POST-ENVIRONMENTAL EVALUATION OF THE RAJJAPRABHA DAM IN THAILAND

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Declaration

*I declare that this thesis is the record of bonafide research carried out by me under the supervision of **Dr. K.C. SANKARANARAYANAN,** Professor and former Head of the Department of Applied Economics, and the Dean, Faculty of Social Sciences, Cochin University of Science and Technology, Cochin 682022. I further declare that this thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar title of recognition.*

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GLOSSARY AND ABBREVIATIONS

1. GENERAL

Abbreviation	Description
ACD	Active Case Detection for malaria
ADB	Asian Development Bank
ADT	Average Daily Traffic
a.m.	Anti Meridian
API	Annual Parasitic Incidence
Amphoe	A political subdivision equivalent to district
ARD	Office of Accelerated Rural Development
Ban	A political subdivision equivalent to village
BAAC	Bank of Agriculture & Agriculture Co-operatives
B/C	Benefit - Cost ratio
B.E.	Buddhist Era
BOD, BOD5	Biochemical Oxygen Demand
CEC	Caution Exchange Capacity
CITES	Convention on International Trade in Endangered Species of wild Flora and Fauna
D.A.	Drainage Area
Dbh	Diameter at Breast Height
DO	Dissolved Oxygen
EEI	Environmental and Ecological Investigation

Abbreviation	**Description**
EGAT	Electricity Generating Authority of Thailand
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
FY	Fiscal Year
GNP	Gross National Product
GPP	Gross Provincial Product
GRP	Gross Regional Product
IBC	International Board of Consultants
IRR	Internal Rate of Return
Khlong	A small streams or canal
Khao	Mountain or hill
MPN	Most Probable Number
msl, MSL	Mean Sea Level
MCH	Mother and Child Health
MVA	Meg Volt – Ampare
MEA	Metropolitan Electricity Authority
Na	Not available
NEA	National Energy Administration
NEB	National Environment Board
OM&R	Operation Maintenance and Replacement
p.a.	Per Annum
PEA	Provincial Electricity Authority

Abbreviation	Description
p.m.	Post Meridian
p.f.	plasmodium falciparum
P.V.	Plasmodium Vivax
PWD	Public Works Department.
PWWA	Provincial Water Works Authority
Q	River flow
RFD	Royal Forestry Department
RID	Royal Irrigation Department
SAR	Sodium Absorption Ratio
SD	Standard Deviation
SPR	Slide Positive Rate
TAT	Tourism Authority of Thailand
TDS	Total Dissolved Solids
Tambon	A township equivalent to a group of villages
V/C	Traffic Volume Capacity Ratio
U.S	United States
Wat	Buddhist monastery

2. UNITS OF MEASUREMENT

Abbreviation	Full Name	Description
฿	bath	Thai Currency
M฿	million bath	Thai Currency
°C	degree Celsius	Temperature Unit
cfs, ftb/s	cubic foot per second	Flow Rate Unit
d	day	Time Unit
cm	centimeter	Length Unit
cms	cubic meter per second	Flow Rate
ft	feet	Length Unit
gal	u s gallon	Volume Unit
g, gm	gram	Weight or Mass Unit
gwh	giga watt-hour	Energy Unit
ha	hectare	Area Unit
h, hr	hour	Time Unit
HP	horse power	Power Unit
HZ	hertz cycle per second	Frequency Unit
JTU	Jackson turbidity unit	Turbidity Unit
kg	kilogram	Weight Unit
km	kilometer	Length Unit
kv	kilovolt	Electric Potential
kVA	kilovolt ampere	Electric Unit
kw	kilowatt	Power Unit

Abbreviation	Full Name	Description
kwh	kilowatt-hour	Energy Unit
L,l	liter	Volume Unit
L,l pcd	liter per capita per day	Water Consumption Rate
mcm, MCM	million cubic meter	Volume Unit
MW	Mega watt	Power Unit
mwh	mega watt-hour	Energy Unit
m	meter	Length Unit
m(msl),m MSL	meter above measured level	Elevation Unit
me	milli equivalent	Weight Unit
mm	milli meter	Length Unit
m^3, cms	cubic meter per second	Flow Rate
mg	milli gram	Weight or Mass unit
mg/l	milli gram per liter	Density Unit
umho	micro-mho	Electric Conductance
mg	micro gram	Weight or mass unit
NTU	Nephelometric turbidity Unit	Turbidity Unit
ppm	part per million	Density Unit
ppt	part per thousand	Density Unit
Rai, rai	rai	Thai Unit of Area
Rpm	revolution per minute	Angular Velocity
s, sec	second	Time Unit
sq km	square kilometer	Unit of Area
yr	year	Time Unit

CONVERSION TABLE

1 inch	=	2.54	cm
1 mile	=	1.6093	km
1 km	=	0.6214	mile
1 m	=	3.28	ft
1 rai	=	0.16	ha
1 ft^2	=	0.0929	m^2
1 m^2	=	10.7584	ft^2
1 hectare	=	6.25	rai
1 km^2	=	100	hectares
1 km^2	=	625	rai
1 rai	=	1,600	m^2
1 ft^3	=	0.0283	m^3
1 m^3	=	35.31	ft^3
1 mcm	=	10,00,000	m3
1 cfs	=	0.0283	cms
1 cms	=	35.31	cfs
1 Mkwh	=	10,00,000	kwh
1 Gwh	=	10,00,000	kwh
1 MW	=	1,000.00	kw
1 kg	=	2.205	pounds
1 ton	=	1,000	kg

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THE APPROACH

1. INTRODUCTION

Post Environmental Evaluation (PEE) of a development project falls within the preview of applied research. The evaluation is done by taking into consideration the environmental consequences of the project. Thus it is a systematic examination of the environmental and socio-economic consequences of the project after its implementation.

Environmental evaluation of Rajjaprabha dam is done in three stages viz., (i) during the project feasibility study stage (ii) during construction stage and (iii) during project operation stage. This study is done in the third stage i.e. the project operation stage.

2. STATEMENT OF THE PROBLEM

The socio-economic infrastructures are instrumental in all developmental efforts and they help in making rural living more comfortable. Creation of infrastructure facilities opens new vistas for employment, ameliorate economic status and enhance the living standards of the common people. Therefore the infrastructure establishments in an area aim to bring about positive changes in welfare and equity. Economic changes lead to better employment and productivity. The total infrastructure, as such, includes transport, communication, rural industries, rural electrification and marketing. The developing countries, which stress industrial development to enhance production for sufficient provision of goods, often experience short fall in energy. Electrical energy is the primary reservoir with 240 MW hydropower plant located about 90 km upstream from Surat Thani province, and irrigation diversion dams with irrigation and drainage systems located in the coastal plain in Surat Thani province. The upstream storage reservoir has about 5,639 mcm storage at its normal high water level. That, hydropower plant had already been implemented by the Electricity Generating Authority of Thailand (EGAT) during 1980-1987. The first phase of irrigation system development for irrigating 144,375 rai (23,100 hectares), net paddy area including the diversion dam at Phun Phin district and downstream flood protection works are presently under construction, with the Royal Irrigation Department (RID) as the implementing authority. The second phase irrigation system planned for irrigating about 313,000 rai (50,000 hectares) area with the diversion dam at Khlong Yan, has not yet been implemented. The beneficial impacts from the project after completion includes: (1) generation of power (about 554 kwh per year from the 240 MW installed capacity plant) (2) irrigation of about 50,000 hectares of paddy land and (3) flood protection and drainage for the towns of Surat Thani and other downstream communities (including the paddy areas in the coastal plain). A detailed project description is given in chapter III.

4. OBJECTIVES

The objectives of the study are:

(1) To investigate in detail all existing environmental resources and values using input output analysis. The impacts will be shown at four levels (Physical resources, Biological resources, Human use values, and Quality of life values)

(2) To evaluate the beneficial impacts of the project.

(3) To compare the actual positive effects with the estimated effects.

(4) To identify the changes vis-a- vis the impacts previously assessed.

5. SCOPE OF THE STUDY

The scope of the study is limited to the Phum Duang river basin. Emphasis is being placed on the areas upstream and downstream of the damsite which are affected directly by the project. The environmental impacts are evaluated at four levels viz., (1) physical resources (2) biological resources (3) human use values and (4) quality of life values. This is based on the methods proposed by U.S. Corps of Engineers, (Battelle Pacific Northwest Laboratories, 1974) which has been adopted as a guideline for environment impact assessment (EIA) preparation by the National Environmental Board (NEB) of Thailand. **This methodology envisages an item-by-item study (case study) of the following effects:**

Level I : Physical Resources

- Climate and Surface Water Hydrology
- Ground Water Resources
- Surface Water Quality
- Soil and Land Capability
- Mineral Resources
- Erosion and Sedimentation
- Salinity Intrusion

Level II : Ecological Resources

- Aquatic Ecology and Aquatic Weeds

- Fisheries Resources
- Forestry Resources
- Wildlife Resources

Level III : Human Use Values

- Land Use Pattern
- Irrigation and Water Supply
- Flood Protection
- Hydropower Production
- Water Pollution

Level IV : Quality of Life Values

- Socio-Economic and Resettlement Aspects
- Public Health and Nutrition Condition
- Tourism, Recreation and Aesthetics
- Archaeological and Historical Values

An overall economic evaluation of the river basin is included in this study.

6. HYPOTHESES

The following hypotheses are formulated for the study.

(1) The adverse effects of the dam are not significant on the physical resources in the project area.

(2) The negative impacts on the ecological resources on the project will be confined to the project area alone.

(3) The Rajjaprabha dam has positive impacts on the economy and the standard of living of the people in the Phum Duang river basin.

7. METHODOLOGY

7.1 Data Collection

Both primary and secondary data were used for the study.

(1) Primary Data

The primary data were collected through field studies. A combination of methods such as:

1. Field reconnaissance through observation to check the land use pattern, mineral resources, ground water resources, erosion, flood and irrigation,
2. Inventory assessment to check the impact on forestry, wildlife, fisheries, and aquatic animals.
3. Took samples for evaluating water quality, water supply, and drinking water.
4. Traffic counting to evaluate the impact on surface transportation and navigation.
5. Field survey using a questionnaire to evaluate the impact on the socio-economic aspects and tourism.

(2) Secondary Data

Secondary data for the study were mainly collected from published sources. The major sources of secondary data were Thai central government office; (i) the Electricity Generating Authority of Thailand (ii) the Royal Forestry Department (iii) the Royal Irrigation Department (iv) the Royal Land Development Department (v) the Fisheries Department (vi) the Department of Mineral Resources (vii) the Highway

Department (viii) the Harbor Department (ix) the Department of Meteorology (x) the Department of Fine Arts (xi) the Tourism Authority of Thailand (xii) the National Energy Administration (xiii) the Provincial Waterworks Authority (xiv) the Communicable Diseases Control Department and (xv) the Ministry of Public Health.

Data were also obtained from various local offices like; (i) Surat Thani Provincial Office (ii) a District Office of Ban Ta Khun (iii) Surat Thani Provincial Public Health Office (iv) Ban Ta Khun district Public Health Office (v) Malaria control zone 4 (vi) Surat Thani Provincial Fisheries Office (vii) Provincial Highway Office (vii) Surat Thani Region Forestry Office (viii) Provincial Accelerated Rural Development Office (ix) Provincial Mineral Resources Office (x) Provincial Agricultural Office (xi) Provincial Land Office (xii) Provincial Public Welfare Office (xiii) Surat Thani and Phun Phin district Waterworks (xiv) Land Development Provincial Office and (xv) Local Royal Irrigation Department Offices at Phang-Nga.

7.2 Data Analysis

The following tests were used for analyzing the data.

(1) Percentile method : This method is used to present the characteristics of the environmental and socio-economic aspect in the watershed area.

(2) Chi Square test : This test is employed to determine if similarity or difference (or neither), in the given parameter during pre and post study (Sidney Siegel. 1956). The formula used is:

$$X^2_{(df,\alpha)} = \sum_{i=1}^{n} \sum_{j=1}^{k} \frac{(f_{o_{ij}} - f_{e_{ij}})^2}{fe_{ij}} \qquad (1.1)$$

where X^2 = Chi-square value

$f_{o_{ij}}$ = Observed frequency

$f_{e_{ij}}$ = Expected frequency

$$= \frac{\left(\sum_{j=1}^{k} f_{ij}\right)\left(\sum_{I=1}^{n} f_{ij}\right)}{\sum_{i=1}^{n}\sum_{j=1}^{k} f_{ij}}$$

df = Degree of freedom = n + k - 1

α = Level of significance

n = Number of characteristic used for comparison

k = Number of groups of samples being compared.

(3) Likert method : This method is used to determine attitudes of the people in the watershed area (Sidney Siegel,1956) employing the following formula :

$$\tilde{X} = \frac{\sum_{i=1}^{n} f_i \; x_i}{N} \quad (1.2)$$

Where $\tilde{X}$ = Likert's weighted score

n = Total no. of opinions designated for a given question

i = i th opinion or attitude expressed when a question is asked

x_i = Designated unit weight of the i th opinion

N = Total number of observation.

$$= \sum_{i=1}^{n} f_i$$

7.3 Evaluation of Environment Values

The three types of economic analysis are employed for the evaluation of environmental values. They are presented below :

7.3.1 Market Value

The net benefit per unit (NBU) is measured using the Halvorsen and Rubby equation (Halvorsen and Ruby, 1981).

$$\Delta EV = P_0 \Delta Q_1 (1/e_s - 1/e_d) [1 + (\Delta Q_1 / 2Q_0)] \qquad (1.3)$$

where ΔEV = Value of environment quality changes

e_s = Elasticity of supply

e_d = Elasticity of demand

Q = Number of product

ΔQ_1 = $Q_1 - Q_0$

7.3.2 Travel Cost Method (TCM)

The travel cost approach is a way to put monetary value on non-priced goods. This approach was initially developed to value benefits received by consumers from their use of an environmental good such as a lake or a dam. The approach imputes the price-quantity reactions of consumers by examining their travel costs. The main idea behind this method is that the cost of travelling to particular site influences the number of visits made to it (Bateman, et.al. 1992).

The relationship can be expressed as :

	V	=	f (TC, X, ...X_n)	(1.4)
where	V	=	number of visits,	
	TC	=	travel cost,	
	$X_1 \ldots X_n$	=	other explanatory variables.	

7.3.3 Survey Techniques

The survey technique is a contingent valuation method (CVM). This study is based on an open-ended questionnaire to evaluate the willingness to pay (WTP) and willingness to accept (WTA), (Direk and Pornpen, 1995).

7.4 Economic Evaluation of Environmental Impacts

The economic evaluation of environmental impacts is conducted at three levels viz., project level, regional level, and the economy of Surat Thani province. The last has been evaluated with the help of input-output analysis.

In order to ascertain the full impact, along with the usual input-output model, household income-consumption matrices and pollution count are also added.

Considering the project area as a closed system does the economic evaluation of environmental impacts on the project region. But this approach has limitations: (i) the benefits and costs that the project generates in the area can be part of a much larger fabric (ii) the project may involve the movement of people into or out of the project area (iii) the project area problem can be better understood in the content of a larger ecosystem.

7.4.1 The Economic Impact of Environmental Consequences

The economic impact of environmental consequences at the regional level is evaluated by:

(a) Collecting basic data on natural resources at regional/sub-regional level;

(b) Collecting social and economic data on key regional and sub-regional variables

(c) Studying the relationship between region and project area;

(d) Defining preliminary regional/sub-regional strategies; and

(e) Assessing implication on regional economics of the project.

The impacts are simply determined by the difference between the conditions with and without the dam. To avoid the difficulty in calculation, the impact calculation will begin with the net irrigated areas receiving water from the dam and proceed to determine the impacts on different aspects by the following formulas:

(1) The impacts on production

(1.1) Production change in province is evaluated using the following formula:

$$q_{ij} = \sum_{t=1}^{n} (Y^{S}_{itj} \quad A_{itj} \; - \; Y^{R}_{itj} \quad A_{itj}) \qquad (1.5)$$

where qij = Change in quantity of commodity in province j

Y^{S}_{itj} = Yield of commodity i in the irrigated area under the project at time t in the province j

$$I_{ij} = \sum_{T=1}^{n} (V_{itj} - C_{ij}) \qquad (1.9)$$

where I_{ij} = Change in income resulted from producing commodity I

V_{itj} = Production value of commodity i at time t in the province j

C_{ij} = Production cost of commodity i at the province j

(3.2) Change in income of the whole project is calculated as follows;

$$I = \sum_{i=1}^{n} \sum_{t=1}^{m} \sum_{j=1}^{s} (V_{itj} - C_{ij}) \qquad (1.10)$$

where I = Change in total income due to the project.

(4) Impacts on cropping patterns and systems

The impacts on the cropping pattern can not be exactly quantified. They, however, can be simply determined by the comparison of crops planted in the wet and dry seasons at the period before and after the construction of the dam. On the other hand impacts on the cropping systems are determined by the differences in areas of rice and other crops planted in year-round. The impacts can quantified in total production value.

7.4.2 Evaluation of Actual Positive Benefits.

The main objectives of this study are the following :

(a) To estimate the demand for electricity and the damages due to electricity interruption.

(b) To evaluate the actual positive benefits after the project implementation and to compare them with the estimated values before the project construction.

(c) To identify all significant changes in benefits from the previously estimated ones; and

(d) To assess the multipurpose water resource development as previously estimated.

To fulfill the above objectives, the following methodologies are adopted. For the first objective, data and information were collected from 12 selected industrial and service units utilizing pre-tested interview schedules. Information was collected on number of workers per industrial unit, labour per hour, value of product produced per hour, cost of electricity per hour, damages due to electricity interruption per hour, ability to generate own electricity, and cost of fuel for generating own electricity per hour. Damage due to electricity interruption includes two components: direct damages and indirect damages. Direct damages consist of loss in quantity and quality of products or outputs and storable inputs during electricity interruption. Indirect damage considered is only the labour cost, which is the cost of non-storable input.

With respect to the second objective, which consists of benefits from hydropower, irrigation, water supply, flood control, fisheries development, transportation and navigation, salinity and water pollution control, tourism, health improvement, and resettlement were evaluated. The data and information used in the evaluation of these benefits were obtained from primary and secondary sources. The methods used in evaluating the various components are as follows:

(a) Benefits from hydropower

= cost of having such electricity from the most competitive alternative source.

(b) Benefits from irrigation

= total net value of crop production with irrigation project - total net value of crop production without irrigation project.

(c) Benefits from water supply

= cost of next cheaper alternative water source for domestic and industrial usage.

(d) Benefits from flood protection

= saving due to reduction in physical damages in the flood prone area + saving in expenses which otherwise would have to be incurred in connection with flood control, increase in transportation cost, etc. + benefit resulting from more efficient and productive uses of the flood prone area owing to protection + health hazard cost reduction + security and loss of life prevention.

(e) Benefits from fisheries development

= increase in value of reservoir fisheries – (value of downstream loss during the construction + value of downstream loss after impoundment + value of loss of migratory species) + benefit of aquaculture using water supply from the project.

(f) Benefits from transportation and navigation

= (cost of using road transportation instead of reservoir and downstream navigation - cost of using reservoir and downstream navigation) - (cost of relocation for transportation instead of reservoir and downstream navigation + maintenance cost for relocated roads).

(g) Benefits from salinity and water pollution control

= (total net value of crop production with salinity intrusion control - total net value of crop production without salinity intrusion control).

(h) Benefits from forestry

= benefits from decreases in deforestation and illegal logging - value of loss of forest products in reservoir area - value of loss of wood from trees in reservoir area.

(i) Benefits from tourism

= revenue received from visitors who come for the purpose of recreation + revenue received from visitors who come for other purposes + revenue from expenditure of visitors.

(j) Benefits from health improvement

= increase in earnings of person resulting from improvement of health + decrease in the cost of health care resulting from improvement of health owing to the project; and

(k) Benefits from resettlement

= Post resettled household income - pre-resettled household income.

The pre-post evaluation form was used to compare the actual positive benefits after construction of the dam with the pre-project evaluation of the benefits from the project outputs (evaluated after the implementation of the dam).

By this method, all significant changes in benefits from the project after its implementation from the previously estimated benefits can be identified, this fulfils the third objective. Thus, the last objective involving assessment of the multipurpose water resource development as previously estimated can be achieved.

7.4.3 Input-Output Analysis

The main objective of this study is to analyze the direct and indirect effects of Rajjaprabha dam on output, income and environment in Surat Thani. Therefore, the administrative boundary of Surat Thani province is defined as a region specific economic system. Production sectors within the area are treated as "domestic" production sectors and those outside are aggregated as "the rest of the world". Inflow of goods and services from the rest of the world are considered as "imports" while outflow of goods and services from the region, "exports".

Methodology

(1) Model : In addition to the usual input-output matrix, household income-consumption matrices and pollution row are included in the model. The model is described as follows:

Material balance equation

$$X = AX + BY + F \quad (1.11)$$

Income equation

$$Y = VX + T \quad (1.12)$$

Imports equation

$$M = CX + DY \quad (1.13)$$

Pollution equation

$$Q = PX + SY \quad (1.14)$$

Where X = column vector of output (baht).

A = input - output coefficient matrix.

B = expenditure - income (value added) (baht).

F = other demands (baht).

V = value added - output coefficient matrix.

T = other net transfer payment (baht).

M = total imports (baht).

C = import-output coefficient vector.

D = import-income coefficient vector.

Q = total pollution (BOD) in kg.

P = pollution output coefficient vector.

S = pollution income coefficient vector.

In matrix form

$$\begin{bmatrix} I-A & -B & O & O \\ -V & I & O & O \\ -C & -D & I & O \\ -P & -S & O & I \end{bmatrix} \begin{bmatrix} X \\ Y \\ M \\ Q \end{bmatrix} = \begin{bmatrix} F \\ T \\ O \\ O \end{bmatrix}$$

$$\begin{bmatrix} X \\ Y \\ M \\ Q \end{bmatrix} = \begin{bmatrix} I-A & -B & O & O \\ -V & I & O & O \\ -C & -D & I & O \\ -P & -S & O & I \end{bmatrix}^{-1} \begin{bmatrix} F \\ T \\ O \\ O \end{bmatrix}$$

The first matrix equation (1.8) shows direct structural linkages, while its inverse in equation (1.9) indicates total (direct and indirect) linkages. Except for pollution, all variables are measured in value terms. Pollution is measured by BOD per baht of output produced.

To analyze the impacts of the project, the model is slightly changed. As indicated before Rajjaprabha dam affects the economy in various ways. The changes primarily caused by the dam are regarded as an exogenous change in the system. This change also generates indirect effects on the economy. The model to derive direct and indirect effects on the economy due to an exogenous change in supplies of particular sectors can be formed as follows:

$$\begin{bmatrix} -I & -A^N & -B^K & O & O \\ O & I-A^N & -B^K & O & O \\ O & -V^N & I & O & O \\ O & -C^N & -D^K & I & O \\ O & -P^N & -S^K & O & I \end{bmatrix} \begin{bmatrix} F^E \\ X^N \\ Y^K \\ M \\ Q \end{bmatrix} = \begin{bmatrix} -I+A^E & O & O & O & O \\ A^E & O & O & O & O \\ V^E & O & O & O & O \\ C^E & O & O & O & O \\ P^E & O & O & O & O \end{bmatrix} \begin{bmatrix} X^E \\ O \\ O \\ O \\ O \end{bmatrix} + \begin{bmatrix} O \\ F^N \\ T^K \\ O \\ O \end{bmatrix}$$

Or $G \cdot H = J \cdot K + L$ (1.17)

$H = G^{-1} (J \cdot K + L)$

where superscript N = refers to sectors not primarily affected by the dam.

E = refers to sectors primarily affected by the dam.

K = refers to household.

The solution gives sectoral output, household income, imports and pollution directly and indirectly generated by the project.

(2) Data The 1975 national input-output transaction table is used as a basis to derive regional technical coefficient matrix. Important production activities are identified based on economic profile of the region. Production activities are aggregated into 36 sectors. Households are differentiated between agricultural and non-agricultural households. The adapted transaction table is used to derive technical coefficient matrix for the regional economy. Technical coefficients for households (income and consumption) are derived from the social account matrix for Thailand. Primary data from survey, spot check and secondary data of various sources are used to cross check the technical coefficient matrix. Certain cells have been adjusted. Observation in the area suggests that air pollution is not an important element. Hence, only water pollution is emphasized. As suggested from water quality studies, few industries have potential to be pollutant generators. Their pollution coefficients are obtained from water quality study. Each row represents supply of goods and services from a row sector to various column sectors. Each column represents demand for goods and services from various row sectors. Row households refer to value added to households while column households refer to consumption of households.

8. LIMITATION OF THE STUDY

The study is limited to the 10 years period from the date of completion of the dam i.e. 1987. It is true that the period of study is not sufficient to appraise the changes and effects of the dam on physical resources such as climate, geology, land capability, etc. Hence, the results emerged from the study are only tentative.

9. SCHEME OF THE STUDY

The thesis is organized under ninth chapters. The first chapter provides the introduction. It explains the statement of the problem, project background, objectives, scope and methodology etc.

The second chapter presents a review of literature in the area of study.

Detailed information about the project such as the project location, project purpose, features, design, etc are provided in the third chapter.

The fourth chapter provides information relating to climate, surface water quality, erosion and sedimentation, ground water resources, soil resources, etc.

Biological resources such as fisheries, forestry, wildlife, aquatic ecology, aquatic weeds are dealt with in the fifth chapter.

The sixth chapter explains human use values that benefit from power production, flood protection, crop irrigation, drinking water, water supply, land use pattern, water pollution etc.

The seventh chapter deals with quality of life values; socio-economic and resettlement aspects, public health and nutrition conditions, tourism, recreation and aesthetics, archaeological, and historical values.

The eighth chapter presents the economic analysis of environmental consequences assessment.

The ninth chapter presents the summary and conclusion.

CHAPTER II

REVIEW OF LITERATURE

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REVIEW OF LITERATURE

1. ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

The guidelines prepared by the National Environmental Board (NEB) of Thailand for Environmental Impact Assessment (EIA) suggests four levels of environmental impact assessment viz., (1) physical resources (ii) biological or ecological resources (iii) human use values and (iv) quality of life values. (NEB.1979). On the other hand, Andrew, divides the environmental impact assessment method into seven categories (Andrew R.N.L. 1973) viz; (1) ad hoc methods (2) checklists (3) matrices (4) overlays (5) networks (6) Quantitative or index methods and (7) models.

Brief descriptions of these categories with examples are given below.

1.1 Ad Hoc methods

This is the most common approach to impact assessment. Basically ad hoc methods indicate broad areas of likely impact by listing composite environmental parameters (for example, flora and fauna) likely to be affected by development activities.

1.2 Checklists

Checklists are an expansion on ad hoc methods in that they list environmental, social and economic components in more detail. Also, some checklists identify typical impacts resulting from certain types of development. Checklists serve as a guide for identification and consideration of a wide range of impacts.

The Multiagency Task Force, (1972) has mentioned that it has also provided a checklist for evaluating environmental impacts. It suggests that the impacts be expressed quantitatively whenever possible. Further for each impact the uniqueness of the affected component and the irreversibility of the expected changes should be considered where appropriate. It is the predicted future state of the environment, and not the present condition, which should be compared with the project proceeds. But it may be seen that the scope of the checklist is rather limited interms of the features to be investigated. For example, when cultural resources such as archeological sites are included, social and economic factors are neglected. However, the explicit consideration of uniqueness and irreversibility distinguishes this method from many others. This forces those who prepare the impact statement to consider the post development situation.

Adkin and Burke have provided a checklist for evaluating the environmental impacts (Adkin.W.G. and Burke D.1974). The components in the checklist are broken down into four categories viz., (i) transport (ii) environmental (iii) social and (iv) economic. Impacts on these components are evaluated on a -5 to +5 rating system. This method is an early attempt to systematize assessment of route alternatives but it suffers from a number of limitations. The coverage of ecological effects is deficient. Also, the rating of impacts and alternative routes require subjective judgement, and there are no guidelines to aid formulation of these judgements.

1.3 Matrices

In matrices used for evaluating environmental impact usually one dimension of the matrix provides a list of environmental, social and economic factors likely to be affected by a proposal. The other dimension provides a list of actions associated with development. These actions relate to both the construction and operational phases. There are many variations to the matrix approach. The best known interaction matrix method was developed by Leopard and has been used more often than any other method in the preparation of EIS in the United States.

Leopold's method, (Leopold, et al. 1971), as mentioned above, is one of the best known and most widely used methods for EIS. It has been adapted in a number of ways for use in particular impact analyses. The method advocated is really an interaction matrix in which the existing characteristics of the environment (for example, endangered species) are listed vertically and proposed project action (for example blasting and drilling) are listed horizontally. 8800 interactions are identified in the matrix. However, preliminary trials indicate that specific projects will result in only 25-50 interactions. For each interaction a score of 1 (least magnitude or importance) to 10 (greatest magnitude or importance) should be given. It suggests that the cells indicating an impact are slashed and the scores for magnitude are placed at the bottom right hand section. A+ (plus) sign in the appropriate cell can denote beneficial impacts. It emphasizes that no two cells in any one matrix are equal and that, if separate matrices were prepared for alternative projects, only the cells indicating the same impact would be comparable. A completed matrix provides a visual representation of an impact statement, as the impact statement should contain a discussion of the impacts identified. The most important criticism of this method involves its focus on direct impacts. Second-and higher order impacts cannot be identified easily. Also the matrix does not allow for change in impacts over time.

Welch H.W. and Lewis G.O. (1976) assessed environmental impacts of multiple land use management. "The multi dimensional analysis for the assessment of land use alternative is considered a useful approach as it can show the interactions between elements". It also provides a system for identifying data requirements and the required scientific expertise. A three dimensional matrix is constructed on the basis of the following dimensions, viz; analysis of the relationships among various land uses, the institutions which influence or control these uses, and the ecological and environmental systems with which the uses interact. The effects of a second home development are used to illustrate its use, and it can be used to identify whether impacts are of first, second, or higher order.

Toftner R.O. (1973) believes that the impact statement might be a useful starting point for better environmental planning. However, impact statements often consider only primary impacts. A matrix, which allows secondary and tertiary impacts, is necessary to have a complete picture. He considers transport developments to cause the most far-reaching effects, for example, on land use patterns, land consumption, population densities expansion of commerce and industry. Through investigations of such secondary and tertiary impacts, the quality of information available to decision-makers will be improved. The matrix discussed serves only as a checklist of primary, secondary and tertiary factors to be considered in an impact statement. Since it is not an interaction matrix the impact cannot be identified. Also, the category intake checklist is broad, leaving the detailed break up of these categories for impact identification to those carrying out impact assessments.

1.4 Overlays

The use of overlay maps has been restricted to route or site selection. Few examples of their use in environmental impact analysis have been reported. A first, series of maps, each containing data on environmental, social and economic variables, are prepared. By overlaying the maps, areas possessing a preferred combination of these variables can be identified.

Mcharc, also studied the comprehensive highway route selection method. (Mcharc I. 1968). His paper contains a description of one of the first methods to be advocated for impact analysis. The method is based on an overlay of map transparencies, each map dealing with specific environmental and land-use characteristics. Each of these characteristics is shaded differently to represent three degrees of "compatibility with the highway." By using overlayed maps, one of which is the proposed route, a comprehensive picture showing the spatial distribution and intensity of impacts can be obtained. This composite picture can also be used to select alternative routes by examining areas showing the greatest compatibility with the highway. This method has served as the basis for a more sophisticated method developed by Krauskopf and Bundle. While resource requirements of the manual overlay method are less demanding than those of computerized versions, this method provides less information.

1.5 Networks

Networks are based on known linkages within systems. Thus, actions associated with a project can be related to both direct and indirect impacts. For example, impacts on one environmental factor may affect another environmental or socio-economic factor and such interactions are identified and listed on a network diagram. This diagram is subsequently used as a guide to impact identification and the presentation of results. While there are few examples of the use of networks in impact assessment, the Sorensen network represents an early attempt to provide a method for tracing impacts using a network format. For example, Gilliland M.W. and Risser P.G. (1977), used system diagrams for environmental impact assessment. The usefulness systems analysis and of energy flows between environmental components as measures of environmental impacts are illustrated using results obtained from impact statement for the white Sands Missile Range, New Mexico. The procedure includes five steps: (i) Construction of a systems diagram representing the important interaction between environmental components and between man and these component (ii) evaluation of the pathways and storage (iii) analysis of the data (iv) identification of impacts requiring more detailed attention and (v) examination of impacts outside the boundaries of the system. Construction of a systems diagram and estimation of the impact of human activities on pre-development estimation of energy flow between specified environmental components permits a quantitative comparison of the impacts of alternatives. Hence, actions to mitigate environmental impacts can be easily made. But it should be noted that a systems approach does not deal with economic, social, and aesthetic impacts, nor does it guarantee that the boundaries for analysis have been chosen correctly. Use of this approach requires collection and interpretation of a large amount of data on energy flows between environmental components. In some locations this data may be difficult to obtain. Consequently, this method is only useful if implemented by a large organization having considerable expertise at its command.

Sorensen J. (1971) has attempted to provide a framework for identification and control of resource degradation and conflict in the case of multiple use of the coastal zones. This structured method allows for identification and control of resource degradation and conflicts in coastal zones. The framework is based on adverse, environmental impacts that occurred in the coastal zone of California as a result of a variety of coastal land use. It is also based upon stepped matrices, occasionally referred to as a network, listing a number of land uses (for example residential development and crop farming). Factors associated with these land uses (for example, fencing) are related to initial condition changes. These, in turn, are linked to consequent condition changes and final effects. Further information may be slotted into the framework (after the column dealing with the effect). For example, physical actions taken to ameliorate impacts can be listed. Similarly, codes of practice or regulations, which may be required to control the effects of a particular land use, can be inserted into the framework. The framework acts as a checklist to possible adverse environmental impacts. Thus, it can be used to identify and control conflicts between different land uses. The compatibility of a particular land use with an existing land use can be identified by investigating its likely adverse impacts using the stepped matrix framework. This approach to impact identification is one of the best known attempts to make the identification of indirect impacts explicit.

1.6 Quantitative on Index Methods

These methods are based on a list of factors thought to be relevant to a particular proposal and are differentially weighted for importance. Likely impacts are identified and assessed. Impact results are transformed into a common measurement unit (for example, a score on a scale of environmental quality). The score and the factor weighting are multiplied and the resulting score is added to provide an aggregate impact score. By this means, beneficial and harmful impacts can be summed up, and the total score can be compared. Additionally all impact scores for two alternative sites can be aggregated and compared. The alternative resulting in the "best" score will be the preferred option.

Dee N., et al (1973), have developed a method for assessing the impacts of water quality management projects. It is based on a checklist of environmental parameters divided into 19 components and a matrix to identify the likely impacts. Impact measurement incorporates two elements. First, a set of ranges is specified for each parameter to express impact magnitude on a scale of 0 to 1. The use of an "environmental assessment tree" is advocated to combine the parameter scores into a summary score for each of the 19 components. Second, a set of weights is used to determine the significance of the impacts on each component. A total score for each alternative can be obtained by multiplying each component score by its weight and summing all the components. The method, especially the assessment trees, has been developed for water resource projects. New environmental checklists and assessment tree would have to be constructed for other types of projects.

Stover L.V. (1972), developed a method for EIA. The most distinctive feature of this method is the approach for aggregating impacts. Environmental impacts are assessed for 50 environmental functions. These functions are grouped into the following categories: ecological and geophysical features, land use, chemical entities, biological communities, and human well being. Separate estimates are made for short-term and long-term impacts of each of the 50 environmental functions. Impacts are classified subjectively into five classes; 1 extremely beneficial, 2 very beneficial, 3 no effect, 4 detrimental, and 5 very detrimental. Very detrimental formations are given a numerical score of -5 on the scale while an extremely beneficial impact is given a score of +5. The score is multiplied by the number of years over which the short-term impact is likely to occur. Long-term impacts are scored on a scale +10 to -10, where +10 stands for extremely beneficial and -10 for extremely detrimental. The aggregate score for environmental impact can be compared with alternative developments or with the situation in which there is no development.

1.7 Models

Recently, considerable attention has been focused on the use of systems modeling in impact analysis. However, the development of models for assessing particular projects is at an early stage. There are few examples of models utilized for the assessment of the wide variety of impacts resulting from major projects. Usually, only a particular impact of great significance or a number of key impacts are modeled (for example, the effects of a nuclear power station on a salmon population). It may require more time before a modeling approach can cope with the wide diversity of impacts. Modeling is being used in the development and assessment of alternative strategies for resource management (but again the models only deal with a few key issues). In the future the use of models in large-scale resource management problems may become common. However, considerable work on assessing the impacts of resource management strategies by models has been carried out at the Institute of Resource Ecology, University of British Columbia by Yorque and Holling.

2. EVALUATION ENVIRONMENTAL VALUE

There are four major categories of direct valuation techniques. These are (i) the use of market prices to evaluate benefits and costs arising from changes in environmental quality (ii) the hedonic pricing approach which decomposes market prices into components of environmental and other characteristics (iii) the contingent valuation approach which is a. non-market techniques using survey to ascertain peoples willingness to pay for environmental aesthetics and (iv) the travel cost approach which is a market based technique that uses travel costs as a surrogate for the price of non-priced recreational and other amenities. Each of these approaches has its advantages and disadvantages, both from a theoretical standpoint and from the standpoint of empirical applicability (Jonathan A. Lesser, et. al. 1996).

2.1 The Use of Market Prices

The first and easiest valuation technique is to estimate environmental costs and benefits from market prices. We cannot measure the value of a lost view simply by walking in to the local shopping mall and inquiring about the price of views. By contrast, it may be possible to place a value on the damage caused to crops by pollution because one can easily determine the market price of crop goods.

A standard result in microeconomics is that if a good is sold in a competitive market and there are no externalities or underemployed resources, the market price will be equal to both the marginal buyer's willingness to pay and the opportunity cost of supplying that good. For example, suppose that pollution reduces wheat yields by only 1 bushel when the same supply of land, labour, equipment, fertilizer, water and other inputs is used. The total production of wheat is measured in millions of tons. Thus, the loss of 1 bushel of wheat can be considered a very small change in supply. The value of the lost production is equal to the market price of that one-bushel of wheat.

2.2 The Hedonic Pricing Approach

The hedonic pricing approach (HPA) is based on a straightforward premise that the value of an asset, whether a piece of land, a car, or a house, depends on the stream of benefits that are derived from that asset. These include the benefits of environmental amenities. One of the most common applications of the HPA has been comparing the values of real estate with different environmental amenities to estimate the value of those amenities. Houses have different views or are located in areas with better schools or lower crime rates. House may also differ in their exposure to pollution. By using regression techniques, an HPA model can, in theory, identify what portion of the property value differences can be attributed solely to environmental differences. From this, we can infer individuals willingness to pay (WTP) for environmental amenities and, therefore, the overall social value of a given amenity. The HPA can also be used to estimate WTP to avoid disamenities.

In the case of environmental externalities, the HPA is often applied to environmental attributes associated with specific commodities. An HPA model may not be applicable to certain environmental externalities if those externalities cannot be decomposed or differentiated within existing market prices. One example is housing prices and atmospheric carbon dioxide levels. Because carbon dioxide emissions are a global issue, one should expect housing price to differ depending on local emissions of carbon dioxide.

2.3 The Contingent Valuation Method

The premise of the contingent valuation methodology (CVM) is straight forward, if one wishes to know the value of something (for example view, clean air, safety, etc.) just ask the people. CVM asks people what they are willing to pay for an environmental benefit or to what extent they are willing to tolerate an environmental cost. Inquiries may be done through the use of direct questionnaires or surveys or through the use of experiments that determine how individuals respond. The biggest potential advantage of CVM is that it is applicable to all situations. Whereas a hedonic study might be unable to distinguish between the effects of different pollutants, a CVM could ask individuals about specific pollutants and the desired environmental change directly. CVM also ask people about choices that they may not actually make in real life, such as making direct payments for cleaner air.

2.4 Travel Cost Methods

The fourth technique used to estimate the value of environmental amenities is the travel cost method (TCM). This method is often used to estimate the value of public recreation sites, which usually have a zero or nominal admission price. The travel cost method is based on three observations. First, the cost of using a recreation site is more than that of the admission price. It includes the monetary and time costs of travelling to the site and may include other costs. Second, people who live at various distances from a recreation site face different costs for using the site. Third, if the value that people place on a site does not vary systematically with distance, travel cost can be used as a proxy for price in order to derive a demand curve for the recreation site.

One can develop the theory behind travel cost models by examining the relationship between distances from a recreation site and number of visits by a single individual. Suppose one wants to know the value that individuals place on trips to a pristine beach that lies within the national park of the cost of Maine. An individual taking a day trip to this beach will incur several costs. The monetary costs of the trip will include gasoline, wear-and-tear, and the admission price to the park. A less obvious type of cost is the opportunity cost of time. Time spent at the beach and travelling to and from the beach could have been spent in other ways. It could have been spent in other leisure activities, it could have been spent studying or writing, it could have been spent working. The value of the time used for the trip toward its next best use is the opportunity cost of time for spending the day at the beach. In many cases, it will be the largest component of total cost.

3. ENVIRONMENTAL ECONOMICS EVALUATION

The methodologies and techniques for evaluating environmental consequences were explained by K.C. Sankaranarayanan and V. Karunakaran (1984). These are mentioned below.

1. Cost - Benefit Analysis (CBA)
2. Input - output Analysis
3. Multiple - Objective analysis (MOA)
4. Cost - Effectiveness Analysis (CEA)
5. Risk Benefit Analysis (RBA)
6. System Analysis and Optimization Models (SAOM)
7. Trade and Investment Models (TIM)

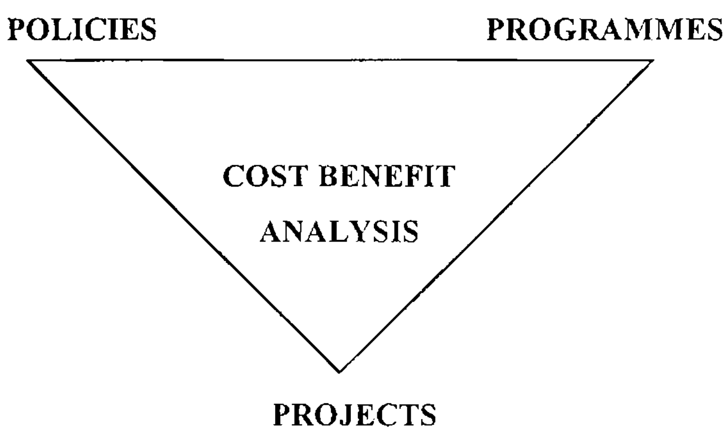
A brief description of the main characteristics of each type is given below.

3.1 Cost-Benefit Analysis (CBA)

Techniques of Cost-Benefit Analysis for evaluating development projects are not very old. (Nail K. Shatter 1991). These were used for the first time in 1930 in the USA for the implementation of water project planning programs. Since then these have been applied to a wider spectrum of projects, though the emphasis has been on schemes requiring a substantial amount of public investments like motor ways, airports, etc. In early years, these techniques have been widely used to evaluate projects whose outputs were designed to increase or improve a product. The classic example being irrigation projects designed to stimulate farm productivity. However, these techniques have limitations as they could suggest evaluation purely in monetary terms. In order to provide a holistic approach for the project appraisal, an alternative technique termed as EIA has been deployed in the USA since 1970. Since then, EIA has superceded CBA as the principal advisory tool for decision-makers, but still there are many reasons to regard them as complementary.

3.1.1 Cost-Benefit Analysis Dimensions

Public investment commitment is a socio-ethical aspects, which is considered by planners, as well as policy makers in order to consider the economic viability of projects. Three important dimensions of CBA have been suggested as an important set of economic techniques.



(a) Projects are concerned with major resource development schemes, such as water supply reservoirs or electricity generating stations.

(b) Course of action is related to categorical and systematic programming, such as commitment to a major electric power programme, as part of an overall energy strategy.

(c) Policies, comprised of a definite programs to achieve socio-economic growth, for example, determination to make energy production self-financing and hence proposing removal of all subsidies from energy costs. Thus, the attempt of CBA procedure is to measure and compare all relevant gains (social benefits) and losses (social opportunity costs) which would result from a given project.

3.1.2 The Basic CBA Procedure

We can divide the basic CBA procedure in four steps:

(a) identification and listing of all the relevant social costs and benefits (project impacts) connected with the project or projects.

(b) collection of the data necessary to quantify the relevant costs and benefits.

(c) evaluation (in monetary terms) of the costs and benefits identified by the analysis.

(d) submission of the finished CBA report and results to the policy makers.

3.1.3 Economic Efficiency : An Important Factor

Consideration of economic efficiency enables any policy making and administrative machinery to judge project desirability, as well as to distinguish relevant costs and benefits. Economic efficiency is said to increase when a reallocation of resources (such as, building of a dam) stimulates an increase in the net value of social output and its associated social consumption. The latter would include, among others, the aesthetic and recreational benefits and also the life support benefits of the environment. The total social costs of a given project must include all the private resource costs and that so called external costs, which are imposed on people who are only indirectly concerned.

In any given project, the total social benefits should include all the direct, as well as indirect gains to users of its output. Dams are constructed primarily for irrigation benefits. They also yield secondary benefits and generate costs, which usually involve changes in some people's well being at the expense of other. In other words, they create redistribution effects and, if the strict efficiency approach to CBA is adhered to such benefits or costs should not be included in the analysis unless there are unemployed resources available.

3.1.4 Measurement of Cost and Benefits

There are two fundamental ethical postulates in relation to any project evaluation. First, it is assumed that only individual human beings matter and that the personal wants of individuals should guide the use of society's resources. Further, it is conventionally assumed that the preferences of the present generation of individuals should dominate over the possible preferences of future generations. In this way, the analyst will be able to determine the effect of a given project on any individual's level of welfare by understanding the individual's own evaluation of wellbeing. Thus, the individual's evaluation of any project's benefits is measured in principle, by posing the question, "what would this beneficiary be willing to pay to acquire the benefits?" Project costs are valued by asking project losers what is the minimum sum of money they would require making them feel justifiably compensated for their losses. Any external costs induced by the project are valued at the minimum amount required by affected parties to compensate them for the imposition of the cost. Thus, the analyst's guiding principle is to value the welfare effect of the project on the individuals concerned as they would value it in monetary terms.

The second assumption is related to the ethical postulate that the prevailing distribution of income in society, whatever it may be, is socially "just" and is, therefore, taken as given. The assumption is then made that all-individual gains and losses induced by a project can be valued equally, regardless of the income level of any individual concerned.

In environmental terms, this can be a very naive assumption, as monetary wealth tomorrow may not always provide solace for the irredeemable loss of quality of the landscapes and altered natural habitats caused by decisions made today.

In 1973 Joskov J. described the techniques of cost-benefit analysis. He has discussed, in detail, the problem of identifying costs (on whomsoever they fall). He also provided some advice regarding assigning monetary issues to environmental costs.

Roberts. H.A. and Sievering. H. (1976) provided some preliminary guidelines for conducting economic impact studies. They also suggested several improvements in the existing methods of evaluation.

3.2 Input-Output Analysis (IOA)

The first attempt to extend input-output analysis to environmental problems was made by the originator of input-output analysis, Leontief, (Leontief, 1970). Input-output analysis for an entire economy is based on the accounting of the flow of goods and services in monetary terms at a particular time. Part of this flow is an inter project flow, foods transferred from the project to be used in the production processes of other projects, and the remainder flow to an exogenously defined "final demand" sector. This sector generally includes households, government, and foreign trade (often lumped together). For an n-industry economy the inter-industry input coefficients are arranged as a matrix $A = [a_{ii}]$... Such an arrangement is shown below.

Input from industry	output of industry 1	2 ------	n
1	a_{11}	a_{12} - - - - -	a_{1n}
2	a_{21}	a_{22} - - - - - -	a_{2n}
.	.	.	.
.	.		.
n	a_{n1}	a_{n2}	a_{n3}

The first column of this matrix explains that to produce a dollar's worth of commodity 1, inputs of a_{11} units of commodity 1, a_{12} units of commodity 2 etc., are needed. Frequently, the matrix is set up in such a way that no industry uses its own output. In that case, all the elements along the principal diagonal are zero.

If industry 1 is to produce an output just sufficient to meet the input requirements of the n industries as well as final demand of the open exogenous sector, its total output designated x must satisfy the following equation.

$$x_1 = a_{11} - x_1 + a_{12}\, x_2 + \ldots\ldots\ldots + a_{1n}\, x_n + d_1$$

where d1 is the final demand for the output of that industry. The equation can be rewritten as follows:

(*) $(1 - a_{11})x_1 - a_{12}\ x_2 - \ldots - a_{1n}\ x_n\ = d_1$

Except for the first coefficient $(1\text{-}a_{11})$, the others are the same as those in the first row of the A matrix (page 52), except they now have negative signs. Similarly, if we write the same type of equation for industry 2, it would have the same coefficients as in the second row of A (but with minus signs), except in position a_{22} where the coefficient would be $(1\text{-}a_{22})$. We can produce this same result in the whole matrix A if we subtract it from the identity matrix 1. Thus we can write.

$$(I - A)X = d$$

where I is an n x n identity matrix, A is the n x n coefficients matrix, and x and d are both n x 1 vectors, X is the variable vector and d is the final demand vector. If (I-A) has the rank n (i.e. is non-singular-meaning that the system of equations it represents has a unique solution), its inverse can be found and the system of n simultaneous equations represented by the above matrix equation will have the solution.

$$X = (I - A)^{-1}\ d$$

Side A provides a solution for the n simultaneous equations, of which equation (1) is an example, representing commodity and service flow from industries to industries and the final demand. The inverse matrix $(I\text{-}A)^{-1}$ has great utility. Once it is available, this inverse and a new solution vector produced for the industry outputs X, always on the assumption that the coefficients of A matrix have not changed, can premultiply d. Since multiplying a matrix by a vector is a simple operation compared with getting entirely new solutions to simultaneous equations, this is a great advantage.

