Kingdom of Thailand

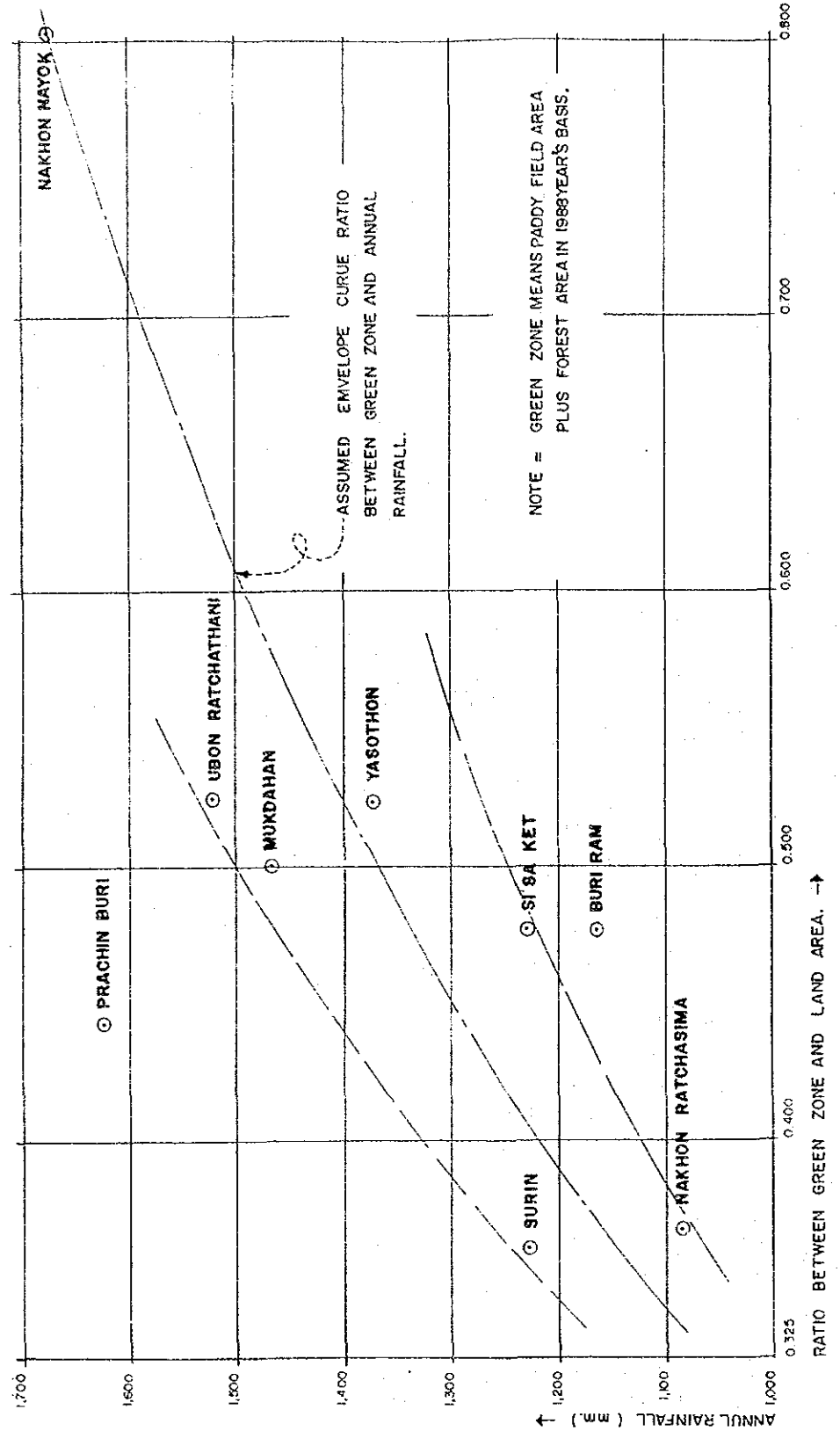

Figure 2.2 Correlation between Green Zone and Annual Rainfall

The Study on the Regional Development Plan for the Lower Northeast and the Upper East Regions in the Kingdom of Thailand

TABLE OF DRAINAGE AREA DISTRIBUTION (TENTATIVE)

AREA NO.	DRAINAGE AREA (Km²)	NAME OF RIVER
I	PRACHIN BURI	
(1)	790.6	Lam Sakae, Khlong Lard Kiw
(2)	528.1	Huai Yang, Huai Yakkah
(3)-1	623.8	Huai Phrom Hor
(3)-2	283.8	Khao Pun
(4)-1	563.1	Khlong Phra Sathung
(4)-2	1,607.9	Khlong Wang Chik
(4)-3	2,834.0	Khlong Phra Sathung
(4)-4	860.0	Huai Saeng
(4)-5	1,513.8	Khlong Phra Sathung, Mae Nam Hanuman
(4)-6	329.4	Khlong In Trai
(4)-7	983.8	Mae Nam Prachin Buri
TOTAL	11,108.3	
II	NAKHON NAYOK	
(5)	487.5	
TOTAL	487.5	
III	NAKHON RATCHASIMA	
(6)-1	1,235.0	D/A of Lam Takhong Dam Reservoir
(6)-2	1,767.5	Lam Takhong
(7)-1	502.5	Mae Nam Mun
(7)-2	1,227.5	Lam Sae
(7)-3	841.9	D/A of Lam Phra Phloeng Dam
(7)-4	1,540.0	Mae Nam Mun
(7)-5	573.8	Mae Nam Mun
(8)	1,128.1	Lam Chakkarat
(8')	178.9	D/A of Lam Choeng Krai Reservoir
(9)	2,030.0	Lam Chieng Krai
(10)	380.0	Huai The Khae
(11)	300.0	
(12)-1	1,380.0	Huai Kraseng, Huai Ban Mau
(12)-2	560.0	Lam Sa Thiet
(12)-3	243.8	
(12)-4	1,680.0	Huai Lue, Huai Ack
(12)-5	627.5	Lam Sa Thiet
TOTAL	15,964.5	
IV	BURIRAM	
(13)-1	488.8	Huai Sai Yang
(13)-2	615.5	D/A of Lam Nang Rong Reservoir
(13)-3	1,026.3	Lam Plai Mat
(13)-4	2,370.5	Lam Plai Mat
(13)-5	1,085.6	Lam Plai Mat
(13)-6	598.2	Lam Plai Mat
(14)-1	803.8	Lam Phang Chu
(14)-2	543.8	Lam Phang Chu
(15)-1	255.0	D/A of Huai Chorakhe Mak Reservoir and Huai Talat Reservoir
(15)-2	1,521.3	Huai Rat, Huai Talat
(16)	536.3	
TOTAL	9,834.6	
V	SURIN	
(17)-1	842.5	Huai Sao
(17)-2	1,782.5	Lam Chi
(17)-3	256.3	D/A of Ampil Reservoir
(17)-4	346.9	D/A of Huai Sanae Reservoir
(17)-5	93.8	D/A of Huai Sanae Reservoir
(17)-6	1,686.9	Lam Nam Chi
(18)	980.0	Lam Phrapphloeng
(19)	632.5	Huai Raan
(20)	249.0	Huai Phai
(21)	190.6	Huai Khayo
(22)-1	748.0	Huai Thap Than
(22)-2	863.8	Huai Thap Than
(22)-3	726.3	D/A of Lam Phok Reservoir
(22)-4	843.8	Huai Thap Than
(22)-5	496.3	Huai Thap Than
TOTAL	10,739.2	
VI	SI SA KET	
(23)-1	1,583.8	Huai Samaran
(23)-2	430.6	D/A of Huai Khlo Reservoir
(23)-3	931.9	Huai Samaran
(24)	362.5	

AREA NO.	DRAINAGE AREA (Km²)	NAME OF RIVER
(25)-1	1,126.3	Huai Tha
(25)-2	237.5	D/A of Tha Reservoir
(25)-3	1,003.0	Huai Khayung
(25)-4	686.3	Huai Khayung
(26)	1,161.3	Lam Sao Yai River
TOTAL	7,723.2	
VII	UBON RATCHATHANI	
(27)	48.9	
(28)-1	2,637.5	Lam Dom Yai
(28)-2	2,210.0	Huai Khayung
(29)	400.0	
(30)-1	825.0	D/A of Sirindhorn Dam Reservoir
(30)-2	2,105.0	D/A of Sirindhorn Dam Reservoir
(31)	429.5	
(32)	191.3	
(33)	3,243.8	
(34)	710.0	
(35)	295.0	
(36)	465.0	
(37)	210.0	
(38)	875.0	
(39)	332.5	
(40)	205.0	

AREA NO.	DRAINAGE AREA (Km²)	NAME OF RIVER
(41)	72.5	
TOTAL	19,309.0	
VIII	YASOTHON	
(42)	2,095.0	
TOTAL	2,085.0	
IX	MUKDAHAN	
(43)	260.0	Huai Chanot
(44)	1,340.0	Huai Bang Sai
(45)	565.0	Huai Muk
(46)	1,332.5	Huai Bang
TOTAL	3,497.5	
GRAND TOTAL	80,759.8 Km²	

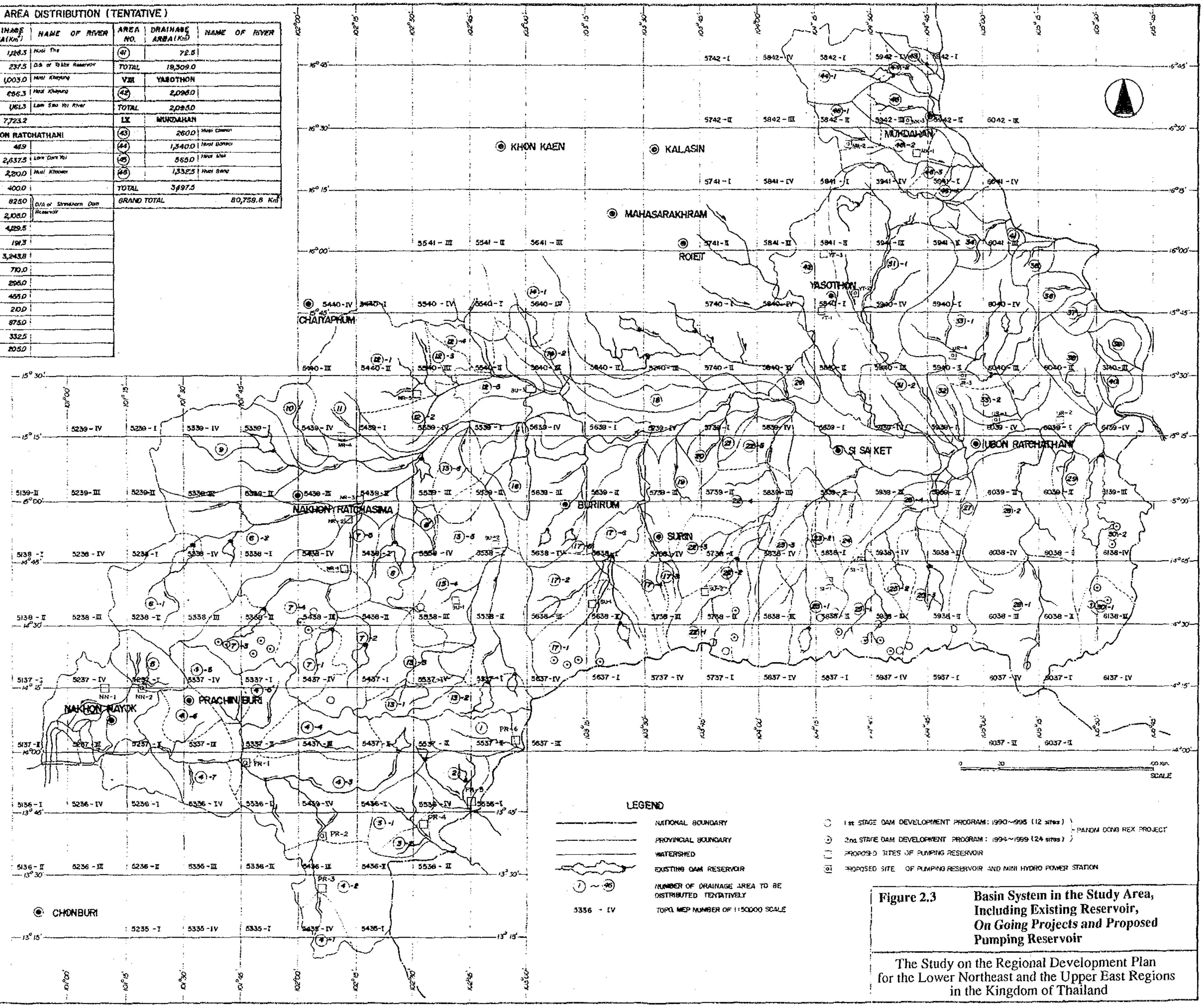

Figure 2.3 **Basin System in the Study Area, Including Existing Reservoir, *On Going Projects and Proposed* Pumping Reservoir**