Applying the Input-Output Model to Environmental Problems

A few years ago, Leontief proposed an extension of the basic national open I-O model, which would permit forecasting of residual emissions and at leas, have gross effects on certain types of policy measured with respect to them. The input-output balance of pollutants included in the system is shown by the matrix equation as following:

ordinary output | residuals reduction activities

ordinary input | residual produced (can be regarded as "impact")

$$\begin{bmatrix} 1-A_{11} & -A_{12} \\ A_{21} & 1-A_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix}$$

ordinary outputs demand = A X = residual reduction "out put"

ordinary goods remaining for final | remaining for final demand

commodities, or industries, are indexed as follows

1, 2 .. i, .. m — ordinary goods

(m + 1) .... k, ... 1 ..... n — residuals

We have m ordinary goods and n-m pollutants, making a total of n inputs and outputs.

Each of the A matrixes is a matrix of input-output coefficients. For example :

a_{ij} is the amount of the kth ordinary input required per unit of the kth ordinary output (sub matrix a_{11})

a_{ik} is the amount of the ith ordinary input required to produce a unit the kth residuals reduction output (sub-matrix a_{12})

d_{ji} is the amount of the jth residual resulting from producing a unit the ith ordinary output (sub-matrix a_{21})

a_{ki} is the amount of the kth residual produced as a result of a unit reduction in the ith residual (sub-matrix a_{22})

To see what is involved in this system of equations, assume that we have three ordinary commodities as two pollutant equation activities, making a total of five outputs, or "inputs", in all. Take, for example, the first equation which is formed by multiplying each member of the first row of A* by the corresponding members of the X vector of industry outputs. Add these products together, thereby obtaining the first member, Y_1 of the vector or final outputs, Y :

$$\begin{matrix} 1 & -a_{12} & -a_{13} & -a_{14} & -a_{15} \end{matrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix} = Y_1$$

or,

$$x_1 - a_{12}\ x_2 - a_{13}\ x_3 - a_{14}\ x_4 - a_{15}\ x_5 = Y_1$$

Note that in the matrices of input-output coefficients a_{ij} and a_{kk} are regarded as zero so that industry output is always net of its one output that it uses itself.

This equation simply says that the total output of the first commodity minus the amount used in the production of x_2 x_3 x_4 and x_5 is equal to the amount of the first commodity, Y_1 going to final demanders. The last four terms account for all of the x_i used in production, whether for ordinary goods or residual reduction.

Now consider an equation in the bottom part of the square matrix, A*, say the last one for the nth commodity, which is a residual. Note that since the output of the residuals processing industry here is measured as residual reduction, the sign of the elements in the two lower quadrants are reversed from those in the two upper :

$$\begin{matrix} a_{51} & a_{52} & a_{53} & a_{54} & -1 \end{matrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix} = Y_5$$

or,

$$a_{51}\; x_1 + a_{52}\; x_2 + a_{53}\; x_3 + a_{54}\; x_4 - x_5 = Y_5$$

This says that the residual which is commodity number five. That is generated in the production of x_1, x_2, x_3 and x_4 minus the amount by which this residual is reduced equals the amount which goes to final demanders.

Thus, in abbreviated matrix form, the input-output balance is $A^* X = Y$, where X and Y are vectors on industry outputs and deliveries of final goods, respectively. Industry outputs include residual reduction, and final goods include residuals received.

The system of equations, $A^* X = Y$, can be solved for the vector X, industry outputs, by pre-multiplying each side by the inverse of the matrix, A^{*-1} Y. Thus, if A^{*-1} has been calculated for a given industrial structure the industry output X would be associated with the specified bill of final goods Y as I indicated in the general discussion of input-output scheme. The main one is that the input coefficients, the a's, are fixed no matter what the size of an industry's output. That is, as also pointed out previously, there is only one way to produce an output; a way that is completely described by one column of coefficients. It is this assumption that facilitates calculations of wide economy effects as a result of certain policy changes on each in final demanders.

3.3 Multi-Objective Analysis

Multi-objective analysis is composed of a wide field of operations research. Often, it consists of a direct, clear-cut application of mathematical programming to actual problems. These problems may vary from industrial, architectural and environmental design to production, organizational or strategic planning. They may also be very personal, such as choosing a place to live, selecting job opportunities, or purchasing a vacuum cleaner, Rietveld, (1980), which define the role of the decision maker who wishes to make a decision in order to solve a problem.

Multi-objective optimization models are formal models. In a mathematical model they describe how a series of objectives is influenced through a number of decision variable. In its most essential form, this can be represented by :

$$\text{Max } w_1(\underline{x}), \ldots\ldots w_n(\underline{x}) \qquad w_i \quad R^k - R, \; i = 1, \ldots n$$

$$\text{s. t. } g_1(\underline{x}) \leq 0$$

$$\bullet$$

$$\bullet \qquad\qquad g_j \quad R^k - R, \; j = 1, \ldots m$$

$$\bullet$$

$$g_m(\underline{x}) \leq 0$$

$$\text{and } \underline{x} \; \Sigma \; A \subset R^k$$

$$m, n, k \, \Sigma \, n$$

where $\underline{x}$ is the vector of decision variables, $g_j(\underline{x})$ are constraints on $\underline{x}$. $W_i(\underline{x})$ are objective functions, determined by $\underline{x}$. A unique optimum for $\underline{x}$ is generally not found. This is where multi-objective optimization methods come in. These methods allow for the calculation of an optimum or a set of optimal solutions, all depending on when and how the decision maker assign priorities to the various objectives.

Multi-objective modeling encompasses an enormous variety of techniques, mathematical representations, computational procedures, etc. Here, we shall treat the characteristics of multi-objective models while distinguishing between the :

a. Decision space, in which a decision is made under varying circumstances;

b. Objective spaces, in which results of the decision are measured;

c. Preference structures, which contains an ordaining in objective space;

d. Optimization procedure, which describes a procedure for finding a set of optimal solution.

Keeney and Raiffa (1976), use the term "Objective" to indicate the direction of improvement on a certain aspect of decision-making. They use the term "attribute" to denote the dimension in which an objective is measured.

From the basics of multi objective analysis, we could make a distinction between choice processes with a limited number of alternatives and choice processes with a continuous set of alternative. The latter category applies to the choice problem that exists when economic, employment and environment policies can be utilized to influence such objectives as economic growth, employment and environmental quality.

Multi-objective analysis provides us with a number of methods which help a decision-maker that is faced with a difficult problem. In such a situation, it may be troublesome for an analyst to assess the preference and make the best choice. It may then be helpful to trace a decision-maker's preferences and his best choice within one and the same interactive procedure. Therefore, we explored the possibilities of a choice method called the "Ideal Point Method".

3.4 Cost-Effectiveness Analysis (CEA)

Cost-Effectiveness Analysis is useful in cases where benefits cannot be readily monitored. This suggests that it may be widely useful for natural resource and environmental problems (K.C. Sankaranarayanan and V. Karunakaran, 1984).

In the general formulation of a cost effectiveness problem, one seeks models of the form by Alfred Blumstein (1971) :

$$E = f(\underline{X}, \underline{Y})$$

Where E = measure of effectiveness, typically a vector with a least two components, cost (E_c), and one or more effectiveness components

$\underline{X}$ = set of alternative systems

$\underline{Y}$ = set of uncontrollable or exogenous variables affecting the effectiveness measures associated with the system alternatives

Moreover, the objective or standard can be varied and another least-cost estimates can be made. The cost curve for pollution abatement leaves and is traced even though an "optimal" level of abatement is not a product of the analysis.

Also, the mere fact that benefits cannot be assessed in monetary terms does not mean that the standards are arbitrary. Standards may be set on the basis of either minimum health levels or on the basis of the judgement of experts.

Cost may be especially difficult to analyze because of distortion in market prices. But economists are now well acquainted with shadow pricing techniques for domestic capital, foreign exchange, labour and income distribution effects.

CEA appears most relevant in the areas of health, air quality and water quality. Protection of endangered species may be another area of application.

Additionally, CEA appears well suited to a wide range of natural resources and environmental problems in developing countries, even though it does not give "optimal" solutions in the sense of optimizing social welfare.

It is important to bear in mind that the EIA would be pointless and even disfunctional if it identified only the negative impacts and, then, does nothing about minimizing them by modifying the project or by substituting it with a project of lower negative impact.

3.5 System Analysis and Optimization Models (SAOM)

System Analysis is best viewed as a process in which data and information are gathered, organized, analyzed and presented in an impact comprehensible format, useful in decision making. A simple schematic of system analysis consists of the following five steps (K.C. Sankaranarayanan and V. Karunakaran, 1984).

(1) Problem identification and formulation.

(2) Selection of solution techniques.

(3) Data collection.

(4) Analysis; and

(5) Review and presentation of results for final decision.

In system analysis, mathematical models provide for more rigorous treatment of data. Commonly used mathematical solution techniques include linear and non-linear programming, dynamic programming, integer programming and optimal control algorithms. Mathematical simulations are non-optimization models used to identify and predict problems and opportunities and to analyze alternative plans.

Linear programming is the most common technique for the maximization of an objective function subject to a set of constraints. Linear programming format can be programmed easily on computers and can be widely used among policy makers. More specialized techniques are available to solve these problems when the co-efficient of the variables are non-linear.

Application of systems analysis to large, complex problems has the following advantages:

(1) It provides a way of putting problems into perspective in a compact form, thus enabling analysts and planners to get a balanced view of the total system.

(2) Since systems analysis emphasizes the use of interdisciplinary study teams, the task of each discipline can be specified explicitly and interaction among disciplines can be made more systematic and effective.

(3) It provides a means of identifying gaps and overlaps of information.

(4) It provides systematic means of synthesizing information and enables rigorous treatment of data on system components, and interactions.

The system analysis is not free from defects. The major drawback of this method are given below :

(1) In order to complete the entire process and achieve the objectives, system analysis requires a vast amount of good quality data. In many instances, systems analysis has been misused because theoretically sophisticated models were built on insufficient data basis and tenuous assumption. Because of these abuses, many decision-makers remain sceptical about the credibility of the approach.

(2) Full-scale application of systems analysis demands a great deal of time, financial resources and technical inputs.

(3) Numerical solutions may be given more credence than they deserve, given the assumption and quality of data employed. Because of these difficulties systems analysis should be used selectively to deal with large and complex problems where many sectors and disciplines are involved and the interrelationship among those sectors are of crucial importance.

3.6 Risk-Benefit Analysis (RBA)

Risk Benefit Analysis is a comparatively new technique developed mainly to assist in decisions about alternative energy systems involving different types of risk. For example, although the probability of a nuclear accident may be very low, it could lead to extensive damage. In contrast, the use of coal tends to involve low level of damage, but damage may occur fairly regularly. RBA requires the estimation of beneficial functions, usually a straightforward task since the main benefit is the economic value of the output. However, a risk function is substituted for, or, preferably incorporated in, the cost function. But if the public's perception of risk is different from the decision-maker's "objective" determination of risk, this method may fail.

Cicehethi and Freeman, (1974) have given the uncertainty in either demand or supply. Suppose a public agency has under review an activity which would result in irreversible distraction of an environmental resource. Therefore, it would foreclose the option to consume the "amenity" services provided by the resource, in the future. That is, the activity causes a loss of opportunity to the individual, which is in addition to the loss of expected consumer's surplus from the "amenity" of risk bearing service. The opportunity loss, in fact, is equivalent to the cost.

3.7 Trade and Investment Models (TIM)

TIM is useful in tracing the environmental impact. It could be used to calculate the export and trade balance consequences of alternative pollution abatement standards for industrial pollution in developing countries. Given the required data on environmental control cost, trade values and import elasticity, these models could be used to evaluate the external cost of alternative pollution abatement levels within the country. Also an input-output model (IOM) could be combined with a TIM to estimate the pollution levels associated with different trade bundles.

An example of the use of TIM is the projection of global supply and demand for renewable and non-renewable raw materials. Each level of consumption implies certain demands on the raw material extraction activities of developing countries, and some likely set of environmental consequences for the raw material extraction, processing and consumption for developing and developed countries.

CHAPTER III

PROJECT DESCRIPTION

1. INTRODUCTION

In the last chapter a description of the different models in evaluating environmental consequences of development projects and their limitations were discussed. In this chapter it is proposed to explain the project in a little more detail.

The "Rajjaprabha" multi purpose dam, formerly called the Chiew Larn multi purpose project is one of the more promising projects being included in the program of the Electricity Generating Authority of Thailand (EGAT) for strengthening the power supply situation in southern Thailand.

The Chiew Larn multi purpose project was selected by the Government of Thailand as one of the projects to commemorate the auspicious occasion of His Majesty the King's sixtieth Birth Anniversary in 1987. After completion the Chiew Larn Dam's name was changed to "Rajjaprabha" Dam by His Majesty the King of Thailand. "Rajjaprabha" means the "Light of the Kingdom"

2. PROJECT LOCATION

The Rajjaprabha dam is designated to be a multi purpose scheme located on Khlong Saeng, a sub-basin of Phum Duang river basin. The dam and its power house is located at Chiew Larn village of Ban Ta Khun district, Surat Thani province, as shown in figure 3.1

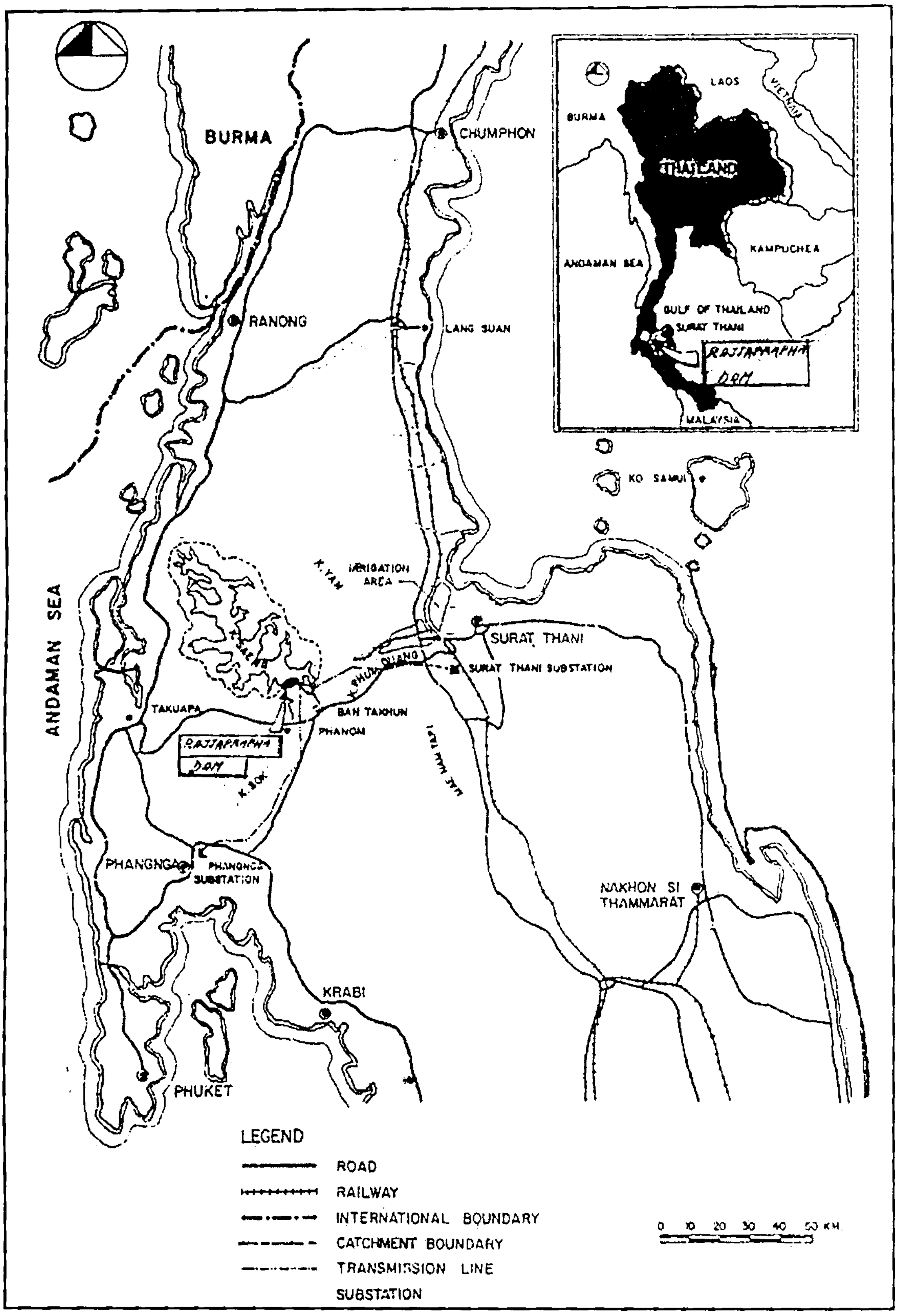


FIGURE 3.1

LOCATION MAP OF THE RAJJAPRABHA DAM

3. THE PROJECT PURPOSE

The purpose of the Rajjaprabha dam, as mentioned in the feasibility report (ELC-Electricconsult, 1973), include:

(1) Hydropower production and integration of the new power plant and transmission lines into the power supply system of the southern region.

(2) Provision of water supply for irrigation development in the lower Khlong Phum Duang and Khlong Phun Phin area covered 23,100 hectare.

(3) Flood damage control in the Phum Duang region, which has down stream from the dam site.

(4) Environmental protection for the delta area of the Phum Duang river at Ao Ban Don (Ban Don Bay).

(5) Fishery development in the dam reservoir, as well as fishery enhancement in the lower river section and in the Ao Ban Don area.

(6) Navigation improvement in the river reach of Phum Duang, in the lower river reaches of the Phum Duang river and Ao Ban Don.

(7) Recreation and tourism development in the reservoir neighbourhood.

4. PROJECT FEATURES

The main features of the project as mentioned in the completion report of Chiew Larn Multi purpose project, (EGAT, 1987) are as follows:

(1) A clay-core rockfill dam, across Khlong Saeng 94 m high and 761 m long on the crest.

(2) Six clay- core rockfill dikes, one of which is a fuse dike.

(3) A diversion tunnel with incorporated an irrigation intake tower and, in its concrete plug, a feeding pipe and irrigation valves.

(4) A power intake equipped with two wheel gates of 4.20 m wide and 10 m high, and a shaft for water supply to the resettlement area.

(5) A 245 m long steel-lined power tunnel, with a diameter of 11.20 m, leading to a steel penstock/distributor.

(6) A powerhouse located at the toe of the main dam, housing three Francis turbines, rated at 80 MW each generators and main transformer.

(7) A low-level outset, connected to the penstock equipped with a radial gate and a maintenance flap gate.

(8) A switchyard, located in front of the powerhouse at the toe of the main dam.

(9) A concrete-lined open channel spillway equipped with four radial gates 10 m wide and 8.477 m high.

(10) An unlined plunge pool and tall channel connecting with the river.

The principal engineering features are as follows:

(1) Purpose

Hydropower, irrigation, flood control, fishery and recreation.

(2) Reservoir

Drainage area	1,435	km^2
Average annual inflow	$3,057 \times 10^6$	m^3
storage at maximum normal water level (95.00 m MSL)	$5,639 \times 10^6$	m^3

storage at minimum normal		
water level (62.00 m MSL)	$1,352 \times 10^6$	m^3
Active storage	$4,287 \times 10^6$	m^3
Reservoir area at max. normal		
water level (95.00 m MSL)	185	km^2
Average regulated annual outflow	$3,010 \times 10^6$	m^3
Probable max-flood (PMF)	5300	m^3/s
Maximum water level with PMF	97.48	m MSL
Maximum exceptional water level		
(All spillway gates closed, only		
fuse dike operation)	98.95	m MSL

(3) Embankments

Crest elevation	100.00	m MSL
Type	clay-core rockfill	

(4) Main dam and dike no.1

Crest length	909	m
(main dam 761 m, dike no.1 148 m)		
Maximum height on the riverbed	94	m
Total volume	6,514,000	m^3
(include upstream cofferdam)		

(5) Saddle dam

Crest length	708	m
Max. height	50	m
Total volume	1,627,000	m^3

(6) Dike no.2 (Fuse dike)

Sill elevation	92.00	m MSL
Crest elevation	97.70	m MSL
Max. height	6.00	m
Crest length	106	m
Total volume	8,000	m^3
Discharge capacity with water level		
at 98.95 (all gates closed)	3,470	m^3 /sec

(7) Dike no.3

Crest length	53	m
Max. height	11	m
Total volume	7,900	m^3

(8) Dike no.4

Crest length	230	m
Max. height	26	m
Total volume	221,000	m^3

(9) Dike no.5

Crest length	160	m
Max. height	20	m
Total volume	105,000	m^3

(10) River diversion

Recurrence internal design flood	500	years
Peak flow of design flood	2,750	m^3/s

(11) Upstream cofferdam

Crest elevation	48	m MSL
Total volume	677,000	m^3
Max. water level for design flood	46.50	m MSL

(12) Diversion tunnel

Concrete lined internal diameter	10	m
Length	497	m

(13) Routed design flood

Routed design flood with water level at 46.5 m MSL	1,350	m^3/s

(14) Downstream cofferdam

Crest elevation	23	m MSL
Total volume	47,000	m^3

(15) Gated spill way

Design flood PMF peak flow	5,300	m^3/s
Radial gates (four)		
Width	10	m
Height	8.477	m
Spillway sill	87.50	m MSL
Gate top El	95.50	m MSL
Discharge capacity		
Reservoir level at El 95.00 m MSL	1,725	m^3/s
Reservoir level at El 96.50 m MSL	2,268	m^3/s
Reservoir level at El 98.00 m MSL	2,858	m^3/s

(16) Low level outlet

Pressure conduit (penstock to gate)

Diameter	6.00	m
Length	53	m

Radial gate

Width	3.00	m
Height	3.50	m

Discharge capacity

Reservoir level at 60.00 m MSL	250	m^3/sec
Reservoir level at 80.00 m MSL	320	m^3/ sec
Reservoir level at 95.00 m MSL	365	m^3/sec

(17) Irrigation outlet

Location : Diversion tunnel plug

Pressure conduit

Diameter	0.8	m
Length	24.0	m

Main valve, Howell- Banger type

Diameter	0.8	m

Safety valve, ring follower valve

Diameter	0.8	m
Discharge capacity	10	m^3/s

(18) Power intake

Wheel gates (two)

Width	4.20	m

Height	10.00	m
Sill El	44.0	m MSL
Trash rack gross area	500	m^2
Power tunnel (penstock) steel lined		
Diameter	11.20	m
Length	270	m
(in tunnel 245 m)		
Max. Normal flow	400	m^3/s
Penstock branches (three)		
Diameter	6.00	m
Length (each)	15.00	m
Design flow (each)	131.00	m^3/s

(19) Power house

Tail water level		
Max./Min. (operating)	15.00/12.00	m MSL
Net head		
Max./Min.	83.50/45.50	m
Max. flow	400	m^3/s
Installed capacity (3 x 80 MW)	240	MW
Annual generation		
Primary	484	GWh
Average	554	GWh

Average plant faction	0.25	
Turbines	Three, Francis type	
Rated capacity	80	MW
Rated flow	127.40	m^3/s
Synchronous speed	176.47	rpm
Runaway speed	355	rpm
Runner diameter	3.80	m
Generators	Three umbrella	
Rated capacity	89	MVA
Power factor	0.9	
Synchronous speed (50 HZ)	176.47	rpm
Fly - wheel effect	6,913	
Rated voltage	13.8	KV
Main transformers	Three, three- phase	
Rated capacity (at 55 degree °C)	89	MVA
Output voltage	230	KV
Powerhouse crane		
Capacity : main hoist	2 x 140	ton
auxiliary hoist	30	ton

5. PROJECT DESIGN

A brief description of the main structures and their functions together with the design parameters and the changes that occurred during the construction stage are presented here.

5.1 River Diversion

The river Khlong Saeng was diverted through a tunnel on the right abutment so that, under the protection of the cofferdams, the constructions of the major structures of the project could be carried out in the riverbed. A risk analysis regarding the consequences of a possible cofferdam overtopping and failure on the densely populated and cultivated areas downstream influenced a quite conservative to the design of the diversion tunnel.

The tunnel is of 497 m long structure, with a diameter of 10 m, located within the right abutment, and can divert a maximum discharge of 1,350 m^3/sec

The upstream cofferdam, designed to be incorporated in the main dam, is of 677,000 m^3 rockfill embankment with an impervious upstream clay blanket.

The downstream cofferdam provides the protection to the main construction area. The upstream end of the tunnel is a bellmounted intake structure that houses two 10 m high and 5.5 m wide slide gates and lost forms that served for the construction of a first concrete bulkhead. The permanent tunnel plug incorporates 0.8 m diameter irrigation pipe. The diversion was closed on April 3, 1986, about two months ahead of the scheduled time, taking advantage of the good progress of the work and of the very favourable weather with respect to the normal regime of the rains. As it happened the river discharge was at its lowest point of the year and all the closure operations went on very smoothly.

5.2 Dam Embankments

The project requires six embankments, to retain water of the reservoir, plus one fuse dike emergency spillway. All six embankments are of the central clay- core rockfill type.

The embankment vary in height:

Main dam	94	m high
Saddle dam	50	m high
Dike no.1	35	m high
Dike no.3	11	m high
Dike no.4	26	m high
Dike no.5	20	m high

The upstream slopes are 1-8 horizontal to 1 vertical in the upper part, 2 horizontal to 1 vertical in the lower part, and the downstream slopes are 1.8 horizontal to 1 vertical.

Design of the embankments was based on a static analysis and a review of slopes of similar existing dams elsewhere. In addition, a check was carried out on the behavior of the embankments during any possible earthquake shaking to ensure, that they would be stable and also not suffer any excessive deformation. The rockfill was specified to come from the required excavations for the various structures and from a quarry beside the spillway tail channel, a few km away from the main dam. The clay was specified to come from suitable borrow area also a few km downstream of the site of its final collocation.

The zoning of the embankments was designed to make the best use of the materials available. The fill was placed in layers of varying thickness depending upon the grain size of the material; from 0.20 m for the clay up to 1.0 m for the rockfill. The clay is protected against erosion on the downstream side, by a fine filter and by a transition containing a significant proportion of fines upstream. Above El. 85.00 on the upstream side, a fine filter is provided up to the maximum water level (El. 97.5) to allow self-healing of any cracks that might form in the clay as a result of seismic shaking. On the upstream face a layer of rip - rap is provided, 3.0 m thick, while oversize rocks (larger than 0.1 m size) provided protective layer on the downstream face.

The foundations of the clay cores rest on good sound rock which was treated by local excavations and filled with concrete, wherever necessary, to prevent the possibility of any seepage across the interface. The rockfill rests on a foundation of weathered rock cleaned by bulldozer.

The clay cores form the water-retaining element of the dam in the main dam it is 4,500 m wide at the base, tapering to 8.0 m wide at the top (El. 99.0). The clay was placed at moisture content of 1 percent above optimum in the lower part of the dam and 23 percent above optimum, in the upper portion, above El. 58.00, and was compacted to at least 98 percent of the standard protector compaction.

The rockfill was placed and compacted without sluicing and achieved densities in excess of 2.2 ton/m^3.

Fuse Dike

The fuse dike is an inclined thin clay core embankment with a gravel downstream shoulder and rockfill upstream. The embankment is designed to be wash away if the reservoir level overtops the structure, and provide an emergency spillway in case of non-functioning or malfunction of the spillway gates. The embankment is 5.7 m high and has upstream and downstream slopes of 2 horizontal to 1 vertical and 1.4 horizontal to 1 vertical respectively.

Design of the fuse plug was based on a review of similar structures elsewhere. In operation, a low point is provided in the crest, through which water will flow and wash out the downstream fill, this erosion will also spread laterally and will, in time, remove all the dike allowing the supporting concrete structure to act as a free-flow spillway.

Cut-Off

A grout curtain under the axes of the clay cores provides the cut-off for the embankments. The grout curtain comprises 2 rows of holes with a maximum depth of 75.00 m in the main dam. In addition, a row of deep consolidation holes is provided 4.0 m upstream of the curtain with a maximum depth of 18.0 m in the main dam. The foundation area below the core is grouted to a maximum depth of 6.0 m to consolidate the surface treatment of the area.

5.3 Spillway

The spillway, located on the right rim of the reservoir at about 500 m from the end of dike no.1, is of the open chute type, controlled by four radial gates and ending with a ski-jump wherefrom the water will return to Khlong Saeng through a plunge pool and a discharge channel.

The gated structure is founded on sound rock at El.76.00 m and is formed by the ogee structure, with sill at El.87.50, controlled by four radial gates 10 m wide and 8.477 m high, separated by piers 2.50 m thick and 32 m long, with crest at El 100.00.

A drainage gallery 2.00 x 2.80 m runs through the weir body, with floor at El.78.50; access is provided from El.100.00 through two vertical shafts 2.00 m diameters, located in the end piers. The radial gates are articulated over steel trunnions and support girders embedded into the piers and deeply anchored by pre stressed tendons. Upstream of the radial gates the piers of the structures are provided with slots for lowering the maintenance stoplogs.

Pressure equalization on these is done by by-pass valves located in the discharge gallery. The winches for the operation of the radial gates located on the top of the piers, at El.100. In the upstream portion, the top of the piers support also a deck 9.20 m wide giving continuity to the permanent road connecting all the various parts of the project.

The chute is formed by an open channel 49.00 m wide and about 5 m deep, with a gradient of 20 percent along the initial 50 m upstream and 11 percent along the remaining 90 m down to the ski-jump, in order to follow the rock profile.

The ski-jump with a cylindrical shape continuous for 27.50 m with 50 m radius, ends with an angle inclined 20 degree upward, with terminal edge at El.61.50.

The air required for aeration will descend from the spaces remaining naturally water-free just downstream of the squared-off each pier.

To limit cavitations care has been taken that construction be done without discontinuity transversal to the flow.

A schematic profile of the spillway chute is given. At about 40 m downstream of the ski-jump a plunge pools 23 m deep and 120 m long is excavated into the rock for energy dissipation.

From the plunge pool the water will be returned to the river, through a channel about 1,500 m long and 100 m wide. During the construction of the dam the following minor changes were effected to the original design:

(1) Due to the good rock conditions the foundations of the gated structure have been raised to El.76.00 from 74.50.

(2) Prestressed tendons have been adopted to anchor the radial gates trunnion girders.

(3) Following the results of the model tests the bottom elevation of the channel had been raised to El.43.00 from 40.00.

(4) The protection slap below the ski-jump had been extended from 12 m to 25 m downstream and had been anchored to the rock by means of tendons and anchor bars.

5.4 Power Intake

The intake structure is located on the right abutment of the main dam, at some 100 m upstream of dike no.1 center line and adjacent to the inlet of diversion tunnel. It is a 58 m high hollow gravity structure, founded on sound rock at El.42.00 and with top deck at El.100.00, encased in a niche excavated into the rock.

The lower portion of the structure forms the real hydraulic intake, with two funnel shaped sluices changing from 11.75 m x 20.00 m upstream to 4.20 m x 10.00 m downstream and a separating wall 1.50-m to 2.60 m thick. The ceiling is formed by 1-m thick slab, with 50-cm diameter pressure equalizing holes.

The upstream mouth of the sluices is protected by trashracks 20.00 x 25.00 m (gross dimensions) supported by two intermediate concrete pillars and two steel beams filled with concrete. Stoplogs and gates are provided for tunnel closure. The top desk at El.100.00 is the service deck, where the gate servomotors are installed and wherefrom the stoplogs can be operated.

All oleodynamic and electric equipments for gate control is installed inside a control building located along the access to the intake structure. The control building is a 13.50 m x 5.00 m construction with concrete foundation slab, columns and beams, masonry walls and removable roof made of steel trusses and steel sheeting. During the construction, the following minor changes were made to the original design.

(1) Two additional wing walls have been built to contain a portion of the definitive backfill and consequently to speed up the erection works for the anticipated diversion tunnel closure;

(2) An additional shaft had been introduced to contain the system of pipes and valves for the resettlement area water supply.

(3) The control building had been moved about 20 m downstream, to base it on sound rock and also eliminate two lateral retaining walls.

5.5 Power Tunnel and Penstock

The power tunnel, excavated through sound rock, is about 245 m long with a gradient of about 16 percent and with a minimum rock cover of about 20 m.

Excavation cross-section is horse shoe shaped, with a 6.4-m upper radius. Conventional rock supports had been procured, to be used as required. As it happened, very little support was used.

The finished cross-section is circular with 11.20 m inside diameter, fully steel lined. The lining is designed to be self-resistant both for internal and external pressures, including contact grouting at 5 kg/cm^2.

The gap between the steel lining and the rock is filled with concrete, with a systematic pattern of consolidation and contact grouting at 5 kg/cm^2 pressure, from inside.

The power tunnel ends about 30 m from the powerhouse, from that point down to the opposite end of the powerhouse, the penstock was installed in the open encased in concrete and then buried under the backfill forming the powerhouse esplanade.

The penstock diameter is maintained constant at 11.20 m from the tunnel outlet to the powerhouse, and then gradually reduced from 11.20 m to 6.00 m, with three identical branches, at 55 degrees, feeding the turbines.

The concrete encasement, running along the powerhouse, has been rigidly connected with it in order to act as a balancing arm or counterweight, contributing to the stability of the powerhouse upstream wall.

All concrete encasement is divided in blocks, with contraction joints grouted after concrete shrinkage. Similarly, the contraction joint between the distributor encasement and the powerhouse is grouted in such a way that the two structures practically form a monolith. Downstream of the last branch pipe, the distributor ends with an expansion joint, which is in its turn connected to the low level outlet. The joint is designed in order to allow relative displacement between the two structures, either for thermal effects on differential settlements. The concrete encasement of the joint forms a 4.00 m x 100.00 m x 100.00 m room, access to which is provided from the powerhouse through a watertight door, designed for the full head up to the maximum reservoir water level.

5.6 Low Level Outlet

The low level outlet is essentially a sluice inclined some 20 degrees upward, steel lined connected upstream with the penstock and discharging into the tailrace channel downstream with the terminal flip edge at El. 24.50 and chute slab down to El. 11.00.

The sluice is controlled by a radial gate operated by servomotors installed on a service deck El. 33.40 above the gate. The trunnion support girder is fitted to the lateral piers by prestressed tendons anchored 25 m deep into the concrete.

Maintenance of the radial gate can be done after closing a pressure flap gate installed just upstream of it, operated by a servomotor installed at El. 31.00 inside a cellular construction, rising up directly from the lining encasement up to the service deck at El. 33.40.

Above the service deck in a control building house the oleodynamic and electric equipment controlling both the flap and radial gates. During the construction the wing wall in the right side of the outlet was extended up to the outlet of the diversion tunnel. No other significant changes were made.

5.7 Irrigation Outlet

The purpose of this facility is to guarantee a constant minimum water release of 10 m^3/s for irrigation needs even when the power tunnel is closed and the reservoir level is lower than the spillway sill (El. 87.50).

The facility includes the following structures :

- The irrigation intake structure, built above the diversion tunnel inlet, just downstream of the concrete inlet plug.
- The upper diversion tunnel stretch, about 124 m long, upstream of the tunnel plug.
- The feeding pipe embedded in the diversion tunnel plug.
- The outlet structure, built inside the diversion tunnel just downstream the plug.
- The lower diversion tunnels stretch, about 390 m long, down to the tailrace channel.

5.8 Powerhouse

The powerhouse is located on the right bank of the river, just downstream of the main dam, parallel to the original river bed. It is an outdoor structure 94.0 m x 43.0 m in plan and 58 m high, founded on sound rock at El. -7.50, housing three generating units and all auxiliary services, the erection area, the administration building and other facilities.

Structurally the powerhouse may be divided into two parts :

- The substructure, from the foundation up to served deck at E.I. 33.40
- The superstructure above the service deck

The service deck has been fixed at El.33.40 with a 0.50-m free board above the maximum possible tailrace water level corresponding to the Probable Maximum Flood (PMF).The superstructure, formed by reinforced columns and beams, with thin perimetral closure walls, is fully exposed.

The substructure formed by a heavy reinforced concrete structure, is either buried under backfill on the upstream side or exposed on the downstream side facing the river. In order to account for thermal shrinkage, the powerhouse has been divided in to four different blocks, one per each unit (20.50-18.00-26.50m long respectively) and one for the erection area (29.00 m long), separated by contraction joints. The joints are sealed by water stops and provided with shear keys from foundation up to deck at El. 33.40.

After concrete shrinkage, the joints have been fully grouted up to El. 20.00 thus turning the substructure practically monolithic. Above El.20.00, conventional contraction joints are provided, with water stops from El. 20.00 to 33.50.

5.9 Switchyard

The switchyard is located on the left abutment of the river, just downstream of the main dam, opposite to the powerhouse, with the finished top surface at El. 40.00. It is a 25,000 m^2 area divided into:

A 230 kv sector, with three overhead lines connected to the step-up transformers at the powerhouse, and two outgoing transmission lines with the possible future extension of two more.

A 115 kv sector, connected to the 230 kv sector through a tie-autotransformer with possible future installation of a second one, in case of expansion, and two outgoing transmission lines with the possible future extension of three more.

A small 33 kv sector, connected to 230 kv sector through a transformer with two outgoing transmission lines with the possible future extension of one more.

The control building is located roughly at the center of the switchyard, between the 230 kv and 115 kv sector connected to the powerhouse by a cable gallery, 2.20 m x 2.50 m x 335 m long, with upper outer face 1.00 m deep under the ground surface.

From the control room depart two main cable trenches which branch out in a three levels trench network, distributing the cables to the outdoor equipment. All cable trenches are in reinforced concrete, 1.20 m x 1.30 m - 1.20 m x 0.90 m - 0.80 m x 0.90m - 0.25 m x 0.25 m respectively, with top edges at 0.10 m above the finished ground surface of the switchyard, covered by checkered plate covers. The ground surface of the yard, out of the roads width, is finished by 0.40 m thick gravel layer.

6. COSTS AND PROGRAMMES

6.1 Estimate and Project Evaluation

6.1.1 Early Studies

The feasibility report was prepared under an agreement economically self-supported by ELC, and the definite study was negotiated with EGAT on a fixed sum basis. These activities were carried out between 1978 and 1981.

6.1.2 Project Feasibility

The feasibility of the report was established on the basis of an installed capacity of 240 MW, an average annual runoff of 3,000 mcm, a live storage volume of 4,300 mcm, and an average energy output of 554 Gwh.

6.1.3 Project Benefits

From the implementation of the Rajjaprapha dam a series of benefits were expected they are:

- Generation of electric power
- Increase of agricultural output as a result of irrigation.
- Additional fishery output from the lower river section as well as from the reservoir.

These were the quantitative benefits on which the feasibility of the project was estimated.

(1) Power generation benefits

The power benefits were estimate in comparison with an alternative thermal plant to be located in the same region to meet the forecast demand of energy.

The thermal alternative consisted of a combination of oil fired and gas turbine power. The reference fuel prices were based at the time on a cost of US$ 14 to 18 per barrel of crude oil. Since then the costs have reached a maximum of US$ 34 per barrel and minimum of US$ 10 to 12 per barrel. At that time they were around US$ 16 to 18 per barrel and the trend is towards a moderate increase over the years; basically the calculation can be considered still valid.

(2) Irrigation benefits

When full production is achieved in the 23,100 ha of net irrigated land, the total irrigation benefits will amount to about ฿ 420 million per year. It is considered that the irrigation benefits will materialize gradually over a period of five years after the completion of the works in each irrigation district.

(3) Fishery benefits

The fishery benefits were evaluated at ฿ 27 million per year. It is assumed that they will start to materialize on the second year after reservoir filling. The time needed to get full fishery benefits is estimated in four years.

(4) Total benefits

On the basis of the costs estimated and of the benefits that were to be derived from the Rajjaprabha dam, the classic parameters usually adopted to assess the feasibility of a project clearly indicated that the project was economically attractive.

- The internal rate of return (IRR) of the project is 16.2 percent.
- The benefit cost ratio (B/C) for i = 10 % is 1.60.

On the basis of these parameters the decision was made to proceed with the implementation of the project. Since that time, as it explained were below because of very favorable concurrence of circumstances, the actual prices of the various contracts were extremely competitive and the actual costs of the project was lower than the estimate, thus confirming once more the extreme economical soundness of Rajjaprabha multipurpose project.

6.1.4 Contract Design and Tender Documents

The agreement for the preparation of the contract design drawings and tender documents was formally signed on November 20, 1981. However, the work had already been started various months earlier, with the Inception Mission. The work was carried out by ELC - Electroconsult in joint venture with SEATEC (South East Asia Technology Ltd.) and was completed in about one year; and the negotiated cost was US$ 1,496,150 and ฿ 6,216,000.

6.1.5 Cost of Construction and Supervision of the Contracts

The cost estimate was based on detailed analysis carried out on the costs of the main works for the project; due consideration was given to current projects under construction in Thailand and in South East Asia.

The basic criteria for construction of the major items of work were defined and schedules of quantities were prepared together with an assessment of the equipment to be installed. From the detailed cost estimate that was prepared, the project cost came to a total amount slightly less than ฿ 5,900 million equivalent to US $ 290 million, including interest during construction. As it is normal in major projects, the cost estimate was made both in foreign currency and local currency.

It was assumed that the foreign currency portion would cover, mainly:

(1) Power Station equipment.

(2) Construction plants, with the relative spare parts when imported.

(3) Special construction equipment.

(4) Hydraulic equipment gates and cranes.

(5) Explosives, additives and special paint.

(6) Instrumentation and controls.

(7) Supervision, overheads and profits of foreign contractors.

(8) Engineering services by foreign consultants.

The local currency portion would cover mainly;

(1) Construction plant and equipment available in Thailand.

(2) Cement, fuel, and reinforcing steel, tiles and other materials.

(3) Fabrication and erection of permanent equipment in Thailand.

(4) Resettlement costs

(5) Salaries and wages

(6) Overheads and profits of local contractors

(7) Import duties and taxes

(8) EGAT administration

During the preparation of tender documents, agreement was reached on the number and type of contracts to be tendered. In an effort to keep the original project implementation schedule, the civil works were divided into two contracts : one for the diversion tunnel and apartment work, and other for the main civil works, which included dams, powerhouse, power conveyance works, flood control works and works relating to switchyard.

The electromechanical works were divided into six contracts: (i) for hydraulic equipment including tunnel lining, penstocks and all the hydraulic gates (ii) for tardiness and generators (iii) for power plant equipment (iv) power station cranes (v) for switchyard equipment and (vi) for transformers and lighting arresters.

The cost estimate was revised in 1981 to an amount of ฿ 7,035 million equivalent in view of some changes that were decided and presented to the cabinet, which approved it in February 1982.

6.2 Source of Funds

The budget adopted for Rajjaprabha dam was composed of both foreign and Thai currencies. The foreign currency portion was financed with loans from the International Bank for Reconstruction and Development (World Bank), the Organization of Petroleum Exporting Countries (OPEC) and the Kuwait Funds for Arab Economic Development (KFAED).The national currency portion was financed by Thai Government subsidy and EGAT's own revenue.

6.3 Actual Expenditure

It has been described in section 6.1 how the initial cost estimate was revised in view of the changes to be approved by the cabinet. The final project cost estimate was updated considering the extra costs due to additional works that would be necessary during the construction period, and also the variations in quantities with respect to the confidential estimates prepared for the tender documents. In the end, the total direct cost of US$ 171.36 million equivalent (฿ 4,313.96 million equivalent) turned out to be an exceptionally low cost for a medium size hydroelectric project like Rajjaprapha dam. In fact, the cost per kilowatt installed is in the order of US$ 714, on extremely low cost for any type of power generation, and especially for a hydroelectric project that is normally characterized by high initial investment and low operation and maintenance expenses.

TABLE 3.1

FINAL PROJECT COST ESTIMATE

Unit Million

Description	Foreign	Local	Total	US$
1. Preliminary Works	-	298.000	298.000	12.360
2. Land Acquisition, Resettlement And Environment Mitigation				
2.1 Land Acquisition	-	158.000	158.000	6.840
2.2 Resettlement	-	166.600	166.600	7.715
2.3 Environmental Mitigation	-	67.600	67.600	2.610
2.4 Construction Equipment	17.72	4.500	22.220	0.915
SUB - TOTAL 2	**17.72**	**396.700**	**414.420**	**18.080**
3. Civil Works				
3.1 Diversion Tunnel	89.12	51.460	140.580	6.100
3.2 Preparatory Works for Civil	-	39.200	39.200	1.710
3.3 Main Civil Work	755.00	630.000	1,385.00	53.820
SUB – TOTAL 3	**844.12**	**720.660**	**1,564.78**	**61.630**
4. Hydraulic Equipment	117.00	68.00	185.00	8.360

TABLE 3.1 CONT'D

Description	Foreign	Local	Total	US$
5. Electro Mechanical Works			185.00	
5.1 Turbines and Generators	615.90	46.00	885.90	31.270
5.2 Powerhouse Cranes	13.66	1.90	15.10	0.600
5.2 Transformers and Lighting A	60.50	4.60	65.10	2.540
SUB – TOTAL 5	**854.06**	**52.50**	**905.56**	**34.410**
6. Transmission System				
6.1 Switchyard Equipment	59.10	18.10	77.20	2.900
6.2 Transmission System	220.00	100.80	320.80	11.960
SUB – TOTAL 6	**279.10**	**118.90**	**398.00**	**14.860**
7. Engineering Services	251.30	99.90	351.20	13.855
8. EGAT Administration	-	196.00	196.00	7.805
TOTAL DIRECT COST	**2,363.30**	**1,950.66**	**4,313.96**	**171.360**
9. Import Duties and Taxes	-	347.54	347.54	13.175
10.Interest During Construction	-	638.50	638.50	22.683
TOTAL PROJECT COST	**2,363.30**	**2,936.70**	**5,300.00**	**207.218**

Source : From completion report of "Rajjaprabha Multipurpose Project.

CHAPTER IV

PHYSICAL RESOURCES

CHAPTER IV

PHYSICAL RESOURCES

1. INTRODUCTION

The physical environment relating to a multi-purpose dam project are classified into climate, water, and land resources. These physical resources may either cause effects to or are affected by the project at different levels, time and locations. The physical resources of the Rajjaprabha dam presented in this chapter are: (i) climate and surface water hydrology (ii) ground water (iii) water quality (iv) soils and land capability (v) mineral resources (vi) erosion and sedimentation and (vii) salinity intrusion.

A review of existing physical environmental resources and the evaluation of the impact of the dam on such resources are considered necessary as they are expected to produce favourable as well as harmful impacts on human use values and quality of life.

2. CLIMATE AND SURFACE WATER HYDROLOGY

2.1 Introduction

The Phum Duang river basin is located in the upper southern part of Thailand. Its area extends from the coastilne of the Gulf of Thailand in Surat Thani province in the east to Phang-nga province in the west. The climate is tropical monsonic, being characterized by rather high temperature and humidity all year round with markedly seasonal distribution of abundant rainfall. It is influenced strongly by both the northeast and the southwest monsoons.

2.2 Objectives

Main objectives of this climate and surface water hydrology study are :

(a) To survey the existing status of climatologic and hydrology gauging station in the river basin.

(b) To update relevant climatic parameters and streamflow data at selected status using data since 1978 up to the latest possible.

(c) To assess trend and potential climatic changes between the pre-and post-impoundment periods.

(d) To assess changes in flow conditions between the pre-and post impoundment periods.

2.3 Methodology of Study

The study was carried out based on the available data and information in the project area. The general climatic conditions of the region were reviewed. Locations of the observation stations and the available records were searched from the governmental agencies concerned. Additional data of recent years were collected from the field office in order to get the most up to date picture of the environment.

These data were analysed to determine their statistical characteristics, including the temporal and a real distributions. The results were then interpreted and described as related to the Rajjaprabha dam.

Gauging Station

There are 8 climatologic stations and 8 stream gauging stations in the Phum Duang river basin which are in operation. Locations of these stations are shown in Figure 4.1. The pre-impoundment perid (or pre-dam) is taken as the period before water year 1987, and the post-impoundment period (or post-dam) is taken as the period from water year 1987 till water year 1997.

These data were analyzed to determine their statistical characteristics, including the temporal and real distributions. Probable effects of the project on the climatic parameters or vice versa were then evaluated based on the literature review, experience and the interpreted results.

2.4 Results of the Study

The study reveals that after about ten years of its existence the Rajjaprabha dam has not produced any significant changes in climatic features found. Whatever minor differences are found in climatic parameters are largely due to their pertinent stochastic nature. Surface water has, on the contrary, been modified by the regulation effect of the Rajjaprabha reservoir. Such regulation gives rise to better utilization of the water from the Phum Duang river.

Comparisons of the climatic parameters and streamflows experienced during the pre-impoundment period and the rather short post-impoundment period are as follows.

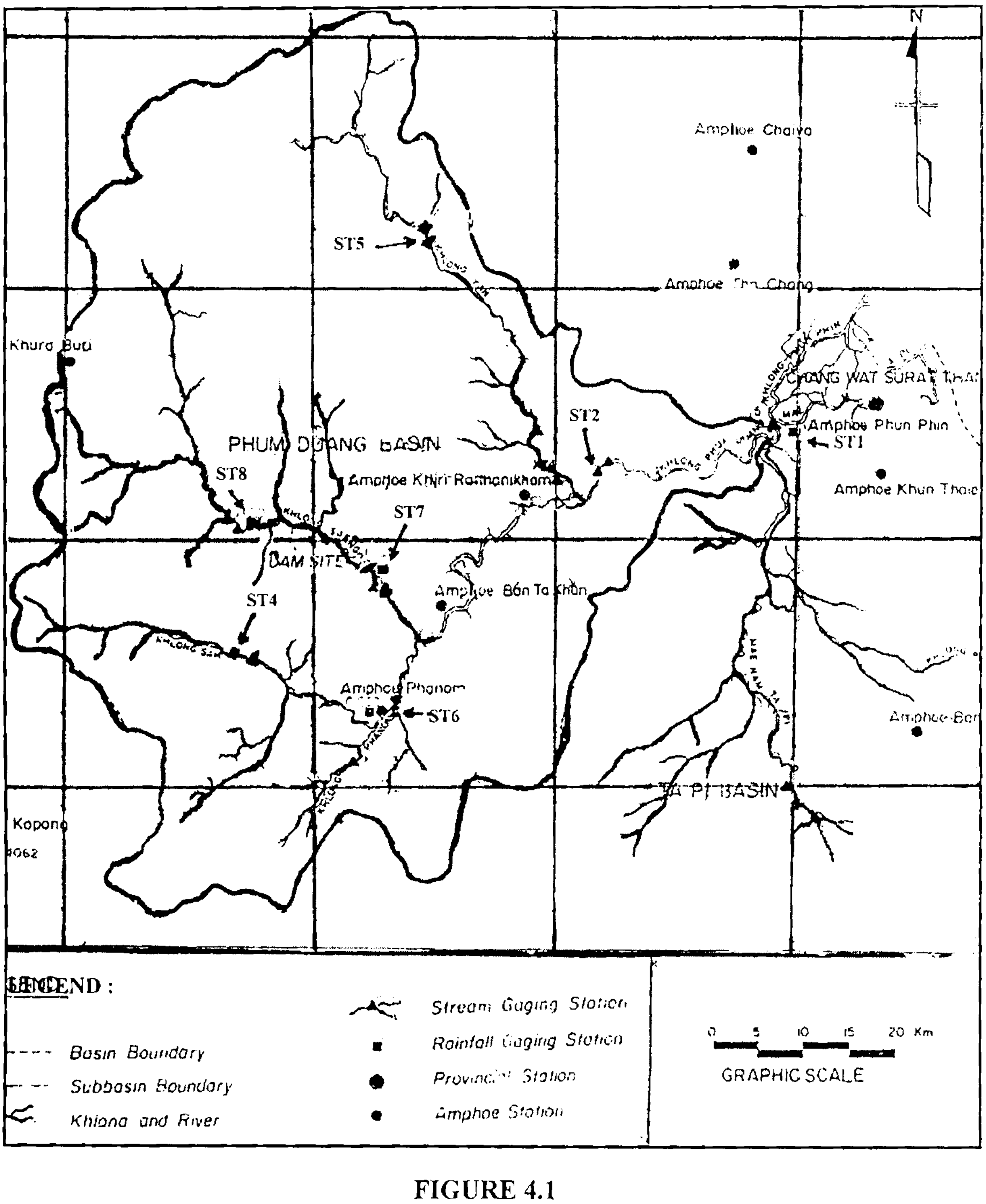


FIGURE 4.1

PHUM DUANG RIVER BASIN AND GAUGING STATION

2.4.1 Rainfall

Temporal distributions of rainfall over the year during the two periods were similar, with heavy rains during September to November and light rains during January to March. Mean annual rainfall over the whole basin increased by about 4.01% from about 2,024 mm during the pre-impoundment period to about 2,106 mm during the post-impoundment period (Table 4.1). The mean annual rainfall over the Rajjaprabha catchment area slightly increased from about 2,035 mm during the pre-impoundment to about 2,087 mm in the post-impoundment period (Table 4.2).

2.4.2 Evaporation and Temperature

Mean annual evaporation of the Rajjaprabha catchment area is estimated to vary slightly during the two periods, from about 1,337.7 mm during the pre-impoundment period to about 1,457.2 mm during the post-impoundment period. The variation is shown in Table 4.3. Temperature, and other climatic features at the dam site experienced during the two periods were almost identical. While relative humidity varied from 52 percent to 98 percent, and air temperature form 14 °C to 39 °C, (Figure 4.2).

TABLE 4.1

STATISTICS OF STATION MEAN ANNUAL RAINFALL

Unit in mm.

Station	* % Diff. mean	Pre-dam 1978-1986	Post-dam 1987-1996
A. Over river basin			
1. Phun Phin district (ST.1)	+ 3.75	1,706	1,770
2. Khlong Phum Duang (ST.2)	+ 5.00	1,520	1,596
3. Khoa Sok village (ST.30)	+ 5.28	3,254	3,426
4. Khlong Sok (ST.4)	+ 6.73	2,140	2,284
5. Khieo Krug village (ST.5)	+ 2.74	1,820	1,870
6. Phra Nom district (ST.6)	+ 2.38	1,680	1,720
Average A	**+ 4.5**	**2,020**	**2,111**
B. Over reservoir basin			
7. Khoa Phang village (ST.7)	+ 5.27	1,728	2,354
8. Khieo Ko village (ST.8)	+ 0.51	2,342	1,819
Average B	**+ 2.53**	**2,035**	**2,087**
All Average (A and B)	**+4.01**	**2,024**	**2,106**

Note * % Diff. mean = $\frac{\text{(Post dam) - (Pre dam) x 100}}{\text{Pre dam}}$

Source of data : Hydrology Division, RID.

TABLE 4.2

AVERAGE ANNUAL RAINFALL OVER RESERVOIR AND RIVER BASIN

Month	**Average rainfall over Reservoir (mm)**		Average rainfall over river (mm)	
	Pre – dam 1978 - 1986	Post – dam 1987 – 1996	**Pre – dam 1978 - 1986**	**Post – dam 1987 - 1996**
Apr	56.7	90.8	73.8	54.5
May	156.1	198.2	182.3	281.2
Jun	147.0	163.7	151.5	139.7
Jul	190.7	147.4	192.7	231.7
Aug	83.6	164.8	168.8	197.6
Sep	132.6	240.6	220.9	290.4
Oct	547.7	370.4	328.0	570.5
Nov	394.2	383.7	338.6	550.5
Dec	92.0	192.8	251.0	227.2
Jan	20.1	69.5	49.0	65.1
Feb	10.4	36.8	45.6	54.5
Mar	9.2	28.7	22.3	24.6
Total	**2,035**	**2,087**	**2,024**	**2,106**

Note * Averaged from two stations : ST 7 and ST 8

** Averaged from six stations : ST 1, ST2, ST3, ST4, ST5, and ST 6

Source Meteorological Department.

TABLE 4.3

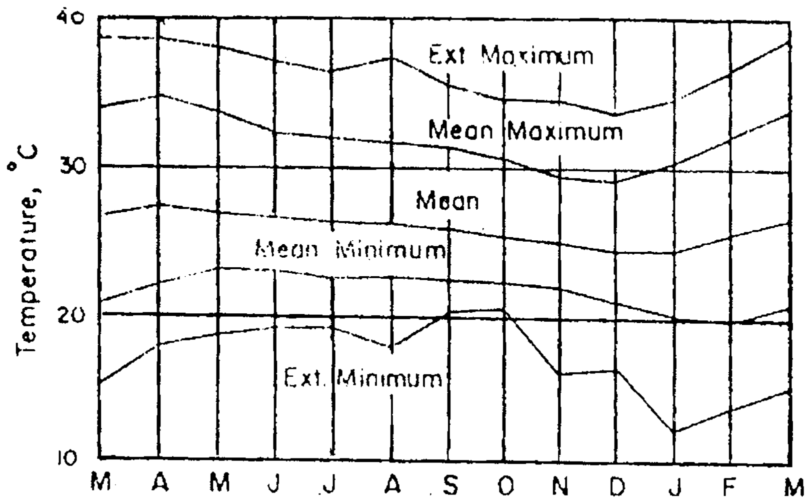
AVERAGE ANNUAL RAINFALL OVER RESERVOIR AND RIVER BASIN

Reservoir Evaporation loss (mm) = 0.7 (Evaporation at Ban Khoa Phang)

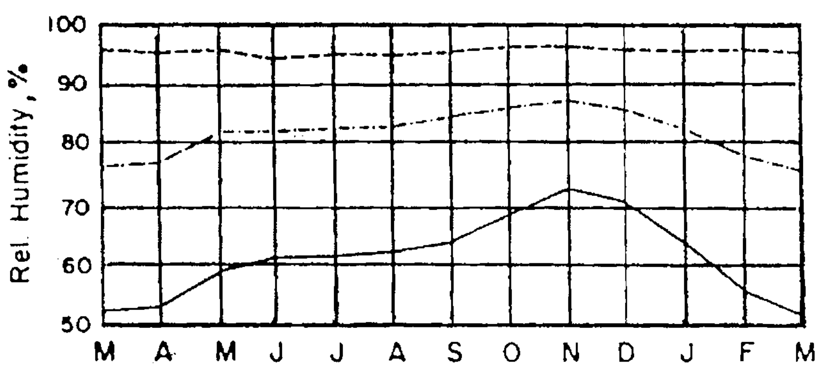
Month	Pre-impoundment * 1978-1986	Post-impoundment ** 1987-1996
Apr	144.7	154.4
May	123.2	135.7
Jun	92.1	130.4
Jul	103.0	114.8
Aug	101.4	120.1
Sep	96.1	106.3
Oct	103.1	92.5
Nov	74.6	87.6
Dec	90.8	98.9
Jan	116.8	119.4
Feb	137.1	128.6
Mar	154.8	168.5

Source : * From investigation and planning division, National Energy Administration

** From Climatological Data of Thailand



A. Temperature



Month

B. Humidity

LEGEND : _ _ _ _ _ _ Mean maximum

_ _ _ _ Mean

________ Mean minimum

FIGURE 4.2

MONTHLY CLIMATICS STATISTICS AT SELECTED STATIONS SURROUNDING KHLONG PHUM DUANG REGION

2.4.3 Surface Runoff

At Rajjaprabha dam site the distributions of mean monthly streamflow during the two periods were of similar pattern. Hydrograph of the monthly flow comprised two peaks, the lower one in May and the higher one in November. Low flows were observed in March and August. Mean annual flow at the dam site increased slightly from about 3,038 mcm observed in the pre-impoundment period to about 3,057 mcm. And further downstream at the town of Surat Thani the mean annual flow increased by about 12.8 % during the two periods, from about 6,411 mcm to about 7,232 mcm (Table 4.4).

TABLE 4.4

ANNUAL STREAMFLOW PRE-AND POST DAM IN THE WATERSHED AREA

Location	Area (km^2)	Annual Streamflow	
		Pre - dam	Post - dam
Catchments area	1,435	3,038	3,057
River basin area	4,668	6,411	7,232

Source : Hydrology Division, Royal Irrigation Department.

3. GROUND WATER RESOURCES

3.1 Introduction

Ground water development in the Phum Duang river basin is rather limited. From 1974 to the present day only about 386 deep wells have been drilled in the area. Most of them are used for domestic water supplies in rural communities, and only a few are used for municipal and urban water supplies. None has been used for irrigation purpose. Shallow wells or hand-dug wells are commonly used for domestic water supplies in almost every village of the study area. The main reason of not using ground water for irrigation is plentiful availability of surface water in the area, where the average annual rainfall varies from approximately 1,596 mm to 3,426 mm (Team Consulting Engineers, 1980). Nevertheless, from water resources management view point ground water resource in the basin is still important. It serves as water supply sources for small towns and rural villages, and also provides supplementary irrigation water to tree crops and vegetables during dry seasons.

3.2 Objectives

The objectives of ground water study are to assess the impact of water impoundment in Rajjaprabha reservoir on ground water resources ;

(a) The use of ground water as a source of domestic water supply for communities in the rural areas.

(b) The use of ground water as a supplementary supply for dry season cropping.

(c) The change in ground water hydrological conditions due to the project implementation affecting soils internal drainage and soil capability.

(d) The effects of salinity intrusion and flood control on ground water resource development.

3.3 Methodology of Study

To achieve the above objectives the following methodology of study has been used :

(1) Collect data on water table, water quality, hydrological maps, and inventory of ground water utilisation from the Department of Mineral Resorces, Office of Accelerated Rural Development, Public Works Department, and Provincial Water Works Authority.

(2) Assess the ground water resource conditions from collected data to verify pattern of chages after the project implementatoin for both upstream and downstream areas. The assessment includes ground water level, yield, utilisation, quality, water logging seepage from/into the reservoir, and the effects of salinity intrusion and flood control on ground water resource.

(3) Observe ground water levels in the irrigation area and the area just downstream from Rajjaprabha dam in order to identify changes in ground water level from the pre-impundment period. This, is used as the basis for the assessment of soil capability, water logging problem, and seepage from the reservoir.

3.4 Results of the Study

3.4.1 Ground Water Geology

Water bearing formations in the watershed area are broadly classified into unconsolidated and consolidated formations. The unconsolidated formations, or aquifer, found in the gulf coastal plain region consist of unconsolidated gravel, sand and clay of fluvial origins. Beach sand aquifers of the unconsolidated group, generally with less than about 7 m thick, are found in the coastal areas. Consolidated aquifers encountered in the upstream hilly and mountainous areas are of carbonate, metasediment, metamorphic, and granitic rocks. These aquifers are recharged by rainfall and inundated water from nearby streams at locations where hydraulic connections to the aquifers prevail.

3.4.2 Ground Water Availability

Ground water availability varies considerably in the project area mainly according to the prevailing types of aquifers. High availability potential areas, with a well yield of more than 50 cm/h are in the flood plain of Phum Duang river in the easthern part of Muang district of Surat Thani province, with unconsolidated aquifer covering Muang district. Lower availability potential areas with a well yield from 20-50 cm/h are also of unconsolidated aquifers in Muang district, Phun Phin district, and a portion of Chaiburi district. The remaining upstream area has the least availability potential, less than 20 cm/h well yield (Department of Mineral Resources, 1981). The number of deep wells in the watershed area is as shown in Table 4.5.

TABLE 4.5

THE NUMBER OF THE DEEP WELLS DRILLED DURING 1974-1996 IN THE WATERSHED AREA

Location	Pre-dam 1974 – 1986	Post-dam 1987 – 1996	Total
1. Upstream area			
Ban Ta Khun district	10	24	34
Phrase Nom district	8	17	25
Sub total 1	**18**	**41**	**59**
2. Downstream area			
Khirirathana Nikhom district	22	66	88
Phun Phin district	25	91	116
Muang Surat Thani district	10	113	123
Sub total 2	**57**	**270**	**327**
Total	**75**	**311**	**386**

Source Ground Water Division, Department of Mineral Resources

3.4.3 Ground Water Utilization

As ground water in most of the project area is of acceptable quality for use as drinking water, it is presently used mainly for domestic water supplies. It is an important source of water supply for rural villages. More than 380 tube wells were drilled during 1974 to 1996 by government offices responsible for rural water supply development. About 98,400 m^3/day of water is estimated to be exploited from the ground water in the project area, about 24 % of which is from wells in the rural villages (Ground Water Division, 1996). Use of ground water for irrigation is rather limited as other convenient and economical sources are mostly available. Ground water is, however, the main source of supplementary water during dry season for deep rooted tree crops in the project area. (Table 4.6)

3.4.4 Ground Water Levels

Effects of the Rajjaprabha dam and other projects on ground water after this short period of impoundment and river flow regulation are not conclusive. Although relatively high ground water level are observed in this study in the downstream irrigation area, 1.0-2.5 m below ground surface, it is not likely to be the results of irrigation as shown in Table 4.7. This inference is based on the fact that application of irrigation water has only recently begun and that too only in a limited area.

Besides, improved drainage due to the newly implemented drainage system, together with the regulation effects of the Rajjaprabha reservoir, should pose a decreasing trend on the ground water level in the irrigation area. Although reported to have increasing trend in ground water level, no systematic record of water level exists for the dug wells locating just downstream from the storage dam. Hence the effect of this project on ground water, as reasonably anticipated in the pre-impoundment environmental and ecological study, should be further assessed in post implementation period.

TABLE 4.6

UTILIZATION OF DEEP WELLS DRILLED

Organization	No. of wells Drilled	Domestic (Hand Pump)	Dug wells
Department of Mineral Resources	131		
Department of Health	8		
Office of Accelerated Rural Development	120	386 wells 72.600 m^3/day	250 wells 25,800 m^3/day
Department of Civil Work	64		
Other Agencies	63		
Total	**386**		

Source From Office of Accelerated Rural Development, Ministry of Interior.

TABLE 4.7

COMPARISON OF GROUND WATER LEVELS IN THE WATERSHED AREA AFTER WITH THOSE OBSERVED IN THE PREVIOUS INVESTIGATION

Location	Water level (May)	Below ground (August)	Surface (m) (January)
Upstream area			
1. Khoa Phang village	1.00	0.70	1.50
	(1.20)	(1.00)	(2.00)
2. Bang Kaew village	0.80	0.60	1.20
	(1.20)	(0.90)	(1.60)
3. Pattana village	1.00	0.80	1.50
	(1.50)	(1.20)	(2.20)
Downstream area			
1. Hat Khan village	1.20	1.00	1.80
	(1.50)	(1.10)	(2.40)
2. Pong village	1.40	1.80	2.20
	(1.80)	(2.20)	(1.40)
3. Phun Phin district	1.50	1.80	2.10
	(1.80)	(2.50)	(2.50)

Notes Number in parentheses is previous investigation

Source Survey data

3.4.4 Effects of Salinity Encroachment and Flood control on Ground water Resource

In the coastal area of the Phum Duang river basin, the Beach Sand Aquifers are in hydraulic continuity with seawater. The lowering of ground water level can result in the encroachment of seawater. This will result in degradation of water quality in the basin or a portion of the basin due to the intruded seawater. There are several means for controlling the encroachment, but the most practical one is by adopting proper exploitation in the coastal area. The Beach Sand Aquifers along the coastal area are not over 6 m thick and yield 5-10 gpm. So in order to control seawater encroachment in the area, the depth of well should be too deep to avoid encountering salt water, and the pumping rate should not be over 5 gpm.

Rajjaprabha reservoir operation regulation for flood protection to the downstream flood prone area has resulted in reduction in flood peak discharge at Phun Phin district. This will reduce ground water recharge potential in the downstream area due to less recharge area and shortened recharge period. However, the flood prone area will be used mainly as paddy fields, hence flooding on the land surface can still be expected during many months in a year. In this case the recharge area and recharge time may not be much different from the condition without flood control scheme.

3.5 Conclusion and Recommendation

In fact, the creation of a storage reservoir will not affect the ground water geology of the area, but it will affect the movement of ground water, i.e. water table and recharge.

However, at this stage of investigation the water impoundment of Rajjaprabha reservoir seems not to have any serious effects upon ground water resources. In order to be able to make quantitative assessment in the next stage of post environmental evaluation study, monitoring program to measure water levels both in the area just downstream from the dam site and irrigated area should be set up.

4. WATER QUALITY

4.1 Introduction

After the Rajjaprabha dam was put into operation in 1987, it was expected that the water quality would chage sigificantly from the pre-impoundment investigation results. The water in the hypolimnion was expected to be rich in organic materials, nutrients, and inorgaic salts. Reservoir releases, which will be low in oxygen and high in iron and mangaese, would be unfavourable to the growth of livig organisms. However, thermal stratification was expected to be mild and therefore should not cause any sigificant problems. An enquiry was conducted to see whether this claim to true or not. This section presents the results off field investigation for water quality conducted, after the reservoir has been put into operation

4.2 Objectives

The main objectives of monitoring of water quality in this project are as follows.

(a) To monitor seasonal variation of reservoir water quality as well as the reservoir ecosystem.

(b) To monitor seasonal variation of surface water quality along the Phum Duang river, downstream from the dam downward to the river mouth.

(c) To evaluate the extent of change in water quality and their effects on environmental parameters.

4.3 Field Investigation

Two field investigations were conducted, the first in the dry season (during 1-7 April 1997), the second in the late rainy season with a higher amount of rainfall during 15-20 November 1997).There are four gauging stations as shown in Figure 4.3. The water quality for the three investigations can be concluded as follows.

4.4 Results of the Study

Water quality in the reservoir has changed significantly from that recorded in 1980 before the impoundment. Mild thermal stratification has occurred in the reservoir. Dissolved oxygen is high in the circulating top layer (epilimnion), and decreases with water depth until it is depleted below the thermocline. The water in the hypolimnion is relatively rich in organic materials, nutrients and inorganic salts. But living organisms do not exist in the bottom layer due to lack of dissolved oxygen, and to some extent due to the presence of hydrogen sulfide. With regard to the overall water quality in the reservoir, it can be concluded that the water quality in the epilimnion (0-5 m layer) and the mesolimnion (5-15 m layer) is very clean. It is suitable for use as a source of water supply, for recreation, and can support aquatic life. In the hypolimnion, which is from 15 m depth to the bottom, oxygen is absent and a great amount of hydrogen sulfide gas prevails. Although this results in minimizing corrosion of the steel lining of the outlet works, there is strong hydrogen sulfide odour stripped from the reservoir release. This nuisance odour will remain for some time, until the biodegradation at the reservoir bottom is completed. The water quality of the gauged stations both the pre-and post impoundment as shown in Table 4.8 and 4.9 respectively.

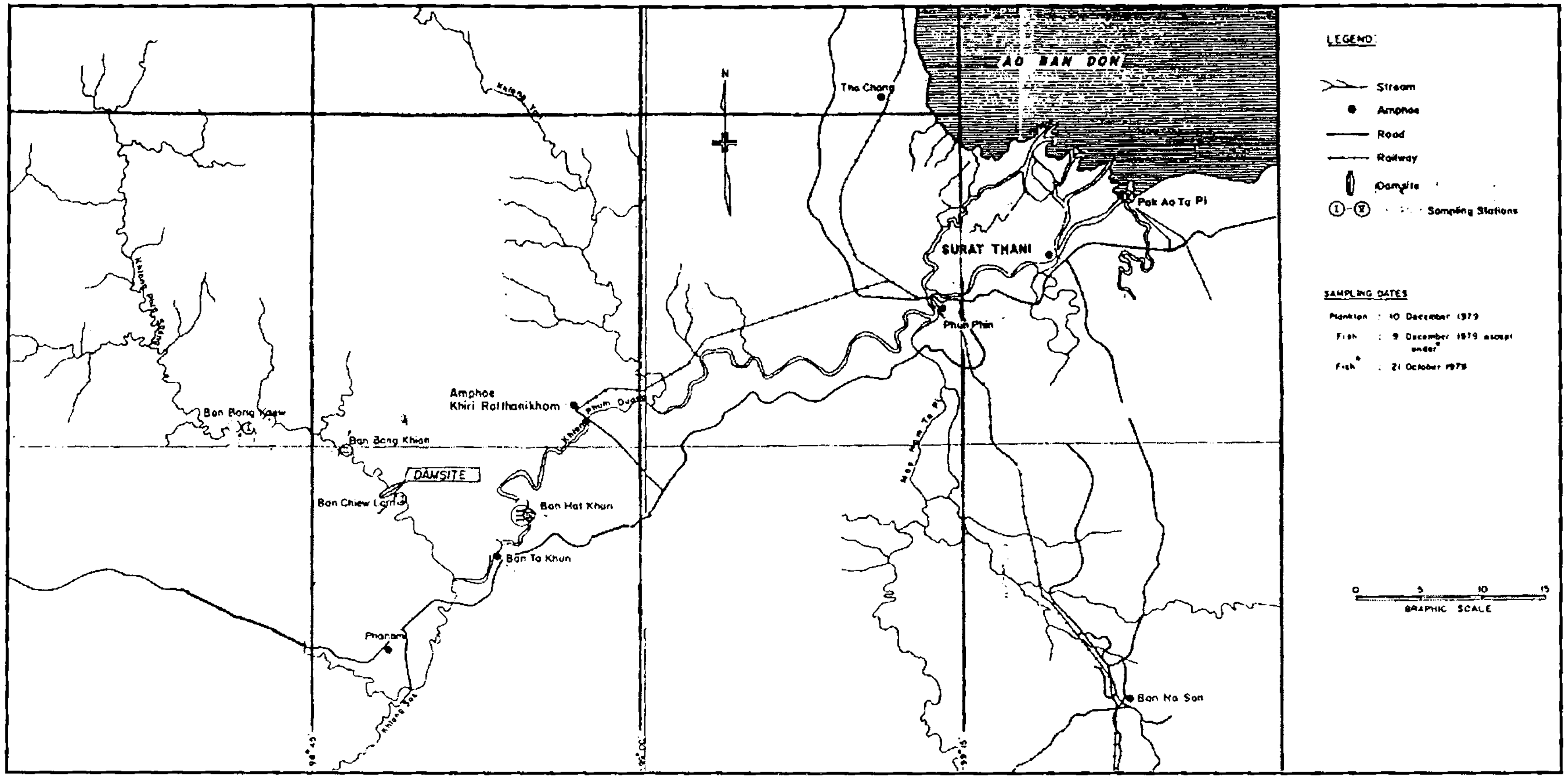


FIGURE 4.3
GAUGING STATIONS OF WATER QUALITY

General characteristics of water quality of the river reach between the storage and diversion dams are suitable for the growth of phytoplankton, the lowest plant organisms in the aquatic food chain. Thus the water is capable of supporting aquatic life including fish. It is also of excellent quality for irrigation use. Water in the reach from about 20 km to 70 km downstream of the storage dam, just upstream of the Surat Thani town, has a quality suitable for use as a source of water supply, especially during dry season when the water is generally clear.

The quality of water of the first 20 km frcm diversion dam to downstream is similar to that in its upstream adjoining reach. It is suitable for water supply. Due to salinity problem, and to some extent due to water pollution, water in the first 10 km of the estuarine reach is not quite suitable for water supply. This is especially true for the first 5 km from the river mouth.

Quality of drinking water sample from Ban Pattana (Pattana village) is generally quite good as most of water quality parameters are within the standard for drinking water.

TABLE 4.8

PHYSIC-CHEMICAL PROPERTIES OF SAMPLES TAKEN FROM RESERVOIR AND PHUM DUANG RIVER ON PRE-IMPOUNDMENTATION PERIOD

Characteristics	Unit	I	II	III	IV
1. Flow rate	m/sec	0.67	0.25	0.36	0.17
2. Transparency	cm	80+	62.5	100+	46.0
3. Temperature, °C	°C				
Air		22.5	26.1	33.5	30.0
Surface		23.2	25.0	26.5	27.5
Mid-water		23.2	25.6	26.5	27.5
4. Light intensity	Lux	800	780	780	800
5. PH, units	Unit	6.4	6.7	7.0	6.7
6. Dissolve oxygen	mg/l				
Surface		6.8	7.3	7.4	5.6
Mid-water	mg/l	6.8	7.2	7.4	5.9
7. Free CO_2					
Surface		4.0	4.0	3.0	7.0
Mid-water		6.0	4.0	4.0	7.0
8. Total Alkalinity	mg/l				
Surface		50.0	76.0	76.0	45.0
Mid-water		58.0	78.0	74.0	48.0
9. Total Hardness	mg/l				
Surface		36.0	60.0	60.0	80.0
Mid-water		36.0	60.0	62.0	92.0
10. Salinity	ppt	-	-	-	9.5
11. BOD	mg/l	0.8	1.0	1.8	0.2

TABLE 4.8 CONT'D

Characteristics	Unit	I	II	III	IV
12. Dissolved Solids	mg/l	180	207	257	220
13. Suspended Solids	mg/l	39.5	80	72	100
14. Bicarbonate	mg/l	65.9	63.9	91.5	56.7
15. Carbonate	mg/l	0	0	0	0
16. Nitrate	mg/l	1.55	3.32	1.55	1.55
17. Phosphate	mg/l	0.36	<0.30	<0.30	<0.30
18. Calcium	mg/l	7.8	12.6	12.8	13.8
19. Magnesium	mg/l	3.4	5.9	5.9	13.5
20. Iron	mg/l mg/l	0.46	0.49	0.68	1.54
21. Manganese	mg/l	0.07	0.10	0.24	0.13
22. Dissolved silica	mg/l	8.3	16.7	8.3	8.3
23. Mercury	g/lμg/l	1.6	1.5	1.1	0.4
24. Asenicnate	mg/lμg/l	0.4	1.2	2.0	0.4
25. Lead.	mg/l	80.0	80	70	80
26. Tin	mg/l	0.24	0.25	0.22	0.25
27. Coliform bacteria	100mpn/ml	250	210	280	540
28. Total Fecal		200	190	240	350

Station I = Bang Kaew village
Station II = Bang Khian village
Station III = Hat Khan village
Station IV = Ao Ban Don

Source Environmental and Ecological investigation report.

TABLE 4.9

WATER QUALITY IN THE RESERVOIR AND PHUM DUANG RIVER
POST-IMPLEMENTATION

Characteristics	**Unit**	**I**	**II**	**III**	**IV**
1. Temperature °C	°C				
Air		28.2	29.6	29.4	29.0
Water		27.9	28.9	29.1	28.8
2. pH,	Units	606	6.9	7.0	7.2
3. DO	mg/l	5.8	7.0	7.2	7.5
4. Salinity	ppt	-	-	-	1.0
5. Conductivity	u mho/cm	186	82	76	310
6. BOD	mg/l	3.2	2.5	5.8	9.5
7. SS	mg/l	134.5	98.0	72.0	192.6
8. TS	mg/l	312.4	132	120	356.2
9. Total Alkalinity as $CaCO_3$	mg/l	24.7	26.4	26.2	54.1
10. Total Hardness, as $CaCO_3$	mg/l	42.2	41	39.4	46.8
11. Chloride	mg/l	8.8	.58.7	6.6	6.7
12. Phosphate	mg/l	0.16	0.24	0.29	0.30
13. Nitrate	mg/l	1.8	-	0.12	0.26
14. Sulphate	mg/l	5.7	12.9	15.2	18.6

TABLE 4.9 CONT'D

Characteristics	Unit	I	II	III	IV
15. Ca	mg/l	8.9	6.5	6.2	5.8
16. Mg	mg/l	4.6	1.4	1.1	1.15
17. Mn	mg/l	0.08	0.01	0.02	0.01
18. Fe (total)	mg/l	0.55	0.18	1.8	0.8
19. Fecal Coliform Bacteria	mpn/100	340	240	360	720
20. As	ml	<0.005	<0.005	<0.01	<0.008
21. Cd	mg/l	<0.003	<0.003	<0.002	<0.003
22. Pb	mg/l	<0.002	<0.002	<0.002	<0.003
23. Hg	mg/l	<0.001	<0.001	<0.001	<0.001
24. Zn	mg/l	<0.003	<0.003	<0.003	<0.003
25. Pesticide	mg/l	0.085	0.084	0.096	0.094

Station I = Bang Kaew village   Station III = Hat Khan village
Station II = Bang Khian village   Station IV = Ao Ban Don

Source Survey data

5. SOIL AND LAND CAPABILITY

5.1 Introduction

A soil property (S) is dependent upon, or is a function of, the soil-forming factors, i.e., Climate (Cl), organisms (O), relief (R), parent material (P), and time (T). These can be presented in a form of an equation.

$$S = f(Cl, O, R, P, T)$$

This implies that it is possible to take any soil-forming factor and consider its variations against the background of the others, thus examining effect of that particular one. However, in studying change in soil of an area, micro-environment of the area, even a small one, may vary considerably. This variation inevitably renders considerable heterogeneity of soil in the area. Effects of micro-environment on soil are thus, to a large extent, masked by variation in micro-environment. Accordingly, to be obserable the effects of micro-environment must be large enough to outrun soil heterogeneity. This means that a soil-forming factor should play its role for a long time, probably not less than a few decades, before its effect on soil is observable, unless effect of soil heterogeneity is overcome.

Land capability clssification is based on properties of soil, topography, erosion, drainage, productivity and environmet of the land. Among these, drainage is practically the only factor that may be changed by the implementation of Rajjaprabha project to an extent that land capability is, in turn, affected by the change. This is mainly through change in uderground water level as a result of irrigation and drainage facilities development, water resource management enchanced by the project.

5.2 Objective and Scope

The main objective of the study on soil and land capability is to evaluate changes in soil and/or land capability after the implementation of the project. In addition, information on soil and land capability of the project area available to date has also been reviewed.

5.3 Methodology

To attain the objectives, the followings are undertaken.

(a) Review and compilation of data on soil, land capability recorded before and after the implementation of the project.

(b) Comparisons of water table levels obtain from the present study with those obtained in the pre-impoundment study.

(c) Evaluation of the effect of changes in water table levels found in (b) on soil and land capability.

(d) Conduct a field reconnaissance survey in the project area to :

(1) Evaluate general soil fertility of different areas by observing growth and visual symptoms of vegetation and/or crops, soil characteristics, topography, and interviewing.

(2) Observe soil cultural practices adopted by the farmers.

(3) Study characteristics of the irrigation system and its progress of development.

5.4 Results of the Study

Soils in the upstream area are mainly of red-yellow Podzolic group derived from shale, granite, quartzite and limestone. Lateritic nodules are scattered in the area. Root penetration and horizon of parent material are rather deep, about 68 cm in depth. Physical and chemical properties of the soils at various elevations vary only slightly with type of land use, elevation, and soil depth. The surface soils range from non-erosive to slightly erosive. Soils covered by tropical rain forest are more stable than those found in rubber plantations and agroculture area. Fertility of the soils range from low to moderate levels. Phosphorus is presumably the most serious limiting factor in most soils. Due to steep slopes and heavy rainfall land capabilities of most soils in the upstream area are limited by high risks of soil damage.

The areas on the soil map are map units, developed during the survey on the basis of soil classification, which followed that of the U.S.D.A. Soil Texonomy. The lowest category of soil classification used here is soil series. In total, 16 map units were distinguished in the project area. They consist of 5 soil series, 2 soil variants, 7 soil associations and 2 miscellaneous land types. The list of these mapping units and area covered by individual units is present in Table 4.10.

TABLE 4.10

LAND CAPABILITY CLASSIFICATION IN UPSTREAM AREA

Unit Number	Name	Capability subclass	Area in ha	% of the Total area
1	Ruso series	U-Iif	17,270	3.70
4	Lumphula series	U-IIs	32,490	6.96
5	Lumphula and Ruso soils	U-IIs	30,250	6.48
6	Lumphula and Krabi soils, undulating phase	U-IIs	72,170	15.46
8	Krabi series	U-IIs	11,530	2.47
9	Krabi, fine loamy	U-IIs	5,130	0.11
	Sub Total		**1,46,950**	**35.18**
2	Ruso, coarse loamy variant	U-IIIf	2,980	0.80
3	Ruso, coarse loamy variant and Ruso soils	U-IIIf	58,630	12.56
7	Lumphula and Krabi soils, rolling phase	U-IIIe	71,560	15.33
10	Krabi and Yala soils	U-IIIs	8,630	1.85
11	Tha sae series	U-IIIs	4,620	0.99
	Sub Total		**1,46,420**	**31.53**

TABLE 4.10 CONT'D

Unit Number	Name	Capability subclass	Area in a	% of the Total area
14	Khlong Teng and Na			
	Thon soils	U-IVs	10,550	2.26
12	Yala series	U-IVs	1,910	0.41
13	Yala and Lumphula soils	U-IVs	2,800	0.60
	Sub Total		**15,260**	**]3.27**
16	Slope complexes, shale,	U-VIIe	119,540	25.61
15	Slope Complexes,	U-VIIIe	8,990	1.82
	limestone Water	-	12,090	2.59
	Sub Total		**140,120**	**30.02**
	Grand Total		**466,800**	**100**

Source : Department of Land Development, Ministry of Agriculture.

In the downstream area detailed reconnaissance soil maps covering the project area in Surat Thani have been published by the Department of Land Development Most of the soils in Surat Thani province are reported to have low fertility. Soil survey and classification were also carried out for the Phase 1 irrigation area during its feasibility study to a semi-detailed level of investigation. Soils in the project area were classified into 6 classes based on their limitation in use for growing upland crops and low land rice. Three in 6 classes were considered as irrigable and suitable for cropping.

Concerning potential land use or land capability, all land in the upstream area is practically unsuited for commercial crops, but suited for woodland or for establishment of watershed protective vegetation. There are two major land types in the downstream area. One type is well suited for wet land rice in the rainy season. And with irrigation it can be used for multiple cropping of rice, vegetables, and other crops. The other land type is wellsuited for many kinds of fruit trees, beverage crops, industrial oil crops, and rubber.

The lands were classified for both rice and upland crop suitability, with subscripts showing their limitation; namely s-for soil deficiency, t-for topographic limitation, d-drainage deficiency, a-salinity hazard, f-annual flooding, and c-vegetation cover.

The results of the land survey (Royal Irrigation Department, 1996) are presented in Table 4.11 and are summarized as follows :

	Area, (ha)	**% of total**
(1) Lands suitable for irrigated rice	16,560	72
(2) Lands equally suitable for irrigated rice and uplands crops	2,850	12
(3) Lands suitable for irrigated uplands crops	2,310	10
Sub total irrigable lands	**21,720**	**94**
(4) Non irrigable lands	1,380	6
Total	**23,100**	**100**

TABLE 4.11

LAND CLASSIFICATION IN PHASE I IRRIGATION PROJECT AREA

Land Classification		Area, (ha)	Area, (ha)	% of Surveyed Lands
Land suited for rice		16,560		72
R1	class		9,310	
	U2s/R1		2,922	
	U2s/R1.c		1,591	
	U3s/R1		1,667	
	U3s/R1.c		384	
	U3sd/R1		2,746	
R2	class		5,010	22
	U3c/R2.c		474	
	U3sd/R2d.f		4,111	
	U6sd/R2sd.f		339	
	U6sd/R2sd.fc		86	
R3	class		2,240	10
	U3sd/R3sd.f		214	
	U6sd/R3d.f		22	
	U6sd/R3sd.f		157	
	U6sd/R3sd.af		940	
	U6sd/R3sd.afcl		907	
Lands equally suited for rice and upland Crops		2,850		12
U2/R2	class		2850	
	U2s/R2.c		580	
	U2s/R2.d		35	
	U2s/R2s		732	
	U2s/R2s.d		73	
	U2s/R2s.c		1,430	

TABLE 4.11 CONT'D

Land Classification		Area, (ha)	Area, (ha)	% of Surveyed Lands
Lands suited for upland crops		2,310		10
U1	class		690	3
	U1/R2s		46	
	U1/R2s.d		34	
	U1/R3s		335	
	U1/R3s.d		69	
	U1/R3s.c		206	
U2	class		1,510	7
	U2/R3s.d		140	
	U2/R3s.c		1,120	
	U2s/R3s		139	
	U2s/R3s.c		67	
	U2st/R3st.d		44	
U3	class		110	
	U3st/R6st.d		83	
	U3st/R6st.c		27	
Sub-total, irrigable lands		21,720		94
Non Irrigable Lands		1,380	1,380	6
Class 6			925	-
	6H		455	4
	Other class 6			2
Total, surveyed lands		**23,100**		**100**

Sources : Royal Irrigation Department.

In the pre-impoundment soil survey in the Phase 1 irrigation area large fluctuations of ground water table was found throughout the year, with peak levels within 50 cm depth. Significant changes in the maximum levels of the ground water table would affect land capability, as the high levels would provide suitable conditions for the water logging problem. The observations of the ground water table in this post-impoundment study, however, reveal no significant change. Therefore capability of the land in the irrigation area has thus far not been significantly affected by the Rajjaprabha dam and its downstream project implementation.

3.5 Conclusion

Most soils in the project area are generally of low to moderate fertility. Practically all soils in the upstream area are not suited for commercial crops due to steep slopes.

The downstream areas are well suited for cropping, though generally requiire appropriate management. Soil improvement, especially in fertility, is needed for crop production in the project area.

Land capability of the project area has so far not been significatly affected by the implementation of the project.

6. MINERAL RESOURCES

6.1 Introduction

The pre-impoundment investigation in the year 1980 indicated that there were very scarce mineral deposites in the reservoir area, and there was no mine in operation in the upper catchment area. Even though the mineral resource development in the basin is not as active as in other parts of the south, the availability of mineral resources which have been investigated by the Department of Mineral Resources have shown considerable potential for development. The study on mineral resources is aimed at the assessment of mineral resources development potential and its relative impacts, in order that its proper development and mitigation can be integrated in the plan.

6.2 Objective

The objectives of this study are :

(a) To evaluate the potential for mineral resources development due to improved access to watershed areas and availability of electric power.

(b) To assess the anticipated impacts of mining activities on surface water quality in the upper and lower catchments area.

6.3 Methodology of the study

The methodology adopted for this study are:

(1) Collecting information on mining locations, mining processes, production statistics, and development potential for each kind of mineral.

(2) Field survey and water sampling for selected mines in the upper and lower catchments area.

(3) Evaluation of the impacts of mining activities on surface water quality in collaboration with the water quality study task.

6.4 Results off the Study

In the pre-impoundment environmental and ecological study in 1980 it was concluded that dolomite and kaolin deposits in the Phum Duang basin area were few uneconomical for mining regardless of other unfavorable circumstances there. However, after about a decade mining activities have not significantly developed. In this post-impoundment study a total of 12 concessions, same as the reported in 1980, covering a total area of about 164.6 ha is in operation (Table 4.12 and 4.13). Most of them are dolomite mines, and located mostly in Khirirattha Nikhom district of Surat Thani province. Mineral production in this area during January-April 1996 were 18,390 tons of dolomite and 1,600 tons of kaolin, of about 6.43 and 0.616 million bhat repectively (Table 4.14), however, production rate is very small compared to those produced in other areas of the south (less than 1 percent).

The minerals already mined in this area are assessed to be of only small portion of the area having mineral reserves. Hence, potential for minings in the area will remain for a considerable period of time. Under the current mining practices, the environmental impact from mining operation in the Phum Duang river basin is under control. As required by the governmental regulation, the environmental impact from mining on land, water, ecology, transportation, socio-economics, and public health must be mitigated in the operation. The investigation on water quality has indicated that the operating mines in the area have not caused any serious problem on surface water quality as most of the mining an open pit mines and they do not use water in the processes.

TABLE 4.12

PREVIOUS MINING CONCESSIONS IN WATERSHED AREA

Concession, No.	Area, ha	Holders
1. 10/2504	15.2	Easter Mining Development Co. Ltd.
2. 24/2504	15.8	Easter Mining Development Co. Ltd.
3. 25/2504	15.6	Easter Mining Development Co. Ltd.
4. 26/2504	15.4	Easter Mining Development Co. Ltd.
5. 46/2505	13.6	Easter Mining Development Co. Ltd.
6. 19/2512	42.4	Easter Mining Development Co. Ltd.
7. 26/2520	15.4	Easter Mining Development Co. Ltd.
8. 27/2520	34.1	Easter Mining Development Co. Ltd.
9. 50/2520	9.5	Rae Samphan Co. Ltd.
10. 64/2522	43.2	Rae Samphan Co. Ltd.
11. 65/2522	43.2	Rae Samphan Co. Ltd.
12. 66/2522	32.0	Rae Samphan Co. Ltd.
Total	**292.2**	

Source : Department of Mineral Resources

TABLE 4.13

EXISTING MINING CONCESSIONS IN WATERSHED AREA

Concession, No.	Area, ha	Holders
Muang district		
1. 23257/14971	1.8	Vimol Yenjai
2. 23283/14700	6.2	Sakol Somrej Co. ltd.
Ban Ta Khun district		
3. 30157	9.3	Subapat Netprapai
Khirirattha Nikhom district		
4. 30152	17.2	Rae Rung Boon Co. Ltd.
5. 30153	32.5	Surat Phatong Co. Ltd.
6. 30160	35.4	Silachai Surat Co.Ltd
7. 30161	3.2	Prayoon Ackaraborworn
8. 30162	10.8	Prayoon Ackaraborworn
9. 23230/14819	7.2	Chokphana (2515) Co. Ltd.
10. 23273/14877	15.7	Surat Ruangkit Co. Ltd.
11. 23280/14936	2.0	Rae Rung Boon Co. Ltd.
Phun Phin district		
12. 30175	23.1	Watcharapong Wongavnich
Total	**164.6**	

Source : Surat Thani Provincial Mineral Resources Provincial Office.

TABLE 4.14

MINES PRODUCTION IN THE WATERSHED AREA

(JANUARY-APRIL 1996)

Unit : in baht

Location	**Mines**	**Tons**	**Values (Bath)**
Khirirattha Nikhom district	Dolomite	18,390	6,436,500
Muang district	Kaolin	1,600	6,16,000
Total			**7,052,500**

Source : Surat Thani Provincial Office.

7. EROSION AND SEDIMENTATION

7.1 Introduction

Generally, erosion and sedimentation are considered important cause of problems in regard to the operation of most dam and reservoir projects. The effects of great concern are sedimentation deposition in the reservoir and riverbank erosion downstream of the dam. The construction of Rajjaprabha will cause the significant change of the natural regime of the Khlong Saeng and, later, Phum Duang river.

Farther downstream to the river estuary where the river discharges to the sea, the carried sediments will settle because of the reduction in flow velocity. Deltas will be formed and that will obstruct navigation. With the presence of the dam there will be change in sediment load and river discharge which will lead to change in estuarine sedimentation process. The impacts as mentioned above are no exception to Rajjaprabha dam. Expect trends and magitudes of these inpacts are evaluated in this study.

7.2 Areas of Study

Since the impacts of the dam on various portions of the river are different in nature, the study is separated into three different areas as follows :

(a) River bank erosion.

(b) Sedimentation in reservoir.

(c) Estuarine sedimentation.

7.3 Results of the Study

7.3.1 Previous Study

The annual suspended sediment, expected to be discharged into the proposed Rajjaprabha reservoir was estimated by EGAT (1979) using the correlation of annual runoff. The ratio of mean annual runoff between Khlong Saeng at damsite and Phum Duang river is about 67.60 percent. Consequently the average suspended flowing into the reservoir would be 3,36,603 tons/year. This amount is quite close to obtained from the analysis of the National Energy Administration (NEA) records. The bed load of sediment transported into the reservoir was estimested by EGAT from the annual suspended load. The annual bed load was assumed to be about 20 percent of the annual suspended load as found from the Pattani multipurpose project (EGAT.1976). The total annual sediment load discharging into the proposed reservoir is as follow.

Annual suspended sediment load	=	3,36,603	tons
Annual bed load = 0.20 x 3,36,603	=	67,321	tons
The total annual load of sedimentation	=	4,03,924	tons

By assuming the unit weight of 1.303 tons/m^3, the total sediment load of 4,03,924 tons comes to 3,09,995 m^3. The corresponding depth of watershed erosion is 0.22 millimeters per year. This rate of watershed erosion is raher high in comparison with other regions in Thailand but is low as compared with the watershed in other contries, as shown in Table 4.15.

TABLE 4.15

ANNUAL DEPTHS OF EROSION IN VARIOUS WATERSHEDS

River basin	Country	Annual Depth of Erosion mm/year
1. Domodar	India	0.95
2. Ching (Yellow)	China	4.86
3. Yantze	China	0.35
4. Mekong	Indochina	0.10
5. Irrawadi	Burma	0.55
6. Ping (at Bhumibhol dam)	Northern Thailand	0.36
7. Wang	Northern Thailand	0.21
8. Yom	Northern Thailand	0.21
9. Nan	Northern Thailand	0.23
10. Upper Ping	Northern Thailand	0.21
11. Nam Pong	Northeastern Thailand	0.13
12. Chao Phraya	Centralthern Thailand	0.14
13. Pattani	Southern Thailand	0.189
14. Khlong Saeng *	Southern Thailand	0.22

Source : EGAT

* Estimated previously and listed herein for comparison

7.3.2 River Bank Erosion

River bank erosion is relatively not serious for the river reach further upstream from Ban Ta Khun district that was found to be of 97,199 tons. More severe erosions are found along Khlong Phum Duang downstream from the Rajjaprabha diversion dam, which is an artificial reach cut long time ago. Bank erosion in this downstream river reach from the diversion dam is still very active. The bank erosion should have decreasing trend since downstream flood potential is minimized by the Rajjaprapha reservoir regulation.

River bed degradation has been assessed from field investigation and from available cross section data. No serious bed degradation at anticipated locations downstream from the Rajjaprapha dam is evidenced.

7.3.3 Sedimentation in the Reservoir

Sedimentation in the Rajjaaprabha reservoir is found to have negligible effect on the useful functions of the reservoir as originally planned. Although lack of, actual reservoir sedimentation survey data, possible effects of increased sediment load from headwater areas of the reservoir are assessed. The post-impoundment which was surveyed by EGAT in 1995 found the sediment load at about 3,74,000 tons per year which should 20 percent increase from the pre-impoundment data. About 20 percent increase in sediment load reservoir sedimentation is recalculated using the Area-Increment Method. It is found that even with the 20 percent increase in the reservoir sediment load most of the conclusions drawn in the reservoir sedimentation aspect in the pre-impoundment study are still valid. And the Rajjaprabha reservoir should be capable of providing its beneficial functions for more than 7,000 years of service life (Table 4.16).