The Study on the Regional Development Plan for the Lower Northeast and the Upper East Regions in the Kingdom of Thailand

Mun River Basin

Station & Province	Name of River	Location	
		Latitude	Longtitude
M2, NR	Lam Takong	15°00'03"	102°15'57"
M5, DK	Mun	15°20'16"	104°09'29"
M6A, BR	Mun	15°17'51"	103°17'51"
M7, UR	Mun	15°13'17"	104°51'39"
M9, SK	H. Samrang	15°07'00"	104°19'20"
M26, SR	Lam.Chi	14°54'03"	103°24'21"
M32, YT	H. Se Bai	15°50'20"	104°27'35"
M33, NR	Sam La	14°35'20"	101°50'30"
M38c, NR	Lam Takong	14°52'06"	101°33'53"
M42, SK	H. Thap Than	15°02'42"	104°01'29"
M43, NR	Lam Takong	14°31'40"	101°24'09"
M49, NR	Lam Sae	14°32'12"	102°10'07"
M50, NR	Lam Sae	14°31'08"	102°14'39"
M66, SK	M. Kanang	14°38'23"	104°39'45"
M69, UR	Lam Se Bok	15°30'19"	104°58'01"
M75, UR	H. Kwang	15°09'53"	105°17'01"
M80, UR	Lam Dom Yai	14°53'53"	106°05'08"
M81, NR	Lam Sae	14°23'51"	102°15'20"
M85, BR	Lam Chi	14°37'54"	103°14'03"
M89, NR	Lam Takong	14°41'46"	101°25'07"
M91, SK	H. Samran	14°29'48"	104°03'29"
M92, BR	Lam Phun Chu	15°32'57"	103°04'20"
M93, BR	H. Seo	14°28'24"	103°06'20"
M98, SK	H. Tha	14°52'39"	104°26'16"
M99, BR	H. Tha	14°36'22"	103°06'30"
M100, SR	H. Saneng	14°37'01"	103°28'44"
M101, SR	H. Thap Than	14°37'42"	103°42'12"
M102, SR	H. Sen	14°36'52"	103°53'24"
M105, NR	Nam Khen	15°00'42"	102°24'25"
M112, BR	H. Ta Khong	15°11'14"	103°12'22"
M121, NR	Lam Plai Mat	14°18'27"	102°26'22"
M123, SK		15°03'53"	104°20'56"
M127, UR	Lam Se Bok	15°34'27"	104°55'57"
M132, UR	H. Saphu	15°34'46"	105°04'00"
M137, SK	Sathing Sala	14°47'31"	104°10'40"
M138, SK	H. Samran	14°46'54"	104°07'32"
M141,UR		15°32'24"	104°58'46"

Chi River Basin

Station & Province	Name of River	Location	
		Latitude	Longtitude
E2, YT	Nam Yang	15°47'06"	104°08'36"
E20A, YT	Chi	15°31'59"	104°15'24"

NR : Nakhon Ratchasima
BR : Buri Ram
SR : Surin
SK : Si Sa Ket
UR : Ubon Ratchathani
YT : Yasothon
PB : Prachin Buri
NN : Nakhon Nayok
MD : Mukdahan

Nakhon Nayok River Basin

Station & Province	Name of River	Location	
		Latitude	Longtitude
NY1, NN	Nakhon Nayok	14°14'22"	101°16'45"
NY1B, NN	do	14°14'45"	101°12'38"
NY3, NN	K.Ban Na	14°17'07"	100°04'26"
NY4, PB	Nakhon Nayok	14°17'23"	104°24'16"
NY5, NN	do	14°18'30"	101°20'60"

Mekong River Basin

Station & Province	Name of River	Location	
		Latitude	Longtitude
KH84, MD	Nakhon Nayok	16°32'15"	104°24'20"
KH85, MD	do	16°31'12"	104°21'58"

Prachin Buri River Basin

Station & Province	Name of River	Location	
		Latitude	Longtitude
Kgt3, PB	Buri	13°59'05"	101°42'32"
Kgt6, PB		13°58'21"	101°30'57"
Kgt9, PB	K.Phra Sathung	13°40'10"	102°04'35"
Kgt10, PB	do	13°48'29"	102°03'35"
Kgt12, PB	K.Phra Prong	13°56'02"	101°58'41"
Kgt 13, PB	K.Phra Sathung	13°58'57"	101°42'46"
Kgt14, PB	H. Yang	14°09'30"	101°52'52"
Kgt15, PB	H. Seming	14°02'37"	101°47'30"
Kgt22, PB	Prachin Buri	13°59'45"	101°13'30"
Kgt24, PB	K. Pha Ka	14°10'34"	101°35'30"
Kgt27, NN	Nakhon Nayok	14°12'02"	101°27'05"