TABLE 4.16

EROSION AND SEDIMENTATION OF EGAT ' S DAM

Name of the dam	Average of sediment, (mcm/year)	Rate of Erosion, (mm/year)	Capacity of the dam, (year)
1. Bhumibhol	2.146	0.070	4300
2. Sirikit	6.006	0.460	670
3. Sri Nakharintrara	1.524	0.088	9400
4. Khao Leam	1300	0.210	3250
5. Ubolrathana	1.500	0.120	125
6. Rajjaprabha*	0.374	0.178	8000
7. Bang Lang	0.409	0.063	1400
8. Kang Krachan	0.085	0.040	2600
9. Chulaporn	0.020	0.024	3050
10. Sirintron	0.226	0.110	1400

Source EGAT

7.3.4 Estuarine Sedimentation

As concerns estuarine sedimentation, the present reduction in the sediment load in the Ao Ban Don estuary due to the presence of the storage and diversion dams is estimated to be rather slight, not more than 15 % reduction from those experienced prior to the dams construction. The slight effect can be explained from the fact that more sediment loads are picked up from the river banks and beds as the relatively clear water, with unsatisfied sediment carrying capacity, traverses the downstream river reach before reaching the estuary. These phenomenons of sediment load picking up downstream from the dams were evidenced during both sets of sediment concentration sampling along the whole river reach. The amount of dredged motional from Ao Ban Don estuary is shown in the Table 4.17.

TABLE 4.17

CHANNEL IMPROVEMENT IN AO BAN DON ESTUARY BY DREDGING

Year	Month	Amount of Dredged motional (m^3)
1989	**October**	64,391
1990	**November**	1,95,280
1991	**December**	2,01,906
1992	January	1,57,290
1993	February	1,16,138
1994	March	1,88,144
1995	April	81,145
1996	May	57,810
Total		**10,62,415**

Source From the Harbour Department

8. SALINITY INTRUSION

8.1 Introduction

Salinity intrusion into the river is a natural phenomenon influenced mainly by the amount of fresh water flow into the estuary and the tidal condition prevailing at the river mounth. Salinity of the water in the estuarine reach varies with the location from the river mounth, being less saline at locations far upstream cfrom the river mounth. At a location in the estuarine river reach the salinity also differs at different depths, being more saline at the deeper depths due to the higher specific gravity of the salt water. The variation of salinity both with the distance from the river mouth and with the river depth is also time dependdent, following the time variatin of the fresh water inflow and the tidal variation. Therefore, under natural conditions the salinity distribution pattern in the estuary continually moves back and forth along the river, with its vertical salinity gradient also varying as the mixing of different layers of water continues

In this study salinity intrusion is investigated to serve as basic information for other related studies.

8.2 Objectives

The objectives of salinity intrusion study are:

(1) To present the salinity intrusion pattern in the Phum Duang estuary.

(2) To establish relations among fresh water inflow, salinity, and distance from the river mouth.

8.3 Salinity Data Collection

The sampling locations of the measurement were about 500 m apart, from the river mounth to about 5 km upstream. Samples were taken from the bottom, mid-depth, and water surface along the river thalweg. The Salinity data are classified into two sets. The first set consists of the measurement during the rising tides, and the second set consists of the measurement made shortly after high water slacks. The rising tide data include the measurements on 6th march, and 20th July 1997. And the high water slack data consists of the measurements on 25th August, and 10th September 1997. River flows measured at the Phun Phin bridge during the days with salinity measurement.

8.4 Results of the Study

8.4.1 Salinity Distribution Pattern

Pattern of salinity distribution in the Phum Duang eatuary are illustrated by line of equal salinity concentration, referred to as haloclines. During the rising tides the haloclines slanted sharply resembling a wedge intruding under the freshwater. The saline water and fresh water partially mixed during these rising tides. The mixing became more effective during the high water slacks when the haloclines were observed to be closer to vertical position. The salinity intrusion patterns observed in these measurements varied from the partially mixed to well mixed type. The maximum intrusion (1 ppt salinity) found in these measurements was less than 2.5 km from the river mouth.

8.4.2 Salinity Intrusion Prediction Equations

(1) Basic Equation

The relationship among the salinity concentration, distance from the river mouth, and the freshwater flow was firstly presented by Ippen and Harleman, and is generally expressed in the modified form (W.W.Massie 1982) as

$$S = S_O \exp\{AQ_f X^n + CQ_f^{0.5}\}$$

where S = Salinity concentration in ppt at a distance X upstream from the river mouth,

So = Salinity concentration in ppt at a section in the sea where its value is uniformly distributed across the depth, taken as 33 ppt in this study,

X = Distance upstream from the river mouth, km,

Q_f = Freshwater discharge, m^3/s, and

A,C,n = Constants depending on estuary characteristics.

In applying this salinity intrusion prediction equation to the Phum Duang estuary at Ao Ban Don the actually observed profile and the corresponding fresh water inflow are required for estimating the constant coefficients A, C, and n in the equation.

(2) Prediction Equation

The salinity profile of 6th March and 20th July 1997 and the profile of 25th August and 10th September 1997 are used in determining the coefficient A, C, and n in the salinity profile prediction equation by a regression analysis.

For the high water slack condition the prediction equation is

$$S \quad = \quad 33.0 \exp\{-0.0658\, Q_f X^{1.65} - 0.076\, Q_f^{0.5}\}$$

And for the rising tide condition the prediction quation is

$$S \quad = \quad 33.0 \exp\{-0.0384\, Q_f^{X\,2.26} - 0.136\, Q_f^{0.5}\}$$

The two prediction equations are verified by using them in fitting salinity concentration profiles to the data measured during different periods, by using trial values of fresh water inflow where the actual flows were unknown.

8.5 Conclusion

Salinity intrusion patterns observed in the Phum Duang estuary in this study are of partially mixed and well mixed types. The maximum intrusion of 2.5 ppt salinity was observed during the field measurements at less than 2.5 km upstream from the river mouth. Even the 0.5 ppt salinity intrusion was observed to be less than 5 km from the river mouth. Results of field measurements of salinity data and their concurrent fresh water inflow into the estuary have been used to establish useful salinity intrusion prediction equations. Salinity concentration at certain location along the river mouth can now be predicted for different fresh water flows in the estuary.

CHAPTER V

ECOLOGICAL RESOURCES

CHAPTER V

ECOLOGICAL RESOURCES

1. INTRODUCTION

In general, the major components of ecological resources relating to a dam/reservoir development project include aquatic biology, fisheries, forests, wildlife, and reservoir ecology. These environmental resources will be affected directly by dam construction and reservoir formation. With respect to fisheries, the effects will be both benefits and losses, depending upon what location along the river stretches they are considered. As for forests and wildlife, the effects are ususlly adverse. Fisheries, aquatic biology, and reservoir ecology are closely related to one another because changes in conditions of any parameter will have impact on the other two parameters. Likewise, forests and wildlife have very close relationships to each other. Thus, in this study, the ecological resources will be presented in four main parts: (i) aquatic ecology and aquatic weeds (ii) fisheries (iii) forestry and (iv) wildlife.

2. AQUATIC ECOLOGY AND AQUATIC WEED

2.1 Introduction

Ecologically speaking, any attemt to change land use patterns bring about changes in environment, both in natural flora and fauna. Thus the construction of a dam and a reservoir will naturally affect biological processes in the area. When the habitat changes, many fauna will also change to adapt themselves to survive.

Investigation and assessment including forecasting probable effects on this aspect were made in the environmental and ecological investigations. At this early stage of impoundment it is very crucial that actual effects be observed and compared with those anticipated so that necessary mitigation measures, if any, can be timely made. Special consideration is given to aquatic ecology aspects of food sources, which in turn, affect fisheries productivity.

2.2 Objectives

Main objectives are to evaluate the reservoir and downstream area in terms of aquatic ecology after 10 years operation of the dam. These include studies of plankton and benthic animals, which represent indicators of the water's productivity. The aim of the study is to gain information on species diversity, species richness and evenness, biomass, and community, including their seasonal variations in both wet and dry seasons. The study results are then compared with the previous study to assess changes, and subsequently utilize for preparing recommendations to enchance beneficial changes.

The specific objectives may be summarized as follows :

(a) To investigate auqqtic ecology and aquatic weeds in the reservoir and downstream river.

(b) To evaluate species diversity, richness and evenness, biomass community, and their seasonal variation.

(c) To compare the results to the previous study.

2.3 Study Area and Duration

Two field investigations were conducted to collect specimens at 6 stations. Of these stations two are in the reservoir and four along the Phum Duang river (see Figure 5.1). The first field investigation was performed in order to collect data to represent dry season conditions, and was conducted during 1-7 April 1997. The second field investigation was performed to collect data for the wet season, and conducted during 15-20 November 1997.

2.4 Methods of Study

The methods used for biotic investigation are as follows.

(1) Benthos

(1.1) Peterson and Ekman Dredges were used to collect soil samples, the contents were sifted with the US standard Sieve No.30. Benthic animals left on sieve were preserved in 5 percent formalin identified, weighed, and counted to calculate the abundance per square meter of the benthos and biomass at each sampling point.

(1.2) Calculations were made to find the Species Diversity Index of benthic animals, which clearly shows the relationship between the species and numbers of animals in that particular point, using Shanon-Weiner Index.

(2) Plankton

(2.1) Clarks Modification of Juday plankton trap was used to collect plankton at 1 meter water depth in the river, and in the reservoir at 1 and 10 meter depths.

(2.2) The collected samples were preserved in 5 percent formalin for subsequent identification and number determination.

(2.3) Calculations were made to find the Species Diversity Index, using Margalef or Shanon-weiner Diversity.

(3) Aquatic Weeds

The aquatic weeds were observed both in the reservoir and downstream at the same station as for benthos and Plankton study. Plant specimens were collected according to the plant types as follows :

(3.1) The marginal type plants were found in the swamp area around the edge of the reservoir and along both edges of the riverbanks. The plant specimens were collected and preserved in herbarium for further identification.

(3.2) The water body type plants consisted of floating species, submerged species and emergent sepcies. Some specimens were dry-preserved and particular plant were preserved in 5 percent formalin or 50 percent alcohol.

2.5 Results of the Study

2.5.1 Animals

(1) Density

The benthic animals specimens collected during the 2 field trips can be classified into 7 groups : Oligochaetes, dragonfly larvae, caddisfly larvae, mayfly larvae, midges larvae, univalves and bivalves. Populations of benthic animals found were not uniform, depending on various factors such as nature of river bed, water currents, etc. The findings are follows :

(1.1) It was found that the bottom of the reservoir was covered with mud and decayed plants. The number of benthic animals found during the dry season ranged from 18 per m^2 (at station No.2) to 678 per m^2 (at station No.1) with 367 per m^2 on an average. During the wet season, the number ranged from 15 per m^2 (at station No.2) to 224 per m^2 (at station No.1) with 118 per m^2 on an average.

(1.2) Between the storage and lower reach, the river bed was mostly covered with mud, sand and gravel, and the water current was strong, except in the upstream from the diversion dam where the river bed was covered with muddy sediments and water moved sluggishly. The number of benthic animals in dry season ranged from 194 per m^2 (at station No.3) to 4,830 per m^2 (at station No.4) with an average of 2,091 per m^2. During the wet season the number ranged from 34 per m^2 (at station No.4) to 1,458 per m^2 (at station No.5) with an average of 636 per m^2.

(1.3) In the lower reach, the riverbed was covered with sandy soil and clay. At Station No.6 at the river mouth the riverbed was very muddy. During the dry season, the number of benthic animals raged from 16 per m^2 (at station No.5) to 4,703 per m^2 (at station No.6) with an average of 2,029 per m^2. During the wet season, the number ranged from 32 per m^2 (at station No.5) to 1,936 per m^2 (at station No.6) with an average of 1,136 per m^2

(2) Biomass of Benthic Animals

The biomass of benthic animals was calculated from the specimens collected during the two field trips, these can be summarized as follows:

(2.1) In the reservoir, the biomass of benthic animals was found during the dry season ranged from 0.53 gm/m^2 (at station No.2) to 163.5 gm/m^2 (at station No.1). During the wet season it ranged from 0.05 gm/m^2 (at station No.2) to 0.56 gm/m^2 (at station No.1) with 0.25 gm/m^2 on an average.

(2.2) It was found that along the dam to lower reach, the biomass of benthic animals in the dry season ranged from 1.85 gm/m^2 (at station No.3) to 24.57 gm/m^2 (at station No.4) with an average of 2.15 gm/m^2. During the wet season it ranged from 0.12 gm/m^2 (at station No.3) to 30.68 gm/m^2 (at station No.4) with 6.50 gm/m^2 on an average.

(2.3) In the river reach the biomass of benthic animals during the dry season ranged from 0.03 gm/m^2 (at station No.5) to 240.5 gm/m^2 (at station No.6) with an average of 120.30 gm/m^2. During the wet season it ranged from 0.95 gm/m^2 (at station No.5) to 22.56 gm/m^2 (at station No.6) with 11.2 gm/m^2 on an average.

(3) Species Diversity Index

The study results can be summarized as follows.

(3.1) It was found that in the reservoir the species diversity index of benthic animals in dry season was 0.96 on an average while in wet season it was 0.34 on an average.

(3.2) Along the dam to the lower reach, the index numbers of benthic animals during the dry season ranged between 0.12 (at station No.3) and 0.98 (at station No.4) with

0.62 on an average. During the wet season, the index numbers ranged from 0.3 (at station No.3) and 1.2 (at station No.4) with 0.68 on an average.

(3.3) In the lower reach, the index number found during the dry season was 0.24 on an average, while during the wet season the number was 0.65 on an average.

(4) Comparison of Benthic Animals before and after Impoundment

The data of the survey before and after the dam construction indicate similarity in the kinds of benthic animals. Apparently, the number of benthos in the reservoir was lower after the construction. The average density of the benthos before the construction was 786.6 per m^2 while the average density of the benthos after the construction in dry and wet seasons were 267.5 per m^2 and 115.84 per m^2, respectively.

The density of benthos in the downstream area was higher in the period after the dam construction than in the period before the construction. The densities of the benthos after the construction in dry and wet seasons were 3,128.2 per m^2 and 243.78 per m^2 on an average respectively, while that of the period before the construction in dry season was 124.6 per m^2 on an average.

2.5.2 Plankton

(1) Density

The plankton specimens collected during the 2 field trips can be classified into 8 phyla, 78 genera. These consisted of 3 phyla 52 genera of phytoplankton, and 5 phyla 22 genera of zooplankton. The findings are as follows.

(1.1) It was found that in the reservoir the number of plankton during the dry season ranged between 1,074 x 10^3 cells/m^3 (at 1m depth) at station No.2 and 12,785 x 10^3 cells/m^3 (at 10 m depth) at station No.1, with 2,895 x 10^3 cells/m^3 an average. Phytoplankton found in abundance were Anacystis, Ceratium and Peridinium, while the zooplankton was Keratella. During the wet season, the number ranged from 385 x 10^3 cells/m^3 (at 10 m depth) at station No.2 to 3,885 x 10^3 cells/m^3 (at 1 m depth) at station No.1 with 1,885 x 10^3 cells/m^3 on an average. The phytoplanktons found in abundance were Anacystis, Cosmarium and Staurastrum while the zooplankton was Keratella.

(1.2) Along the dam to lower reach, the number of plankton found during the dry season raged from 185 x 10^3 cells/m^3 (at station No.3) to 1,686 x 10^3 cells/m^3 (at station No.4) with 685 x 10^3 cells/m^3 on an average. The phytoplanktons found in abundance was Anacystis. During the wet season, the number ranged from 185x10^3 cells/m^3 (at station No.3) to 885 x 10^3 cells/m^3 (at station No.4) with 315 x 10^3 cells/m^3 on an average. The phytoplanktons found in abundace were Anacystis and Surirella.

(1.3) It was found that in the lower reach, the number of plankton during the dry season raged from 80 x 10^3 cells/m^3 (at station No.5) to 155 x 10^3 cells/m^3 (at station No.6) with 80 x 10^3 cells/m^3 on an average. The phytoplanktons found in abundance was Anacystis, During the wet season, the number ranged from 85 x 10^3 cells/m^3 (at station No.5) to 786 x 10^3 cells/m^3 (at station No.6) with 365 x 10^3 cells/m^3 on an average. The phytoplanktons found in abundace were Thalassiosira.

(2) Species Diversity Index

The study results can be summarized as follows:

(2.1) It was found that in the reservoir the index number of plankton in dry season ranged between 1.21 (at 10 m depth) at station No.2 and 2.15 (at 1 m depth) at station No.1 with an average of 1.62. During the wet season, the number ranged from 1.48 (at 1 m depth) at station No.2 and 2.20 (at 10 m depth) at station No.1 with 1.80 on an average.

(2.2) Along the dam to lower reach, the index number of plankton in dry season ranged between 1.25 (at station No.3) and 2.11(at station No.4) with an average of 1.28. During the wet season, the index mumber ranged from 0.92 (at station No.3) and 1.94 (at station No.4) with 1.59 on an average.

(2.3) In the lower reach the index number of plankton in dry season ranged between 1.37 (at station No.5) and 2.24 (at station No.6) with an average of 1.74. During the wet season, the number ranged from 1.98 (at station No.5) and 2.19 (at station No.6) with an average of 2.05.

(3) Comparison of Benthic Animals before and after Impoundment

In the reservoir, surveys were condducted during dry season before and after impoundment. The results showed that the amount of plankton were similar; the density averaged 3,780 x 10^3 cell/m^3 as compared with 3,910 x 10^3 cell/m^3 found in this study. The density of plankton for the wet season taken during 15 November 1997 was 1,840 x 10^3 cell/m^3 on an average.

In the downstream area, the density of plankton before the impoundment was much higher than that after impoundment (Team Consulting Engineers Co. Ltd., 1980). Moreover, the density of plankton in April was much higher than that in November. The survey before impoundment was taken during 19-26 March 1980, while after impoundment were taken in April and November 1997. The results showed the densities of plankton for the two periods were 3,680 x 10^3 and 1,126 x 10^3 cell/m^3.

2.5.3 uatic Weed

Results from the first investigation revealed the existence of 41 species, 35 genera and 28 families of aquatic plants. These were marginal, submerged and floating plants. Results from the second investigation indicated that the types of aquatic plants and their numbers were slightly different from those of the first investigation. The number of aquatic plants found at each sampling station can be summarised as follows:

(1) In the reservoir, at all stations a small number of aquatic plants were found. This is due to the fact that when the inflow water was impounded in the reservoir the higher level of water completely destroyed the original submerged plants grown in the river. However, some new species of aquatic plants have appeared above the water level along the edge of the reservoir.

(2) Along the lower reach of the dam (station No.3,4) the density by weight of plants ranged between 567 gm/m^2 (at station No.3) and 1,812 gm/m^2 (at station No.4) Aquatic plants found in abundance were <u>Brachiaria</u> Sp. And <u>Hydrilla</u> Sp.

(3) It was found that in the river reach, the density by weight was 2,512 gm/m^2 (at station No.5) while at the river mouth no aquatic plant was found.

2.6 Conclusion

In the pre-impoundment environmental and ecological studies conducted in 1980, biological conditions of the river were investigated at only 3 sampling stations: one near the storage dam site, one at the upstream, and one at the downstream. Thirty-two species of planktonic organisms were then observed, including 21 species of phytoplankton and 11 species of zooplankton. The presence of plankton was reported to be relatively high as compared with the amount observed in other rivers in the country. Benthic organisms were, however, found to be of low as the river bottom at the sampling sites was sand and gravel.

In this post-impoundment study, aquatic ecology has been investigated at 6 selected sampling stations; two stations in the reservoir and four stations along the river.

Field investigations were performed in both dry and wet seasons: during 1-7 April 1997 and during 15-20 November 1997, respectively. The amount of plankton in the reservoir is not different from the amount found in the vicinity of the dam site in the pre-impoundment period. Along the river between storage dam to the lower reach, the amount of plankton is significantly less in the post-impoundment period. But, the benthic animals in the post-impoundment period are more abundant. Both planktons and benthic animals were more abundant during the dry season than during the wet season in the reservoir and in the downstream river reach. Dowmstream from the diversion dam, planktons are less abundant than in the upper river reach. Benthic animals in the vicinity of the river mouth are more abundant.

Aquatic plants in the reservoir are scanty. They were more prevalent in the river reach between the storage and diversion dam, and even more prevalent downstream from the diversion dam. However, they were not found near the river mouth.

The aquatic ecology condition in the reservoir reveals its suitability for aquaculture development. This is also true for the downstream river reach, but perhaps to a somewhat lesser extent.

3. FISHERIES

3.1 Introduction

Rajjaprabha reservoir is a man-made lake located in Surat Thani province, with a water surface area of about 185 km^2 or 18,500 ha. After the dam was built, the river's ecosystem changed significantly. Some species of fish formerly living in the river adapted themselves to survive in the new environment, while other species of fish could not survive. They gradually disappeared and have been replaced by other species. This process has had an impact on the fish population and the local people engaged in fishing.

The changes in the aquatic ecosystem due to the creation of the dam and reservoir, the patterns and life cycles of riverine fauna including fish and macroinvertebrate species are interrupted. Migration of the fishes to upstream of the dam is not possible. The impoundment fisheries are affected by the changes in the water quality as well as other physical changes in the reservoir. In most cases, after the impoundment, an increase in the amount of reservoir fish is observed, and they represent a significant economic asset of the projects. From the fishery point of view, it is important for proper fishery management to conduct a study to assess changes, which have already occurred, and to propose a proper management plan to enhance the reservoir fisheries development.

3.2 Objectives

The objectives of this study are as follows:

(1) To investigate the existing condition of fisheries' resources.

(2) To investigate the socio-economic condition of fishing households in the project area; and

(3) To formulate an administrative plan and regulations for fisheries activities in the reservoir and downstream, in order to enhance maximum sustained yield of fishes.

3.3 Study Methodology

The field work for the fisheries study originally consisted of two field investigations, one in the dry season during 1-7 April 1997 and another in the wet season during 15-20 November 1997. The fish sampling was obtained from four stations: two from the reservoir, and another two stations from a downstream in Phum Duang river.

Data on fisheries activities and related socio-economic conditions of local residents in the proposed reservoir area and downstream river reaches were gathered in a fisheries socio-economic survey. The data was collected using a structured schedule, as well as by inteviews with local fisheries officials. In the reservoir area, the samples consisted of 100 households. They were selected on the basis of a simple random sampling method. The sample size was about 26 percent of the total number of 385 households in the resevoir area. In the downstream area a total of 80 sample households were selected randomly, representing 10.5 percent of the total number of 762 households in the villages. In the delta area, interviewing a small number of fishermen carried out data gathering.

3.4 Previous Investigation

Information regarding fishery resources in the Phum Duang river basin during pre-improundment was obtained from the environmental and ecological investigation report. The information is summarized as follows.

3.4.1 Species composition

Ninety-three compositions of species were found. Among the number of species found, cyprinids were ranked first (having 53 species about 66 percent) followed by catfish (11 species or 11.8 percent), Conbitids (7 species or 7.5 percent), Mastacembelids 5 species (5.4 percent), and miscellaneous fish with 17 species (about 18.3 percent). The fish species were arbitrarily divided into "less common", "common" and "abundant". The proportions of these categories were 7.5, 80.2 and 12.3 percent respectively. Of the 93 species found in the reservoir and downstream, the "less common" species can be regarded as "rare" as far as the Phum Duang basin, in concerned. But they cannot be considered as the "endangered" species because they still exist in considerable quantities in other part. They include Pla Peap Khao (oxygaster maculeanda), Pla Peap Bai Phai Douronensis, Barb (Pantius colemari), Mu (Botia Beauforti), and Katting Fai (Mastacembelus erythotaensis). Of the 93 species was found, 21 species (about 23 percent) were classified as the species of commercial values.

3.4.2 Major Fish Species and Standing Crop

Cyprinidae were family of fishes the most important, ones found in the area. They constitute 96.89 percent of the total catch in term of number and 90.56 percent in term of weight. On the other hand Pristolepicadae constituted 5.17 percent, Belonidae 2.18 percent, and Ohicephalidae 1.29 percent in term of weight.

The most prevalent species in the area was Pla Siew (Rasbora Rasbora Hamilton), which constitute 58.94 percent in term of number and 27.73 percent in term of weight. The other species included Pla Siew (Rasbora restrodorasalis H.M.Smith), 18.61 pecent in term of number and 17.00 percent in term of weight, Pla Ta Daeng (Raboras lineathus Sauvage), 8.95 pecent in term of number and 5.71 percent in term of weight, Pla Yisok (Mystacoleucus chilopterus flower), 1.83 pecent in term of number and 8.70 percent in term of weight, Pla Siton (Corica gonisnothus Bleeker), 1.16 percent in term of number and 0.06 percent percent in term of weight. Although fishes belonging to the family of Cyprinidae was the most abundant, their size was generally small, the average weight a fish of this family was only 3.17 gm. This was followed by those of family Prestolepidae with an average weight of 76.95 gm/fish, family of Belonidae with an average of 21.93 gm/fish and family Anabantidae with an average weight of 20.0 gm / fish.

The Fish/Crop (F/C) ratio, defined as the ratio of the total amount of forage fishes to the total weight of carnivorous (piscivorus) fish in a fish population, was about 9.8 for the fish caught in Khlong Saeng This indicates an unbalanced fish population, in comparison with the most desirable F/C ratio range of 3.0-6.0.

The standing crops of fish in the Phum Duang river basin are shown in Table 5.1. In November, when the river stage was very high and the river flow was rapid, there were few suitable locations, i.e, at Ban Ta Khun. The standing crop of fish was only 2.20 kg/rai * (1 rai = 0.16 ha) which was relatively low. In December when the river stage subsided, the flow velocity was still high and four suitable sampling locations could be found. The average standing crops of the four seining hauls was 6.60 kg/rai (1.25 kg/ha). Although this average standing crop was not high, it ws about 3 times as much as the value found in November. Since the number of hauling in both periods were very small, a meaningful statistical comparison could not be made. Thus, it is not possible to conclude that the difference in the standing crops of these two sampling periods was due to seasonal variations. Rather it was likely caused by the conditions of the river stage and flow. The simple average standing crop was 5.86 kg/rai and the weighted average was 6.10 kg/rai.

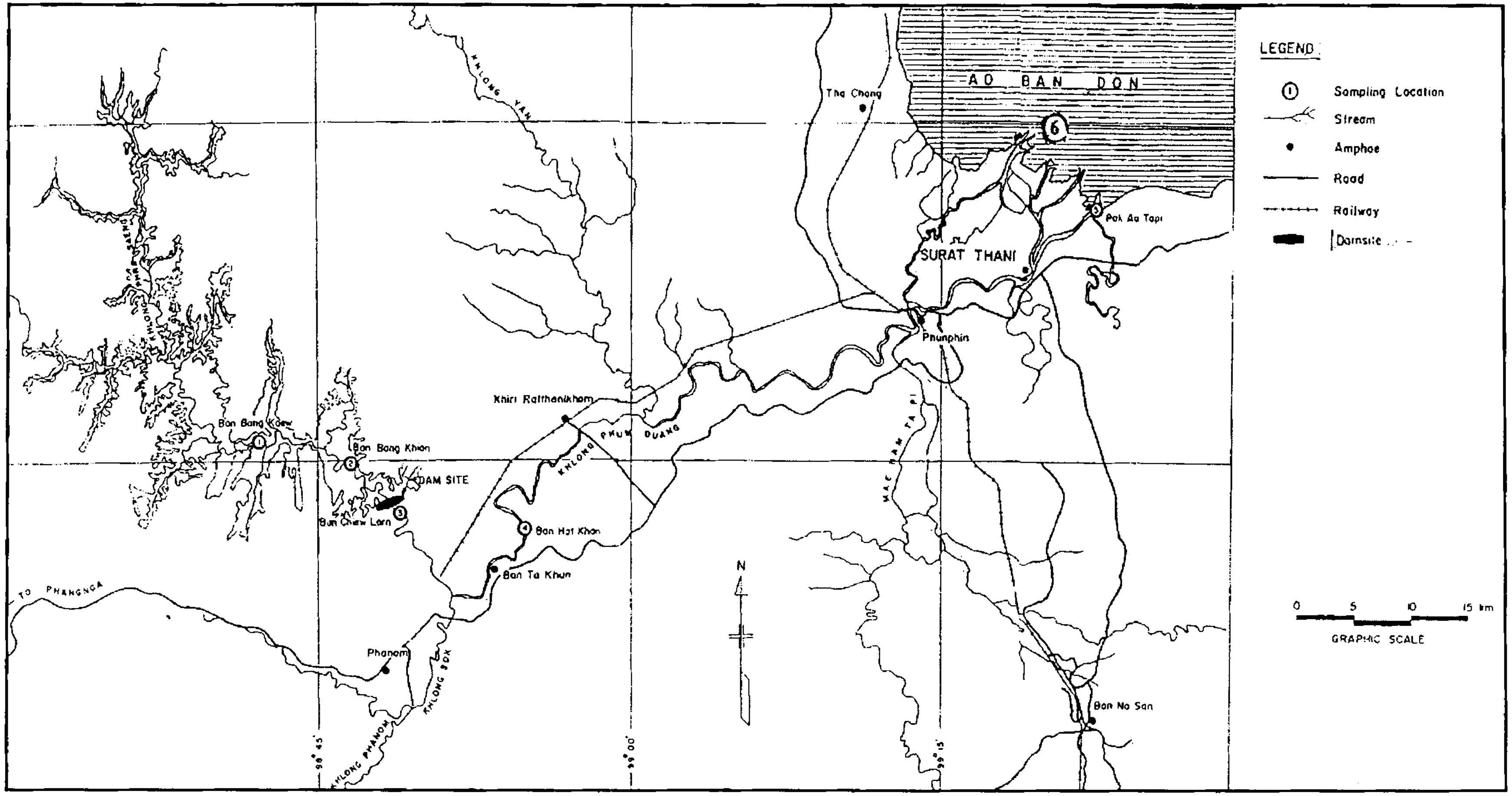


FIGURE 5.1

PLANKTON AND FISH POPULATION IN PHUN DUANG BASIN

TABLE 5.1

STANDING CROPS OF FISH POPULATION IN PREVIOUS INVESTIGATION (DECEMBER 1980)

Location	Area Anclosed m^2	Total Fish Caught, kg	Standing Crop, kg/rai
1 Ta Khun village	1,600	2.195	2.20
2 Bang Kaew village	1,920	18.006	15.01
3 Bang Kaew village	1,280	4.721	5.90
4 Bang Kaew village	1,760	3.340	3.04
5 Bang Khian village	1,440	6.291	6.99
6 Hat Khan village	1,600	2.036	2.04
Average	-	-	**5.86***

Notes (1) * Simple average

(2) Weighted average = 6.10 kg/rai

Source : Environmental and Ecological Investigation Report.

3.5 Existing Conditions of Fishery Resources

Two field investigations were conducted. The investigation of the fish populaion was conducted in two areas. The first area was in the reservoir and the other covered the downstream area. The survey results are gives below:

3.5.1 Species Composition

In both the areas, 54 species belonging to 10 families of fish including one specie of shrimp were found. In the reservoir, 34 species belonging to 10 families including one specie of shrimp were found. The shrimp belong to the family of Palaemionidae. The dominant species was Tapien Khao (Punitus Qunionotus). In the downstream area, there were 20 species of fish belonging to 15 families and one specie of shrimp (Palaemon sp.) The Mor Chang Yeab (Pristolepis fasciatus) was the dominant specie. In the reservoir, the percentage of Tapian Khao was 26.40, rasboras 18.52, barb 15.20, carnivorous 4.18, oaches 10.76 freshwater cat fish 6.13, snake head 5.65, and carp 3.34. In downstream area, the percentages of fish were as follows: Mor Chang Yeab Pristolepis sasciatar 32.56, snake head 26.38, barb 21.89 carnivorous 16.26, and monor 2.10.

3.5.2 Standing Crop

The standing crop, in terms of yield per rai, reveals that the reservoir produced an average of 8.60 kg./rai. The area near the dam site produced a minimum yield of 1.40 kg/rai because of the high slope which is not a good habitat for fish. The standing crop of the downstream reach averaged 5 kg/rai. Downstream from the diversion dam at Ban Chiew Larn, the yield was 4.5 kg/rai, while at Ban Hat khan the yield was 6.50 kg/rai.

TABLE 5.2

STANDING CROP OF FISH IN RAJJAPRABHA RESERVOIR

AND DOWNSTREAM AREA

Area	Location	Total Caught, (gm)	Area, rai (1,600 m^2)	Standing Crop kg/rai
Reservoir	Bang Kaew village	1024	1	10.24
	Bang Khian village	696	1	6.96
	Average	**860**	**1**	**8.60**
Downstream	Ban Chiew Larn	350	1	3.50
	Ban Hat Khan	650	1	6.50
	Average	**500**	**1**	**5.00**

Note : The information is derived from the fishery survey results conducted in this study.

3.5.3 Preliminary Comparison of Fish Population during the Pre and Post Impoundment Periods

The number of fish species has decreased from 93 species before the impoundment to 54 species after impoundment. However, this may either be due to the change in the environment or the collecting technique. A change in environment 176 can cause a change in fish species, i.e., riverine to lucustine species. In the reservoir, the dominant species found during the pre impoundment study was Pla Siew (Rasbora rasbora) and the dominant specie found during the post-impoundment period was Pla Tapien Khao (Puntius gonionotus).

TABLE 5.3

COMPARISON OF FISH POPULATION DURING
PRE AND POST IMPOUNDMENT PERIODS

Fish population	**Pre Dam**		**Post Dam**	
	Downstream	**Reservoir**	**Downstream**	**Reservoir**
Species composition	40	53	20	34
Dominant species	Pristolepis Fasciatus	Rasbora Rasbora	Pristolepis Fasciatus	Puntius Gonionotus
Standing crop	6.5 kg/rai	4.5 kg/rai	5.0 kg/rai	8.6 kg/rai

Source : Survey data.

3.5.4 Fishery Economics

Fishery economic information was obtained through personal interviews and from observations. The survey results presented under the heads socio-economic status of the fishing households, fishing activities, costs and earnings.

3.5.4.1 Socio-economic Conditions Relating to Fisheries

(1) Reservoir Area and Downstream Area

The general information on household characteristics in both reservoir and downstream areas is summarized in table 5.4 The average household size of the two areas was 4.52 and 5.80 persons respectively. The proportions of males to females were almost equal in both the areas. Fruit tree farming was the main occupation in the two areas. The major supplementary occupations in the proposed reservoir area were driving of passenger boats, and wage earning. Rice farming, merchandinsing and wage earning were the major supplementary occupations in the downstream area. It is imporatant to note that no household regarded fishery among the major supplementary occupations. In the reservoir area, the average household income was 56,854 bahts/year and the average household expense was 38,400 bahts/year. No data on this matter was given by the downstream residents.

Table 5.5 presents the general information on fishing occupations among the sample households in the reservoir and downstream areas. All of the households in the reservoir area have participated in fisherey as their subsistence occupation, which only 61.0 percent of the households in the downstream area caught fish for cash income. The main fishing season for the reservoir residents is between January and May for the downstream residents is between December and May. But the reservoir residents caught fish primarily during the main fishing season, while the downstream residents operated fishing activities all year round. The monthly average fishing trips were 8 and 15 for the reservoir and downstream households respectively.

The average numbers of hours spent on each trip were 12 and 6 respectively, and the average number of family members participating in fishery activities were 2 for both the groups. Hence, the fishing effort of the downstream residents was more than twice the effort of the reservoir residents, averaging 2,160 hours per year compared with 960 hours per year of the reservoir residents.

TABLE 5.4

GENERAL INFORMATION OF SAMPLE HOUSEHOLDS IN RESERVOIR AND DOWNSTREAM AREA

Information	Upstream	Downstream
1. Total no. of households surveyed	70	60
Percent of total households	25.0	10.6
2. Average household size, persons	4.52	5.80
3. Average no. of children per household	2.42	3.00
4. Sex		
Male (%)	49.69	46.85
Female (%)	50.31	53.15
5. Religion		
Buddhism (%)	100.00	100.00
Muslim (%)	-	-
6. Main occupation	Fruit tree Farming	Fruit tree Farming
7. Average no. of years participating in Main occupation	13	>20
8. Major supplementary occupations	Boat driving Mineral Prospecting Wage earning	Rice farming Merchandising Wage earning
9. Average household income, baht/year	56,854	No data
10. Average household expense, baht/year	38,400	No data

Source : Surat Thani Provincial Fisheries Office.

TABLE 5.5

GENERAL INFORMATION ON FISHING OCCUPATION OF HOUSEHOLDS IN UPSTREAM AND DOWNSTREAM AREA.

Information	Reservoir	Downstream
1. Average percentage of household participating in fishing activities	100.00	100.00
2. Status of fishing occupation *		
As main occupation (%)	-	-
As supplementary cash income (%)	-	39.00
As subsistence occupation (%)	100.00	61.00
3. Main fishing season	Jan-May	Dec-May
4. Major fishing ground	Reservoir	Phum Duang River
5. Time spent on fishing		
Average no. of months per year	5	12
Average no. of trips per month	8	15
Average no. of hours per trip	12	6
6. Average no of family members used in fishing	2	2

Note : As percentage of the total number of sample size in each location.

Source : Surat Thani Provincial Fisheries Office

Twenty four different types of fishing gear were observed and described by local residents. The most important ones included set gill net, cast net, and set line. The percentages of the major types of fishing gear used in Phum Duang river are summarized below:

Fishing Gear	Percent of Total	
	Reservoir Area	Downstream Area
Cast net	40.0	80.0
Set gill net	30.0	10.0
Set line	20.0	0.0
Bamboo trap	5.0	0.0
Boat trap	0.0	1.0
Others	5.0	9.0
Total %	**100.0**	**100.0**

The average catch per trip of households in the reservoir area was 28 kg, which was 7 times as much as the average catch in the downstream area inspite of the fact that the average time spent for each trip in the former area was only twice that of the latter area. The average fish catche per month in these two areas were found to be 224 kg and 60 kg respectively. The value of which was 2,600 baht and 675 baht respectively. Barb (Osteochilus spiropleura) was the most important specie in both the areas, while catfish (Mystus nemeus) was equally important catch in the downstream area. Other important commercial fish species included barb (Puntius gonionotus), black shark barb (Morulius chrysophekadion), featherback (Notopterus borneesis), and others (mainly forage fish).

A striking difference is observed between the two groups of people with respect to catch per unit fishing effort. The average catch per man-hour for these two areas was 1.17 kg for reservoir and 0.33 kg, for downstream area respectively, with the value for the former treas being about 3.5 times that of the latter area. The cause for this difference were not studied. The probable reasons might have been (i) fish were more abundant in the reservoir area than in the downstream area, (ii) fish caught by set gill net and set line was more efficient than by cast net (Eighty percent of fishing gear in the downstream consisted of cast nets while 70 percent in the reservoir area consisted of either set gill nets, or set lines), and (iii) the use of better accessory equipment (such as motor boat) in the reservoir area than in the downstream area, as explained in the following paragraph.

A large chunk of the fish caught by the upstream residents was processed for sale while the rest was either consumed at home or given to neighbours. But about 72 pecent of fish caught by the downstream residents, were consumed at home. Information with respect to disposal of fish catches is presented below:

	Percent of Total Catch	
Fish Disposition	**Reservoir Area**	**Downstream Area**
Consumed at home (fresh)	3.5	72.0
Given to neighbour (fresh)	18.0	0.0
Sold (fresh)	0.0	28.0
For household consumption	78.5	0.0
Processes for selling	0.0	0.0
Total %	**100.0**	**100.0**

Fishing costs consisted of depreciation of gear (excluding boat and its engine which were bought mainly for other purposes), operating cost, and maintenance cost. Since the downstream fishermen used simple accessory fishing equipment such as paddleboats, they had no operation and maintenance costs. On the other hand, the upstream fishermen depended on motorboats for fishing. So they incur a considerable sum for fuel. The monthly fishing expenses of these two groups of fishermen come to 865 and 40 baht/household, respectively. The details of expenses are given below:

	Cost, baht/household	
Cost Item	Reservoir Area	Downstream Area
Depreciation of gear	85.0	40.0
Fuel cost	765.0	0.0
Maintenance cost	15.0	0.0
Total	**865.0**	**40.0**

By using the above-mentioned data, the net annual benefits from fishing activities per household with respect to residents of reservoir and downstream area are estimmated. The estimate is made on the assummption that the average lengths of fishing time was 5 months for the upstream area and 12 months for the downstream area. The estimated income annual to 8,475 bahts and 7,620 bahts respectively to households of reservoir area and downstream area. These benefit accounted for 20 percent of the average household income of the upstream households and about 51.8 percent of the downstream households.

(2) In Delta Area of Ao Ban Don

Fishing activities are carried on in a sall scale basis in the delta area of Ao Ban Don at Pak Nam Phum Duang. Fishing activities here are greater than the subsistence fisheries operated by the residents in the upper part of the Phum Duang river. Fishery activities here are carried out year round with at least 20 fishing trips per month. The main types of fishing gear used include setline, cast net, and gill net, which are used for catching giant freshwater prawns (Macrobrachium rosenbergii)

The average fish catch came to about 60-100 kg of fish per boat per month. The catch is mainly giant freshwater prawns. In this area, capital investment in fishing was generally high commpared within the Phum Daung river. The monthly earnings from fisheries here ranged from 8,000 and 14,000 baht per household.

(3) Some Additional Aspects of Freshwater Fisheries in Surat Thani

Aquaculture is not very popular in Surat Thani. In 1995, seventy-seven households in this area carried out fish farming in a total area of only 10 rai, which averaged about 208 m^2 of fish farm per household (Department of Fisheries 1997). The number of households carrying out fish farming increased to 127 in 1996 and the average size of the farm per household stood at 213 m^2. These average fish farm sizes were quite small. Fish were raised exclusively in ponds, not in rice paddies, ditches, or cages.

The quantities and values of fish produced by aquaculture in these two years are shown in Table 5.6. The table shows that the average fish yields were 1.03 ton/rai (134 kg/ household) and 1.32 ton /rai (137 kg/household) respectively. And the average values were 12,630 baht/rai (1,640 baht/household) and 22,830 baht/rai (3,002 baht/household) in 1995 and 1996, respectively. In 1997, six favourite fish species were found to be farmed in Surat Thani, including Sepat-Siam, Nile tilapie, Java tilapia, common carp, catfish, and freshwater catfish, with climbing perch and gourami being the two main by-products. These fish are shown along with the ranges of their annual yields in Table 5.7. Two species of catfish, namely Pangasius sutchi Fowler and Clarias batrachus Linnaeus, were the most productive species, with annual yields of 1.2-2.1 tons/rai and 3.0-3.3 tons/rai, respectively.

In October 1997 at local markets in Surat Thani retail prices of certain freshwater fishes were reported as follows:

		Price, baht/kg	
Type of Fish	**Small Size**	**Medium Size**	**Large Size**
Barb	-	-	55
Serpent head fish	-	50	-
Freshwater catfish	-	-	70

3.5.4.2 Socio-Economic Benefits

As stated above, the annual production of reservoir fisheries are about 1,550 tons, assuming full exploitation of the available resources. The existing average catch of the upstream and downstream households are about 224 and 60 kg/month, respectively, and the weighted average for the two groups is about 120 kg/month. Assuming that these households were participate in reservoir fishing operations with the same amount of monthly fishing effort as at present and with the abundance of fish to about three times its size, the average household catch was about 360 kg/month, or about 2 tons per year (assuming 6 months is spent on fishing and the other six months for crop cultivation). Thus, about 750-800 households can participate in reservoir fisheries resulting in considerable additional household incomes.

The fishing cost can be divided into two categories: operation costs and depreciation costs. The operation costs consist of the expenses for fuel, lubrication, food, fishing gear and maintenance costs. From the cost analysis it was found that the operation cost was the major cost, being 85 percent of the total cost. It included about 50 percent for the fishing gear cost and about 24 percent for the fuel cost. The average total cost of fishing households was 113,960 bahts/year, while the average total sale was 140,000 bahts. Hence each household had an average profit of 26,040 bahts/year with the rate of return of 18.6 percent.

The socio-economic benefits will be gained not only by fishermen, but will also be shared by those involved in the fish marketing chain, including middlemen, wholesalers, and retailers. While the benefits will exist along the line, it is also important to provide measures which will prevent or minimize exploitation of fishermen by those higher up in the market chain.

Due to steep slopes of the reservoir fringe area, it may be difficult for fishermen to build permanent type of houses along the shoreline. Floating houses seem to be more suitable in this particular case.

TABLE 5.6

PRODUCTION OF SOME FISH SPECIES CULTURED IN PONDS IN SURAT THANI

Fish Species	1995		1996	
	Quantity, Ton	**Value, Baht**	**Quantity, Ton**	**Value, Baht**
Nile tilapia	4.5	68,800	12.9 small	236,300
Common carp	0.6	8,200	0	700
Thai carp	0	0	0	0
Sepat-Siam	0.2	2,400	5.5	300
Freshwater catfish	3.0	45,700	3.0	94,200
Serpent head fish	0	200	0.6	42,800
Tilapia	0.2	800		6,900
Total production	10.3	126,300	22.0	381,200
Average production, per rai	1.03	12,630	1.32	22,830
Ave.production, per household	0.134	1,640	0.137	3,002
Total No. of household	77	127		
Total farm area, rai	10.0	17		
Ave. farm size, m^2/household	208	213		

Source : Fisheries Economic and Planning sub-division, Department of Fisheries.

TABLE 5.7

FAVOURITE SPECIES OF FISH RAISED IN PONDS IN SURAT THANI, 1997

Common Name	Scientific Name	Production (kg/rai/year)
Sepat-Siam	Trichogaster pectoralis (Regan)	100 - 125
Nile tilapia	Tilapia nilotica Linnaeus	150 –2 00
Java tilapia	Tilapia mossambica Peters	120 - 175
Common carp	Cyprinus carpio Linn	200 - 250
Catfish	Pangasius sutchi Fowler	1,200 - 2,100
Freshwater catfish	Clarias batrachus Linnaeus	3,000 - 3,300
Climbing perch*	Anabas testudineus (bloch)	-
Gourami*	Trichogaster microlepis (Gunther)	-

* By-product

Source : Surat Thani Provincial Fisheries Office.

4. FORESTRY

4.1 Introduction

Forest vegetation plays an important role in an eco-system both from socio-economic and ecological view points. In terms of socio-economics, forests provide timber and other forest products which bring income to the rural people, as well as to the country as a whole. Forest activities and forest industry partly help to alleviate labour force problems. Moreover, forest land has long served agricultural growth, thus helping to reduce pressure on land use for farmers. This results in an increase in occupation and income and a reduction in social problems. Ecologically, forests are well recognized as the best vegetative protective cover for watershed area, thus minimizing soil erosion and flood problems. They also serve as moisture holding media and provide natural water storage functions, which help regulate water flows throughout the year. Another very important function of the forest is in serving as a habitat and food source for wildlife.

4.2 Objectives and Scope

Rajjaprabha dam was constructed during the years 1980-1987 and has been in operation for about 10 years. It is at this early stage of operation this study on forestry has been carried out to assess environmental impacts which may have already been felt and to suggest appropriate measures for minimizing further deforestation. The study covered the following aspects.

(a) Comparison of actual net benefits derived from forest clearing and the value estimated before the project implementation.

(b) Plant community by species, composition, relative abundance, and their importance to fauna as habitat and food sources.

(c) Forestry management in the upper catchments area (agro-forestry and wood plantation, etc.) before and after project implementation

(d) Rate of deforestation in the upper catchments area affecting soil erosion and sedimentation in the watershed area.

(e) Actual budgets for forest protection in the upper catchments area and forest clearing in the reservoir

The scope of the study covers the present status, the current trend, and the potential of forest resources in the Phum Duang river basin. The study has been focused on the upper catchment areas, including the resettlement area and reservoir, the power transmission line right-of way, and other developments induced by the project.

4.3 Methodology

The method of investigation as following.

(1) General

(a) Review of information collected from various sources.

(b) Interpretation of remote sensing data. False Colour Diazochrome images with a scale of 1: 1,000,000 from LANDSAT were used to determine two broad land use category, viz.; forestland and non-forest land. A random ground check was also conducted.

(c) Economic evaluation of forest resources.

(d) Forecasting of future forest scenarios using available data.

(2) Field Investigation

For the vegetation community study, the upper catchment area of Phum Duang river basin was categorized into 3 major land use types: (i) tropical rain forest, (ii) para-rubber plantation and (iii) agroculture area.

A field investigation was conducted during 25-30 November 1997. For this study, sample stands of 20 m x 20 m size were allocated at different elevations points, viz; 100, 200, 300, 400 m (msl), and in areas of different geological rock types (limestone, shale and granite) in the tropical rain forest area. The following data was recorded in each stand : (i) species composition, (ii) diameter at breast height (dbh) and height of each tree, and (iii) species and number of individual seedling and saplings.

For the Para-rubber plantation, the same size of sample plots (20 x 20 m) were identified in the same manner, but the selected elevations were 125, 200, 250, and 300 m (msl). The diameters at breast height (dbh) and the heights of rubber trees within each plot were measured. Species and number of individual plants under canopy or undergrowth were also recorded. In agroculture areas, sample plots were marked at the elevations of 100, 150, and 200 m (msl).

In each sample stand (20 m x 20 m), the number and species of the upper trees with diameter over 10 cm at breast height (1.30 m from ground level) were recorded. The diameters were measured by using a diameter tape and the heights were measured by using a comparative method with 5 m standard measuring tape. An 8m x 8 m sample plot was randomly laid out in each sample stand and the number and species of saplings and shrubs (dbh less than 10 cm ad height over 1.30 m) were recorded. For the under growth (tree seedlings and other plant species with height less than 1.30), number and species were recorded in a 2 m x 2 m sample plot within the sample stand. The elevation of the center of each sample stand was measured by using an altimeter.

4.4 Review of the Previous Study

Prior to the implementation of the Rajjaprapha dam, environmental and ecological investigations, including forestry study, were conducted in 1980. Emphasis was on the catchment area of the damsite and the porposed reservoir area. Sample stands (20 m x 20 m in size) were laid out to investigate comunities. The results are shown in Table 5.8. Moreover, a forestry inventory study was also conducted.

The results showed that the tropical evergreen forest, agrocultual area and shifting cultivation and river bank area constituted, respectively, 66.10, 16.52 and 12.60 percent of the reservoir area at 110 m (msl) level. The rest was composed of cleared areas, paddy fields, and agrocultural areas. The total volume of valuable timber was found to be very small and considered to be of low value for logging. In total, the net value from clearing both forest trees and all types of commercial trees in the reservoir area was found to be 324.40 million bahts is shown inTable 5.9.

TABLE 5.8

FOREST TYPES IN THE RESERVOIR BEFORE IMPOUNDMENTATION

Land Use Type	Area, ha	% of the total
1. Tropical Evergreen Forest	11,105	66.10
2. Riverbank forest	803	4.78
3. Shifting cultivation area Or secondary growth forest	2,117	12.60
4. Agro-cultural area	2,775	16.52
Total	**16,800**	**100**

Source Environmental and Ecological Investigation Report

TABLE 5.9

SUMMARY OF NET PROFIT FOR ALL TYPES OF TIMBER IN RESERVOIR

(Max. Elev. = 110 m MSL)

Type of Product	**Total Volume, m^3**	**Total Net Profit, baht**	**Net Profit, Baht/ha**
Sawtimber Grade A	449,632.2	177,900,000	10,600
Saw timber Grade B	414,741.0	84,600,000	5,000
Fuel wood	539,390.3	48,500,000	2,900
Bamboos	13,423,600.0*	13,400,000	800
Total	-	**324,400,000@**	**19,300**

Notes : (1) Estimated average price of fuel wood and bamboo

(a) Fuel wood = 90 baht/m^3

(b) Bamboo = 1 baht/ culm

(c) * in number of culms

(2) @ Total net benefit from logging timber from the entire area

Source : Environmental and Ecological Investigation Report

4.5 Results of the Study

4.5.1 General Condition of Forest Resources

Forest type vegetation in the Phum Duang river basin covers an area of about 307,900 ha (3,079 km^2), or 65.96 percent of the total area of the river basin. Table 5.10 illustrates forest classification in the watershed area, consisting mostly of terrestrial forest (65.45 percent) and mangrove forest (0.51 percent). The terrestrial forests are classified according to their physical and ecological characterstics as tropical rain forests.

The tropical rain forests were found distributed over the large area on the hills on both banks of the river at elevations over 300 m (msl) and with slopes of more than 50 percent. The forest covers about 24 percent of the total areas is the upper catchment area. About 42 percent of the downstream area the tropical rain forests were found distributed over small hill tops with high slopes. The non-forest area forms about 158,900 ha, or 34 percent of the total area. The mangrove forest covers a total area of about 2,400 ha along the shoreline, and in mud flat areas at the mouth of the canal and the Phum Duang river.

4.5.2. Forest in the Upper Catchments Area

The upper catchment area of the dam is located in Khlong Saeng subbasin. General geography of this is hilly or mountainous with altitudes of more than 150 m (msl) and slope of more than 40 percent. It covers about 143,500 ha, or about 30.8 percent of the river basin. The population in the area number 12,638 or 5.1 percent of the total population in the river basin, which consists of 50.89 males and 49.13 percent females. The major occupation of the people was in planting para-rubber and orchards.

TABLE 5.10

FORESTRY TYPES IN THE PHUM DUANG RIVER BASIN

Forest type	Upper Catchment, ha	Lower Catchment, ha	Overall River basin ha	% of the total
1. Forest area	112,000	195,900	307,900	65.96
Tropical rain forest	112,000	193,500	305,500	65.45
Mangrove forest	-	2,400	2,400	0.51
2. Non-forest area	31,500	127,400	158,900	34.04
Total	**143,500**	**323,300**	**466,800**	**100**

Source : Land use study in Chapter VI of this study.

4.5.3 Vegetation Communities

The upper catchmet area of Khlong Saeng sub-basin consists of an area of 143,500 ha (1,435 km^{2}). The major land use pattern here is as follow: Tropical rain forest, 78 percent, agricultural land including para-rubber plantation and mixed orchards, 20 percent, abandoned land, 2 percent. The area covered by forest vegetation is normally found on slopes greater than 50 percent and on hills tops of about 300 m (msl) in elevation. The other areas have been encroached and occupied by local residents. Generally, they divide the area into plots and cut down the trees in order to use the land for agriculture. With regard to Para rubber plantations, new high yielding variety rubber trees are generally planted. The remaining old variety rubber trees are found only in areas with high slopes and in the national reserved forest area where the cultivators cannot get land title deeds. In almost all deforested areas the inhabitants prefer to grow the new variety of rubber trees. Mixed orchards are found in the areas with elevations not exceeding 250 m (msl), especially in small lots of land located near living quarters and on stream banks.

Abandoned land is found scattered in sloping areas covered with grasses, herbs, and small shrubs. Some areas were formerly used for agriculture and the regrowth of some remaining vegetation can still be seen. Moreover, many areas are completely cleared and are ready for cultivation.

In this study, the upper catchment area was divided according to elevation and geological conditions. Sample plots were selected in representative areas of land use types. These sample plots were randomly distributed throughout the area in the elevations ranging from 100 to 400 m (msl) for field investigation. The results of vegetation community are as follow.

(1) Tropical Rain Forest

Results of the study indicate that there are various species of upper trees, saplings, shrubs, and seedlings in the tropical rain forest. The density of stems was found to vary from 400-500 trees/ha, averaging 458 trees/ha. Plant communities are less abudant at lower elevation than at higher elevations. The average density of plants is about 3,240 tree/ha. The common dominant plant species found in this type of forest were Shorea leprosula, Shorea faguetiana, Saraca sp. Intsia palembanica, Fissistigma bicolor, Parashorea stellata, Aglaia andamanica, Gironiera sp., Hopea sp., Hopea ferrea, Tetrameles nudiflora, Dipterocarpus grandiflorus, Hydnocarpus illicifolius, Anisoptera oblonga, Premna tometosa, Xylia kerrii. The density of the undergrowth show a decreasing trend as elevation increase. This is due to the fact that vegetation at lower elevations has a better chance to receive a greater intensity of light.

With regrad to the relation between forest and wildlife, in general, the forest is a habitat and a food source of wildlife. In this study it was also found that many kinds of vegetation, especially fruits, were food for wildlife, most notably birds. These vegetations were: Castanosis javanica, Baccaurea motleyana, Pithecellobium jiriga, Termialia chebula, Bouea oppositifolia, Artocarus Lanceifolius, and Mangifera sp., etc. These vegetations were found scattered throughout the study area. However, other types off vegetation such as mixed orchards, are also food sources for the wildlife.

(2) Para-rubber Plantation

Para-rubber plantations are quite popular among the inhabitants of the upper catchment area. This can be confirmed by the existing situation whereby rubber plantations are found from the plain area near the river bank upward along the slopes to the hilltops. Most of the para rubber plantations are the new, high yeilding variety which are promoted by the Department of Agricultural Extension. The old variety of rubber tree was cleared away before growing the new variety.

Results of the study show that the density of rubber trees in different areas does not differ greatly. It ranges between 300 and 525 trees/ha. With an average of 438 trees/ha. The old ruubber trees are planted in areas at above 400 m (msl) elevation with slopes exceeding 60 percent. The density was low due to greater spacing requuirement, it can be said that the density of rubber trees is less as elevations increase over 250 m (msl). The basal area of the trees ranges from 10 to 30 m^2/ha with an average of 20 m^2/ha. The estimated timber volume varies from 174 to 574 m^3/ha, averaging 368 m^3/ha. The common undergrowth species covering the plantation floor were rubber seedling (Hever brasiliensis), Croton sp., Rhynchosora sp., Euatorium odoratum, Imerate cylindrica, Lygodium olystachyum, aederia tomentos, and Caryota mitis.

When compared with the results of the previous study, the results of the present study show higher values for some rubber tree characteristics. This is probably due to the replacement of the rubber tree variety which resulted in the plantation being even in age and size structures, the introduction of soil and water conservation measures, and the improved in management as promoted by the provincial agricultural extension office.

(3) Agro-culture Area

The results of the study on the structural characteristics of the agroculture indicate that the upper coverage species of trees commonly found were Cocos nucifera, Durion sp., Artocarus chameden, Parkia speciosa, Coffea sp., Rambutan(Nehelium laaceum) and Musa sp. The under-growth was composed of seedlings of those trees mentioned above, including Piper sp., Eupatorium odoratum, Combretum trifolistum, Melastoma sp., Imperata cylindrica, Saccharum arundinaceum, Lygodium flexuozum and Ficus sp.

In general the agro-cultural area is not very dense depending on the type of mmajor crop grown. The ground cover is in the range of 75-85 percent of the total area used for agrocultural purposes. The types of agroculture commonly found are of mixed types around living quarters and in rhe area near the river bank. The major structural characteristics are similar at those described in the previous study. However, it can be said that at present the managemment practices of the farmmers consist of the minimum ammount of care and maintenance. This will not necessarily result in adverse effects to amount land area used. It should be note that, with a mixed types of crop grown, the structure of plant community looks similar to the natural habitat, i.e., the tropical rain forest, with a higher species diversity and greater stability of the communities. Also a high production per area can be expected in the long run.

4.5.4 Estimation of Forest Reduction

As about 36 percent of the present forest coverage in the river basin is located in the upper catchment area, the forest reduction rate reported by the Royal Forestry Departent for Surat Thani can be taken approximately as the reduction rate in the upper catchment area. During the years1980-1987, the period of the Rajjaprabha dam was construction and its beginning of operation, the reduction rate of forest area averaged of 2.12 percent of the area recorded in 1980, or about 6,528 rais. The average percentage of reduction was higher than the average value for Surat Thani province or for the southern region, and even for the whole country. There was deforestation in the settlement area for allocate land to the people in the resettlement areas of Ban Pattana. The total area cleared was estimated by Rajjaprabha dam officials to be 2,100 ha (personal communication). Moreover, there were roads constructions in the resettlement area. Construction of the relocated highway No. 401 to replace the old inundated road, and the deforestation for an area of 40 km around the dam construction site which was estimated to be 6,400 ha. In addition, many people took advantage during the construction period for illegal logging. This can be confirmed by statistics of confiscated timber volume and total number of arrest cases. This indicates a higher timber volume cofiscation during the construction period of about 50 percent compared to the recorded volume of confiscation during the pre-project implementation period (1980-1987). Then, it declined rapidly after 10 years of operation. The ratio of illegal logging in the upper catchment area to that of the watershed area in terms of tmbers confisated, decerased from, 67 percent before the dam construction to 34 percent during the construction period, to only 3 percent during the reservoir operation period.

After the dam was put into operation, the reduction rate of forest area showed a decreasing trend with an average of 2.20 percent during 1988-1996, or about 2,800 ha per year. This is 44 percent of the annual forest reduction during the project construction time. The decrease in forest area reduction in the upper catchment area might be due to poor accessibility in the remaining forest areas being located on high hills. Moreover, the number of valuable trees in the remaining forest area in the upper hills is also low compared to the forest in the lower areas.

In conclusion, the reduction of forest area in the upper catchment area during the year 1980-1996 was at an average rate of 2.60 percent of the total forest area or about 3,200 ha per year. During the period of construction and beginning of operation the reduction rate was considerably higher, 3.2 percent or about 4,600 ha per year. Then it decreased to 2.20 percent per year or 2,800 ha in the operation period.

An attempt is made to forecast forest area reduction in future under four different scenarios. These are presented as Case A, B, C and D as follows.

Case A : An average reduction rate of 2.12 % per year based on the data obtained during 1987-1996. The assumptions underlying this estimate is that the socio-economic situation both in the river basin and in the upper catchment area continues to have a similar trend as in the past 10 years. Therefore, demands for logs and land for agriculture will also have a similar trend.

Case B : An average reduction rate of 1.06 percent per year, or half of the value in Case A. This is based on the assumption that it is difficult to gain access to the remaining forest area. Moreover, more effective measures are introduced for forest management, such as the establishment of a national park, reforestation programmes, forest protection unit, etc.

Case C An average reduction rate of 3.16 percent per year. This is based on the assumption that the socio-economic situation in the river basin and the upper catchment area receives stimulation from external factors. Therefore, the demands for logs and land for agriculture and various infrastructure also receive a strong stimulation and have a consequential impact on reducing forest area.

Case D : Similar to Case A for 10 years, then the rate changes to Case B. Management measures are not yet implemented but are in the preparatory stage during the first 5 years. When they are implemented (e.g., reforestation, forest protection, etc.) the reduction rate decreases according to Case B.

To forecast the remaining forest area, the following equation is used :

$$F_n = F_o (1 + r)^n$$

Where F_n = forest area at year n,

F_o = forest area at base year,

R = reduction rate, percent, having negative value according to the assumptions used for the 4 cases,

N = number of year

The calculation results are presented in Table 5-11. From the 57.9 percent forest area in the upper catchment area in 1997 only 35.8 to 49.1 percent will remain in the area by the year 2005, depending on the forest reduction rate. The future reduction rate that depends on watershed management objectives and other related developments. For example, the occurence of Case B depends on the establishment of the national park which is curretly under way, also to be many other proposed developments.

To serve as a guideline for promiting or planning future developments in the upper catchment area, benefits and consequences of each investigated scenario are summarized as follows.

Case A : The benefits to be obtained are from timber, para rubber production, and others which need the forest land as a production factor. However, it will result in an increasing the trend of suspended soil concentration carried by runoff into the reservoir.

Case B : The major benefits from the forest will be in terms of forest protection which will be more efficient than at the present. Moreover, this will benefit the reservoir in reducing and controlling the sediment discharge into the reservoir. However, this case will require an increased budget to be used in protection and conservation of the forest.

Case C : The major benefits to be obtained are forest production and agricultural production, including some other man-made environment such as roads, and living quarters, etc. In this case, no increase in budget is required in the protection and conservation of the forest. However, the sediments discharge into the reservoir is expected to be higher than in Case A.

Case D : The benefits in the first phase will be forest products according to the capability of existing forest productivity and agricultural products. In the second phase, there should be an increase in reforestation along with the application of protection and conservation measures. This will ensure good long term result in regards to the useful service life of the dam and reservoir.

4.5.5 Effect of Reduction of Forest Area on Soil Erosion and Sedimentation in the Reservoir

Quantitative estimate of soil erosion in a river basin is usually derived from the Universal Soil Loss Equation (United State Department of Agricultural, 1978).

$$A = R\,K\,L\,S\,C\,P,$$

Where A = computed soil loss per unit area; obtained by multiplication of the remaining factors.

R = rainfall factor; the number of erosion index units (EI-units) in the period of consideration. The erosion index is a measure of the erosive force of specific rain.

K	=	soil erodibility factor; the erosion rate per unit of erosion index for a specific soil, in a cultivated continuous fallow on a 9 percent slope, 22.1 m (72.6 ft) long.
L	=	slope length factor; the ratio of soil loss from the field slope length to that from a 22.1(72.6 ft) length on the same soil type and grade.
S	=	slope gradient factor; the ratio of soil loss from the field gradient to that from a 9 percent slope, on the same length.
C	=	cropping-management factor; the ratio of soil loss from a field with specific cropping and management to that from the fallow condition on which the factor K is evaluated.
P	=	erosion control practice factor; the ratio of soil loss with contouring, strip cropping or terracing to that with straight row farming, up and down slope.

As can be interpreted from the soil loss equation, the change in forest area will effect the soil loss through the C-factor. The degree to which the reduction of the forest area affects the soil loss cannot be explicitly determined because of the varying nature of the other affecting factors in the soil loss equation. Without adequate data on all relating factors in the upper catchment area, further attempts to quantitatively determine the specific relation between the remaining forest area and soil erosion rate of the catchment area would only generate misleading results.

With such limitations, preliminary evaluation based on available related data is made for providing management guideline as follows.

(1) An environmental impact study of Rajjaprabha dam showed that the total suspended sediment transportation at Phum Duang river within the 2,690 km^2 catchment area was 497,200 tons per annum. The depth of soil loss was estimated from the suspended load plus 20 percent bed load at 0.17 mm per year. The sediment transport into the reservoir was calculated to be about 0.22 mm per annum, which is relatively high as compared to other basins in Thailand.

(2) The annual depth of erosion and annual sediment load of Phum Duang river basin were still lower than the values recorded in the natural forest. It was also lower than the recorded values of other types of forests in the northern and southern region with the exception of the dry dipterocarp forests which have poor soil conditions. This is true in both the periods before and after the dam was put into operation. Also, from a reservoir sedimentation study in Chapter IV, it is concluded that, even though the sediment inflow is increased by 32.5 percent, there is not going to be any appreciable change in uesful storage in a 100 year period. The reservoir can be utilized at its full benefit as planned.

The information described above indicates that, even though the forest area at the upper catchment area has a decreasing trend, the soil erosion and sedimentation rate is still considerably lower than that of other catchment areas. Moreover, the erosion will not significantly affect the reservoir operation during the 100 years period. Therefore, it can be concluded that the reduction of forest area in the upper catchment area at present has not caused any significant impact regarding sedimentation in the reservoir. However, deforestation should be terminated in order to avoid future adverse impact. Management measures, therefore, should focus on protection and conservation particularly of the steep slope areas (over 40 percent slope) which cover about 42 percent of the upper catchment area.

TABLE 5.11

FORECAST OF FUTURE FOREST AREA IN THE CATCHMENTS AREA

Case A		Case B		Case C		Case D		Year
Area Km^2	% UCA	Area Km^2	% UCA	Area Km^2	% UCA	Area Km^2	% UCA	
1120.00	57.17	1120.00	57.17	1120.00	57.17	1120.00	57.17	1997
1096.49	55.97	1108.25	56.57	1084.74	55.37	1096.49	55.97	1998
1072.98	54.77	1096.49	55.97	1049.47	53.57	1072.98	54.77	1999
1049.47	53.57	1084.74	55.37	1014.21	51.77	1049.47	53.57	2000
1025.96	52.37	1072.98	54.77	978.95	49.97	1025.96	52.37	2001
1002.46	51.17	1061.23	54.17	943.68	48.17	1005.20	51.31	2002
978.95	49.97	1049.47	53.57	908.42	46.37	984.43	50.25	2003
955.44	48.77	1037.72	52.97	873.16	44.57	963.67	49.19	2004
931.93	47.57	1025.96	52.37	837.89	42.77	942.90	48.13	2005

Case A reduction rate - 2.12 %/year

Case B reduction rate - 1.06 %/year

Case C reduction rate - 3.16 %/year

Case D reduction rate - 2.12 %/year for the first 5 years and -1.06 %/year

UCA = Upper catchment area.

4.5.6 Forest Economics

The objective of forest economics evaluation is to estimate damage as well as values generated from different causes to the forest in monetary terms. Basic data, especially sale price of log and productivity of the forest, are based on the results of the pre-impoundment environmental study prepared in 1980. The reason for this is that the damage values estimated for the year 1980 are also required for comparison purposes.

(1) Damages of Forest due to the Invasion of People

Damages of forest caused by the invasion of people can be estimated by using the forest productivity data from the survey results of the Royal Forestry Department. It was assumed that generally the forest condition in the upper catchment area is distributed unrevenue and has very low tree abundance. This is due to the fact that large valuable trees have already been cut down which in turn, has resulted in the invasion of people to use the land for agricultural purposes. By using the average productivity of a forest of 0.12 m^3/ha and other data obtained in this study, the following analyses are made.

(a) Period before and during construction: It was found that the reduction in forest area averaged 6,528 ha per year or 783.4 m^3 in terms of timber volume. The monetary value for this can be estimated using an estimated sale price of 950 bahts/m^3 as follows :

value of forest damage	=	783.4 x 950	
	=	744,230	bahts/year.

(b) During operation period : It was found that the reduction in forest area was, on an average of 2,864 ha per/year or 343.7 m^3 in terms of timber volume.

value of forest damage = 343.7 x 950

= 326,515 bahts/year.

From the above analysis, it can be concluded that the value of forest damage in the operation period is about 43.9 percent of the value in the pre-project implementation period.

(2) Damage of Forest Caused by Illegal Logging

Timber volume confiscated from illegal logging activities and the price data at 689 bahts/m^3 (Team Consulting Engineers, 1980) are used for evaluating the damage value. It was found that before the operation period (1980-1987), the timber volume from illegal logging was 145.6 m^3/year, while in the post-impoundment period (1987-1996), the average volume was 5.6 m^3/year. The average of the two periods was estimated at 110.8 m^3/year. From these data, the damage values can be calculated as follow :

Damage value of forest in the

pre-impoundment period = 145.6 x 950

= 138,320 bahts/year.

Damage value of forest in the

post-impoundment period = 5.6 x 950

= 5,320 bahts/year.

Damage value of forest averaged

during 1980-1996 = 87 x 950

= 82,650 bahts/year.

The above data indicate a difference in damages to the forest caused by illegal logging between the pre-and post-impoundment period. In general the efficiency of illegal logging is considerably low. This is due to the fact that only good quality and valuable trees are selected and cut down in order to get a high price. Moreover, careful logging practice is always neglected, this results in damages to small trees and to natural breeding condition of the forest.

With regard to the evaluation in (1) and (2) it can be concluded that in the pre-impoundment period the damage value caused by the invasion of people and illegal logging was about 0.64 million bahts/year. In the post-impoundment period the damage value has dropped to about 0.24 million bahts/year, or 38 percent of the damage in the pre-impoundment period.

(3) Damage to Vegetation Communities in the Inundated Area

The evaluation of forest economics in the inundated area is based on the data from the 1980 study. Forest economics is re-evaluated due to the fact that the previous study emphasized the analysis of economic feasibility on investment cost rather than forest economics itself. During the construction period, it was found that there was also logging in the settlement areas. The timber volume taken from the total areas of 2,727 ha was estimated at 6,727 m^3. Using the unit investment and the timber value data from the study in 1980, the net benefit of logging can be estimated as follows.

Investment cost	=	540 bahts/m^3 x 6,727 m^3	
	=	3,632,580	bahts

Benefit	=	950 bahts/m^3 x 6,727 m^3	
	=	6,390,650	bahts
The net benefit obtained	=	2,758,070	bahts.

When this net benefit is compared with the timber value of about 1.54 million bahts, the resulting damage value of forest due to the dam construction comes to about 0.53 million bahts, or 34.7 percent of the total estimated damage value of the forest.

An interview with the official responsible for clearing the area around the dam site during the construction period revealed that it took about 6 months in 1979 to clear an area of 8.22 km^2, or about 14.3 percent of the total reservoir area. The vegetation in the clearing area was mostly para-rubber, the remainder were forest and other agricultural products.

The para-rubber plantation in the inundated area included a productive area of about 27.77 km^2, with about 156,000 para-rubber trees (Team consultant Co. Ltd. 1980). The income arising from this in terms of rubber sheets, was estimated at 3.75 million bahts/year. During the construction period, the farmers could still receive benefit from the rubber production until the impoundment began in 1987. Therefore, during the 7 year period of the dam construction it can be estimated that the farmer still benefited from rubber production at 13.4 million bahts (1980 price). After that no benefit was obtained due to the impoundment and project operation. The total damages were estimated at 36.3 million bahts less, or 22.9 million bahts or 63 percent of the total damages, as previously estimated.

The para-rubber trees in the cleared area of 5 km diameter in the year 1987 covered an area of about 5.15 km^2. It is estimated that about 28,930 rubber trees with a timber volume of about 25,430 m^3 were cleared and burnt. If these rubber trees were all taken out of the inundated area and used for chip board production, for fuel in mining industry, and for charcoal production, at an estimated local market price of 20 bahts/m^3, the total value would be about 0.5 million bahts. Subtracting this value from the value estimated in pre-impoundment (2.7 million bahts), the para ruber trees in the inundated area would be valued at 2.2 million bahts.

In conclusion, the construction of the Rajjprabha dam is re-estimated to result in 0.53 million bahts damage to the forest and 25.1million bahts damage to Para-rubber plantation. The total damage would be 25.6 million bahts, significantly less than the damage estimated prior to the dam construction.

(4) Damages Caused by Transmission Line

A 115 kV transmission line from Rajjaprabha power plant to Surat Thani substation is about 70 km and 20 km from powerhouse to main junction line. A strip 50 m wide along the line has been cleared for safety purpose, which amounts to about 7.28 km^2 or 728 ha. The results of a field survey revealed that most of the forest area, as previously mentioned, had already been invaded and replaced by Para-rubber plantation during the pre-construction period itself. The remaining forest area is on the hill tops of limestone formation with moderate to steep slopes unsuitable for cultivation. Therefore, it can be concluded that the impacts from the transmission line to the forest are practically negligible.

(5) Benefit from Timber Cutting

Total benefit from timber logging in the overall reservoir area before impoundmentation is estimated at about 324,400,000 bahts (19,300 baht/ha).

(6) Economics of Uncut Forest

The average increment of forest stock for the whole country, which was studied by M..D Backer for the RFD is used as the basis. This study estimated the average increment of a tropical ever green forest to be about 2.5 percent. By multiplying 0.025 (2.5 percent) with the growing stock volume of the forest in the reservoir area, the total annual increment is estimated at 35,094 (2.09 m^3/ha).

The future value of net income are calculated as shown in Table 5.12 along with the expectation values of the uncut forests. Economically speaking the expectation value, sometime called net present worth, of an investment is the net value at some point in time (usually at present) of expected future incomes that have been discounted back to that time at a give rate of interest. This value is utilized in estimating the present of future net worth of an interest. For project evaluation, the expectation value of the future net worth of different investment alternative can be compared to select the most desirable program.

In case of the Rajjaprabha project, the present values of agro-cultural and forest products are estimated, based on the criteria given previously, to be about 89.51 million bahts for a 10 year period, 106.93 million bahts for 20 year period and 72.53 million bahts for 50 year period.

These are direct benefits in which direct benefits, such as those from non-forest products and wildlife resources, are excluded. Additionally, other factors, including increases in timber values due to inflation and due to benefits from forest clearing and those from the uncut forests under the without project condition cannot be compared because some of the most important aspects, environmental changes due the permanent loss of the forest inundated are not included in evaluating the economic effects.

TABLE 5.12

TOTAL PRESENT AND FUTURE VALUE OF NET INCOME FROM UNCUT FORESTS MANAGED ON SUSTAINED YIELD BASIS (INTEREST RATE = 12 PERCENT)

Time Year (n)	**Annual net return (AR) (Annual net income), MB**	**Future value (FV) of Net income, MB ***	**Present value (PV) of Net income, MB ****
1	18.01	18.01	18.01
10	18.01	278.00	89.51
20	18.01	1031.50	106.93
30	18.01	2962.50	98.88
40	18.01	7970.00	85.65
50	18.01	20960.00	72.53
60	18.01	57660.00	64.24
70	18.01	141000.00	50.58
80	18.01	368700.00	42.58
90	18.01	956700.00	35.58
95	18.01	1540800.00	32.51
Indefinite	-	-	-

Note : * Future value (FV) of a sum which is compounded annual by equal sums, all bearing intent, $FV = \frac{AR\ [(1+P)^n]}{P}$

** Present value (V) or discounted value of future series of equal annual incomes at compound interest, $PV = \frac{AR\ [(1+P)^n]}{P\ (1+P)^n}$

Other (1) Net income per m^3 assumed constant

(2) AR = Annual return = 18.01

(3) P = Interest rate (expressed inflation) = 0.12; and n = number of year

5. WILDLIFE

5.1 Introduction

All development projects, along with generating benefits also creates certain environmental and ecological problems. Generally, these ecological alterations may favour some animals which carry problems for others at the same time. So only those who are favoured and those who can adapted to the new condition can survive and multiply while those less-adaptable become scarce and eventually become extinct from the area. So it is important to know the ecological consequences of each development project, to initiate remedial measures to minimise consequences.

5.2 Objective

The objective of the study regarding wildlife is to provide basic information about the naturally existing wildlife after the constructed of the Rajjaprabha dam. This will help to compare with the previously collected information in the pre-impoundment environmental impact study and therefor help to ascertain changes in plant and animal species in the area as results of the construction of the dam. The following aspects were investigated during this study :

(a) Wildlife species composition and population of the wildlife in the watershed and the reservoir areas including their status as resident or migrant.

(b) Plant communities and species abundance in relation to fauna for habitat and food sources.

(c) Suitable and unsuitable habitats for wildlife in the two zones.

5.3 Study Area and Method

5.3.1 Concern of the Study

This study concerns mainly 4 groups of vertebrate animals, i.e. birds, mammals, amphibians and reptiles. Surveys and samplings for each group were conducted during two field trips, representing the dry and wet seasons so as to obtain a better picture of year-round wildlife existence. The first trip during the dry season from 25-30 March 1997, while the second, was in wet season from 10-15 November 1997.

5.3.2 Study Method

An extensive survey was conduucted to ascertain the nature and evolution of wildlife. The surveys were conduucted in day and night in the aquatic and terrestrial habitats, in the rubber plantation and the original forests. In each site, 3 survey routes (transections), each have 500 m long, were set for detailed using two main data-collecting techniques.

(1) Direct Observation

Only easily recognized animals such as birds and mammals were observed with the help of binoculars in the daytime and by torchlights in the nightime along the 3 survey routes. The identity, abundance, preferred habitat and observed behaviour of the wild animals were carefully recorded. This technique was supplemented by track finding, animal remains inspection, and by interviewing the local inhabitants. Survey time of birds were conducted from 6.00 a.m. to 9.00 a.m. and 3.00 p.m. to 6.00 p.m., which is considered to be their periods of highest activity. In the case of nocturnal mammals, amphibians and reptiles surveys were conducted during night.

(2) Collection

This technique requires the actual procurement of the wild animals through various methods. Because of the secretive habitats and similar appearances of some animals groups, (for instance, bulbuls and the wild rodents), they should be studied from close proximity to determine their exact identification. In some cases the captured animals were sacrificed for internal autopsy for determining reproductive conditions. The following three methods were used for collecting specimens.

(a) Netting : For birds and bats, six mist nets were used to collect specimens in each survey route. Each net, 24 m long, was set up at an interval of 100 m, both day and night, for collecting purpose.

(b) Trapping : Trappings were maded in the 3 survey routes, in catch 100 traps in each, for capturing small mammals during the night. Three successive night catches from each habitat site were taken as a representation of the existing population.

(c) Cruising Amphibians ad reptiles were obtained by the method of intensive searching along the route. Every animal collected was studied in detail on all pertinnet data concerning the capture, vegetable habitats, and the vertical and/or horizontal position when first found.

5.4 Results of the Study

Wildlife study conducted in this post-environmental evaluation reveals a total of 1,769 species, including 97 birds, 50 mammals, and 32 amphibians and reptiles. These are presented in Table 5.12. The majority of birds are of residential status and only about 12 percent are of migrant type. The preferred habitat for the birds is rubber plantation.

Only 23 percent show high degree of forest dependence. The characteristic of the rain forest in possessing a high resident species and low population density is evident. About 52 percent of the bird species are regarded as rare and 24 percent very rare.

Of the 50 mammal species reported in this study, about 80 percent were observed and collected. The rest were identified from strategic interviews of reliable local inhabitants. Here only the Asian Two-horned Rhinoceros is regarded as a preserved wild animal. Twenty-two other mammals are classified as proteced wild animals, while some are also treated as endangered by international agencies. The mammals in this area are characterized by a high degree of forest dwellers (58 percent) and a high number of species showing high forest dependence (50 percent).

Ten of the 32 species of the amphibians and reptiles are legally protected. Of these protected species only the Malayan Giant Frog (Ranablythi) is regarded as the protected wild animal under the game and food category. Of these only 10 species show high degree of forest dependence.

Of the many fruit trees found growing in the area, those favoured by birds and mammals are rose apple (Eugenia), Chinese lantern (Baccaurea), plum mango (Bouea), and mango (Mangifera). These favoured tree species are abundant in density (25-50 trees/ha.) The wild animals that seem to favour the artificial rubber plantation are Common Wild Boar (Sus scrofa), Dusky Langur (Presbytis obscura) and Malayan Flying Lemur (Cynoceph alus variegatus). They feed on the fruits of the rubber trees or shelter in the thick foliages of the rubber tree. In general, the food sources of wildlife are numerous in species but less in individuals. A proposal to establish an area as a national park is underway.

TABLE 5.13

WILD ANIMAL IN THE RIVER BASIN PRE AND POST IMPOUNDMENTATION

Animal group	**Pre impoundmentation**	**Post impoundmentation**		
	Species	**Species**	**Genus**	**Family**
Birds	69	78	53	31
Mammals	38	50	39	23
Amphibians and reptiles	15	21	17	10
Total	**122**	**149**	**109**	**64**

Source : Survey data

5.5 Wildlife Impact

The wildlife impact is non-quantifiable for two main reasons. First it is not possible to estimate the amount or number of animals affected by Rajjaprabha dam. Second, the value of wildlife are intangible. Without observation on people's willingness to pay for enjoyment of wildlife, it is impossible to estimate economic value of the affected wildlife.

CHAPTER VI

HUMAN USE VALUE

CHAPTER VI

HUMAN USE VALUES

1. INTRODUCTION

Human use values are among the environmental values, which will be affected by any large-scale development project, especially dams and reservoir projects. Construction of dams is proposed to improve the water resource conditions in the project area, which changes the existing conditions in the human utilisation of water. The development of the reservoir project will affect the present land use pattern in the proposed reservoir area and the planned project area. Provision of more stable water supply will change the existing water use conditions in many ways, e.g. irrigation, water supply and navigation. As related to the project development, a road system may also be developed which may initiate changes in the existing transportation system. In the case of a hydroelectric project, the power generation output will affect the electrical power supply conditions of the region. Thus the impacts of the project on the human use values will be one of prime importance to be evaluated in connection with project development.

For the Rajjaprabha project, the human use aspects taken into consideration include: (i) land use (ii) irrigation and water supply (iii) flood protection (iv) transportation and navigation (v) power production and (vi) water pollution. These aspects are reviewed, analysed and evaluated, item by item and presented in a sequential from the following sections.

2. LAND USE

2.1 Introduction

In the environmental system of the river basin, land resources are one of the main resources for supporting lives, production, and human activities. The utilisation of land is reflected by land use patterns which are the consequence of various environmental conditions, i.e., soil fertility, water availability, topography, socio-economic condition, etc. In turn the use of land and its changes can affect other environmental elements, such as the hydrologic regime, climate, human use values, and quality of life.

Land uses information and the consequences of land use changes are extremely necessary for environmental evaluation. To obtain a complete picture of land use and consequence in its long term change, the past information relating to the present land use pattern needs to be re-evaluated together with other related aspects which indicate land use potential.

2.2 Objectives

The objectives of the land use study are:

(a) To identify the changes in land use in the resettlement and in the irrigation areas after the implementation of the dam.

(b) To identify beneficial impacts of Rajjaprabha project to the application of land use.

(c) To support information to other related studies.

2.3 Methodology

The study was conducted using the following methodology:

(a) Survey has been carried out using the 1: 5,000 scale aerial photos taken in 1995 and 1996 together with 1:50,000 scale topographic maps. Aerial photos were interpreted through mirror stereoscope employing deduction methodology.

(b) Reviewing the existing information on land use prior to the project implementation.

(c) Improving the pre-impoundment land use information in the area.

(d) Evaluation of the land uses according to the objectives.

2.4 Land Use before the Project Implementation

2.4.1 Land Use in the Reservoir and Resettlement Areas

Land use in the reservoir and in the resettlement areas are classified into six classes according to their purpose of use during the survey period, (Team Consulting Engineers Co. LTD, 1980) Descriptions of these land use types are given below.

The reservoir covers an area of 172.44 km^2 (17,244 ha). The major land use types were: (1) forest area (69.32 percent), (2) farm land (12.84 percent), (3) old clearing area (12.15 percent), (4) mixed orchard/residential area (2.82 percent), (5) rubber trees (0.27 percent) and (6) water body i.e. canal (2.59 percent). The summary of area covered by each type of land use is presented in Table 6.1.

TABLE 6.1

LAND USE IN THE RESERVOIR AREA BEFORE PROJECT IMPOUNDMENT

Unit	Legend	Area, (ha)	Percent
1	Forest	11,956	69.33
2	Old clearing area	2,096	12.15
3	Farm Land	2,213	12.84
4	Mixed orchard/residential	480	2.82
5	Rubber trees	47	0.27
6	Water body	446	2.59
	Grand Total	**17,244**	**100**

Source : Environmental and Ecological Investigation Report.

2.4.2 Phase 1 Irrigation Area

The land use study of the Phase I irrigation programme of the watershed area in relation to the Rajjaprabha dam was carried out based on the available information in the comprehensive master plan study and the feasibility studies of the Rajjaprabha project. The irrigation project boundary is estimated to cover about 23,100 ha or 8.21 percent of total project area. Land use in the irrigation project boundary comprises mainly of rice lands (64 percent), brush lands (27 percent), and garden lands and villages (9 percent). This is shown in Table 6.2.

TABLE 6.2

LAND USE IN IRRIGATION AREA, AS OF 1980

Legend	Area, (ha)	% of Total
Rice Land	14,700	64
Rice fields	10,100	44
Rice and sugar palm	450	2
Rice and anthills	2,050	9
Rice and shrubs	2,100	9
Brush Land	6,350	27
Shrubs	4,550	19
Mangrove like forest	1,500	7
Grass	200	1
Swamps	100	-
Garden Lands and Villages	2,050	9
House with garden	1,100	5
Village and garden	950	4
Total	**23,100**	**100**

Source : Royal Irrigation Department (RID).

2.5 Present Land Use Pattern

The present land use pattern in the watershed area is found out from the 1:15,000 scale aerial photos taken in 1996 and 1: 50000 scale topographic maps.

The watershed area which covers about 466,800 ha, includes the upstream and downstream area of 143,500 and 323,300 ha respectively. Major land use in the watershed area can be classified as forest (including tropical rain forest and mangrove forest), Para-rubber plantation, mixed orchards (mainly coconut, mangosteen, rambutan, durian, banana), paddy field, town and village, mines and non-productive or abandoned land. Table 6.3 shows the present characteristics of land use types. These are described in the following paragraphs :

(1) Forest : The forest area covers about 307,900 ha, which constitute approximately 65.90 percent of the total basin area. The forest can be classified according to its ecological condition. The forest in the upper watershed is terrestrial forest, which covers about 112,000 ha. It is in the mountainous area, and is not suitable for agriculture. The forest in the downstream area covers about 195,900 ha, which constitute mainly of tropical rain forest on steep land on mountainous areas, and mangrove forest in the estuarine area in the eastern part of the river basin.

(2) Para-rubber Plantation Para-rubber is the major crop in the upper watershed area. It is usually the first choice of the farmers for plantation. Thus those move into the upland area by clearing the forest. Some of them are grown on steep land. The Para-rubber plantation area covers about 59,600 ha, which forms approximately 12.77 percent of the total project area. This area consists of about 4,800 ha in the upper watershed area, and about 54,800 ha, in the downstream area.

(3) Paddy Field : Because of the suitability of soils, topography, and water condition rice can be grown only in the downstream area. From the survey it is found that the paddy field area is constitute about 15,475 ha, which forms approximately 3.32 percent of the total project area.

(4) Mixed Orchards : Mixed orchards cover about 3,880 ha in the upper watershed area, and 34,200 ha, in the downstream area (8.16 percent of the total basin area). They are generally native crops, and are concentrated around households. Many of them are grown in the areas, which are not suitable for rice.

(5) Mine : Mine area is estimated at about 0.03 percent of the project area, or about 165 ha, in the downstream area.

(6) Water Source Water source in the watershed area, (including the reservoir, pond, river, and swamp) cover about 32,100 ha, which forms approximately 6.87 percent of the total area. This area consists of about 19,500 ha in the upper area, and about 12,600 ha in the downstream area.

(7) Non-productive and Abandoned Land : The present abandoned area is about 890 ha in the upper watershed area and about 1,860 ha in the downstream area. These form approximately 0.59 percent of the river basin area. The areas were abandoned because of shifting cultivation and unsuitable physical or chemical soil condition.

(8) Town and Village : The river basin includes the area of Head Quarter, Phra Nom district, Ban Ta Khun district, Khirirattha Nikhom district, Phun Phin district and Muang Surat Thani district. Towns and villages cover an area of about 10,730 ha, i.e., approximately 2.30 percent of the total area. Of these about 2,430 ha are in the upper area and about 8,300 ha, in the downstream area. They are composed of residential areas, commercial areas, religious places, and industrial areas,

TABLE 6.3

PRESENT LAND USE IN THE PHUM DUANG RIVER BASIN

Land use type	Upstream area, ha	Downstream Area, ha	Overall river basin, ha	Percent of the total
Water source	19,500	12,600	32,100	6.80
Forest	112,000	195,900	307,900	65.90
Rubber plantation	4,800	54,800	59,600	12.77
Mixed orchard	3,880	34,200	38,080	8.16
Paddy field	-	15,475	15,475	3.32
Mine	-	165	165	0.03
Non-productive and abandoned land	890	1,860	2,750	0.59
Town and village	2,430	8,300	10,730	2.30
Total	**143,500**	**323,300**	**466,800**	**100**

Source : Aerial Photos interpreted.

2.6 Change in Land Use Pattern

A comparison between the present land use and the land use prior to the project implementation is made in order to identify the changes in land use after the implementation of the dam, and to identify the beneficial impacts of Rajjaprabha project on the utilisation of the land. Since land use information prior to the project implementation is available only for the reservoir and resettlement area and the Phase 1 irrigation area, direct comparison is possible only in these areas. The changes in land use in the areas outside the irrigation areas are not direct the impact of the project. It is rather the impact of other factors that fall within the value of socio-economics factors, such as increase in population, and political factors.

2.6.1 Change in Land Use in the Reservoir and Resettlement Area

The pre-implementation information on land use in the reservoir and resettlement area is very limited. On the basis of the available information the following changes are noted.

Main portion of the area has been changed into water body. So also in the draw down zone of the reservoir area. The remaining upland portion with rather steep slope has partly been turned into resettlement areas. Since the topography, soil condition, and climate are well suitable for upland crops, these areas have been altered from forestland into rubber plantation and mixed orchards.

In the mountainous area there is not much change and to the area is still covered by tropical rain forest. The changes in land use pattern in the reservoir and resettlement areas are shown in Table 6.4.

2.6.2 Change in Land Use in the Phase I Irrigation Area

Comparison of land use in the Phase 1 irrigation area before and after the implementation of the project is summarised in Table 6.5.

TABLE 6.4

COMPARISON OF LAND USE IN THE UPSTREAM AREA BEFORE AND AFTER THE DAM IMPLEMENTATION

Land use type	Before		After		Area Change
	Area, ha	%	Area, ha	%	
Paddy field	384	1.68	-	-	- 384
Mixed orchards	138	0.60	621	2.70	+ 483
Rubber plantation	91	0.40	768	3.35	+ 677
Old clearing area	336	1.46	143	0.62	- 193
Forest	21,896	95.25	17,920	78.05	- 3,949
Water body	87	0.37	3,120	13.57	+ 3,033
Village	56	0.24	389	1.69	+ 333

Source : The Environmental and Ecological Investigation Report and surveyed data.

TABLE 6.5

CHANGE OF LAND USE IN THE PHASE 1 IRRIGATION AREA BEFORE AND AFTER THE DAM IMPLEMENTATION

Land use type	Before		After		Area change
	Area, ha	%	Area, ha	%	
Paddy field	14,700	63.60	15,475	67.0	+775
Mangrove like forest	1,500	6.50	1,340	5.80	-160
Shrub	4,550	19.70	3,500	15.15	-1050
Grass	200	0.87	125	0.54	-75
Swamp	100	0.44	60	0.26	-40
House with garden	1,100	4.77	1,350	5.84	+250
Villages and garden	950	4.12	1,250	5.41	+300
Total	**23,100**	**100**	**23,100**	**100**	-

Source : The Environmental and Ecological Investigation Report and survey data.

Presently, paddy field covers about 67 percent of the irrigated area (or approximately 15,475 ha). This indicates an increase of only about 3.4 percent from the previous condition. The nominal increase in paddy area is high due to the fact that area suitable for paddy has already been used to the maximum extent.

House with garden, and villages and garden area has increased from 950 ha to 1,250 ha and from 1,100 ha to 1,350 ha, respectively, This accounts 5.14 and 5.84 percent increase respectively. Corresponding the areas under shrub, grass, swamp and mangrove forest decreased.

2.7 Economic Analysis of Para-rubber Plantation

In order to evaluate the benefits of land resources in the reservoir and resettlement areas a basis economic analysis of Para-rubber are presented in Table 6.6

Table 6.6 presents the economic analysis of Para-rubber plantation per hectare. The present value (at the first year of plantation) of net return is calculate at 87,700 bahts/ha while the annual equivalent net return in the 50 years period is 9,296.25 bahts/ha.

Table 6.7 Shows the economic analysis of the agricultural potential in the agricultural area for the assumed crop potential area of 8,768 ha. The total net return from the agricultural potential discounted to the present amounts to 274.43 million bahts or the annual equivalent of 27.61 million bahts.

From the feasibility study of the project (ELC-Electroconsult, 1979) the net benefit from irrigation development have been estimated about 200.4 million bahts on an annual equivalent basis.

TABLE 6.6

ECONOMIC ANALYSIS OF PARA-RUBBER PLANTATION

(Interest rate = 10 percent)

Year	Yield (B / ha)	Income (B/ha)	Farm Expenses (B/ha)	Net Return	Note
1	-	-	11,393.75	-1823	Present value net
2	-	-	6,112.5	-978	return
3	-	-	6,028.1	-964.5	
4	-	-	46,81.25	-749	= 87700Bha
5	-	-	4,584.3	-733.5	
6	800	14,400	3,053.1	11,346.9	Annual
7	1,030	18,580	2,784.3	15,486.9	Equivalent
8	1,260	22,680	2,796.8	19,895.7	= 9,296.25 B/ha
9	1,420	25,560	3,053.1	22,763.2	
10	1,520	27,360	3,053.1	24,310.9	
11	1,560	28,080	3,053.1	25,026.9	
12	1,580	28,440	3,053.1	25,386.9	
13	1,560	28,080	3,053.1	25,022.9	
14	1,530	27,540	3,053.1	24,486.9	
15	1,350	24,300	3,053.1	21,246.9	
16	1,310	23,580	3,053.1	20,526.9	
17	1,270	22,860	3,053.1	19,806.9	
18	1,230	22,400	3,053.1	19,806.9	
19	1,190	21,420	3,053.1	18,366.9	
20	1,190	21,420	3,053.1	18,366.9	
↓	↓	↓	↓	↓	
50	1,190	21,420	3,053.1	18,366.9	

Source Rubber Replanting Aid Fund Board, Bangkok.

TABLE 6.7

ECONOMIC ANALYSIS OF AGRICULTURAL POTENTIAL

(Interest rate = 10 percent)

Year	Cash Crop and Fruit Trees			Para-rubber			Total net Return (M ฿)
	Net Return (฿/ha)	Area (ha)	Net Return (M ฿)	Net Return (฿/ha)	Area (ha)	Net Return (M ฿)	
1	3,687.5	2,747	10.13	9,296.25	2,138	19.89	30.02
2	3,687.5	2,747	10.13	9,296.25	2,376	22.09	32.22
↓	↓	↓	↓	↓	2,614	24.3	34.43
					2,851	26.51	36.64
					3,089	28.72	38.85
					3,326	30.92	41.05
					3,564	33.13	43.26
					8,768	81.5	91.63
9					8,768	81.5	91.63
10					↓	↓	↓
11							
12							
13		2,747	10.13				
14		2,476	9.13				
15		2,476	9.13				
↓	↓	↓	↓	↓	↓	↓	↓
49	3,687.5	2,476	9.13	9,296.25	8,768	81.5	90.63
50	3,687.5	2,476	9.13	9,296.25	8,768	81.5	90.63

Notes : (1) Assume a period of 50 year, which is the same as the economic life of the dam.

(2) From socio-economic survey off present net income per hectare.

(3) 2,747 ha are the present land available for agricultural development and 2,476 ha are assumed remaining land use for cash crop and fruit trees.

2.8 Conclusion

Land use in the Phum Duang river basin is presently classified under seven major types : (1) forest, (2) rubber plantation, (3) mixed orchards, (4) paddy field, (5) non-productive and abandoned land, (6) mine area, and (7) town and village. The use of land and changes in land use are largely due to a combination of various factors such as land capability, water availability, prevailing agricultural technology, economic factors (i.e., market demand and prices of agricultural produce) social and political reasons. The implementation of Rajjaprabha project has induced the changes in land use mainly in the reservoir area only. This was directly due to the impoundment of water in the reservoir and the establishment of resettlement villages. The changes of land use in the downstream areas are due to the introduction of irrigation and drainage systems, which increase agricultural production potential in the areas. The choice of crops to be grown is, however, determined mainly by the capability of land and economic conditions. The net benefits resulting from land use development has been estimated to be 660 million bahts at on interest rate of 10 percent and for the 50 year period. This net benefit is 65 million bahts on an annual equivalent basis.

3. IRRIGATION AND WATER SUPPLY

3.1 Introduction

The irrigation development of the Phum Duang river basin was part of a comprehensive study carried out by the Royal Irrigation Department (RID). The phase 1 irrigation project to be developed along with the reserve consists off an area of 23,100 ha located on the left bank of Khlong Phum Duang and Khlong Phun Phin. The irrigation project is planned to be divided into 6 districts each to be served by a pumping plant.

3.2 Irrigation

3.2.1 Objectives

Objective of this study is to estimate irrigation benefit under four different aspects:

(1) Actual irrigation benefit realized at present;

(2) Potential or planned irrigation benefit;

(3) Beneficial estimates of water discharge to irrigation area achieved by the project operation; and

(4) Irrigation benefit estimation by farm enterprise analysis.