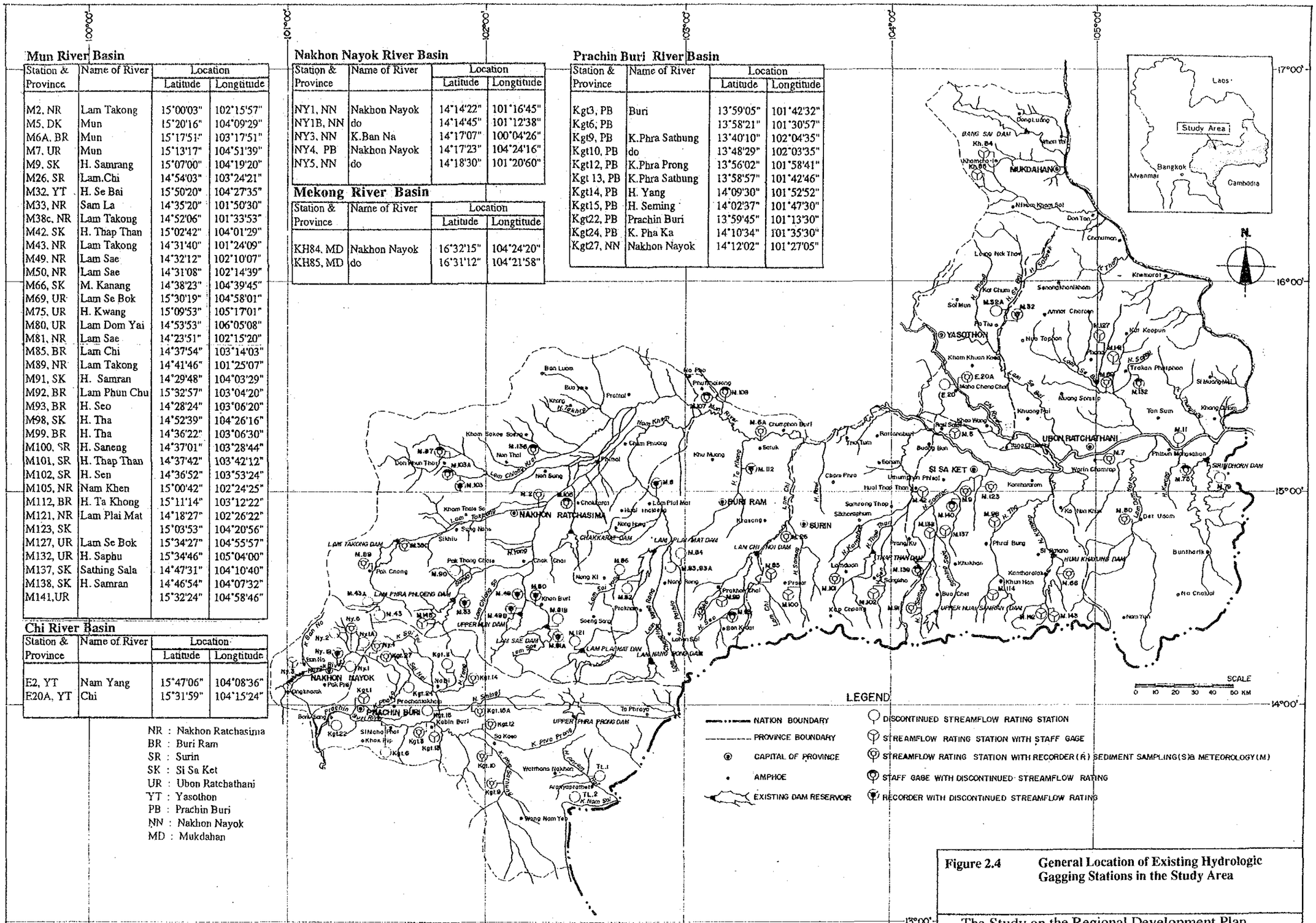

Figure 2.4 **General Location of Existing Hydrologic Gagging Stations in the Study Area**

The Study on the Regional Development Plan
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in the Kingdom of Thailand

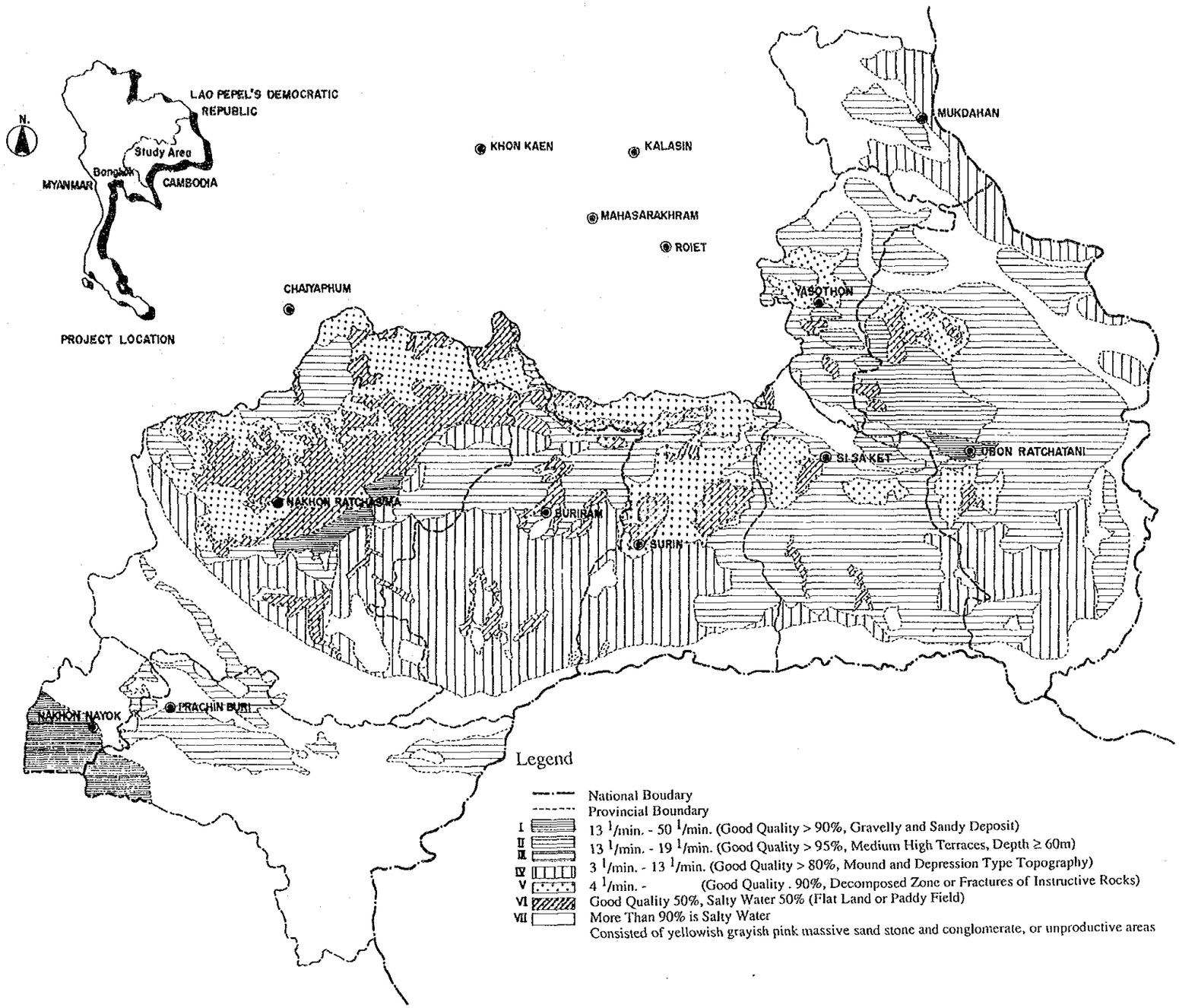


Figure 3.1
General Location of Ground Water Potential

The Study on the Regional Development Plan
for the Lower Northeast and the Upper East Regions
in the Kingdom of Thailand