All study aspects except the farm enterprise analysis are presented in this section. The farm enterprise analysis, requires field data from socio-economic investigation was described in the section on socio-economic.

An attempt is made here to assess and update relevant information on irrigation component, emphasizing the progress in implementation and present and future trend of irrigation water requirement.

3.2.2 Previous Investigation and Planning

Irrigation and agricultural development planning were done, and presented in the June 1980 Environmental and Ecological Investigation (EEI) Report. The findings and the formulated plans were later summarized in the EIS report. Relevant features planned and presented were as follows paragraph :

The planned irrigation development scheme has been divided into two phases. Phase I development plan called for the construction of the Rajjaprabha reservoir on Khlong Saeng and diversion of parts of regulated water to irrigate about 23,100 ha, with double cropping by low lift pumping. Phase I irrigation area was on the left bank of Khlong Phum Duang and Khlong Phun Phin below the confluence of Khlong Yan and Khlong Phum Duang and extended down to the delta area. The Phase II development, suggested to be implemented 20 years after Phase I, consisted of the creation of the Chiew Krung reservoir on Khlong Yan, a diversion dam at Wat Nam Hak and 80 km irrigation main canal to supply water for double cropping of 50,000 ha of which 13,280 ha, was included in Phase I.

Irrigation waters requirement averaged 98.4 mcm per year varying from 2.6 mcm in December to 24.2 mcm in March. Irrigation benefit estimated at 200.4.0 million bahts per year (1980 value).

3.2.3 Results of the Study

(1) Updated Information on Irrigation Component

Rajjaprabha Irrigation Project presently being implemented by the Royal Irrigation Department consists of the remaining components of the first stage of the overall Phum Duang basin development, following the Rajjaprabha dam and hydropower development in the headwater area. It has been planned mainly for irrigated agriculture development of about 23,100 ha area in Surat Thani province. In addition, the project has been planned for flood protection of the planned irrigation area and urban communities along the Phum Duang river, for prevention of seawater encroachment into the low agricultural land along the coast, and for fishery development. Another planned irrigation area in the vicinity of the town of Surat Thani was also been planned for development as the second phase, and that includes another diversion dam and distribution system for irrigation on both banks of Khlong Phum Duang (Figure 6.1). This second phase has not yet been implemented. The first phase of the Rajjaprabha Irrigation Project presently being implemented consists mainly of:

(i) tidal canals

(ii) irrigation systems;

(iii) drainage systems;

(iv) flood control dike;

(v) service roads

(vi) on-farm works;

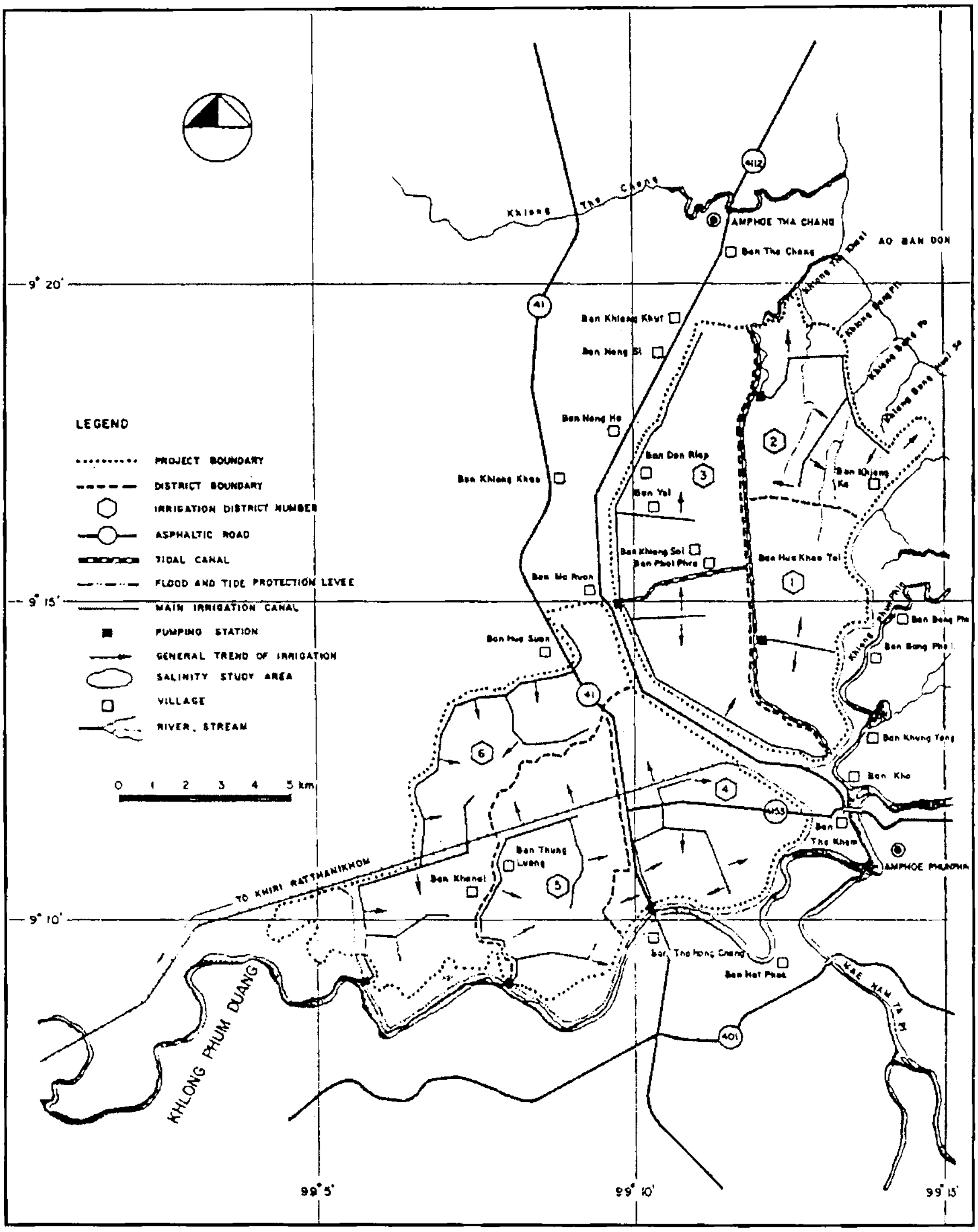


FIGURE 6.1

IRRIGATION AREA

(2) Current Implementation Plan and Progress

From the beginning of project construction in the fiscal year 1980 to the end of November 1995, about 55 percent of the planned project construction have been completed. With respect to the tidal canals, irrigation system, drainage systems, flood control dike, service roads and on-farm works, the works accomplished are summarized below:

(2.1) Tidal Canals

A main tidal canal is proposed to be excavated from Khlong Phun Phin to Khlong Tha Khoei, a tributary draining into Ao Ban Don. The purpose of this tidal canal is to feed the water into the irrigation Districts 1, 2 and 3 to facilitate the drainage and for navigation. The total length of the main tidal canal is 14 km.

Along the canal there were some drain inlets equipped with flap gates and minor vehicular bridges to control the drainage. Another tidal canal is proposed to branch off from this canal to feed the water into District 3. This Ma Luan canal was also feed the flood water of Khlong Ma Ruan directly into the main tidal canal and used for navigation up to the village of Ma Ruan village.

(2.2) Irrigation System

The irrigation systems are designed to supply the water into the district areas. The main components include pumping station, main canals, laterals and sub-laterals. The components of each district are outline below:

District 1

Gross area	2,000	ha
Main canal length	1.9	km
Laterals & sub-laterals	14.9	km
Pumping station		
peak flow	1.71	cms
maximum life	2.94	m
capacity	80	kw

District 2

Gross area	2,000	ha
Main canal length	6.9	km
Laterals & sub-laterals	14.7	km
Pumping station		
peak flow	1.71	cms
maximum life	3.55	m
capacity	90	kw

District 3

Gross area	4,500	ha
Main canal length	15.8	km
Laterals & sub-laterals	45.0	km
Pumping station		
peak flow	3.69	cms
maximum life	4.17	m
capacity	230	kw

District 4

Gross area	2,500	ha
Main canal length	4.4	km
Laterals & sub-laterals	23.4	km
Pumping station		
peak flow	2.2	cms
maximum life	4.4	m
capacity	140	kw

District 5

Gross area	2,400	ha
Main canal length	7.8	km
Laterals & sub-laterals	17.9	km
Pumping station		
peak flow	2.07	cms
maximum life	5.70	m
capacity	170	kw

District 6

Gross area	3,900	ha
Main canal length	14.5	km
Laterals & sub-laterals	35.1	km
Pumping stations ; peak flow	3.30	cms
maximum life	6.90	m
capacity	320	kw

(2.3) Drainage System

The drainage system was provided by improvement of existing drainage ways and excavation of drainage canals for the whole project area. Effective drainage canals were required to take of the excess water from the low land areas which are presently flooded most of the tie. The improvement for the cross drainage condition was made to discharge the runoff from adjacent lands into the main tidal canal, controlled by flap gates.

In some parts of the area the drain canals have to drain across the flood protection dike into Khlong Phun Phin and Khlong Phum Duang. Flap gates were installed at the outlets to control the backwater effects.

Flap gates were also being equipped at the outlets of the drainage canals, which drain directly into the sea to prevent saline intrusion problems. The total drainage improvement is estimated to include excavation of about 1.0 million cubic meters of earth.

(2.4) Flood Control Dikes

As most parts of the irrigation area are presently subject to frequent flooding from Khlong Phum Duang and Khlong Phun Phin, the flood protection system comprising the low cost dikes for the irrigation project.

The District 1 area with a 10 km, long levee along the left side of Khlong Phun Phin. No flood protection dike is required for District 2.

District 3 protected by the tidal canal and the Phun Phin road embankment. The boundaries of districts 4 to 6 also diked to protect from the floods from the Khlong Phum Duang.

These dike were height of about 2.3 m on an average and a maximum height of 3 m. The total embankment volume is estimated about 600,000 m^3.

(2.5) Service Roads

Within the irrigation area, apart from the construction of tidal canals to facilitate the navigation, new service roads were provided along the tidal canals, on flood protection dikes and along the side of irrigation canals. The total length of new roads was constructed for the area of 10,000 ha of District 1, 2 and 3, about 110 km, while that for an area of 9,000 ha of Districts 4, 5 and 6 about 100 km.

(2.6) On-farm work

The on-farm works including land leveling, land consolidation, irrigation ditches, drainage ditches, improved track, and miscellaneous works, were also for the phase1 irrigation project to prove water management, particularly to minimize the drainage problems.

(3) Benefit from Irrigation

The objective of this evaluation is to measure the incremental benefits from better irrigation system after completion of the dam construction. Therefore the year 1987 is taken as the reference year after which incremental benefits from crop cultivation resulting from expended irrigated area in both the wet and dry seasons was measured against. The steps of calculation are summarized as follows:

(3.1) Measuring the incremental values of output from cropping each year from that of the year 1987 by the formula:

$$\Delta V_t = \sum \Delta V_{ti} = \sum \Delta A_{ti} \ \Delta Y_{ti}$$

where ΔV_t = incremental values of outputs of all crops.

ΔA_{ti} = difference in irrigated area between year t and year 1987 of crop i.

ΔV_{ti} = difference in yield per ha of crop i in year t between irrigated and rain fed areas.

(3.2) Taking the difference between the unit prices and the unit production costs of individual crop, then multiplying each of these values to the output values of each crop to obtain the benefits of the dam to each framing, i.e.

$$\Delta B_t = \sum \Delta B_{ti} = \sum(P_{ti} - C_{ti}) \Delta V_{ti}$$

ΔB_t = total incremental irrigation benefits in year t;

P_{ti} = unit price of crop i in year t.

C_{ti} = unit cost of crop i in year t.

(3.3) Projecting the increase in irrigated areas throughout the project's life, taking into consideration the irritable area constraint and the rates of expansion of irrigated areas in the wet and dry seasons.

(3.4) Estimating the future incremental benefit throughout the project life and computing the present values of the estimated benefits as usual at the discount rate of 12 percent.

The resulting estimates of the incremental benefits are present are as follows.

Based on the previous plan and estimates in the feasibility report, the planned irrigation benefits were estimated at about 199.0 million bahts per year (1980 constant price), depending on the time required for full agricultural development. However, with the update values of economic farm gate price for paddy and estimated implementation schedule of the irrigation project reflecting the current progress it is estimated that the optimistic estimated of the planned irrigation benefit, is 2,064.14 million bahts (1996 constant price). And the beneficial estimate of the irrigation water is about 0.06 bahts per cubic meter.

3.3 Water Supply

3.3.1 Objective

The major objectives of studying the water supply aspect are to present the existing water supply conditions, and to assess benefits of all downstream water supplies, including water supplies for domestic and industrial water uses and for salinity intrusion control.

3.3.2 Methodology

Data on water supply were obtained from literature review as well as from data collection from different concerned agencies including the Provincial Water Works Authority (PWA), the Health Department and Surat Thani Water Works. The last office was also visited during field trip to gather additional data on its operation and on water quality of the Phun Phin raw water. Projection of population growth was carried out based on the data collected from different sources including the National Economic and Social development Board (NESDB), and that future water demand was undertaken based partially on the previous study of Public Work Department. Review of the surface water hydrology study related to the Rajjaprabha project was also conducted to obtain the data needed for evaluation of probable effects, including the parts relating to reservoir operation and downstream flow regulation.

3.3.2 Previous Study

In the EEI report, (Team Consulting Engineers Co. Ltd. 1980) the total demand for water supply for Surat Thani municipalities was expected not to exceed about 1.2 cms by the year 2000. Since this constituted only slightly more than 1 percent of the long term average flow at Surat Thani no separate inclusion of this demand was made in the reservoir operation studies. Maximum flow requirements below the Rajjprabha diversion dam have not been established. But more detailed study was found in the project report. It presents the status of water supply in the Phum Duang river basin in the pre-dam period. Projections for growth in population and water demand were also given. The population growth rates for Surat Thani were estimated to be 4.5 percent per annum. The total water demand for Surat Thani forecast for the year 1996, 2000 and 2005 were about 25, 28, 31 mcm per annum, respectively. The forecast was very close to the maximum of 1.2 cms for the year 2000 as estimated in the previous study.

As for the minimum flow requirement, the recommended value for the lower reach of Khlong Saeng river was 44 mcm per month, which is the recorded minimum flow at Rajjaprabha dam site.

3.3.3 Result of the study

(1) Projected Population

The projected population for the entire Surat Thani province is shown in Table 6.8. The population in the urban area is about 0.992 million by year 1995. While the population in the rural area is approximated about 0.297 million for the year 1995.

TABLE 6.8

PROJECT POPULATION IN SURAT THANI AND IN PHUM DUANG RURAL ZONE

Area	Annual Growth Rate (%)	1995
Surat Thani Province (total)	3.27	992,516
Phum Duang Rural Zone (Approx. 30 % of provincial total)	-	297,755

Source : Surat Thani Provincial Office

(2) Water Supply Status

Water supply in Phum Duang river basin can broadly be classified into two categories i.e., urban and rural.

(2.1) Urban Water Supply

At present, urban water supply in Surat Thani are managed by the local municipality and are supported technically by the provincial Water Supply Division of

Public Works Department (PWD). Consideration is being made to transfer the management and operation of the water supply systems to the Provincial Water works Authority (PWWA). The total water consumption in urban area (Surat Thani municipal and Phun Phin district) is about 6.07 mcm in the year of 1995 as shown in Table 6.9.

(2.2) Rural Water Supply

Rural areas of the Surat Thani province (Khlong Phum Duang Rural zone) have relatively low population density. Also rain, surface water, and ground water are plentiful here and that represent convenient Sources for rural water supply. As a result there are only few rural water supply systems in this area. The total water consumption in rural zone is about 5.22 mcm for the year of 1995 (Table 6.9).

(3) Future Demand for Water Supply

Future water demands was estimated taking into account growth in population, industry, and developments in tourism sectors in Surat Thani. Major industries in Surat Thani are rice mills, fabrication plants, and engine repair shops. Earthenware home industry found in Surat Thani consumes only small amount of water. The demand for water form miscellaneous industries estimated at about 12 percent of domestic water demand in the urban areas. Majority of industries are related to agricultural and fisheries production ceramics, earthenware, wood, electronics and electrical products. An industry complex is under implementation in Surat Thani. It is located on 2,500 rai on the eastern side of Surat Thani. Water supplies for this complex are planned to be from the Phum Duang river. Based on the planned production target for each type of industry and its corresponding water consumption rate, the Surat Thani Water Supply Division of Surat

Thani municipality has estimated the potential water demand for this complex at 3,000 m^3/day, or 1.09 mcm/year.

The construction of infrastructures was scheduled for completion by the end of 1990, the full water demand is conservatively estimated in 1995.

Demand for water with respect to tourism was estimated from the number of hotel rooms. At present there are 46 hotels with a total of 1,850 rooms. Capacity of these hotels is judged adequate up to 1995. After 1995 and increase of 150-250 rooms per year were assumed for Surat Thani province. Based on the future development described above, the following criteria are assumed for estimating future water demand:

(a) Per capita consumption of 100 litres per day per person for the year 1995-1999, 110 litres per day per person for 2000-2004, 120 litres per day for 2005-2009, and 130 litres per day per person in the year 2010 for urban area in Surat Thani.

(b) Per capita consumption of 80 litters per day per person for the year 1995-1999, 90 litres per day per person for 2000-2004, 100 litres per day per person for 2005-2009, and 110 litres per day per person in the year 2010 for rural area; and

(c) 1.2 m^3 per day per room for hotels including services and supporting facilities.

The annual water demand from Phum Duang river will increase from 12.42 mcm in the year 1995 to 28.84 mcm in the year 2010 as shown in Table 6.10.

TABLE 6.9

WATER CONSUMPTION IN SURAT THANI MUNICIPALITY - PHUN PHIN AND KHLONG PHUM DUANG RURAL ZONE (1995)

Community	**1995**
Urban	
Domestic Uses	
Population served (No.)	125,300
Consumption rate (litres/person/day)	100
Water demand	4.57
Industry Uses	
Water demand	0.55
Tourism Uses	
No. of room	1,850
Consumption rate (litres/person/day)	1.2
Water demand	0.92
Sub total	**6.07**
Rural Area	
Population served 60 % of the total (No.)	178,653
Consumption rate (litres/person/day)	80
Water demand	5.22
Total	**11.29**
Total consumption + 10 % loss, m^3/yr	**12.42**

Source : Estimated by I. Kruger A/S consulting Engineers in Master Plan and Feasibility Report.

TABLE 6.10

PROJECTION OF FUTURE WATER DEMAND (1995-2010)

Community	Water Demand (mcm)			
	1995	2000	2005	2010
Urban				
Domestic Uses				
Population served (No.)	125,300	162,000	202,500	264,000
Consumption rate (day/person/day)	100	110	120	130
Water demand	4.57	6.50	8.87	12.53
Industry Uses				
Water demand	0.55	0.78	1.07	1.51
Tourism Uses				
No. of room	1,850	2,850	3,850	4,850
Consumption rate (day/person/day)	1.2	1.2	1.2	1.2
Water demand	0.92	1.25	1.70	2.13
Sub total	**6.07**	**8.58**	**11.63**	**16.17**
Rural Area				
Population served 60 % of the total (No.)	178,653	209,836	226,540	250.200
Consumption rate (day/person/day)	80	90	100	110
Water demand	5.22	6.89	8.27	10.05
Total	**11.29**	**15.42**	**19.90**	**26.22**
Total consumption + 10 % loss, m^3/yr	**12.42**	**16.96**	**21.80**	**28.84**

(4) Water Demand for Salinity Intrusion Control

Controls of salinity intrusion into the Phum Duang river are the objective of the studies. The amount of fresh water flow and required for this purpose is estimated from the relations of fresh water flow salinity intrusion established in this study. The objective is to control salinity concentration at 250 ppm or 0.25 ppt at a distance 5 km from the river mouth. The fresh water flows required for this are 5.4 m^3/sec and 3.5 m^3/sec for the high water slack and to floor the rising tide condition, respectively. Hence 5.4 m^3/sec or about 15 mcm/month is the fresh water flow required for control the salinity intrusion.

(5) Water Supply Benefits

The water supply benefit is estimated based on the cost of having alternation source for the planned water supply systems, which depend on raw water from the Phum Duang river. Benefit from the use of water from Phum Duang river as raw water for eater supply systems along the river is assessed from the cost of the ground water alternative source. The present worth value (1996 price level) of raw water from the Phum Duang river during the years from 1987 to 2037 for domestic, industrial and other miscellaneous uses is estimated at about 140 million bahts or about 0.56 baht per cubic meter.

Limiting salinity intrusion at a location 5 km upstream from the river mouth is anticipated to enhance utilization of the river water in the vicinity of Surat Thani town. With the salinity intrusion control, the Surat Thani municipal water supply system can safely draw its raw water from the river. Salt-water encroachment problems in the coastal agricultural land along the river reach can rely better on the river water for purposes like domestic earthenware industry. Although monetary value of these benefits, from salinity intrusion control is rather small compared to other benefit, significant positive impacts on socio-economic of residents in the estuarine communities can be expected.

4. TRANSPORTATION AND NAVIGATION

4.1 Introduction

Transportation system is very essential for development. In the southern region roads have been sufficiently provided. The length of roads provided per unit area of land in this region is greatest in comparison with other regions of the country. In 1980, the total length of highways was reported to be about 4,800 km. Generally, the traffic is low here with an average traffic volume of about 1,500 vehicles per day. But in Hat Yai the traffic is the heaviest, (over 3,600 vehicles per day).

Navigation along the whole reach of the Phum Duang river is limited. The EIS study showed that only small number of people used waterways for communication and transportation. Relatively small numbers of motor boats were used in the vicinity of Ban Ta Khun and Khirirattha Nikhom district.

4.2 Objective

The objective of this study is to evaluate the existing situation of transportation and navigation, in order to assess changes induced by the implementation of Rajjaprabha project. Beneficial impact will be quantified for subsequent use in the environmental impact evaluation.

4.3 Methodology

The study is carried out by reviewing all data available from various government agencies and from other related studies. Additional data were obtained from field observations at various stations on main roads in Surat Thani. The navigation data were also obtained from field observation in various parts of the river.

4.4 Result of the study

4.4.1 Land Transportation

The present condition of land transportation in Surat Thani was assessed from the data obtained from field observations. These data include: vehicle composition, average daily traffic volume (ADT), and peak traffic volume. Moreover, the data on traffic volume on main highways in the project area recorded by the Highway Department from the year 1985 to 1996 were used for assessing in changes induced by the Rajjaprabha project.

(1) Present Traffic Condition

(1.1) General Description

The traffic assessment of main highways in Surat Thani was undertaken primarily for estimating the present traffic condition in relation to those previously investigated. Traffic counts were made on 17and 18 May 1997. The stations were selected at the main road entering and leaving the towns of Surat Thani. Traffic counts were performed during 7.00-19.00 hr. All four stations were counted during the same period of time. The roads are two-way flow, asphaltic concrete pavement with an average width of about 3 m per lane. The vehicle types are classified as follows:

Motorcycles (MC)		
Passenger car (PC)	-	private passenger cars and taxis.
Light bus (LB)	-	minibuses and modified pick-up trucks for passengers with two long parallel benches.
Heavy bus (HB)	-	buses with more than 20 seats.
Light truck (LT)	-	trucks and pick-up trucks.
Heavy truck (HT)	-	6 wheel and 10 wheel trucks and trailers.
Other	-	non-motorized vehicles, mainly bicycles and tricycles, which are normally modified from bicycles.

(1.2) Vehicle Composition

Results of this investigation revealed that motorcycles were widely used in the areas, this forms about 50 to 60 percent of the total number of vehicles observed. Pick-up trucks were found to be about 15-20 percent of the total, vehicles. These are mainly used for transporting material for commercial purposes. Passenger cars including taxis constitute about 10 percent, with an almost equal share. Heavy trucks and lights buses were account for about the same percentage as in the case of passenger cars. Heavy buses and other (non-motorized vehicles) account for only less than 5 percent, except in the low traffic area of Ban Ta Khun district where bicycle percentage was found to be a little higher than in other places. The average percentage of traffic composition as shown in Table 6.11. The details of vehicle composition found on working days and holidays, respectively. The peak traffic was observed at 8.00-9.00 hr and 17.00-18.00 hr.

TABLE 6.11

AVERAGE PERCENTAGE OF TRAFFIC COMPOSITION ON 15,16 MAY 1997

Station	MC	PC	LB	HB	LT	HT	Other
Station 1	106.8	58.2	87.5	22.8	38.4	39.6	17.4
Station 2	88.6	32.7	68.5	17.1	26.4	24.8	11.5
Station 3	69.2	25.3	37.0	9.8	10.6	15.7	6.3
Station 4	27.2	8.2	14.5	1.8	5.4	6.8	2.6

Notes : Station 1 : The route of Muang District to Phun Phin district

Station 2 : The route of Phun Phin district to Khirirattha Nikhom district

Station 3 : The route of Khirirattha Nikhom district to Ban Ta Khun district

Station 4 : The route of Ban Ta Khun district to Rajjaprabha dam

(1.3) Average Daily Traffic Volume

In the absence of 24 hour count, average daily traffic volume (ADT) are estimated by adopting a criterion that vehicle flows during 10 hour count (07.00-17.00 hr.) represent about 70 percent of daily traffic volume (Sinclair & Associate, 1983). Comparison is also made with the ADT calculated from peak hourly flow, which is taken as 8 percent of the daily traffic. Numbers of vehicles are converted into number of cars by equivalent factors before calculating the ADT. The factors used are the same as those used in EEL report, i.e., 2.5 for HB and HT, 0.25 for MC and others, and 1.0 for the rest of them. Results of ADT calculation are shown in Table 6.12.

TABLE 6.12

AVERAGE DAILY TRAFFIC VOLUME

Station	Hourly Peak		ADT estimated From peak		Traffic volume 07.0-17.0		ADT estimated From 10 hrs, count	
	In	Out	In	Out	In	Out	In	Out
Station 1	181.25	175.50	2265	2,194	1,396.75	1500.50	1,995	2,144
Station 2	247.25	322.75	3,091	4,034	2,035.50	2,279.75	2,908	3,257
Station 3	125.25	96.75	1,250	1,385	1,630.50	1,786.75	1,530	1,460
Station 4	56.00	60.25	700	753	391.25	431	559	616

Notes : Station 1 : The route of Muang District to Phun Phin district

Station 2 : The route of Phun Phin district to Khirirattha Nikhom district

Station 3 : The route of Khirirattha Nikhom district to Ban Ta Khun district

Station 4 : The route of Ban Ta Khun district to Rajjaprabha dam

Source: Highway Department

It is found that the ADT values estimated from both bases are very close, in the order of 2,000 to 4,000 for Muang Surat Thani and Phun Phin stations. At Khirirattha Nikhom and Ban Ta Khun stations the ADT is wound to be lower, at least than 1,000.

The average ADT at the counting station in this investigation are summarized in Table 6.13

TABLE 6.13

AVERAGE DAILY TRAFFIC FROM FIELD INVESTIGATION

Station	Average Daily Traffic		
	In	Out	Average
Station 1	2,644	2,646	2,636
Station 2	2,532	2,539	2,536
Station 3	1,236	1,246	1,240
Station 4	798	794	796

Source : Survey data

(1.4) Peak Volume to Capacity Ratio

Volume to capacity (V/C) ratios are calculated from the basic capacity of 1,300 vehicles/hr (Sinclair. 1983). On this basic V/C ratios exceeding 1.0 are possible, and in practice may be as high as 1.5 or 1.6. However, V/C greater than 1.0 would limit the vehicle speed to not exceeding 20 to 25 km/hr. The interpretation of traffic condition from the value of V/C ratios are as follows:

V/C ratio	**Traffic Condition**
Less than 0.7	satisfactory
0.7 to 1.0	moderate to high congestion, general not satisfactory.
1.0 to 1.4	very low level of service road operates near practical capacity

1.4 or more	extensive queues and delays, road at practical capacity with existing traffic composition

(1.5) Peak Hour Capacity

Adequacy of existing road capacity can be assessed by comparing nominal road capacity with the maximum one-way flow record over any hour. The road capacity is taken as 1,300 vehicles/hour/lane. The V/C ratios of less than 0.7 are considered satisfactory and 0.7 to 1.0 as congested. The results obtain from this study show the V/C ratios of less than 0.7 even during peak hours as shown in Table 6.14. Therefore the present traffic condition are still under the road capacity.

(2.) Growth of Traffic Volumes

The growth of traffic volumes is used as an indicator for evaluating the impacts from the project implementation on traffic conditions. Past records on traffic volumes obtain from the Highway Department are used in this evaluation.

The ADT values of route No. 401 at various station along the highway from Surat Thani to Phang-Nga vary considerably. For example, in 1995 the ADT varied from highest of 2,460 to the lowest 618, which was about four times in magnitude. The ADT between Phun Phin to Ban Ta Khun district recorded by the Highway Department was found a little higher than the values obtain from this study. Major increase in traffic volumes on this section of highway can be observed from the year 1980 to the present. Part of this may result from Rajjaprabha dam implementation. But no significant increase has been observed from other sections of route no 401. The impact of Rajjaprabha dam on land transportation, as judged from the presented traffic information, can not be conclusive as this stage.

TABLE 6.14

VOLUME TO CAPACITY RATIOS

Station	Hourly Peak		V/C ratios	
	In	Out	In	Out
Station 1	276	322	0.21	0.25
Station 2	221	219	0.16	0.16
Station 3	86	74	0.07	0.07
Station 4	72	65	0.05	0.05

Source : Survey data.

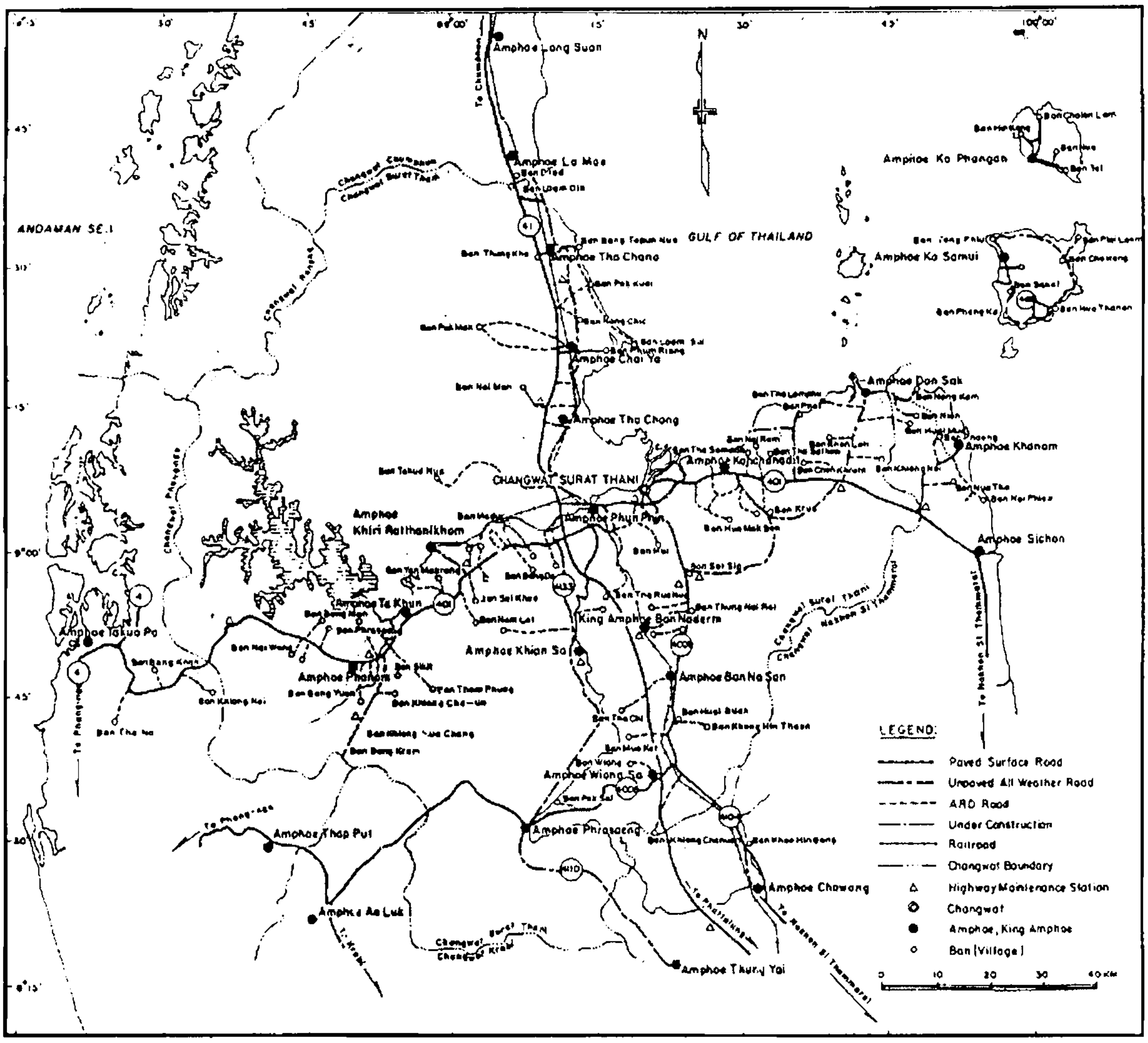


FIGURE 6.2

ROAD NETWORK IN SURAT THANI

4.4.2 Navigation

The present condition of navigation is assessed by field observation in three parts of the river, viz:

(a) The reservoir.

(b) The upper reach downstream from Rajjaprabha dam; and

(c) The lowers reach.

(a) Navigation in the reservoir

Field observation was made in the Rajjaprabha reservoir in May 1997. Many types of boats were observed then. They were used mostly for fishing. In non-fishing period, boats were also used for transportation among villages located along the reservoir rim.

(b) Navigation in the Upper Reach

Observations were made at Ban Ta Khun district and Khirirattha Nikhom distict for a period of 6 hours. During the observation 32 boats were found sailing among the villages and both district above mentioned.

(c) Navigation in the lower reaches

More navigation activities were observed in the lower river reach downstream from Phun Phin district to river mouth and from river mouth to the sea. Most of the boats observed were transporting articles for fishermen households and boats for sea fishing.

Boats sailing along the river in the section between the river mouth and Phun Phin district were also counted at two hours interval. During 10.0-12.00 hours 154 boats of all types were found sailing to and from the river mouth, respectively (See Table 6.15).

TABLE 6.15

NUMBER OF BOATS COUNTED AT SURAT THANI FISHERIES STATION DURING 2 HOURS PERIOD

Type of boat	Number of boats	
	Phun Phin to River mouth	To the sea
Small	69	17
Medium	18	12
Large	11	25
Total	**98**	**54**

Source : Survey data

4.5 Conclusion

The situation with respect to transportation and navigation was updated in order to assess possible changes due to the development of Rajjaprabha dam and its downstream project. The land transport systems, both at the regional and local level, are found to be adequate for supporting development in the basin. The implementation of the Rajjaprabha project has induced no material change in traffic load to the land transport system, except during the project construction. However, better road accessibility has been provided for rural resettlement villages.

Improved navigability is provided in most of the river reaches, both upstream and downstream from the Rajjaprabha dam, by its flow regulation. However, this improvement has so far not any caused significant increase in water transport in the river. And the anticipated navigation benefit in the pre-impoundment environmental study has not yet been realized.

5. HYDRO POWER PRODUCTION

5.1 Introduction

Hydropower system for hydropower production at Rajjaprabha dam consists of:

(a) Rajjaprabha reservoir with 5,639 mcm capacity;

(b) Powerhouse with three 80 MW generating units; and

(c) 230 kv and 115 kv transmission system of 50 km length to join the southern grid at Surat Thani substation in Surat Thani province.

5.2 Objectives

The main objectives of this study are:

(a) To estimate hydropower production benefits in term of the cost of using alternative sources or sources of equivalent power generation;

(b) To provide beneficial estimates of hydroelectric generation per kWh to residential, industrial, commercial, service and communication;

(c) To assess damages due to lack of hydroelectric power in a minute and a day.

5.3 Methodology

The study has been carried out based upon the review and evaluation of existing reports and documents prepared by EGAT related to the hydroelectric development of the Rajjaprabha dam and the region.

In order to fulfill the above objectives the following tasks are identified.

(1) Conventional Estimation of Hydropower Benefit:

This represents an estimate of monetary value of the electricity (power and energy) from the Rajjaprabha powerhouse, in terms of the cost of using alternative sources (or the next cheaper source) of equivalent power generation, so that it will satisfy objective (a) mentioned above.

(2) Beneficial estimates of power generation of various sectors:

To fulfill the objective (b) different investigations are needed mainly to identify users and characteristics of load and power market of the generated electricity

(3) Assessment of damages due to lack of hydroelectric power:

The damages under this study aspect concern both financial damages and economic implication of the electricity supplied to various sectors of users. The lack of the normally supplied electricity is likely to give rise to consequential damages to the various users at different degrees.

5.4 Previous Power Facilities in Southern Region

5.4.1 Power Supply System

The power supply system in southern Thailand (EGAT's Region 3) is shown in Figure 6.2 The power plants available in the EGAT's Region 3 consisted of seven power plants. Of the seven power plants, three were oil-fired, one was lignite-fired, and three were diesel-fired. The total installed capacity was 197.6 MW of 21 units. In Surat Thani, there were three gas turbine units and one oil-fired unit totaling 75 MW located in Phun Phin district.

According to the EGAT's Region 3 generation records from the1973 to 1978 fiscal years, the average increases in power and energy demands were 19 and 18 percent, respectively. The load forecast has been revised currently which included the PEA development programme in southern provinces in the consideration. Accordingly, the power and energy requirements in the 1990 fiscal year were 598 MW and 2,978 GWh, with the yearly load factor of 57 percent.

5.4.2 Alternative of Thermal Power and Rajjaprapha Power Plant Economic

The feasibility study of the Rajjaprabha project considered the alternative thermal plants in comparison with the installation of Rajjaprabha power plant. With the consideration of the role of Rajjaprabha project, the combination of oil fired and gas turbines are assumed to be a suitable alternative.

In Stage I, when the Rajjaprabha project operated with a plant factor of about 0.5, the most appropriate combination was 80 MW oil fired working at a plant factor of 0.74 and a 40 MW gas turbine working at a plant factor of 0.05

In the Stage II, an additional unit of 60 MW gas turbine was installed to resemble the peak generation character of the hydropower plant. The characteristic of these combined power plants was an 80 MW oil fired working at plant factor 0.69 and a 160 gas fired working at plant factor 0.05.

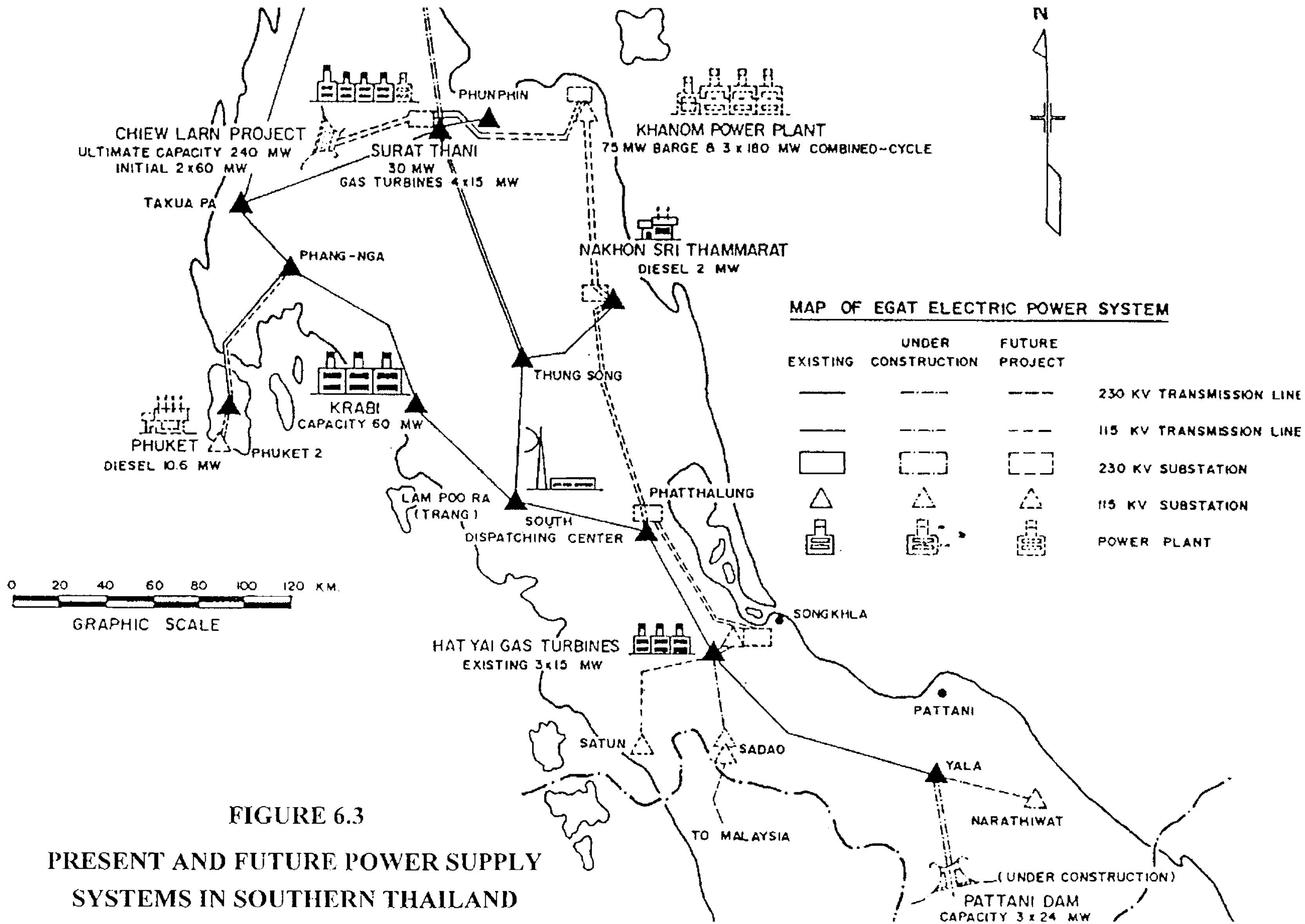


FIGURE 6.3

PRESENT AND FUTURE POWER SUPPLY SYSTEMS IN SOUTHERN THAILAND

The main characteristics of the alternative plants are summarized below

	Stage I	**Stage II**
Installed power (MW))	**120**	**240**
Oil fired unit	80	80
Gas turbines	40	160
Generating Energy (GWh)	**537.5**	**553.7**
Oil fired unit	520.0	520.0
Gas turbines	17.5	33.7
Plant factor (average)		
Oil fired unit	74 %	74 %
Gas turbines	5 %	5 %

These alternative thermal plants were used to determine the benefits of the Rajjaprabha dam on power production.

5.4 Results of the study

Potential for hydropower production at the Rajjaprapha power plant has been re-evaluated using the reservoir operation simulation technique, and also adopting the revised performance characters of the hydropower generating facilities along with 25 years actually observed reservoir monthly inflows. According to the revised estimate an average annual energy generation of about 554 GWh can only be expected when there is water constraint on the reservoir operation.

5.4.1 Power System

Ever-increasing load in EGAT southern region has resulted in a much improved electrical power system from the pre-impoundment condition. Power and energy demands have increased at a much higher rate in the post-impoundment period. As a consequence EGAT has constantly been working on continual improvement and development of its power system.

Rajjaprabha power generation provides three major contributions to the power system in the EGAT southern region, namely energy, power, and system operation flexibility and reliability. When the plant started its operation at full potential during 1987 to 1996 period, the average annual energy was about 554 GWh. This was approximately 28 percent of the energy demand of the whole southern region during the same period. The peaking power of the Rajjaprabha plant also provided significant contribution to the peak demand in the southern region, especially for the area of Phan-nga province. It provided about 31 percent of the peak demand during 1995-1996. Providing peaking power, quickly low maintenance requirement and a marked flexibility and reliability to the EGAT power system are the advantageous abilities of the Rajjaprabha power plant.

5.4.2 Conventional Estimation of Hydropower Benefit

The stream of benefits expected to be obtained from the dam are summarized in table 6.16, While the stream of investment and operation cost are presented in Table 6.17. The overall project (included power, irrigate and fishes) evaluation shown the B/C ratio of 1.60 while the internal rate of return is 16.2 percent. A sensitivity analysis was made considering the power benefit alone; the internal rate of return of 14.68 while the B/C ratio of 1.44 at 10 percent interest rate were obtained.

TABLE 6.16

BENEFIT FLOW OF RAJJAPRABHA PROJECT

Year	Benefits (in Million Baht)			Year	Benefits (in Million Baht)		
	Invest.	O&M	Fuel		Invest.	O&M	Fuel
1	0	0	0	26	123.00	58.00	681.00
2	53.00	0	0	27	102.00	606.00	704.00
3	107.00	0	0	28	107.00	626.00	724.00
4	213.00	0	0	29	213.00	642.00	747.00
5	303.00	0	0	30	229.00	661.00	769.00
6	552.00	0	0	31	650.00	681.00	792.00
7	164.00	29.00	273.00	32	484.00	704.00	815.00
8	0	36.00	353.00	33	148.00	724.00	841.00
9	0	36.00	362.00	34	0	747.00	864.00
10	0	36.00	372.00	35	0	726.00	890.00
11	221.00	36.00	384.00	36	0	58.00	916.00
12	369.00	36.00	396.00	37	0	58.00	945.00
13	148.00	36.00	408.00	38	0	58.00	973.00
14	0	58.00	470.00	39	0	58.00	1,002.00
15	0	58.00	492.00	40	0	58.00	1,032.00
16	0	58.00	509.00	41	0	58.00	1,063.00
17	0	58.00	522.00	42	0	58.00	1,095.00
18	0	58.00	538.00	43	0	58.00	1,128.00
19	0	58.00	554.00	44	0	58.00	1,160.00
20	0	58.00	571.00	45	74.00	58.00	1,196.00
21	0	58.00	587.00	46	123.00	58.00	1,232.00
22	0	58.00	606.00	47	49.00	58.00	1,270.00
23	0	58.00	626.00	48	0	58.00	1,307.00
24	0	58.00	642.00	49	0	58.00	1,347.00
25	74.00	58.00	661.00	50	0	58.00	1,388.00

Source : EEI report

TABLE 6.17

COST FLOW OF RAJJAPRABHA PROJECT

Year	Costs (in Million Baht)			Year	Costs (in Million Baht)		
	Civil.	Elmec.	Trans.		Civil.	Elmec.	Trans.
1	56.00	0	0	26	30.00	15.00	5.00
2	76.00	0	0	27	30.00	15.00	5.00
3	396.00	45.00	21.00	28	30.00	135.00	14.00
4	890.00	120.00	3.00	29	30.00	197.00	40.00
5	1,007.00	182.00	92.00	30	30.00	163.00	113.00
6	338.00	148.00	158.00	31	30.00	39.00	20.00
7	130.00	46.00	27.00	32	30.00	15.00	5.00
8	29.00	10.00	5.00	33	30.00	15.00	5.00
9	29.00	10.00	5.00	34	30.00	15.00	5.00
10	29.00	10.00	5.00	35	30.00	68.00	5.00
11	36.00	83.00	5.00	36	30.00	105.00	5.00
12	46.00	100.00	5.00	37	30.00	115.00	5.00
13	35.00	110.00	5.00	38	30.00	15.00	5.00
14	30.00	15.00	5.00	39	30.00	15.00	5.00
15	30.00	15.00	5.00	40	30.00	15.00	5.00
16	30.00	15.00	5.00	41	30.00	15.00	5.00
17	30.00	15.00	5.00	42	30.00	15.00	5.00
18	30.00	15.00	5.00	43	30.00	15.00	17.00
19	30.00	15.00	5.00	44	30.00	15.00	8.00
20	30.00	15.00	5.00	45	30.00	15.00	60.00
21	30.00	15.00	5.00	46	30.00	15.00	55.00
22	30.00	15.00	5.00	47	30.00	15.00	12.00
23	30.00	15.00	5.00	48	30.00	15.00	5.00
24	30.00	15.00	5.00	49	30.00	15.00	5.00
25	30.00	15.00	5.00	50	30.00	15.00	5.00

Source : EEI report

From the above analysis, is can be considered that in the absence of th Rajjaprabha project the thermal plants of equal capacity would have to be installed. Wit respect to the environmental pollution, the alternative thermal plants will result in muc more pollution problems.

5.4.3 Financial Benefit of Power Generation

Electricity generated from the Rajjaprapha power plant is mainly consumed in Phan-nga, Ranong, Pattalung, Surat Thani, Nakhorn Sri Thammarat. About half of the energy is consumed in Surat Thani and Nakhorn Si Thammarat. Among the users, industrial users consume more than a half of the generated energy. Residential and small business users consume the remaining.

(1) Benefit to EGAT

Financial benefit to EGAT from the sale of the generated electricity to Provincial Electricity Authority (PEA). The average annual energy benefits during 1987 to 1997was about 518.42 million bahts per year as shown in Table 6.18.

(2) Benefit to PEA

Financial benefit to PEA from users for the year 1987-1997 are estimated and shown in Table 6.19, that the financial benefit average about 685.98 million bahts/year

5.4.4 Financial Damages Due to lack of Hydroelectric Power

Monetary benefits of power generation at the Rajjaprabha plant, taken as direct incomes to EGAT and PEA from the sales of electricity, are described in the previous section. Financial damages due to lack of such electricity are just the losses of such incomes. The financial losses by EGAT and PEA would average 351 and 424 million bahts per year respectively.

It should, however, be noted that the lack of the normally supplied electricity is likely to give rise to consequential damages to the various users at different degrees. Such economic losses are covered in the section on environmental economic evaluation, usi the data on electricity utilisation specially collected for such economic losses assessment.

TABLE 6.18

FINANCE BENEFIT TO EGAT

Unit : Million of Baht

Year	Classification					
	Residential	Small Business	Industrial	Street light	Other	Total
1987	38.00	30.00	81.00	0.90	0.80	150.70
1988	42.00	36.00	98.00	1.40	1.00	178.40
1989	76.00	55.00	124.00	1.80	1.40	258.20
1990	82.00	65.00	187.00	2.00	1.60	337.60
1991	96.00	78.00	230.00	2.30	-	406.30
1992	112.00	96.00	290.00	2.40	-	500.40
1993	122.00	120.00	320.00	2.50	2.20	566.70
1994	128.00	135.00	375.00	2.60	2.50	643.10
1995	134.00	154.00	420.00	2.80	2.80	713.60
1996	146.00	168.00	455.00	3.00	3.50	775.50
1997*	120.00	146.00	380.00	3.40	4.30	653.70
Total	**1,096.00**	**1,083.00**	**2,960.00**	**25.10**	**20.10**	**5,184.20**
Average per year						**518.42**

Notes * 1997 (during January to August)

Source EGAT

TABLE 6.19

FINANCE BENEFIT TO PEA

Unit : Million of Baht

Year	Classification					
	Residential	**Small Business**	**Industrial**	**Street light**	**Other**	**Total**
1987	56.80	55.20	124.80	1.30	1.20	249.30
1988	65.30	74.50	186.50	1.50	1.50	339.30
1989	65.30	94.60	226.50	1.80	1.60	422.10
1990	87.60	102.50	310.60	2.20	1.80	534.60
1991	107.50	118.90	356.80	2.50	1.50	612.10
1992	122.40	133.50	386.50	2.80	1.70	671.30
1993	136.80	145.60	412.70	3.10	2.10	722.00
1994	148.50	170.50	434.20	3.40	2.30	783.20
1995	162.80	186.80	465.50	3.60	2.50	847.00
1996	178.60	198.50	496.80	3.70	3.50	903.00
1997*	190.50	177.50	422.30	3.20	3.60	775.00
Total	**1,322.10**	**1,415.20**	**3,823.20**	**29.10**	**23.30**	**6,858.90**
Average per year						**685.89**

Notes * 1997 (during January to August)

Source PEA

6. FLOOD PROTECTION

6.1 Introduction

Flood control is one of the major components proposed in the Phum Duang river basin development plan. The feasibility study report gives a brief describing of past flood events. On the basis of this flood protection strategy was planned, and a preliminary design of the plan was proposed in the report. Later in 1980 an Environmental and Ecological Investigation of Rajjaprabha Multipurpose Project was prepared for EGAT. In this description on historical flood events was prescribed along with results of the preliminary flood hydrology study. It also assessed flood control benefits and probable environmental effects of such assess. In the update versions of the report the protection plan proposed in the feasibility study remained unchanged. Only the quantities of construction material and costs were revised.

6.2 Objectives

Main objective of this aspect of water resources management is to reassess flood protection benefit using additional data and information collected up to water year 1996. To accomplish this objective the following study aspects are carried out and presented in the following sections.

(a) Flood damage data compilation and analysis;

(b) Review of previous flood protection benefit estimations;

(c) Reassessment of flood protection benefit.

6.3 Methodology

The methodology employed for determining the flood control benefits was the comparison of the flood damage condition for the case with and without the project. By assuming that the flood damages are directly proportional flood peak magnitudes, the relationships of flood peak magnitudes and damages are constructed at the control points by using the available data of flood damages

Finally, the flood damage reductions or flood control benefits were then estimate from the relationships of flood peak, flood damages and flood frequencies. These would then be the beneficial effects of the Rajjaprabha dam reservoir on the downstream flood damages control.

6.4 Previous Study

The previous study present some collected data on paddy damage in the crop years of 1969-1970, 1976-1977 and 1980-1981 by systematic questioning the province and district officers, as well as individual farmers during the field surveys. Only results of Phun Phin and Ban Na San districts are available as shown in Table 6.20

TABLE 6.20

PREVIOUS FLOODED AREA IN SURAT THANI

Districts	Flooded Area,(rai)		
	1969-1970 (Dec.)	1976-1977 (Sept.)	1980-1981 (July)
Phun Phin	597.6	612.2	587.5
Ban Na San	450	46	34

Sourcé : Surat Thani Provincial Office.

6.4 Results of the Study

The investigation indicates that the major cause of flood is the heavy storm during the northeast monsoon season i.e. November through January. The river basin upstream of Khlong Phum Duang and including the town of Phun Phin district covers an area of 4,668 km^2. About 2,960 km^2 of this is the steep mountainous area above Rajjaprabha damsite. From Rajjaprabha to Khirirattha Nikhom district is the rolling hillside area of about 2,291 km^2. The average ground slope of this area is considered as moderate. From Khirirattha Nikhom district to Phun Phin district lies a vast flat paddy field of alluvium deposit. The average river bed slope above Khirirattha Nikhom district is approximately 0.02, and decreases abruptly to about 0.025 when it enters the town of Khirirattha Nikhom. The river bed slope becomes even flatter as it runs downstream. Such topographic features produce streamflow of high peak and large volume, which reaches Khirirattha Nikhom district rapidly. By rationing with the size of the catchment area, about 60 percent of total flood volume should be from drainage area above the Rajjaprabha dam.

6.4.1 Flood Protection Components

Before the construction of Rajjaprabha dam the river reaches downstream from the damsite were subjected to flooding of varying severity for almost every year. Therefore flood protection was considered as one of the main purposes of Rajjaprabha and its downstream project development. The flood control storage provided at the Rajjprabha reservoir and the downstream flood control system were planned to minimize, or completely alleviate damages from all less severe flood events than the 100 year project designed for flood control. The upstream flood protection system consists of reserved flood control storage, varying from 135 to 217 mcm depending on the time of the year, and a service spillway with 4,500 cms design capacity. The downstream flood protection system, which is still being implemented, consists of: (a) flood protection dikes on both banks of the river upstream from the diversion dam (b) service and emergency spillway of the diversion dam (c) flood training dike along the center main canal (d) a system of main drains with control gates and pumping stations and (e) two orifice/flume structures for flood flow diversions to suit downstream channel capacities.

Many components of the downstream flood protection system are presently being implemented. According to the recent implementation plan, significant flood protection for the Surat Thani town will be provided when the construction of stage II of the right bank dike upstream from the diversion dam is completed in the fiscal year 1988. Also the Ban Ta Khun town and its vicinity area will be significantly protected by the fiscal year 1992 when the planned flood training dike along the right bank of Khlong Saeng downstream from the diversion dam is completed. The upstream flood control component at the Rajjaprabha dam significantly contributes to flood protection of the downstream flood prone areas. On an average it provides reduction of flood peak discharge at Surat Thani by about a half. Although the planned downstream flood control component has not yet contributed to its full potential, it has presently very significantly shortened flood duration in the downstream agricultural area in Surat Thani. This has resulted a marked reduction in agricultural flood damages.

6.4.2 Flood Damages Estimated

Damages in Khlong Phum Duang and Khlong Phun Phin river basin are mainly on the paddy rice and some on the upland crops grown in the wet season. An analysis is made in connection with thid study to determine, on a preliminary basis, the flood damages in Phun Phin, Khirirattha Nikhom, Ban Ta Khun and Muang Surat Thani district were collected and reviewed.

Table 6.21 present the summary of estimated flooded areas and damages on the agricultural production of available crop years, separated into district as Phin Phin, Khirirattha Nikhom and Ban Ta Khun incombination and Muang Surat Thani district. The flooded areas was shown in Figure 6.5.

TABLE 6.21

ESTIMATION OF FLOOD DAMAGES SEPARATED ONTO DISTRICTS

Unit : Million of Baht

Location	September 1989			July 1990			September 1991			September 1992			July 1993			September 1993		
	Flooded Area		Damage Cost	Flooded Area		Damage Cost	Paddy		Damage Cost	Paddy		Damage Cost	Paddy		Damage Cost	Paddy		Damage Cost
	Paddy	Other Crops		Paddy	Other Crops		Paddy	Other Crops		Paddy	Other Crops		Paddy	Other Crops		Paddy	Other Crops	
Phun Phin	9955	-	6.22	992	-	5.83	1,678	72	10.60	1,606	598	10.97	-	-	-	1,600	800	11.25
Khirirattha Nikhom & Ban Ta Khun	*	*	-	*	*	-	512	236	3.67	635	209	4.29	192	8	1.21	614	1853	4.12
Muang Dist.	*	*	-	*	*	-	-	128	0.20	682	79	4.79	-	-	-	363	38	2.33

Notes :

(1) Flooded area is expressed in hectare.

(2) "Other Crops" means field crops and vegetables.

(3) Unit damages costs on agricultural productions are assumed as 1,000 baht per hectare for paddy and 250 baht per ha for other crops

(4) * means data are not available

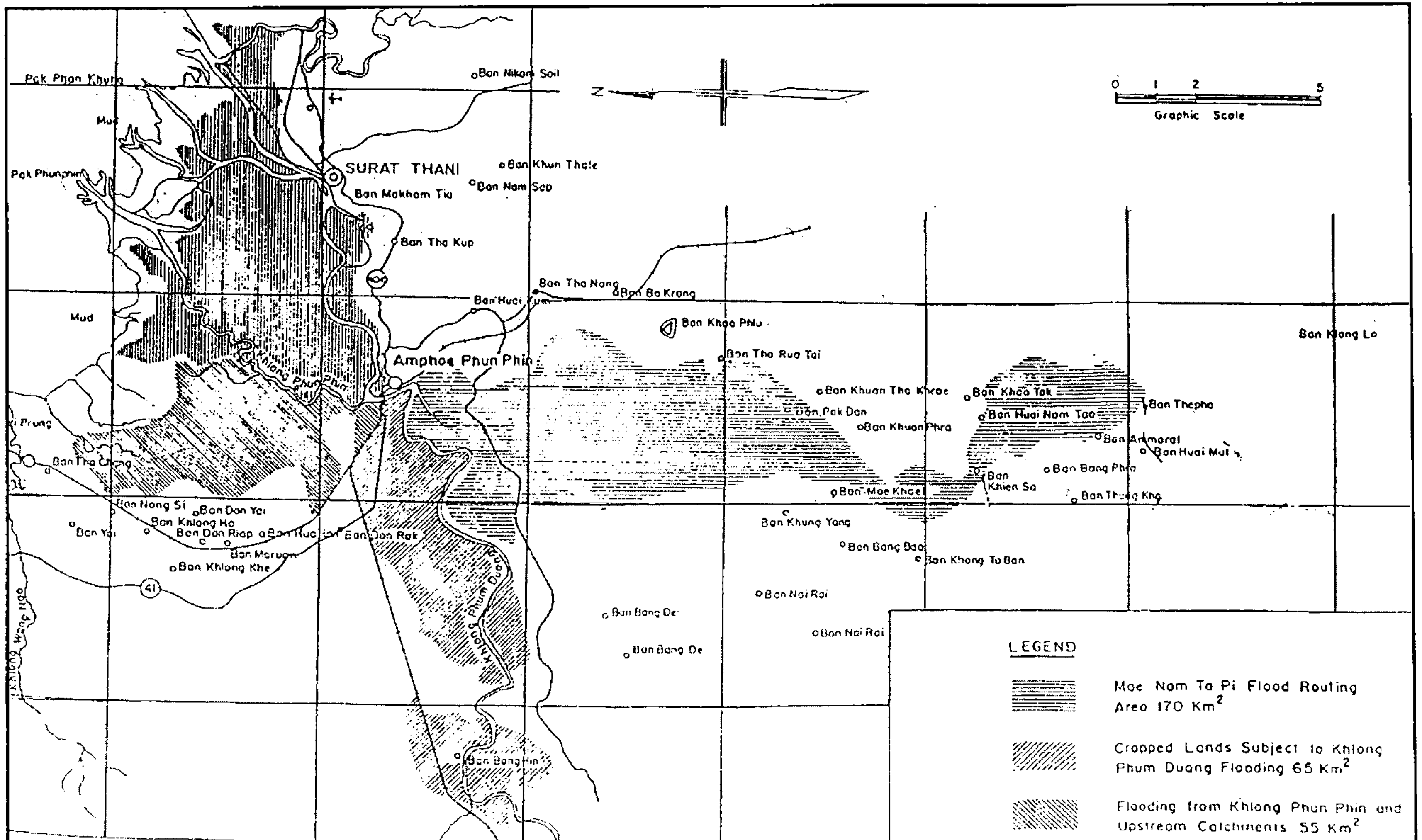


FIGURE 6.4

FLOOD AREA SUBJECTED TO EXCEPTIONAL FLOOD EVENT PHUM DUNG RIVER BASIN

Flood damage data presented in Table 6.21 alone are not sufficient to derive the relationship between the magnitudes of flood peaks and damages, since the available data are in the range of floods having low return periods. To overcome this problem, the boundaries of the maximum extent of the area that is under threat of flood was outlined in the topographic map of scale 1:50,000 to estimate the possible upper limits of the flooded areas separated for each district. These upper limits of the flooded areas and corresponding damages were used as additional data in deriving the relationship of the flood peak magnitude and damage. It is estimated that the flood damages of 24.3 million baht for Khirirattha Nikhom and Ban Ta Khun district (in combination) and 56.2 million baht for Phun Phin district are expected to be the upper limits of damages corresponding to the flood with the return period of 1,000 years.

Based on the available data and assumptions of flood damages described above, the relationships of flood peaks and damages are constructed for the above tabulated flood zones.

For Khirirattha Nikhom and Ban Ta Khun district in combination, the derived relation is :

$$D = 19.161 \ln Q - 138.808, \text{ for } Q > 1{,}400 \text{ cms}$$
$$= 0, \text{ otherwise}$$

In case of Phun Phin district, the similar relation is

$$D = 36.405 \ln Q - 266.722, \text{ for } Q > 1{,}520 \text{ cms}$$
$$= 0, \text{ otherwise}$$

D is expressed as the flood damage in million baht, Q the magnitude of flood peak in cms.

As the flood frequency and flood peak relationships are already analyzed for these control points, the transformation of flood damage and flood peak relationships, to the flood damage frequency can be systematically carried out. These relationships, which are expressed as the flood damage and the number of occurrence in 100 years, i.e. 100 divided by return period at control points and flood zones are presented in Figure 6.6 and 6.7 for Khirirattha Nikhom and Ban Ta Khun district, and Phun Phin district, respectively.

The area under the curve is the total flood damages expected to occur in 100 years. Hence, the existing annual flood damage, in case without the Rajjaprabha reservoir, for each particular zone is determined by diving the total area under the curve by 100. The estimated annual flood damages in case without the proposed reservoir are about 3.487 and 9.893 million bahts for Khirirattha Nikhom and Ban Ta Khun district, and Phun Phin district, respectively. This represents the existing flood damage condition of the Phum Duang river basin.

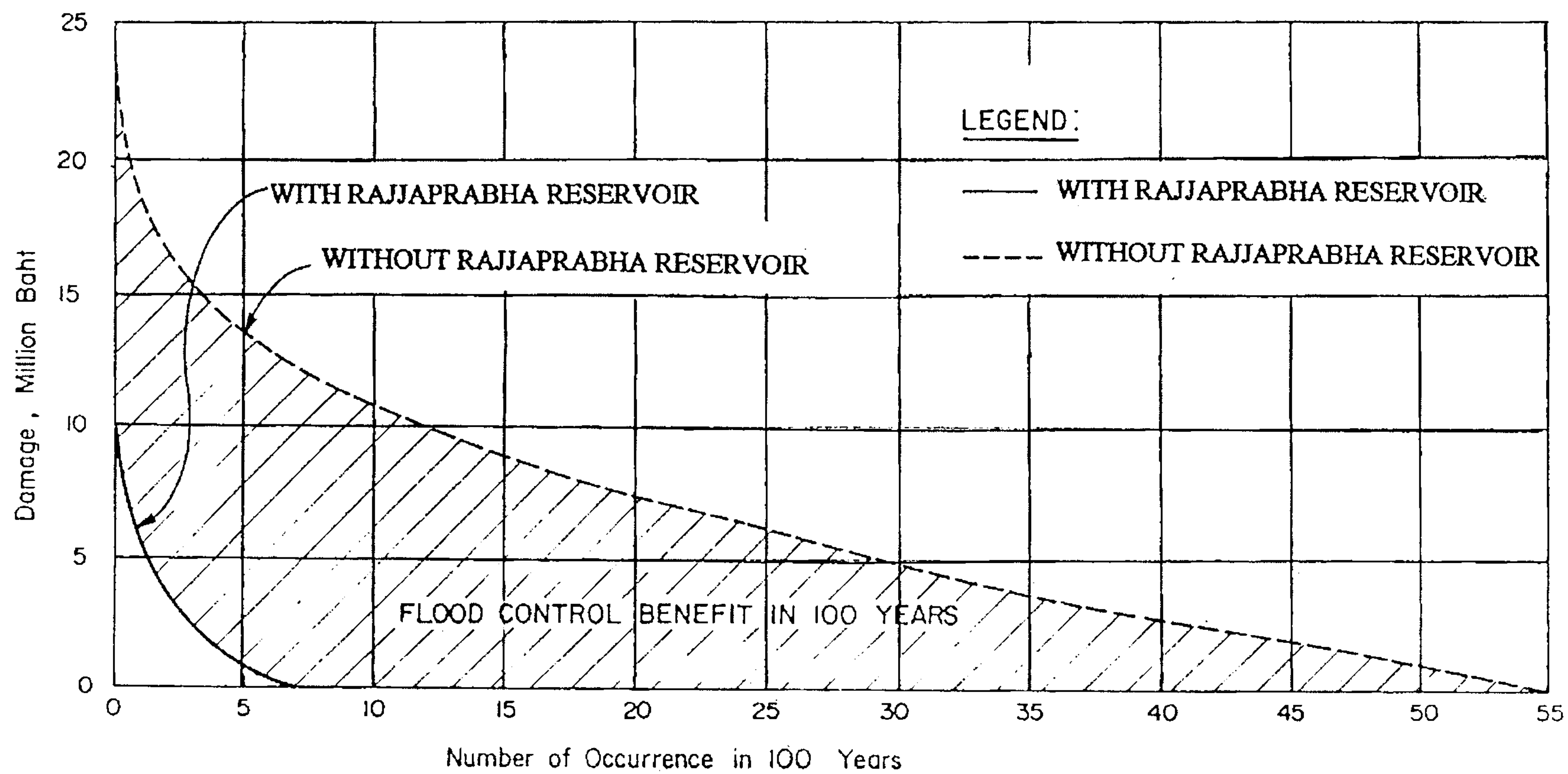


FIGURE 6.5

FLOOD DAMAGE FREQUENCY CURVE OF KHIRIRATTHA NIKHOM AND BAN TA KUN DISTRICT IN COMBINATION

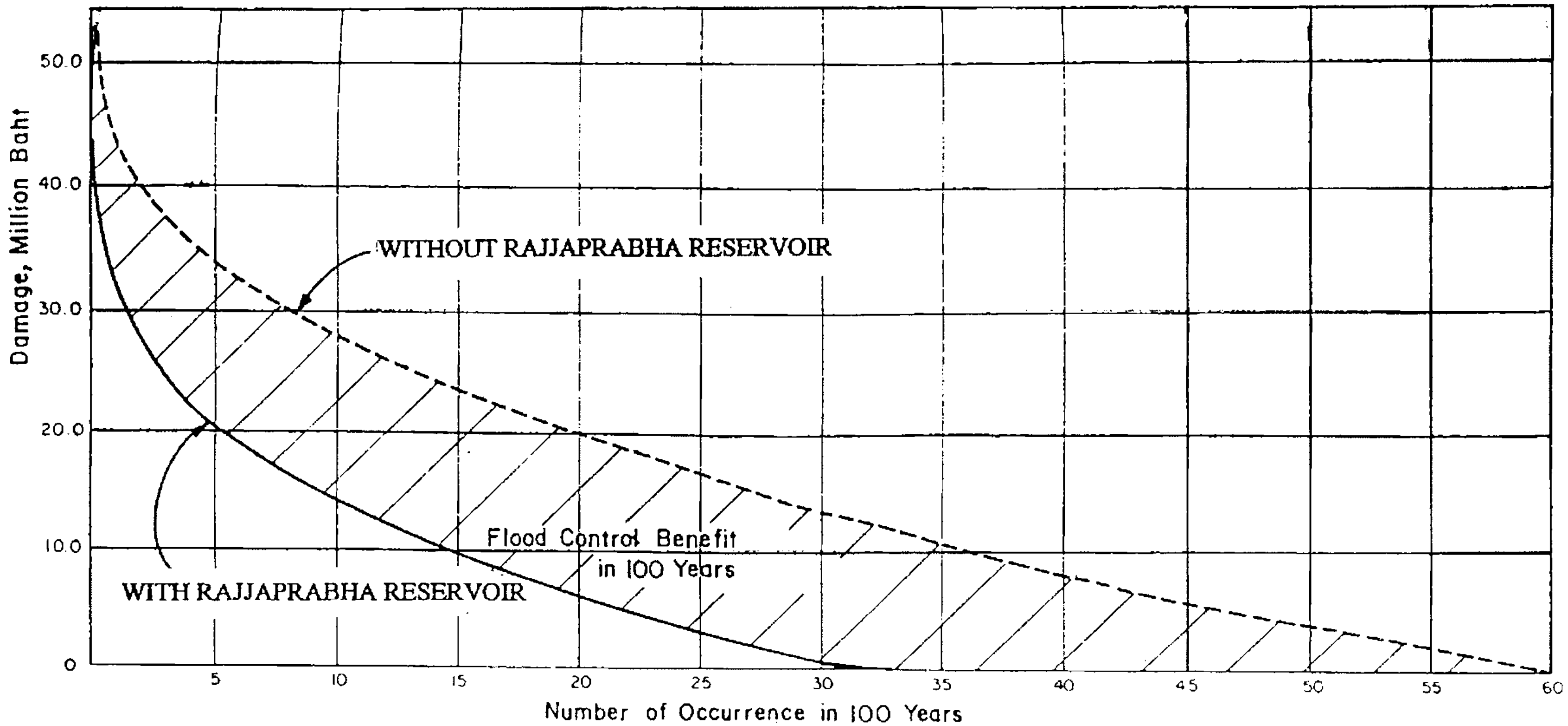


FIGURE 6.6

FLOOD DAMAGE FREQUENCY CURVES OF DISTRICT

6.4.4 Flood Protection Benefit

Benefit of a flood protection project is naturally the reduction in flood damages prevailing under the without project condition. Nature of flood damage characters and flood responses of residents in the flood prone and vicinity areas indicate that the flood protection benefit can be categorized into three types: direct flood protection benefit, indirect flood protection benefit, and benefit from more intensive utilization of lands and properties enhanced by the flood protection.

It can be seen that the flood damage can be significantly reduced in the areas of Khirirattha Nikhom and Ban Ta Khun district. The residual flood damages for case with the Rajjaprabha reservoir are estimated to be 0.187 and 3.830 million bahts annually for Khirirattha Nikhom and Ban Ta Khun district in combination, and Phun Phin district, respectively.

The flood damage frequency curves for the selected zones, shown in Figure 6.6 and 6.7, describe the flood damage reduction to be resulted from the implementation of the Rajjaprabha dam.

The areas between the flood frequency curves for the curves without and with the Rajjaprabha reservoir, divided by 100, will be expected annual flood control benefit of the project the estimated annual flood control benefits are 3.30 and 6.06 million bahts for Khirirattha Nikhom and Ban Ta Khun district in combination, and Phun Phin district, respectively with the total amount benefit of 9.36 million bahts. This estimated flood control benefit is only for the reduction in flood damage on agricultural productions.

7. WATER POLLUTION

7.1 Introduction

The 90-km length of the Phum Duang river downstream from the dam has been planned for multiple uses. The major water uses of interest from a water pollution control viewpoint are:

(a) Water supply including municipal, sanitary district, self-supplied industrial and rural domestic utilization:

(b) Water contact and non-water contact activities, e.g., bathing, fishing, and riverside parks;

(c) Navigation; and

(d) Irrigation

To serve these multiple uses, the quality of the river water must be maintained to meet all criteria for these water uses. In conjunction with the water use activities, the river also receives pollution loading from various sources both directly and indirectly, e.g., municipal and industrial wastewater, irrigation return flow, and various non-point pollution loading. The river itself can assimilate the pollution loads to a certain limit, and still maintaining the river water quality. The capability of the river to assimilate waste loads depends on various environmental factors of both the manageable and unmanageable types, e.g., the physical and hydrological characteristics of the river, climate, and the nature of waste loads.

The study on water pollution is, then, aimed at the preliminary identification of major pollution sources and the consequence of water quality deterioration subjected to the environmental factors, both of the manageable and unmanageable types. The study results serve as guidelines for the planning of water quality management.

7.2 Objective and Scope

The main objective of this study is to evaluate the direct and indirect effects of water pollution and benefits on pollution control from the regulation of water in the project implementation. The scope of the study includes the following aspects:

(a) Assessing major pollution sources, i.e., domestic wastewater, industrial wastewater and agricultural wastewater.

(b) Evaluating the extent of pollution, then, estimation of assimilative capacity of the Phum Duang river; and

(c) Assessing the benefits on pollution control from the regulation of water.

7.3 Assessment of Pollution Sources

The pollution loading to the 90 kilometer length of the Khlong Phum Duang river are of three main categories: (1) domestic wastewater, (2) industrial wastewater, and (3) irrigation return flow. Various pollution sources discharge pollution loads to river according to their water-related activities along the river reach. During this study period no irrigation return flow was observed due to rather limited application of the irrigation water.

7.4 Evaluation of the Pollution Sources

The evaluation of pollution sources is carried out with respect to the three main sources, i.e., domestic, industrial and irrigation.

7.4.1 Domestic Wastewater

Wastewater discharges from the four communities viz., (i) Ban Ta Khun district (ii) Khirirattha Nikhom district (iii) Phun Phin district and (iv) Muang Surat Thani district are estimated from population data and water consumption. Characters of the generated wastewater were assessed from the samplings and analyses of wastewater samples collected during this study. Then total domestic pollution loading, in term of ultimate BOD loading, was estimated for the three communities to increase from about 1,760 kg/day in 1996 to about 2,530 kg/day in 2000 and to be 3,780 kg/day in the year 2005 as shown in Table 6.22.

7.4.2 Industrial Wastewater

Major sources of industrial wastewater discharges into the Phum Duang river are in the towns of Surat Thani. The main sources of these discharges are fishery related and food processing industries, the fish-landing pier of the Fish Market Organization. Total ultimate BOD_5 loading from industry wastewater and the fish-landing pier is estimated to grow from about 20,360 kg/day in 1996 to about 26,000 kg/day in 2000 and to be 32,480 kg/day in the year 2005 as shown in Table 6.23.

7.4.3 Irrigation Return Flow

At present negligible irrigation return flow can be expected, as the irrigation water supply is very limited. So, pollution loading in terms of BOD from irrigation return flow will be negligible compared to other sources. Therefore, the total ultimate BOD loading is estimated to grow from about 22,100 kg/day in 1996 to about 28,300 kg/day in 2000 and to be 34,670 kg/day in the year 2005 as shown in Table 6.24

TABLE 6.22

ESTIMATION OF DOMESTIC BOD LOADING TO THE PHUM DUANG RIVER

Community	BODμ Loading, kg/day		
	1996	2000	2005
Muang district	670	830	1,220
Phun Phin district	538	760	1,050
Khirirattha Nikhom district	320	540	860
Ban Ta Khun district	232	400	650
Total	**1,760**	**2,530**	**3,780**

Source : Adopted from Surat Thani Provincial Industry Office.

TABLE 6.23

ESTIMATION OF INDUSTRIAL AND FISH LANDING PIER BOD LOADING TO PHUM DUANG RIVER

Source of Wastewater	**BODµ Loading, kg/day**		
	1996	**2000**	**2005**
Industrial	1,585	3,882	4,680
Fish landing pier	18,835	22,718	27,800
Total	**20,360**	**26,000**	**32,480**

Source : Surat Thani Provincial Industry Office.

TABLE 6.24

ESTIMATION OF BOD LOADING FROM IRRIGATION RETURN FLOW

Source of Wastewater	**BODµ Loading, kg/day**		
	1996	**2000**	**2005**
Paddy, Crops	3,900	4,740	6,634
Livestock	18,200	23,560	28,036
Total	**22,100**	**28,300**	**34,670**

Source : RID

7.5 Estimation of Assimilative Capacity of the river

Having estimated the pollution loading the waste assimilative capacity (WAC) of the Phum Duang river is preliminarily estimated using the Streeter-Phelps oxygen sag equation given below.

$$D = \frac{Kd\ Lo}{Ka - Kr} [\exp(-Kr\ x/u) - \exp(-Ka\ x/u)]\ Do\ \exp(-ka\ x/u)$$

where	D	=	Oxygen deficit, mg/l.
	Do	=	Initial oxygen deficit at the point of waste discharge, mg/l.
	Lo	=	Ultimate BOD at the point of discharge, mg/l.
	X	=	Distance downstream from the point off discharge, km.
	U	=	Velocity of flow in the river, km/day
	Kd	=	BOD deoxygenation rate, day^{-1}
	Kr	=	BOD decay rate, day^{-1}
	Ka	=	Re-aeration rate of the river day^{-1}

The degree of accuracy in the estimation of WAC in this study is of preliminary level. Estimation of some parameters are based on both field data, and information derived from literature.

Assuming a safe level of dissolved oxygen of 4 mg/l the Phum Duang river is assessed to have adequate waste assimilative capacity for the BOD_5 loading in the year 2000, provided that a minimum flow of 44 mcm/month is maintained. However, if the minimum flow of only 15 mcm/month for salinity intrusion control is maintained the assimilative capacity will reduce to about 8,000 kg/day. In this case the capacity will be adequate only for the domestic loading and the wastewater from the Surat Thani fishery port must be properly treated.

CHAPTER VII

QUALITY OF LIFE VALUE

CHAPTER VII

QUALITY OF LIFE VALUES

1. INTRODUCTION

Quality of life values are among the most important environmental resources values with which the public is concerned in developing any kind of large-scale projects. With respect to a large dam and reservoir development like the Rajjaprabha dam, one of the primary concerns is that related to adverse socio-economic effects on the people which have to be evacuated and relocated due to impoundment of water in the reservoir. This is due to the fact that, while unaffected people would benefit from power generation, flood protection in the downstream areas, fisheries development in the reservoir area, and the irrigation scheme, but the existing inhabitants of the proposed reservoir will have to suffer, at least psychologically, once they are informed of their fate in the near future.

The quality of life values which were investigated in relation to the Rajjaprabha dam included (i) socio-economic and resettlement (ii) public health and nutrition (iii) tourism and recreation, and (iv) archaeology and historical values. Since the first life value is related directly with the people who has to be evacuated and resettled, they were given the first priority. Alteration of public health, recreation, archaeological and historical caused by the project can also be a significant environmental complication.

2. SOCIO-ECONOMIC AND RESETTLEMENT ISSUES

2.1 Introduction

The overall objective of the study is to identify the socio-economic impact owing to the significant changes occurred after the project implementation. The study has focussed on the resettlement and irrigation areas. In the resettlement area, emphasis has been given to the quality of life of the farmers before and after moving into the resettlement area and also to the means to improve the quality of life of farmers living in the resettlement area. In the irrigation area, other comparative analysis of farm enterprises between irrigated and non-irrigated farm groups is evaluated in order to identify benefits from irrigation. Meanwhile, the problems confronting the farmers were also investigated. Moreover, socio-economic structure of the people in the river basin was also investigated to understand the overall structure of the people living in the area. This was done by analysing the village profile.

The results of the analysis are presented in three sections viz., (i) analysis of farm enterprises in the irrigated area vis-a-vis the non-irrigated area (ii) illustration of the quality of life of the farmers prior to and after resettlement and (iii) summarizing the socio-economic structure of village profile of the river basin using data from the survey of the Community Development Department.

2.2 Irrigation Project

2.2.1 General Characteristics of Farm Samples

In order to evaluate the benefits from irrigation, farmers from Bang Yai village and Tha Kham village were randomly selected and classified into two groups, namely the irrigated group which refers to farmers who have access to irrigation water, and non-irrigated group which refers to farmers who live in non-irritable irrigated areas at time of this study.

There are sixty farmers in the irrigated as well as in the non-irrigated farm group. There is no difference in the average age of the heads of the families who are in the mid-forty age group as shown in Table 7.1. However, the farmers in the non-irrigated group seem to have higher formal education, i.e., more than 60 percent of them received education at primary level.

The main occupations of farmers of both the groups are Para-rubber and paddy farming. Some farmers are also involved in growing fruit trees, trading, and some work as hired labour.

2.2.2 Housing and Other Facilities

Most of the farmers in the study area are the owner of lands and houses. However, 92 percent of them are reported to have proper lavatory facilities. Eighty-six percent of the farmers in the irrigated area and 90 percent in the non-irrigated area have access to electricity. Therefore a higher percentage of the farmers in the non-irrigated area are using electrical appliances as shown in Table 7.2

TABLE 7.1

GENERAL CHARACTERISTICS OF FARMERS IN THE STUDY AREA

Item	Irrigation	Non-irrigation
Number of Sample	60	60
Age (Head of family)	44	46
Education, %		
No formal education	26	15
1st – 4th grade	58	66
Higher than 4th grade	16	19
Household member, %		
Male	51	51
Female	49	49
Occupation :		
Main occupation, %		
Para-rubber	48	32
Paddy	30	26
Hired labour	6	7
Fruit tree	12	18
Trading	4	14
Other (e.g., fishing)	-	3
Second Occupation : %		
Para-rubber	28	34
Paddy	36	32
Hired labour	7	12
Fruit tree	10	8
Trading	9	4
Others	8	10

Source : Community Development Department and survey data.

TABLE 7.2

HOUSE AND OTHER FACILITIES

Item	Irrigation	Non-irrigation
Access to owned land and house, %	94	96
Access to lavatory, %	92	94
Access to electricity, %	86	90
Access to electrical appliances, %		
Television	75	78
Radio	100	100
Refrigerator	22	31
Electric fan	60	68
Pump	20	40
Others (e.g., cooker)	50	62

Source : Survey data

2.2.3 Land Tenure and Land Utilization

As mentioned earlier, most farmers have their owned land. However, due to smaller farm size, especially in the irrigated area, some farmers rented additional land or farmed in relatives land without paying rent. The average cultivated area in the irrigated area is 12 rais, while those in the non-irrigated area is 16 rais per household. Rented land in the irrigated farm group accounted for nearly 10 percent of the total cultivated land. About 20 percent of the cultivated area in this group are outside the irrigated area.

Paddy is the most important crop in irrigated farm group sharing 51 percent of the cultivated area in wet season, and rubber which shares 36 percent of the area. In non-irrigated farm group, on the contrary, area planted to rubber is 56 percent while only 25 percent are paddy land. It is surprising that only 51 percent of the farmers in irrigated area reported using irrigation water. In dry season, very few farmers grew paddy.

2.2.4 Production and Distribution of Farm Products

In both irrigated and non-irrigated areas, paddy is grown mainly for sale. The average product per grower in irrigated area was 2,100 kg, of which 750 kg was sold at the average price of 4.5 baths per kg as shown in Table 7.3. It can be observed that paddy is a cash crop in the study area. Therefore, there is incentive to grow it in the dry season despite the government effort to promote high yielding rice variety as the second crop. Moreover, there is more opportunity to work in rubber plantation. Hence, effective utilization of irrigation water in dry season is accomplished.

2.2.5 Cost and Return per Hectare of Paddy

Table 7.4 illustrates cost and return per hectare of paddy cultivation in wet season of both irrigated and non-irrigated areas. Cost of production is divided into cash cost and non-cash cost, which includes cost of unpaid family labor and owned inputs. There was no significant difference in the cost of production between irrigated and non-irrigated areas. A slightly higher cost of production in the irrigated area was mainly due to more fertilizer application and harvesting cost. Yield per ha, in the irrigated area was 1,250 kg, 250 kg higher than in the non-irrigated area. The average selling price was also higher at 4.50 bahts per kg. Due to relatively low yield and high cost of production, the non-irrigation area show negative (-190 baht) net return. However it only cash cost is considered, net return over cash cost was 4,850 bahts per ha, in the non-irrigated area, and 5,445 bahts per ha, in the irrigated area.

Cost and return of paddy in dry season is shown in Table 7.5. Due to unusual low yield at 112 kg per ha, net return over cash cost was only 3,640 bahts per ha.

2.2.6 Family Income and Expenditure

Gross family income is shown in Table 7.6 Para-rubber is the major income of farmers in both the areas. For those who do not grow rubber, working in rubber plantation also provides reasonable income. The overall gross income per family was 50,300 bahts in the irrigated area and 77,200 bahts in the non-irrigated area. This higher income in the non-irrigated area is partly due to larger land holding. Annual household expenditure classified by type of expenditure is illustrated in Table 7.7. Food was the major item expense in both the areas, (37.5 percent of the total expenditure). It was followed by expenditure on education of family members, (26.96 percent and 25.51 percent respectively) in the irrigated and the non-irrigated areas.

2.2.7 Indebtedness of Farmers and Source of Credit

Indebtedness of farmers reveals the standard of living and the opportunity to invest. It was found that 24 percent of the farmers in the irrigated area borrowed money from different sources. The major source of credit was neighbour, sharing of 50 percent of those who reported indebtedness in the irrigated area and 40 percent in the non-irrigated area as is shown in Table 7.8. The average loan was 4,500 bahts and 12,200 bahts per borrower in the irrigated and the non-irrigated are respectively. This loan, however, was not totally for farming purpose. About 38 and 40 percent of the borrowers reported that borrowing was for household consumption.

2.2.8 Flood Damages before and after the Construction of Dam

Percentage of farmers in the irrigated area who reported damages by floods increased from 77 percent to 81 percent after the dam construction. This was, according to the farmers, due to the blockages of flow during irrigation canal construction. However, flooded area declined from 40 to 31 percent of the total area, and the damage cost decreased from 482 to 344 bahts per household.

In the non-irrigated area, construction of the dam reduced the damage area from 43 to 35.7 percent of the total area, and the damage cost decreased from 571 to 232 bahts per household. Therefore, it can be concluded that the construction of the dam has positive effect in reducing flood problem.

TABLE 7.3

PRODUCTION AND DISTRIBUTION OF FARM PRODUCTS

Crops	Area planted per grower ha	Total product per Grower Kg	Distribution of product		Other	Ave. sale Price baht/ kg
			Sold	Home Consumption kg		
Irrigation Area						
Wet season 1996/97						
Paddy	1.2	2,100	750	1,200	150	4.5
Rubber	1.1	1,440	1,440	-	-	21
Dry season 1997						
Paddy	0.8	900	550	300	50	4.5
Non-irrigation Area						
Wet season 1996/97						
Paddy	1.0	1,500	-	1,500	-	4.5
Rubber	5	4,000	4,000	-	-	21

Source : Royal Irrigation Department.

TABLE 7.4

COST AND RETURN PER HECTARE OF PADDY IN 1996/1997

Unit in baht

Activities	Irrigation				Non-irrigation			
	Cash	**Non cash**	**Total**	**%**	**Cash**	**Non cash**	**Total**	**%**
Land preparation	1,120	430	1,550	21.40	1,050	480	1,530	22.04
Seed	-	180	180	2.48	-	250	250	3.60
Planting	-	1,750	1,750	24.10	-	1,600	1,600	23.05
Fertilizer and fertilizer application	810	120	930	12.80	750	160	910	13.11
Weeding, insecticide and insecticide application	20	50	70	0.96	50	80	130	1.87
Harvesting and transport	480	2,300	2,780	38.28	320	2,200	2,520	36.33
Total variable cost	2,430	4,830	7,260	100	2,170	4,770	6,940	100
Cost per kg	1.38	2.76	4.14		1.44	3.18	4.62	
Yield Per ha			1,750				1500	
Price per kg			4.5				4.5	
Gross return			7,875				6,750	
Net return			615				-190	
Net return over cash cost			5445				4580	

Source : Survey data

TABLE 7.5

COST AND RETURN PER HECTARE OF PADDY IN IRRIGATED AREA
DURING 1997

Unit in baht

Activities	Cash	Non-cash	Total	%
Land preparation	480	860	1340	22.64
Seed	-	150	150	2.53
Planting	-	1200	1200	20.27
Fertilizer and fertilizer application	780	30	810	13.68
Weeding, insecticide and insecticide application	160	60	220	3.72
Harvesting and transport	-	2200	2200	37.16
Total variable cost	1420	4500	5920	100
Cost per kg	1.26	4.0	5.26	
Yield per ha			1125	
Price per kg			4.5	
Gross return			5062	
Net return			-858	
Net return over cash cost			3642	

Source : Survey data.

TABLE 7.6

FAMILY INCOME CLASSIFIED BY SOURCES OF INCOME

Sources of income	**Irrigated**		**Non- Irrigated**	
	No. of Household	**Ave. income Baht/year**	**No. of household**	**Ave. income Baht/year**
Paddy	47	5,850	28	4,500
Para-rubber	34	30,240	32	84,000
Fruit tree	26	18,600	18	15,800
General merchant	3	72,000	4	75,000
Hired labour (rubber tapping)	29	12,600	20	12,800
Hired labour (other farm and non-farm work)	28	14,400	16	14,600
Average income per Household	50	**50,300**	50	**77,200**

Source : Survey data.

TABLE 7.7

HOUSEHOLD EXPENDITURE IN IRRIGATED AND NON-IRRIGATED AREA

Type of Expenditure	Irrigated		Non-irrigated	
	Baht/year	%	Baht/year	%
Food	18,000	40.40	21,000	35.72
Clothing	2,000	4.40	2,500	4.85
Medical care	100	3.30	2,000	3.40
Travel expense	3,000	6.70	3,100	6.12
Recreation	1,200	2.60	1,500	2.55
Tuition	12,000	26.96	15,000	25.51
Electricity	1,800	40.00	2,000	3.40
Religious & donation	1,000	2.00	1,200	2.04
Others	5,000	11.20	10,000	17.00
Total	**44,500**	**100**	**58,800**	**100**

Source : Survey data.

TABLE 7.8

INDEBTEDNESS OF FARMS AND SOURCES OF CREDIT

Item	Irrigated	Non-irrigated
Percentage of farmers with debt	24	12
Average loan per borrower, baht	4,500	1,200
Source of credit, %		
Neighbour	35	30
Relative	50	42
BAAC	15	28
Objective of borrowing, %		
Purchasing of land	12	8
Farming activities	40	50
Household consumption	38	42

Source : Survey data.

2.3 Resettlement Area

2.3.1 Scope and Methodology

Field survey was conducted in the resettlements. Sample farms were randomly selected from the two locations. Number of samples is approximately 25 percent of the total households who actually resided in the area at the time of this survey, including 80 farmers who were head of the families. There are no differences in general characteristics between farm samples from different settlements. All farmers in the resettlement area are Buddhists.

2.3.2 Land Ownership and Animals

Before joining the resettlement programme, the farmers reported having an average of 25 rais per household of Para-rubber plantation. At present, farmers in Ban Pattana (Pattana village) are allocated 19 rais of Para-rubber per household. However, most farmers also maintain Para-rubber plantation outside the resettlement area at an average of 10 rais per household.

3.3.3 Household Income and Expenditure

Para-rubber was the major source of household income 74 percent prior to joining the resettlement program, this can be seen from Table 7.9. At present, share of income from para-rubber declined because of immaturity of Para-rubber plantation. However, income from fishery has increased drastically for farmers living in the resettlement area. On the average, household income declined after moving into the resettlement area. Table 7.10 illustrates annual expenditure of farmers in the two locations by types of expenditure. Food was the major type of expenditure sharing more than 50 percent of the total expenditure.

TABLE 7.9

AVERAGE ANNUAL HOUSE INCOME BEFORE AND AFTER RESETTLED

Source of income	Before resettled	%	After resettled	%
Para-Rubber	24,800	74.35	36,400	67.14
Fishery	1,680	4.32	6,800	12.54
Para-rubber tapping	2,800	8.05	4,250	7.38
Hired	4,450	13.28	6,760	12.48
Average	**33,730**	**100**	**54,210**	**100**

Source : Survey data.

TABLE 7.10

AVERAGE ANNUAL HOUSEHOLD EXPENDITURE IN 1996/1997

Expense	Baht	% of the total
Food	16,000	50.31
Clothing	1,800	5.66
Medical Care	1,600	5.03
Education	10,000	31.45
Recreation	1,000	3.14
Religious & donation	800	2.51
Electricity	600	1.88
Average	**31,800**	**100**

Source : Survey data.

2.3.4 Household Assets

Values of house and other properties, excluding land, were estimated in order to value household assets as shown in Table 7.11.

2.3.5 Saving and Indebtedness

Apart from income and expenses, farmers were also asked whether they have any saving. It was found that 58 percentage of farmers can save in such location. Farmers in Ban Pattana prefer to save their money by keeping cash or gold at home. However, about 30 percent of those who can save reported depositing money in the bank. More than 10 percent are keeping in the form of land and others.

The percentage of farmers with debt were quite similar in all locations at around 30 percent of farm sample. Values of loan per borrower in Ban Pattana averaged between 1,000 to 5,000 bahts. Nearly half of the borrowers used the money for household consumption and neighbors were the most common source of credit. Some of the farmers borrowed money from relatives, Bank of Agriculture and Agricultural Cooperative (BAAC), and merchants.

2.3.6 Standard of Living before and after Resettlement

Farmers were asked to compare their ways of life in various aspects during the periods before and after moving to the resettlement areas. There is no significant difference in the responses to the questions. Majority of farmers reported better housing, better public utility and security. A bout half of the farmers reported better standard of living, 8 percent reported no change, and 2 percent worse, than before. However, on an average, around 5 percent of the farmers wanted to migrate from the resettlement area, especially farmers having insufficient farm land and less opportunity to earn a living.

TABLE 7.11

HOUSEHOLD ASSETS AND ELECTRICAL APPLIANCES

Unit : In Baht/Household

Properties	**Values (Baht)**	**% of The Total**
House	96,000	61.85
Car	15,600	10.05
Motor cycle	24,000	15.46
Boat	6,000	3.87
Radio	4000	2.58
Television	4,500	2.89
Refrigeration	4,200	2.70
Sewing machine	450	0.29
Electric cooker	360	0.23
Electric fan	180	0.12
Average	**155,210**	**100**

Source : Survey data.

2.4 Village Profile in the Phum Duang River Basin

The overall objective of this section is to describe the socio-economic structure of household in the basin. Data and information used in the analysis were obtained from the survey of the Community Development Department, covering 268 villages in the rural areas of the basin. Results of the analysis are used as basic information for the environmental development planning.

The Phum Duang river basin covers an area of about 4,668 km^2 in Surat Thani. The area can primarily be divided into upstream and downstream areas. Upstream area refers to the area upstream of Rajjaprabha dam which includes the reservoir area and the resettlement area. This upstream area accounts for nearly half of the basin. The downstream area, however, varies in both physical and socio-economic conditions. The Phase I irrigation project in Amphoe Phun Phin presently under construction is planned to develop about 23,100 ha of paddy land. And another 50,000 ha has also been planned for Phase II irrigation development. Therefore, to reflect these different basin geographical features and specific urban characters of Muang district and Phun Phin district the village profile has been segmented into 6 different zones (Figure 7.1) as follows.

Sub basin I	Khlong Saeng Sub basin Area.
Sub basin II	Khlong Sok Sub basin Area.
Sub basin III	Downstream Area Outside Irrigation Area.
Sub basin IV	Khlong Yan Sub basin Area.
Sub basin V	Irrigation Area.
Sub basin VI	Coastal and Urban Area

Socio-economic structure of each individual sub-basin is described in the following sections.

(1) Sub basin 1 : Upper Catchments Area

Sub basin 1 consists of 3,505 households in 29 villages, excluding the urban area of Ban Ta Khun district. The total area covers about 1,435 km^2, of which 78 percent is forest area and 3.35 percent is rubber plantation. The population of this sub basin is 1,2318 persons with a population density of 6.1 persons per km^2, and a growth rate of 0.05 percent annually.

Since rubber area covers 3.35 percent of the total area, 90 percent of the households are involved in rubber plantation as rubber is the main source of income, averaging 36,000 bahts per household annually. Fisheries are also another source of income for households living near the reservoir. Almost all villages in this zone receive health volunteer services. However, nearly half of the villages showed high incident of malaria.

(2) Sub basin II : Khlong Sok Sub basin

Sub basin II covers villages in Pha Nom district. There are 5,405 households in 53 villages. The total area covers about 1,211 km^2. The population in this sub basin is 27,330 with a population density of 22.5 persons per km^2, and a growth rate of 0.57 percent per year.

Ninety percent of the households in this sub basin earn their income from rubber, with an average of 21,000 bahts per household. Thirty-five percent of the households also earn their incomes from fruit crops and field crops. It was reported that 86 percent of the households farmed in their own land. Health conditions of households in Zone 2 are the poorest among the different zones. Almost all villages in this zone show high incidence of malaria both in children and adults.

(3) Sub basin III : Downstream Area Outside Irrigation Area

Sub basin III covers the basin area located downstream from Rajjaprabha dam and upstream from the Phase I and II of irrigation projects. It covers Khirirattha Nikhom district with a total area of about 314 km^2. The total population is about 20,114 persons, with a population density of 61.1 persons per km^2. Population growth in this downstream area is higher than the upstream areas, about 0.42 percent per year.