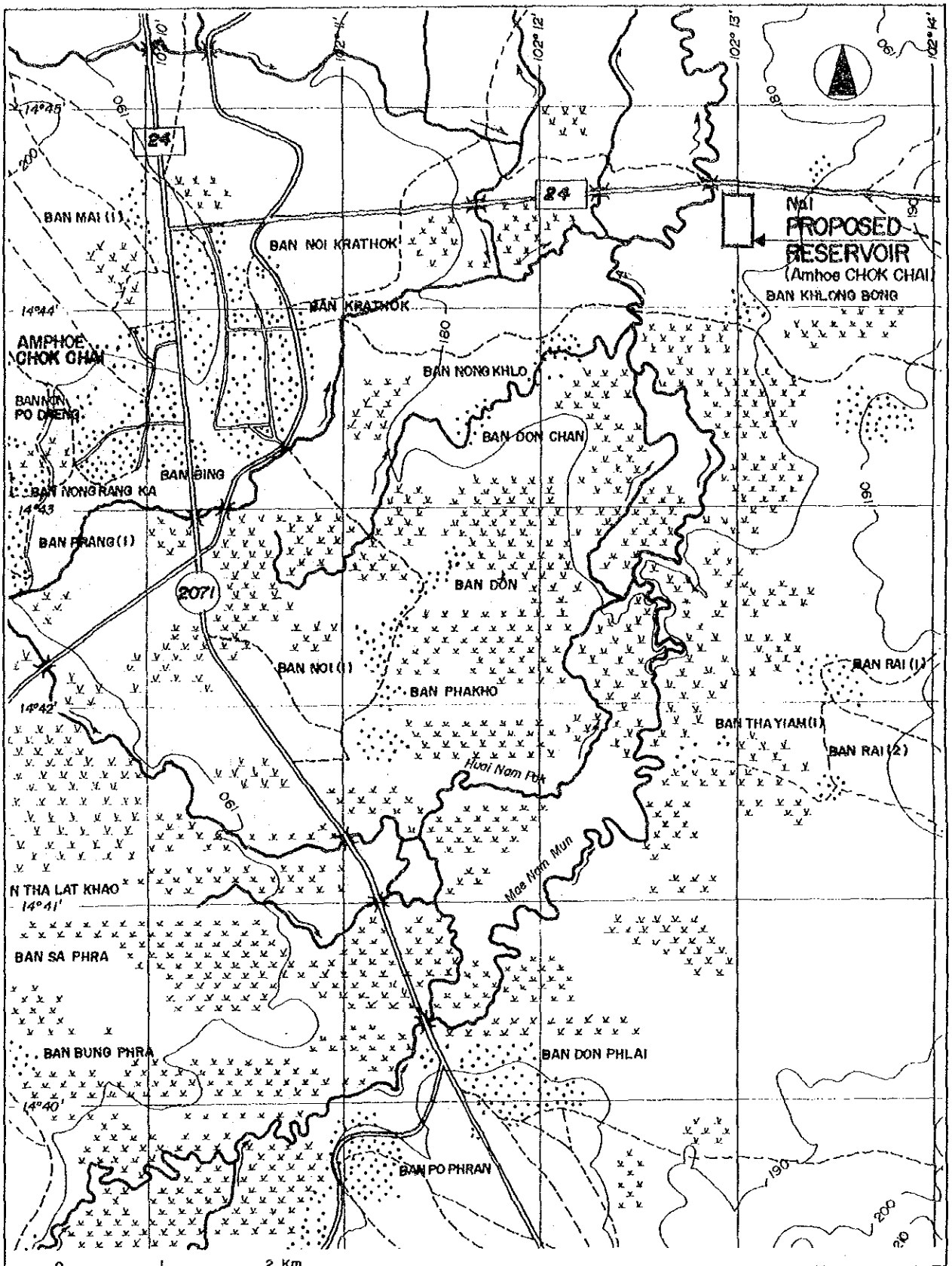
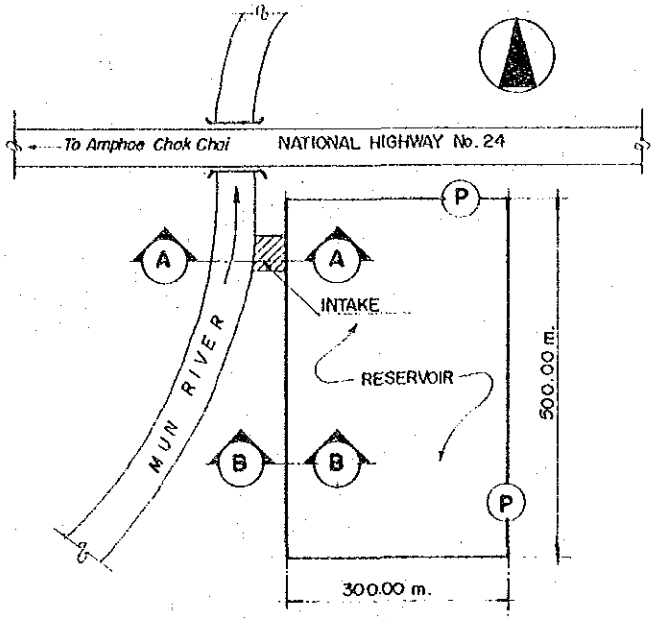
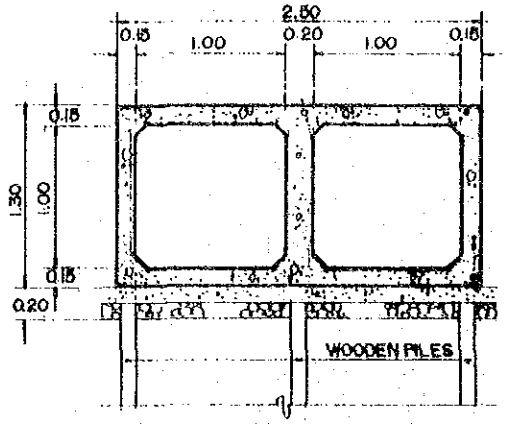


Figure 4.1
Location of Proposed Chok Chai Pumping Reservoir (NR-1)

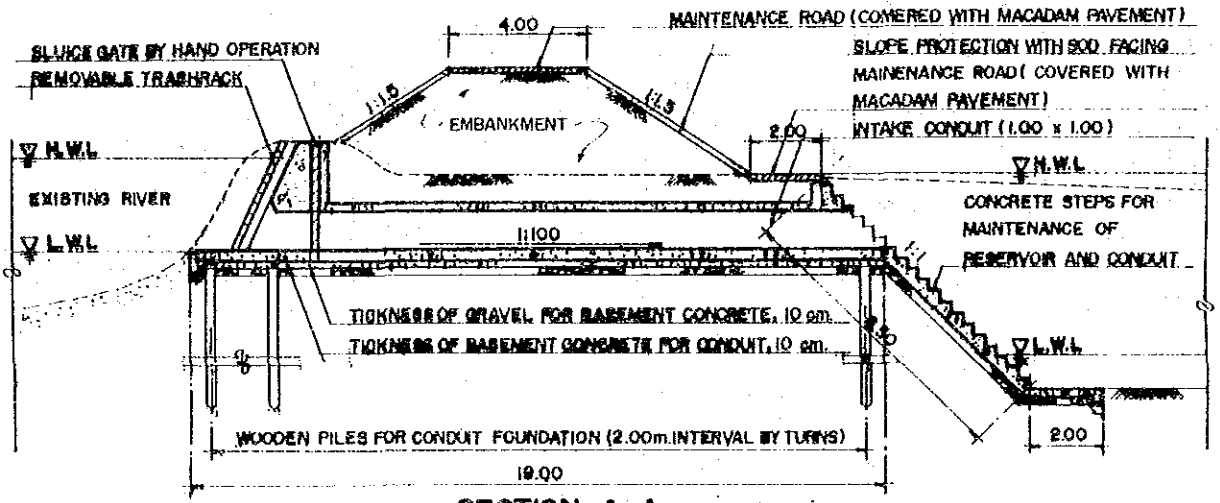
The Study on the Regional Development Plan
for the Lower Northeast and the Upper East Regions
in the Kingdom of Thailand



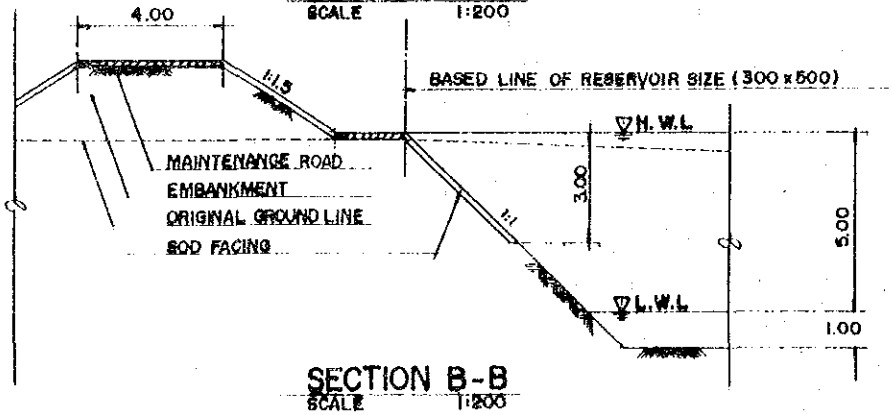
SKETCH OF RESERVOIR LOCATION
NON SCALE



SECTION OF CONDUIT
SCALE 1:50



SECTION A-A
SCALE 1:200



SECTION B-B
SCALE 1:200

Figure 4.2
Preliminary Design of Reservoir and Intake on Proposed Chok Chai Pumping Reservoir

The Study on the Regional Development Plan for the Lower Northeast and the Upper East Regions in the Kingdom of Thailand

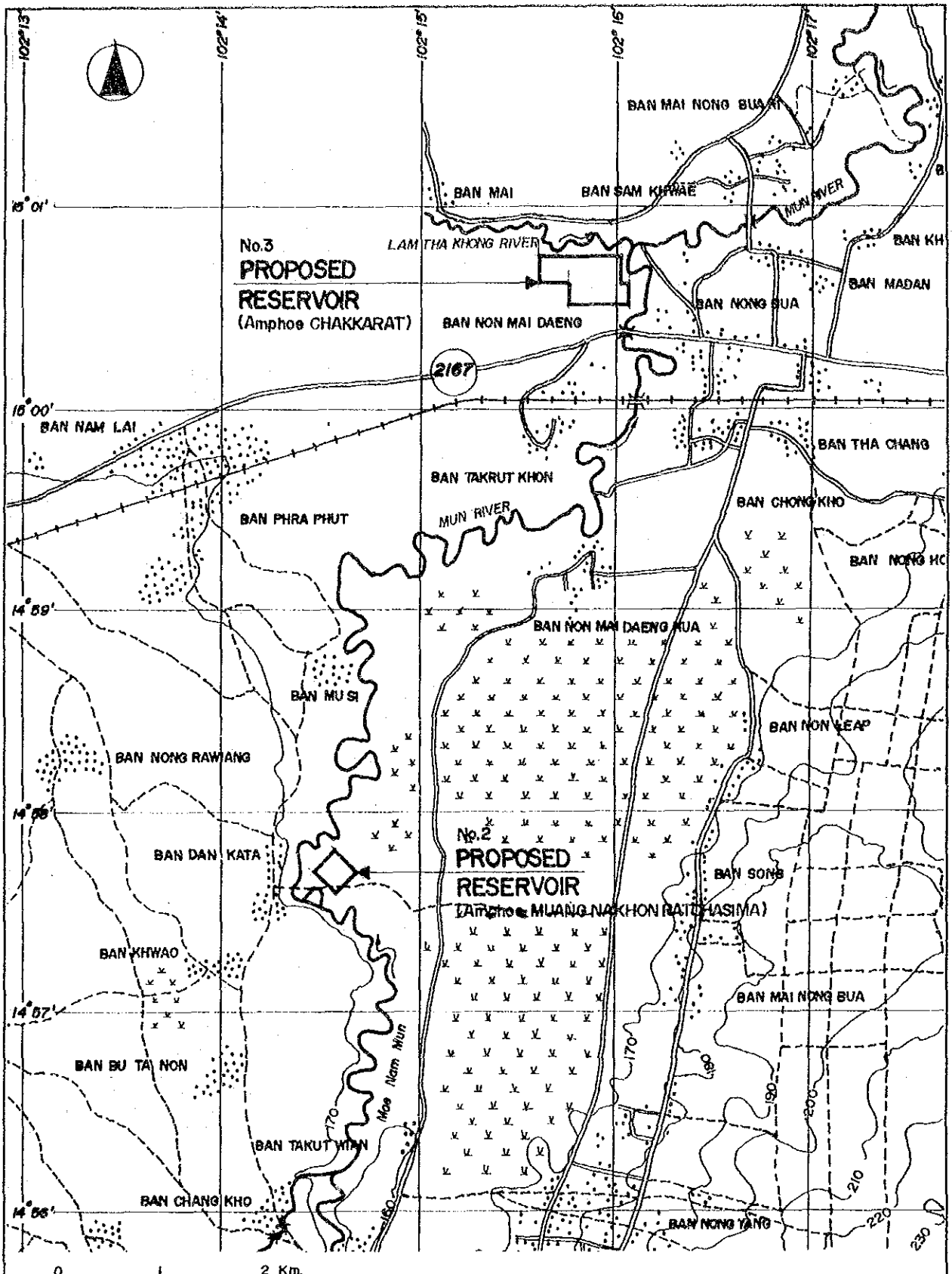
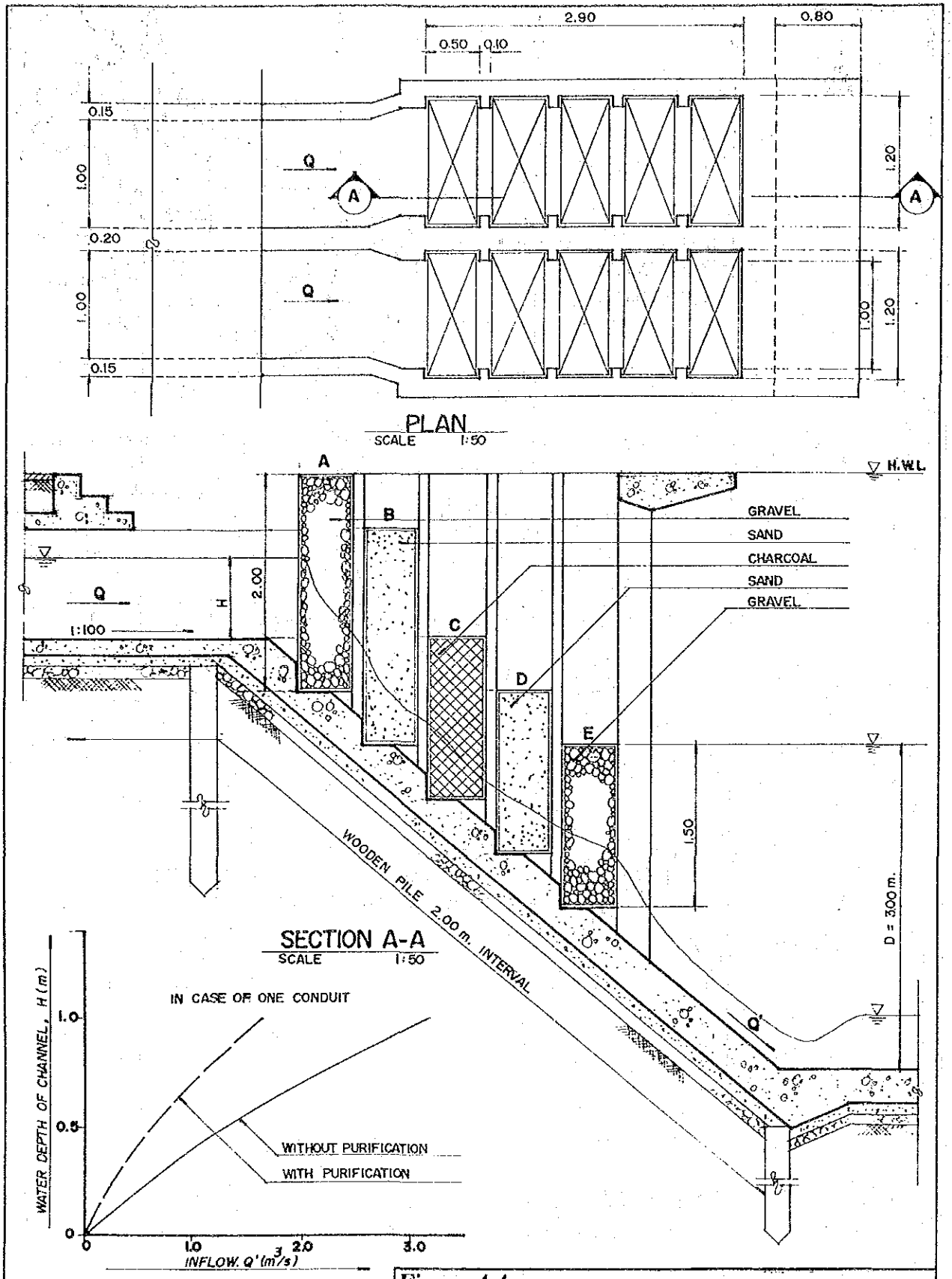


Figure 4.3
Location of Proposed Ban Dan Kata and Tha Chang Pumping Reservoir (NR-2, Nr-3)

The Study on the Regional Development Plan
for the Lower Northeast and the Upper East Regions
in the Kingdom of Thailand



RELATION BETWEEN CONDUIT WATER DEPTH AND RESERVOIR INFLOW

Figure 4.4
Purification Method at Intake of Pumping Reservoir

The Study on the Regional Development Plan
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DRAINAGE AREA OF PANOM DONG REX WATER RESOURCES DEVELOPMENT PROJECT

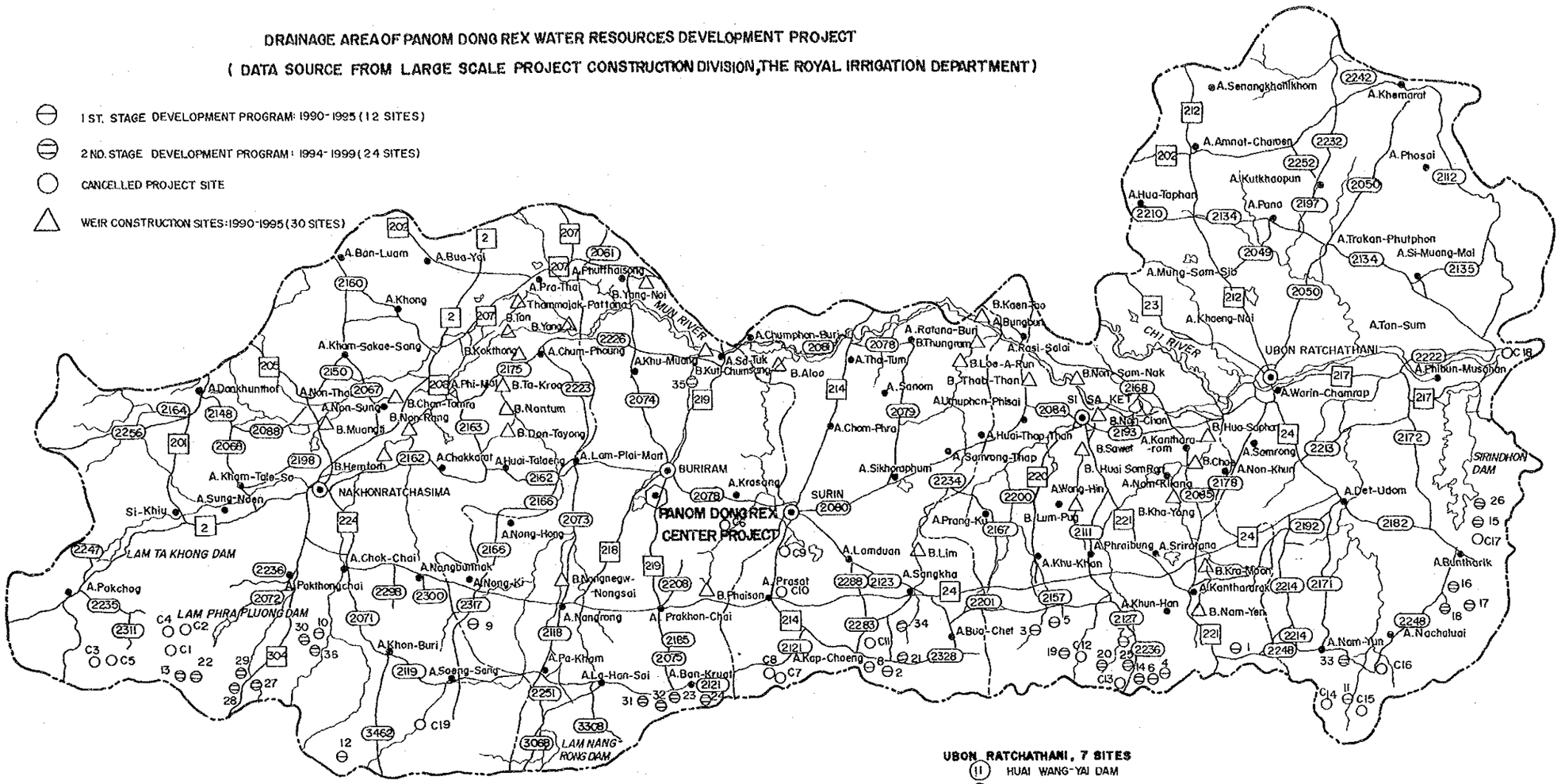
(DATA SOURCE FROM LARGE SCALE PROJECT CONSTRUCTION DIVISION, THE ROYAL IRRIGATION DEPARTMENT)

⊖ 1 ST. STAGE DEVELOPMENT PROGRAM: 1990-1995 (12 SITES)

⊖ 2 ND. STAGE DEVELOPMENT PROGRAM: 1994-1999 (24 SITES)

○ CANCELLED PROJECT SITE

△ WEIR CONSTRUCTION SITES: 1990-1995 (30 SITES)



NAKHON RATCHASIMA, 9 SITES

(10) BA-I-TAN DAM
(12) HUAI THAB KRUA DAM
(13) LAM PRA PEANG 1 DAM
(22) KAM-SI-MA DAM
(27) KLONG PHAI 2 DAM
(28) KLONG PHAI 3 DAM
(29) KLONG BONG 1 DAM
(30) HUAI HOO DAM
(36) HUAI TA-PHROM

CANCELLED PROJECT, 6 SITES

(C1) HUAI KROK-TE DAM
(C2) LAM PHRA PEANG 2 DAM
(C3) HUAI KLONG-DUA DAM
(C4) HUAI WUA-TAI DAM
(C5) HUAI DIN-DAM DAM
(C19) KLONG LAM-LAK DAM

BURIRAM, 6 SITES

(9) HUAI YANG DAM
(23) HUAI TA-KHIAW DAM
(24) HUAI TA-KO DAM
(31) HUAI SEA (UPPER) DAM
(32) HUAI PLU DAM
(35) LAM-TA-KONG DAM

CANCELLED PROJECT, 1 SITES

(C6) HUAI KRA-BUNG DAM

SURIN, 4 SITES

(2) HUAI KHA-NAD MON DAM
(8) HUAI CHEANG DAM
(21) HUAI KRA-LENG-WAK DAM
(34) HUAI SEN DAM

CANCELLED PROJECT, 5 SITES

(C7) HUAI O-DAI-KRA-HOM DAM
(C8) HUAI SA-NENG (UPPER) DAM
(C9) O-CHIAW DAM
(C10) HUAI TA-CHIAW DAM
(C11) HUAI KRA-OON

SI SA KET, 10 SITES

(1) HUAI KHA-NUN DAM
(3) HUAI SAM RAN DAM
(4) HUAI SANG-KOT DAM
(5) HUAI TIK-CHOO DAM
(6) HUAI DAN-1 DAM
(7) HUAI THA DAM
(14) HUAI KHA-YONG DAM
(19) HUAI O-TA-SAT DAM
(20) HUAI CHAN DAM
(25) HUAI TA-BANG DAM

CANCELLED PROJECT, 2 SITES

(C12) HUAI TA-PANG DAM
(C13) CHONG-PHRA-PLAI DAM

UBON RATCHATHANI, 7 SITES

(11) HUAI WANG-YAI DAM
(15) HUAI TONE DAM
(16) HUAI SA-PONG-NOI DAM
(17) HUAI DEAN-HA DAM
(18) HUAI LA-MUED DAM
(26) HUAI NAM-KHIAW DAM
(33) HUAI PHLAN DAM

CANCELLED PROJECT, 5 SITES

(C14) HUAI BET DAM
(C15) HUAI YANG DAM
(C16) HUAI LUANG DAM
(C17) HUAI DIN-DAM-YAI DAM
(C18) LAM-DOM-YAI DAM

Figure 4.5 Phanom Dong Rek Water Resources Development Project

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