Even though paddy land shares only 7 percent of the total area, 29 percent of the households grow rice mainly for their own consumption. Rubber is the important source of income, contributing to about 70 percent of the households of this sub basin while another 25 percent of the total households earn their incomes from fruit crops. Eighty two percent of the farmers in this sub basin farmed in their own land, and 83 percent of the villages also reported having farmers associations. Health problem in this downstream area is less serious than those in the upstream area since less than 15 percent of the villages reported having incidence of malaria.

(4) Sub basin IV : Khlong Yan Sub basin Area

Sub-basin IV covers about 1,178 km^2 with a population of about 16,200 persons. There are 33 villages with the largest number of households (3,508). About 80 percent of this area are covered with forest, and 15 percent is rubber plantation. The population density is at 13.7 persons per km^2, with a population growth of 1.01 percent per annum. Only small number of households receive income from other cash crops, such as fruit trees. Standard of living of households in this sub basin is not much different from those located outside the area.

(5) Sub basin V : Irrigation Area

Sub-basin V is the proposed Phase I irrigation area in Phun Phin district and Muang district of Surat Thani province. It covers about 350 km^2 and 94 villages. Fifty five percent of the area is rubber plantation and 38 percent paddy land. There are about 63,052 persons living in the area, with a population density of 119 persons per km^2. Population growth rate is the highest in all sub-basins (1.26 per annum). Since it is close to the urban area, public utility and health service are better than the other areas. It was found that 96 percent of the villages have electricity and almost all the villages have health volunteers.

Rice is the major crop in the area. Eighty-two percent of the households engage in paddy cultivation. Rice and rubber is the main cash crops of 67 percent of the total households with an average income of about 68,000 bahts per year. Households in some areas also earn additional income from fruit crops. Due to better public utility, this zone has less health problem, especially concerning malaria.

(6) Sub basin VI : Coastal and Urban Area

Sub-basin VI covers a large portion of the coastal area. The total area of this zone is 298 km^2 with a population of about 74,600 persons. Nearly 60 percent of the population is involved in paddy cultivation. Field crops and fruit crops are important sources of income (72,400 bahts per household). In addition to farming, people living along the coast also earn their living from fisheries and coastal aquaculture.

2.5 Conclusion

General characteristics of various parts of the project area as well as socio-economic structure of households in the basin are considerably different. For the upper catchment area where most of the area is covered with forest and rubber plantation, the development should be considered the appropriate allocation of land between forest and rubber plantation. In the reservoir and resettlement area where rubber and fisheries are two important sources of income, the development should gear toward the improvement in quality of life of the residents by providing better living conditions as well as occupation opportunity.

Downstream areas consist of irrigation area, non-irrigation area, coastal area, and urban areas. The irrigation areas, though yet to be completed, has good potential paddy production, while outside the irrigation area rubber is the main source of income. In the coastal area, on the contrary, aquaculture promotion should be emphasized. The urban areas of Surat Thani are the concentration of commerce and industries with high population density. They both are the major demand centers for water supply, and the main sources of water pollution. The development of urban areas should take into account the impact caused by water pollution in the coastal area, so that the environmental condition of the coastal area can be maintained.

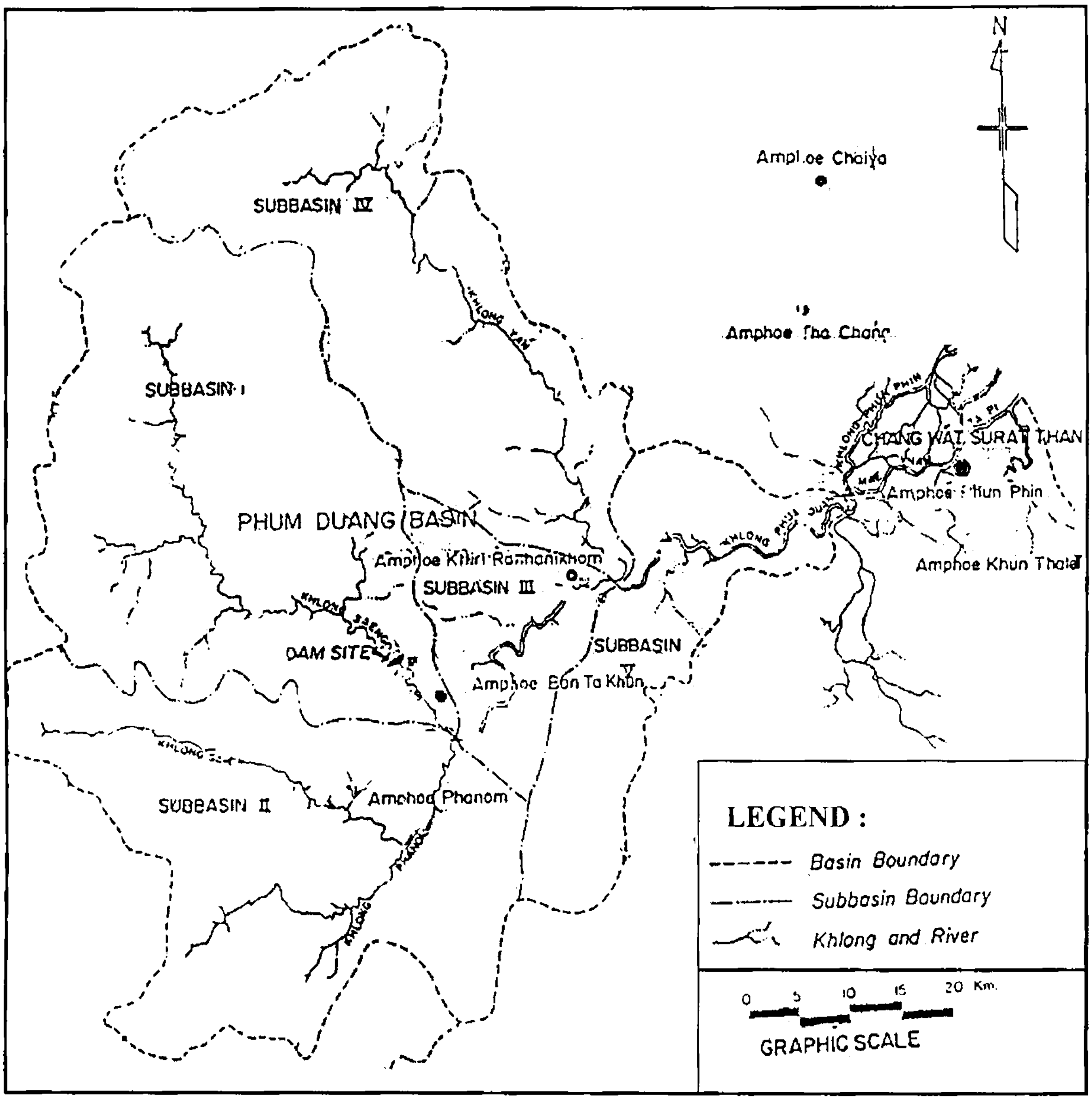


FIGURE 7.1

SUP-BASIN IN THE PHUM DUANG RIVER BASIN

3. PUBLIC HEALTH AND NUTRITION

3.1 Introduction

These development projects are undertaken in order to improve the economic situation of the country as a whole, and of the population in the project vicinity in particular. Although the overall economic situation may be favorably influenced by the water resources development, the immediate effects on health and well being of population groups in the neighbourhood of dams and reservoirs need to be assessed. Environmental changes usually accompany the creation of artificial lakes, which may provide favourable environment for the survival of great number of intermediate hosts, such as snails, and mosquitoes that transmit diseases such as malaria, elephantiasis, schistosomiasis.

3.2 Objectives

The objectives of this study aspect include:

(a) To study the health and nutrition profiles including the parasitic infection, sanitation and quality of drinking water of the people in the resettlement areas.

(b) To assess the endemic vector-borne diseases and intermediate host created from the reservoir; and

To fulfil these objectives various study aspects are carried out including health and nutrition status, parasitic infection, malacology, malaria, and drinking water quality.

3.3 Methodology

This investigation has been carried out using the following methods of data collection.

(a) Health and nutrition data were collected by questionnaire enumeration and from interviews with responsible staff members related to health centres;

(b) The data about : (i) nutritional status of preschool children from birth up to 60 months old, (ii) Parasitic infections rates of intestinal helminthes and trematode, (iii) malaria and (iv) logic of freshwater snails and clams, were obtained from medical and health division of the EGAT 's reports.

(c) Water samples from sources of water consumption of the majority of villages were examined for their physical, chemical and bacteriological properties according to the Standard Methods.

3.4 Study Area and Population

The resettlement villages are considered to be more influenced by the Rajjaprabha dam. Residents in this village is referred to in this study as the "study group". Another village called Ban Khao Sok is also located near the dam site in Pha Nom district, but it is not influenced by the dam and reservoir, hence regarded as the "control area" in this study.

3.5 Health and Nutritional Status of the Villagers

In assessing the health and nutritional status emphasis was made on the most vulnerable groups in the community, which included pregnant and lactating women, newborn infants and preschool children up to 60 months of age. Adverse effects on health and nutrition are normally recognized in these groups first.

3.5.1 Mother and Child Health

The number of newborns in the 2 villages under investigation within the past 12 months had been assessed through questionnaires. From the total population 7 babies or 5.5 percent of population had been born in the last 12 month. The age of the mothers ranged from 17 to 38 years. The number of boys born were in excess of girls with a ratio of 1.75 : 1.58.

At the time the questionnaires were completed, only 5 women were pregnant in the 2 villages. Judging from this small number of current pregnancies, attendance of prenatal care was poor because only 3 of the women made use of this service, either in the hospital, health station, or mother and child health (MGH) center. The other two were either afraid, or claimed that they did not like to use such services.

Only one infant death was reported in Khao Sok village, during the least 12 months. There was no death in other villages. The death in Khao Sok village was due to acute and preventable infectious diseases such as diphtheria, tetanus and measles.

3.5.2 MCH Care in the Health Station

In order to get a better picture about family health, particularly of women and their children, information was collected from those mothers who had children of 0 to 5 years. Information collected indicated that all deliveries which took place at the health stations were without complications. This may be due to the fact that only those women who did not expect any complication incident while giving birth delivered at the health stations. According to the responses of the mothers, majority of birth attendants in the health station were traditional midwives. There was only one qualified midwife in the health station.

Weight at birth is an indicator of the nutritional status of women in the child bearing age. Records were incomplete on this aspect particularly for the control village at Ban Khao Sok. Information collected show that 50 percent of the parents adopted family planning. The reasons for not adopting family planning were religious belief, and uncertainty on safety. Some of the villagers simply did not want to practice it because they wanted to have more children.

3.5.4 Nutrition

A semi-quantitative survey was undertaken in order to find out the dietary pattern of the population. The staple food of all villages under investigation was rice. Milk vegetable oil and lard were used to a great extent for cooking purpose. Generally green-leaf vegetable was very popular in the whole study area, whereas fresh fruits were not commonly consumed on a daily basis. Kinds of supplementary food include rice, banana, egg, chicken, fish, milk and sweetened condensed milk. It appeared that supplementation was inadequate as it was started too early. In the majority of investigated cases supplementary feeding started at the age range between 1 to 4 months, when it should actually start after 4 months. On the other hand, the children who were weaned too late were observed during pregnancy by approximately 20 percent of the women questioned. Between 50 percent to 90 percent of all women questioned observed some food taboos in the lactating period. The reason for observing food taboos during pregnancy was the belief that eating certain kind of food will result in omitting, morning sickness, and even abortions. Reasons for avoiding certain food stuffs in the lactating period were fears such that the wound healing would be impaired, the muscle might ache, the construction of the uterus might not take place or this organ might be infected, the edema might occur or it might cause stomach-ache. Sometimes special reasons could not be given, only a general fear towards certain food staffs was expressed, or it was claimed that the midwife did advice to restrict certain food items.

The nutritional status of preschool children judged from anthropometric measurement seems to be quite good. Based on the Gomez classification (WHO. 1976), and a Thai standard, abnormal nutritional status was found only in Khao Sok village where 11percent of the preschool children were underweight of the second and third degree. About 9 to 12 percent of the school children in the resettlement villages were found to be malnourished. This is better than the condition in the control village of Khao Sok village in which about 14 percent were malnourished. However it should be kept in mind that quite a number of children are rather short, so the weight seems to be appropriate to their height.

When judging the overall nutritional status of all preschool children according to the SD scores in comparison with the North American standard, (W. Keller, WHO Bulletin 1977) it appears that the weights of the children fairly relate to their heights in the resettlement village.

3.5.5. Utilization of Health Stations

The overwhelming majority of the villagers used the service of health stations. The most common reason for this was to purchase medicine when they had fever. In quite a number of cases the visits to health stations were for the treatments of malaria and gastrointestinal infection.

3.5.6 Morbidity

About 75 percent to 80 percent of the interviewed samples in the villages claimed to have been sick during the previous 12 months period. Almost all cases were infectious diseases. Malaria was quite prevalent in the area, ranging from 20 to 45 percent of all cases reported by the two villages. About 30 to 40 percent of the villagers were sick because of common cold. Approximately 20 percent of the cases, patients suffered from ill-defined diseases claimed as fever.

3.6 Study on Parasitic Infection

Data were obtained from EGAT. The results shown indicate rather high prevalence of parasitic infection in all investigated villages, with the highest prevalence in the control village at Khao Sok village, the detail of protozoa and helminthic infections as follows.

3.6.1 Protozoal Infection

The prevalence of Entamaeba coli, Entamaeba histolytica, Giardia lamblia in the two investigated villages were about 6 to 12 and 2 to 7 percent in Khao Sok village and Pattana village respectively. Entamaea coli, Entamaeba histolytica and Giardia lamblia were the main protozoas prevalent in all villages, indicating contamination of food and drinking water. These parasites cause dysentery and/or diarrhea.

3.6.2 Helminthic Infection

The prevalence of hookworm, Ascasis lumbricoides and Trichuris triciura in the two investigated villages were about 20 to 43 percent and 5 to 36 percent is Khao Sok village and Pattana village respectively. Helminthic parasites in the investigated area are soil-transmitted helmiths (Hookworm, As. Lumbricoides, T. trichiura). Hookworms can enter human body through larva penetration through the skin. Hookworm eggs are excreted in feces, and under favourable conditions the eggs will develop into infective larvae within one week. They can survive for many months in the soil. Men get infection from eating food and vegetables contaminated by the eggs, and unhygienic personal habits.

The investigated villages are therefore endemic for soil-transmitted helminths and protozoa due to poor environmental sanitation and lack of personal hygiene.

3.7 Malacological Study

There were reports of widespread snail intermediate host (Bithnia Snail), and of Thai liver-fluke (Opisthorchiasis) after reservoirs were created, especially in the northern and north-eastern part of the country due to bad habit eating raw fishes.

In the resettlement areas, many samples of clay and silt from the bottom of reservoir and waterways were examined. But nowhere water snail was found. This result was confirmed by parasitic survey in the resettlement areas and the control area of Khao Sok village. Again no case of liver-fluke in the fecal samples was found.

3.8 Malaria Study

Evaluation of each year activity for the whole country at the end of 1995 revealed that malaria death rate was only 2.4 per 100,000 persons. Annual parasitic incidence was 6.3 and the Slide Positive Rate (SPR) or percentage of positive cases as examined from blood smears (Ministry of Public Health, 1995) was 4.6. But the malaria situation in Surat Thani province from 1990 to 1995 was similar from that of the whole country. It was found that in the beginning of 1995 the slide negative rate at Pattana village was quite low, and dropped after May. The 6 month SPR value of Pattana village of about 8 percent was much lower than the value of about 9 percent experienced in Ban Ta Khun district (during the same 6 months period in 1995). By this evidence, it could be said that there was low malaria infection rate in Pattana village. At the time of peak infection rate residual insecticidal spraying team was called from the Malarial Control Sector in Surat Thani to spray in the houses around the villages. So the case dropped out in the following months.

The SPR value of Pattana village was about 15 percent in 1995. However, the monthly distribution of the SPR reveals higher rates only in August and September 1995. At Khao Sok village, it was found that slide positive rate was about 18 percent in 1995. The parasitemia had more or less the same pattern as Pattana village i.e. the parasite was found in August, September and October. While slide positive rate at Khao Sok village was about 5 percent only, the parasitemia was found in March, April and May, which had the same pattern as Ban Pattana.

3.9 Drinking Water Quality

Six samples of drinking water were collected from the resettlement area: three samples each from Pattana village, and Khao Sok village. It was found that all samples of drinking water were rain water. The water supply provided by EGAT is runoff from the mountain which is stored in a reservoir. It is distributed without any treatment. The quality parameters of water such as hardness, chloride, and iron are within the standard of drinking water. The physical quality parameters such as color and turbidity are very high, depending on the seasons.

Most of the water samples contain high alkalinity, which is not suitable for drinking. It causes irritation and itching. The residents of Khao Sok village (control area) complained about itching when they take bath. Coliform bacteria is used as an indicator of water contamination. The results show that most of the drinking water samples in these two areas have higher bacteria content than the standard. It means that water is not safe for drinking,. However the quality of the drinking water can be improved by filtration and boiling.

3.10 Comparative Evaluation

An attempt is made to assess the change in public health status of the people living in the study area. This is done by comparing the results of the pre-impoundment study with those found in this study. Although the results are not, in a strict sense, comparable due to differences in the methods of data collection and in the studied population, they are compared for qualitative interpretation.

(a) Malaria situation in the study area has improved, although the values of annual parasitic incidence (API) found are not much different. This is largely because of the fact that many incidences were not reported in 1985 due to poor accessibility at that time.

Parameters	**Pre-impoundment Study**	**Post-impoundment Study**	**Qualitative Change**
Malaria:			Better
API	30,5/1000 (in 1985)	23.3/1000 (in 1995)	
Parasite	P.f. > P.v.	P.f. > P. v.	Same
Intestinal parasitic	5.5/1000	90/1000	Not
comparable			
Medical service usage	70.8%	97.6%	Better
Mother and child health:			Better
Completed vaccination	50.7%	60.8%	
Family planning	14.9%	16.5%	
Nutritional status :			Same
Milk consumption	42.5%	20.3%	
Green-leave vegetable			
consumption	92.3%	91.9%	

(b) Intestinal parasitic evidence is judged to be not comparable between the two studies, although the stool examination in this study shows a much higher parasitic infection rate. The very low rate of 5.5/1000 or 0.55% reported in the pre-impoundment study seems unrealistically low for such a developing country as Thailand.

(c) Medical services and the mother and child health are better during this post-impoundment period mainly due to the increased number of related facilities, and the improvement in accessibility to the rural villages. Nutritional status was judged to be the same during both periods, or slightly better after the impoundment.

4. TOURISM, RECREATION AND AESTHETICS

4.1 Introduction

The national tourism policy is to spread the benefits of tourism throughout the country. The development and promotion of Rajjaprabha dam and the surrounding area as tourist destinations can play a part in spreading the benefits of tourism to the people of Surat Thani province.

4.2 Objectives

The objectives of this study are firstly to reassess the tourist and recreational potential of the dam after its construction, and to suggest how the dam might be promoted as a tourism resource ; secondly to reassess the impact of dam on the aesthetic quality of the environment; thirdly to reassess basic data on tourism so as to make a sound estimate of the benefits from tourism in monetary terms.

4.3 Scope of Study

The study covered tourism resources (including aesthetics), tourist services and marketing. Although the study area covers the Phum Duang river basin in Surat Thani province, the study was concentrated on the Rajjaprabha dam. Tourism development was studied to some extent at the regional and provincial levels but this was mainly to establish the context for a more detailed study of the dam.

4.4 Methodology

The methods used in this study includes :

(a) Desk studies of secondary data;

(b) Questionnaire survey of visitors to the dam;

(c) Informal interviews with key personnel'

(d) Field study of tourism resources and services; and

(e) Travel cost approach to estimate the benefits of the dam in monetary terms.

Further details of the methods used are presented in later sections of this report.

4.5 Regional Tourism Context

In assessing; the regional context of tourism we can immediately identify a triangle whose points are locations of relatively intense tourism activity, i.e., Krabi, Phang-nga, Phuket, Surat Thani, Ko Samui, Nakhon Si Thammarat. These resorts attract international visitors as well as visitors from Bangkok and other parts of Thailand. Moreover all of them are still undergoing rapid development and are being vigorously promoted by the Tourism Authority of Thailand (TAT). They have much more diverse and attractive scenery than Rajjaprabha dam as well as a higher level of services and wider range of available activities.

4.6 Provincial Tourism Context

4.6.1 Provincial Tourist Attractions

Tourist attractions in Surat Thani province which used to be the land of ancient civilization some 1,200 years of age, with its center being situated around the area nowadays known as Chaiya district. Many valuable and well known arts have been preserved as the evidence of the old civilization. Besides, some religious assets of newer historic periods and several attractions exist in this province. These interesting sites are shown in Figure 7.2 a brif description of which is given below.

(1) Historical and Religious Assets

Phra Borommathad Chaiya : Phra Borommathad Chaiya is regarded as the most important pagoda in the south. It is situated in the vicinity of Wat Phra Thad Chaiya about 1 km from the district's railway station. The pagoda is of prime importance and highly revered by Surat Thani people as well as the southern citizens. The pagoda is said to contain a piece of the holy Bone of the Lord Buddha, and was built during the "Sri Vichai period" which was more than 1,200 years old. The artistical construction patterns are completely of the Sri Vichai Art which are relatively rare and valuable at the present time.

Wat Tham Singkhon : Wat Tham Singkhon is located in Khirirattha Nikhom district approximately 35 km downstream from the proposed damsite. The temple was built hundreds of years ago and, at present, serves as a center of religious reverence by local people. A cave is also present in the vicinity of this monastery.

Wat Khao Phra Anon and Wat Nam Rob These two temples are the ancient religious assets located in Phun Phin district. They are important monasteries and are the centers of respects of the people of this district.

Wat Wieng Sra : This old monastery, which is about 100 years old, is located in Wieng Sra district. In the vicinity of this district there exist some ancient remains and an old town surrounded by a canal, dug to protect the town from enemies' attacks. These remains are still present.

(2) Natural Attractions

Ko Samui Ko Samui is the largest island along the eastern shoreline of southern Thailand and is the third largest island of the country. Actually, the term "Ko Samui" represents groups of more than 80 small islands, located approximately 80 km off-shore the town of Surat Thani. It possesses a number of attractions comprising several waterfalls, beautiful beaches, other attractive scenaries and marine resorts. Ko Samui is one of the well known tourist places in the southern region and of the country. Recently, the highway department has been to construct a 80 Km long concrete pavement road around the island to facilitate transportation on the island and to boost tourism potential of the area.

Suan Mokkha Plaram : Suan Mokkha Plaram, locally called "Wat Tarn Nam Lai", is a religious institute located in a natural park of very beautiful, peaceful and pleasant surroundings. The park is highly suitable for Buddhists who want to study the Buddhist Teaching. There is a religious study hall and an exhibition hall where religious pictures are complied. Poems, and Lord Buddha's words are inscribed on the wall of the exhibition hall.

Phum Rieng Village : Phum Rieng village is located in Chaiya district. It is very famous in southern Thailand as a place, which produces hand woven silk cloths with different patterns and styles. These products are also available on sale in the town of Surat Thani under the trade mark "Pha Mai Phum Rieng"

Vana Uttayan Khao Tha Petch : Vana Uttayan Khao Tha Petch is a natural park located along the highway linking Muang district and Ban Na San district approximately 9 km from the provincial hall. The well-known Sri Surat Pagoda is present at this place. There also exists a hill in this natural park, and the beautiful scenery of Surat Thani town can be viewed from the hill top.

Ko Pha-Ngan Ko Pha-Ngan is another offshore island in Surat Thani province where the district office is situated. It is located to the north of Ko Samui and is surrounded by a number of small beautiful islands.

Beach in Don Sak District : This is a long and clean beach lying along the coastline of Surat Thani province. A very long line of coconut is existing along the beach with number of fishermen house scattered in line behind the coconut trees in the beach presents an attractive scenery.

Uttayan Nok Nam : Uttayan Nok Nam, or water birds park, is located in the vicinity of Khian Sa district. It consists of a pond where a great number of lotus plants are grown, and is surrounded by an area covered with large trees and rolling hills, which provide shade and peace to the area. There are thousands of water birds especially wild ducks feeding and living in this area, thereby creating an interesting scenery in the park.

Water falls : There exist some beautiful waterfalls in Surat Thani province of which the interesting sites are the following:

Na Muang and Hin Lad falls	in Ko Samui district
Paeng and Tarn Sadej falls	in Ko Pha-Ngan district
Viphavadee fall	in Don Sak district

Eleven-Storeyed Waterfall : A beautiful waterfall has recently been discovered by the National Park Division personnel of Royal Forest Department. It is located in Khlong Sok village of Pha Nom district about 45 km from Ban Ta Khun district along highway No.401, and is said to consist of 11 steps of falls. The waterfall and surrounding area had been in the process of proclamation as national park, and a plan has been set up by the National Park Division to construct an office near the water fall.

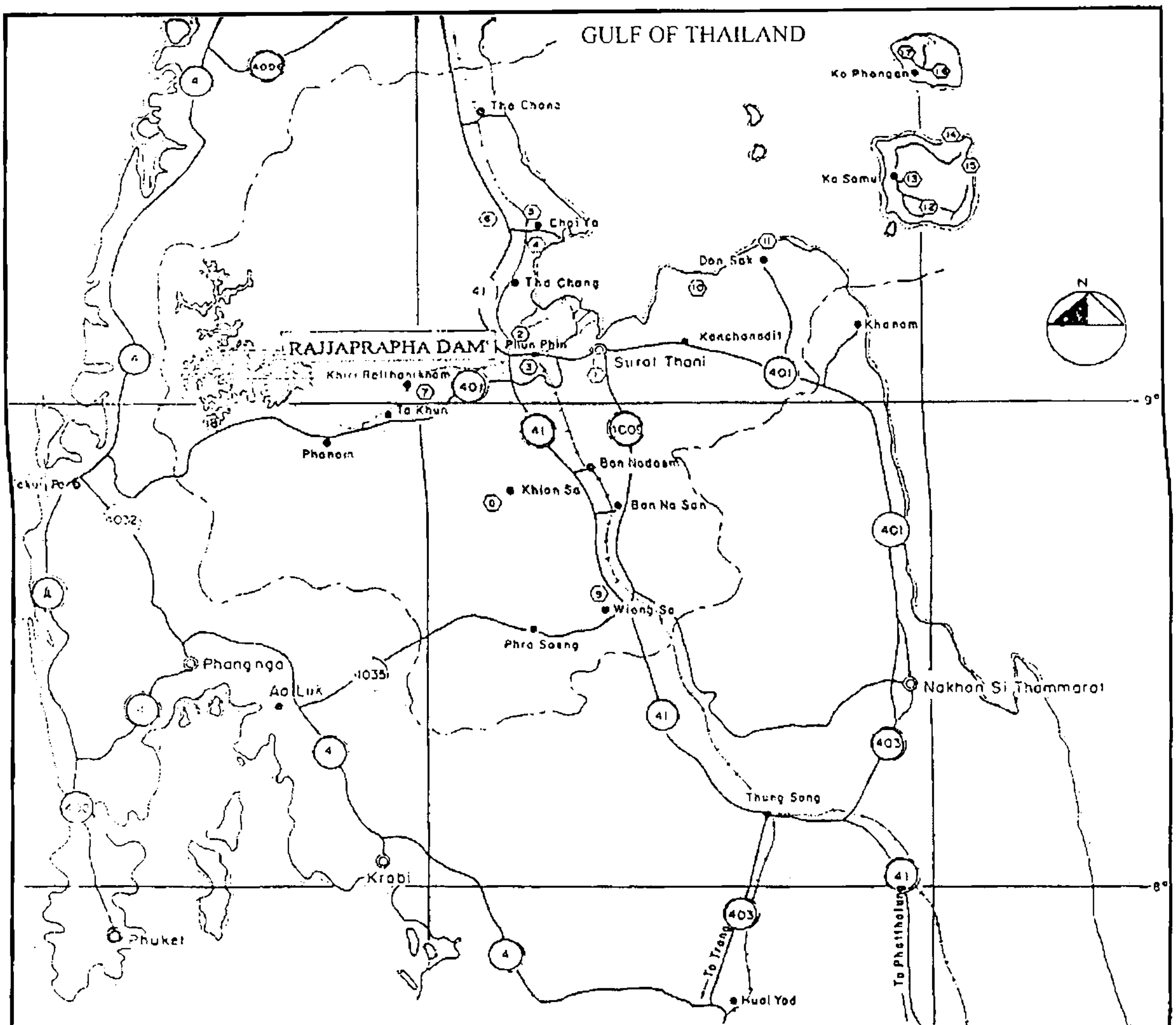
4.6.2 Service Sector of Surat Thani

Tourist Accommodation facilities in Surat Thani : Accommodation facilities are considered to be of prime importance which should be provided at a tourist place to boost tourism potential of the place. According to the records obtained from the Surat Thani provincial police station, such facilities, which are available in the province, at present are described below.

(a) First class Hotels : Ta Pi hotel and Wang Tai hotel are the existing tourist class hotel in the vicinity. It is located in Muang district and has total capacity of 618 rooms. Two hotels of the same class are under construction in the same district, and would contain 480 rooms in total.

(b) Second Class Hotels : According to the most up-to-date record, there exist 18 hotels which can be regarded as the second class hotels with 968 rooms. Majority of them are located in Muang district. Among these hotels, there are high quality hotels comparable to that of the first class hotels with a total capacity of 370 rooms.

In Ban Ta Khun district, where the proposed dam and reservoir will be located, no hotels or tourist accommodation facilities of any kind exist at present.



Remarks	Location	No.	Description
	Amphoe Muang Surat Thani	1	Vana Uttayan Khao Ta Pet
	Amphoe Phun Phin	2	Wat Nam Rob
		3	Wat Khao Phra Anont
	Amphoe Chai Ya	4	Suan Mokkha Plaram
		5	Phra Barom Thad Chaiya
		6	Phum Riang Village
	Amphoe Khiri Ratthanikhom	7	Wat Tham Singkhon
	Amphoe Khian Sa	8	Uttayan Nok Nom
	Amphoe Wiang Sa	9	Wat Waing Sa
	Amphoe Don Sak	10	Viphavadee Falls
		11	Don Sak Beach
		12	[illegible]
	Amphoe Ko Samui	13	Hin Lad Falls
		14	Ko Fan
		15	Chowe[illegible] Beach
	Amphoe Ko Phangan	16	Tharn Sadet Falls
		17	Paeng Falls
	Amphoe Phanom	18	[illegible] Storeyed Water fall

Legend:

- National Highways
- Railroad
- Tourist Sites
- Reservoir Boundary
- Amphoe (District)
- Changwat (Province)
- International Boundary
- Changwat Boundary

5 10 20 30 40 KM.
GRAPHIC SCALE

Source:

1. Base Map of 1:1,000,000 from Department of Highways as of 1979.
2. Tourism Authority of Thailand.

FIGURE 7.2

LOCATION OF TOURIST SITES IN SURAT THANI PROVINCE

4.6.3 Tourist Activities in Surat Thani

With respect to the tourist places mentioned in Sections 4.6.2 (1) and (2), the most important one is Ko Samui, which is visited both by national and foreign tourists. Another important site is Phra Borommathad Chaiya, which is toured mainly by domestic tourists and by small numbers of international tourists. No official records of tourist at these two sites are available, either at the TAT head office or at local government agencies.

With aspect to other tourist places in Surat Thani, visits by national and local tourists are the main tourism patterns. At present there is a plan to develop it as a major international tourist resort. No mention of these places are there in the tourist records..

According to data obtained form the Statistics Division of the TAT, hotel occupancy record are available only for 1997. The records show that the total number of visitors to Muang district in that year was 160,000 and that the monthly distribution was relatively uniform. Due to lack of a long record of data, future trends of tourist volumes to Surat Thani cannot be projected. According to the hotel records, majority of the visitors were businessmen, with small numbers of government officials and tourists whose actual destinations were Ko Samui and/or Chaiya district.

Southern Thailand is linked with the upper part by highway No.4 from Chumphorn downwards. This highway runs along the west coast, bypassing Surat Thani. There is a highway along the east coast, passing through Surat Thani, Nakhorn Si Thammarat and Songkhla/Hat Yai. Thus, both of them are equally important as far as tourism is concerned.

Surat Thani is linked with Phang-nga and Phuket by highway No. 401, but domestic and local tourists who want to travel from Surat Thani to these two western provinces seldom use this route because of security problems. Rather they make a trip to Songkhla first and then cut across to the western province via highway No. 4, normally by regular local buses.

4.7 Natural Attractions and Aesthetic Quality in Project Area

Existing natural setting along Khlong Saeng upstream of the damsite is quite beautiful. In the vicinity of the proposed project, there are a number of beautiful natural sceneries. A series of limestone and shale mountains exist along both banks of the stream, and most of them are covered with relatively dense evergreen forests. The mountains are of steep slopes, and precipitous cliffs are also present here and there, some of which extend upward from the stream banks. Forests on slope complexes and on tops of high mountains are still relatively virgin, due to difficult accessibility which makes forest clearing difficult at most of these places. The mountains and forests combine to form pleasant sceneries of the reservoir area, as shown.

On the left bank of Khlong Saeng, there exists the Khlong Saeng wildlife sanctuary which consists of rich tropical rain forests. The areas above the high water level of the reservoir also have pleasant natural aesthetic quality like the proposed reservoir. On the right bank, which is composed of logging concessions at present, the area will be converted to a forest reserve which would consist of a natural park. The remaining parts of the prospective forest reserve will lie along the western shoreline of the reservoir area, and the prospective natural park will be located near the reservoir shoreline. Parts of these areas have aesthetic values, similar to that of the reservoir areas.

Khlong Saeng itself possess enough natural beauty. It consists of several turns which presents interesting and pleasant views to new comers. Rapids consisting of large rock outcrops exist in the stream at some locations. Large trees are present along the banks in most areas except where villages and fruit tree plantations are located. Some of these trees bear flowers at different seasons of the year, and some are naturally decorated with climbers covered with numerous colorful flowers. In few areas, mountains and/or cliffs exist on both banks forming a U shape with the stream. Since the proposed reservoir area is difficult to access by land and since it is not an existing tourist place at present, the natural beauty of the stream and surrounding areas seem to be of minor aesthetic value.

4.7.1 Market Analysis of Rajjaprabha Dam

The data recorded by EGAT officers for the years 1987-1996 show that the number of visitors to the dam fluctuated from year to year (Table 7.12). January and February appear to be the most popular periods to visit because of important long holidays falling in these months. The number of visitors in other months is fairly uniform, and seems to indicate that the amount of rainfall does not play a large part in determining individual difference. However, it is still possible that the amount of rainfall has an effect on the total number of visitors to the dam. Majority of visitors are Thais and a small minority, foreigners. If we compare the number of visitors at Rajjaprabha dam and the estimated number of visitors who stayed overnight at Surat Thani (there is an approximate ratio is 1:5) we can conclude that Rajjaprabha dam has a better potential to increase the number of visitors by increasing its share of visitors to the province. It should be noted however that this figure does not represent the real number of visitors to the province as it does not include day-trip visitors and visitors who stay with friends or relatives, or any other non-commercial accommodation. If we use the real number of visitors the proportion received by Rajjaprabha dam would be much smaller.

Unfortunately the EGAT officials only recorded the number of visitors and therefore little is known about their characteristics, e.g., the province they came from, income, etc. Such information would have been very valuable, and should be collected in future.

TABLE 7.12

NUMBER OF VISITOR AT RAJJAPRABHA DAM

Year	**Number (Person)**
1987	20,519
1988	61,662
1989	61,466
1990	64,207
1991	58,419
1992	58,546
1993	67,456
1994	71,172
1995	78,070
1996	88,048
1997 (Jan-Oct)	78,187
Total	**670,986**

Source : From EGAT.

4.7.2 Visitors Profile and Experience from the Questionnaire Survey

This section presents the results of the questionnaire survey. The questionnaire survey was conducted during two periods: i.e. from 7th April to 12nd April 1997 and from 5th to 10th January 1998. Questionnaires were distributed to approximately 25 percent of the total number of visitors on each day of the survey. It was impossible to conduct random sampling and therefore the sample was chosen "accidentally". This of course means that the sample of visitors surveyed is not truly representative, and therefore the interpretation of the results must be treated with caution. But it is earnestly that the data collected will give acceptable indications for planning purposes. A total of 240 questionnaires were collected, and tabulated. As was suspected, majority of the visitors to the dam came from the southern provinces for the purpose of recreation. Male visitors slightly outnumbered females. Most of the visitors were in the age range of 15-45. Majority of the visitors were government officials or students. Majority (38.4 percent) of the visitors had an income of 3,001-5,000 bahts, 19.6 percent had an income within the range of 5,001-10,000 bahts and more than 20 percent stated that they had no income. These were generally students who were still supported by their parents. Majority of this latter group were generally well dressed and brought with them enough food. So we can tentatively assume that most of the visitors have enough income to spend on their trip if given the opportunity to do so.

Most of the visitors heard about the dam from friends or relatives, and this support the idea that the best form of publicity is a good visitor experience. Very few visitors came alone or with their family. Many chose to come with friends or colleagues. Most of them came by private cars or rented buses. This may partly be a reflection of lack of public transport in the area. Approximately 96 percent of the visitors came on a day trip, but as accommodation is only available for official visitors one cannot conclude that people do not want to stay overnight.

The preferred activity was enjoying the natural scenery. Viewing the type of construction they had not seen before follows this.

Just over thirty percent revealed that they had been to Rajjaprabha on a previous occasion, and this perhaps indicates their satisfaction with the experience. It also perhaps indicates that if sufficient activities and facilities are provided it may not be too difficult to persuade visitors to return. When visitors were asked to state what types of facilities or services they would like to have at the dam the majority (just over 32 percent) expressed the view that they would like to have water sports and tour services. About 20 percent said that they would like to have food and souvenirs at the site while 10 percent said that they would like to have accommodation. About 13 per percent wanted more information or a guide service, and around 12 percent wanted improvement of the site.

Around 60 percent of the visitors to Rajjaprabha came as part of a day trip itinerary. Among the most popular other places visited in Surat Thani were Ko Samui, Phra Borommathad Chaiya, Khao Sok national park etc. The remaining 40 percent stated that they intended to visit Rajjaprabha only. It seems likely, therefore, that these visitors especially would be quite willing to stay longer at the dam site if more opportunities to participate in some activities were available.

3.5 Summary of the Main Results

(a) There are high attraction of places in the Southern Region and the location of Surat Thani town for tourism development. There is still plenty of opportunities to attract a higher number of visitor from the lower southern part of the country.

(b) The quality and quantity of accommodation in Surat Thani is the obstacle to tourism development. In fact as stated earlier even if the present number of tourists in Surat Thani is doubled the average hotel occupancy rate would still only be around 85 percent.

(c) Rajjaprabha dam has a high potential to attract visitors from the lower southern provinces and perhaps to a minor extent from Malaysia.

(d) Many visitors to Rajjaprabha tend to stop over only for a short time as they also visit other nearby attractions. This suggests that one of the main strategies for promoting Rajjaprabha is to promote it not only as a single destination but as part of a route trip itinerary.

(e) Many visitors came to Rajjaprabha after hearing about it from friends. This points to the importance of providing a good experience for visitors and thus encouraging them to give Rajjaprabha some "free" advertising.

(f) Many visitors would appreciate the opportunity to participate in some kind of recreational activity at the dam.

(g) Lack of regular public transport to the dam from Surat Thani as well as around the surrounding attractions is an obstacle to tourism development that needs to be tackled.

(h) Official promotion and marketing of Rajjaprabha and the surrounding area may contribute significantly to counteracting the negative image of security in the province.

4.9 Present Benefit from Tourism in Monetary Terms

The travel cost approach is a way to put a monetary value on non-priced goods. This approach was initially developed to value benefits received by consumers from their use of an environment good such as a lake or a dam. The approach includes the price-quantity reactions of consumers by examination of their travel costs. The main idea behind this method is that the cost of travelling to a particular site influences the number of visits made to it.

This relationship can be expressed as,

$$V = f(TC, X_1 \ldots X_n), \qquad (7.1)$$

where V = number of visits,

TC = travel cost,

$X_1 .. X_n$ = other explanatory variables.

Observations on people using the dam site allowed the derivation of equation 7.1. This equation gives a prediction model explanation of visitation behaviour in terms of travel cost and income.

For the second part of this approach, assumption is made that visitors to the dam would react to the charging of an admission fee in the same manner as they would to increase in travel cost to the site. If we accept this assumption then this allows the visitation prediction model to be used to estimate visitation to the dam at various admission charges by adding admission fees to the travel cost variable.

Although in reality no fees are charged, the assumption that changes in admission fees affect the consumers the same way as changes in travel costs allow us to predict visitation behaviour under various fee levels by using equation 7.1, and calculate how consumers would react to similar increases in travel costs. The resulting price (fee) quantity (visitation) observations provide a demand schedule for the site and can be displayed in the form of a curve. The area under the curve gives a measure of the consumer's surplus enjoyed by the visitors to the dam at zero admission fee (i.e., total consumers willingness to pay) which is a measure of the value of the dam to its users.

An alternative method of estimating the benefits of the dam is to assume an admission fee and multiply this by the predicted number of visitors. This was done using the average willingness to pay from the questionnaire survey. Both methods of estimating benefits are presented.

It must never be forgotten that the travel cost approach is based on a number of assumptions and has a number of inherent shortcomings (M.M.Hufschidt, 1983). Nevertheless used with caution it is a convenient way of estimating the benefits of resources development projects like Rajjaprabha dam when limited time and data are available. The details of the travel cost method as applied to Rajjaprabha dam are presented below.

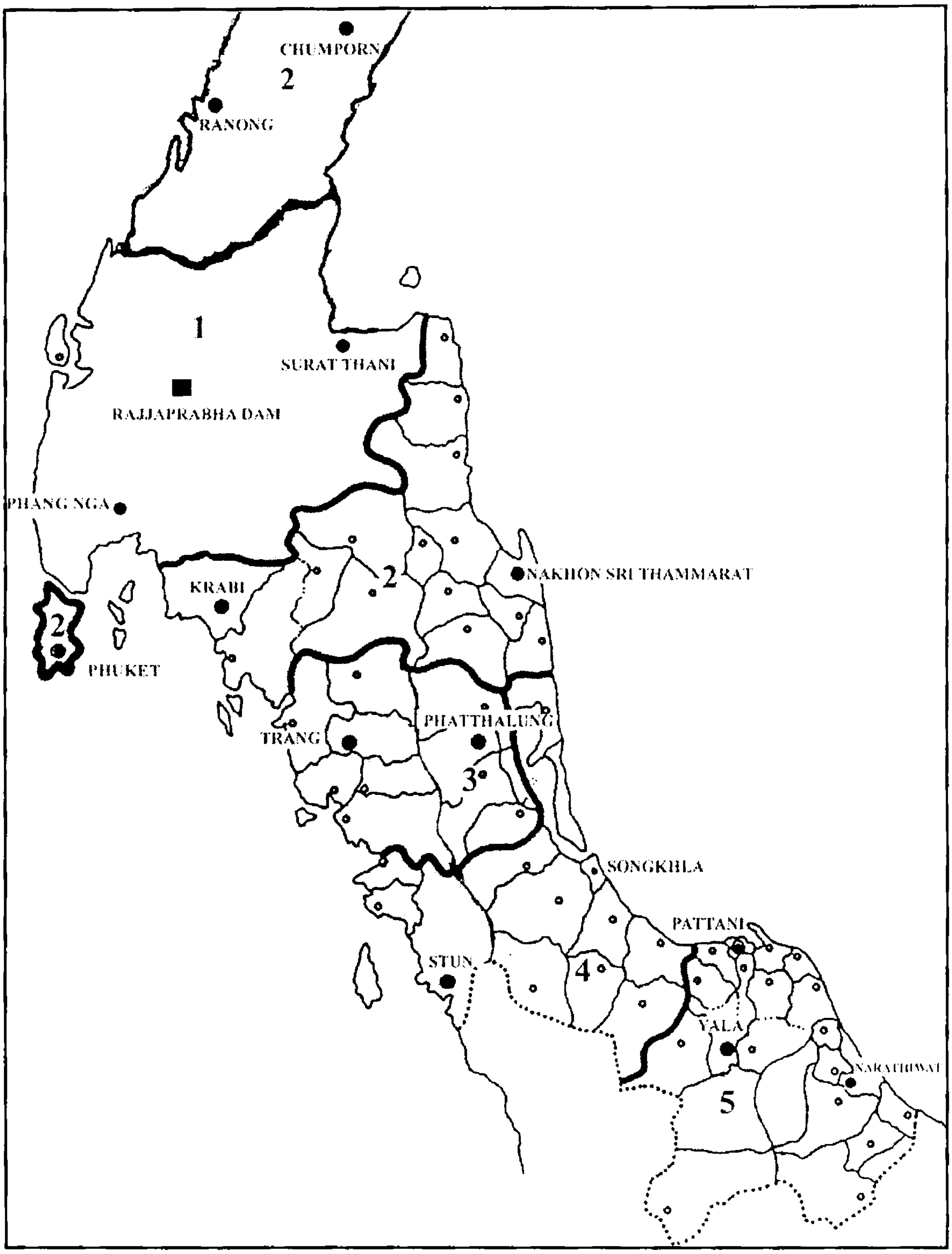


FIGURE 7.3

ZONES USES IN TRAVEL COST APPROACH

4.9.1 Application of the method to a valuation of the Benefits

(1) Introduction

To apply the travel cost approach we identified the recreation site (Rajjaprabha dam) and divided the surrounding area into zones of increasing distance (taken as the road distance between the main province center, Muang district, and the dam) which represent increasing levels of travel costs. These zones are present in Figure 7.3 and Table 7.13. A survey of users is then conducted at the recreation site to determine their place of visitation rates, travel costs and some socio-economic characteristics. The standard charge of the ordinary bus by the Department of Land Transport was used in place of the actual travel costs as it was found that the results from the questionnaire were not clear. The information from the sample of visitors is then analyzed and the data from this are used to measure visitation rates on travel cost and income.

$$V_{1i} = f\ (TC, X_{1i}), \tag{7.2}$$

where V_i = is the visitation rate (number of visitors from zone per 1,000 population in zone),

TC = is travel cost, and

X_1 = is income.

By the use of multiple regression, the hypothesis that TC do in fact have an impact on visitation rates, was tested. The inclusion of income helped to eliminate the effects of at least one component not related to TC out of total visitation rates (Eq. 7.2). With the data present in Table 7.13 multiple regression was used to analyse the relation of 3 variables, viz., visitation rate, travel cost, and visitors income per year from each zone.

TABLE 7.13

BASIC DATA FOR TOURISM BENEFIT ESTIMATION

BY THE TRAVEL COST APPROACH

A. **ZONE DATA***

Zone	Distance km	Average km	Province	Total Population
1	1-150	75	Surat Thani, Phang-Nga	1,574,680
2	151-300	225	Chumporm Nakhon Si Thammarat Ranong, Krabi and Phuket	7,811,064
3	301-450	375	Phatthalung Trang	1,554,685
4	451-600	475	Songkhla and Satun	1,273,076
5	601-750	675	Pattani, Yala, Narathiwat	2,674,307

* A number of visitor zones have been excluded from the calculations and from this table as the number of visitors from these zones was so small. However an adjustment has been made for this in the final calculation.

(B) SURVEY DATA

Zone	Average Distance km	Population 1,000	Number * of visitor	Visits /1000	Travel ** Cost, B	Income*** B/year
1	75	1,474.680	29,486	20.0	64	74,760
2	225	7,811.064	27,256	3.49	128	76,950
3	375	1,554.685	11,268	7.22	196	58,420
4	475	1,273.076	8,762	6.88	250	64,840
5	625	2,674.307	5,547	2.07	320	42,560

Notes : * Number of visitors who do not visit on official business.

** The standard charge for the ordinary bus by department of Land Transport was used.

*** Data from the questionnaire

The results from the equation are as follows:

$$Y = a + b_1 x_1 + b_2 x_2, \quad (7.3)$$

Where Y = visits/1000 population in each zone,

x_1 = travel costs from each zone (2 way),

x_2 = average income of the visitors in each zone.

$$Y = -3,27293 + 289.896\ x_1\text{-}1 + 3.8854 \times 10\text{-}5x_2$$

From the results we can indicate that if x_1 or travel cost increases the visitation rate will decrease, and the visitation rate will increase with an increase in income, but the rate of increase is very small.

(2) Demand Forecasting

From equation (7.3) the predicted total number of visitors in each zone is transformed by using the following formula.

$$TV = \sum_{i-1}^{7} Pi\,(-3.27293+289.896x\,X_{1i}^{-1} + 3.5734 \times 10^{-5} \times X_{2i}) \quad (7.4)$$

where TV = Total number of visitor from all.

P_i = Population in each zone.

X_{1i} = Travel Cost in each zone.

X_{2i} = Average income of the visitors in each zone.

According to EGAT's records the actual number of visitors to Rajjaprabha dam in 1996 for all purposes was 88,048. From the questionnaire survey approximately 62 percent of the visitors from the 5 zones identified came for recreation and 38 percent came for official business. Assuming that these proportions are constant in future years the predicted total number of visitors can be divided by the same proportions. An adjustment can also be made for visitors from zones other than the 5 zones previously assumed to be 2 percent per annum until 2000, and then 1.1 percent per annum from 2000-2030. The income growth of visitors in each zone is assumed to be 3 percent per annum from 1987-2030. The total number of visitors is then forecaste as shown in Table 7.14.

PRICE BAHT	0	10	30	50	70	90	110	130	150	167
No OF VISITORS	14,205	10,713	7,080	4,948	3,497	2,429	1,601	938	392	—

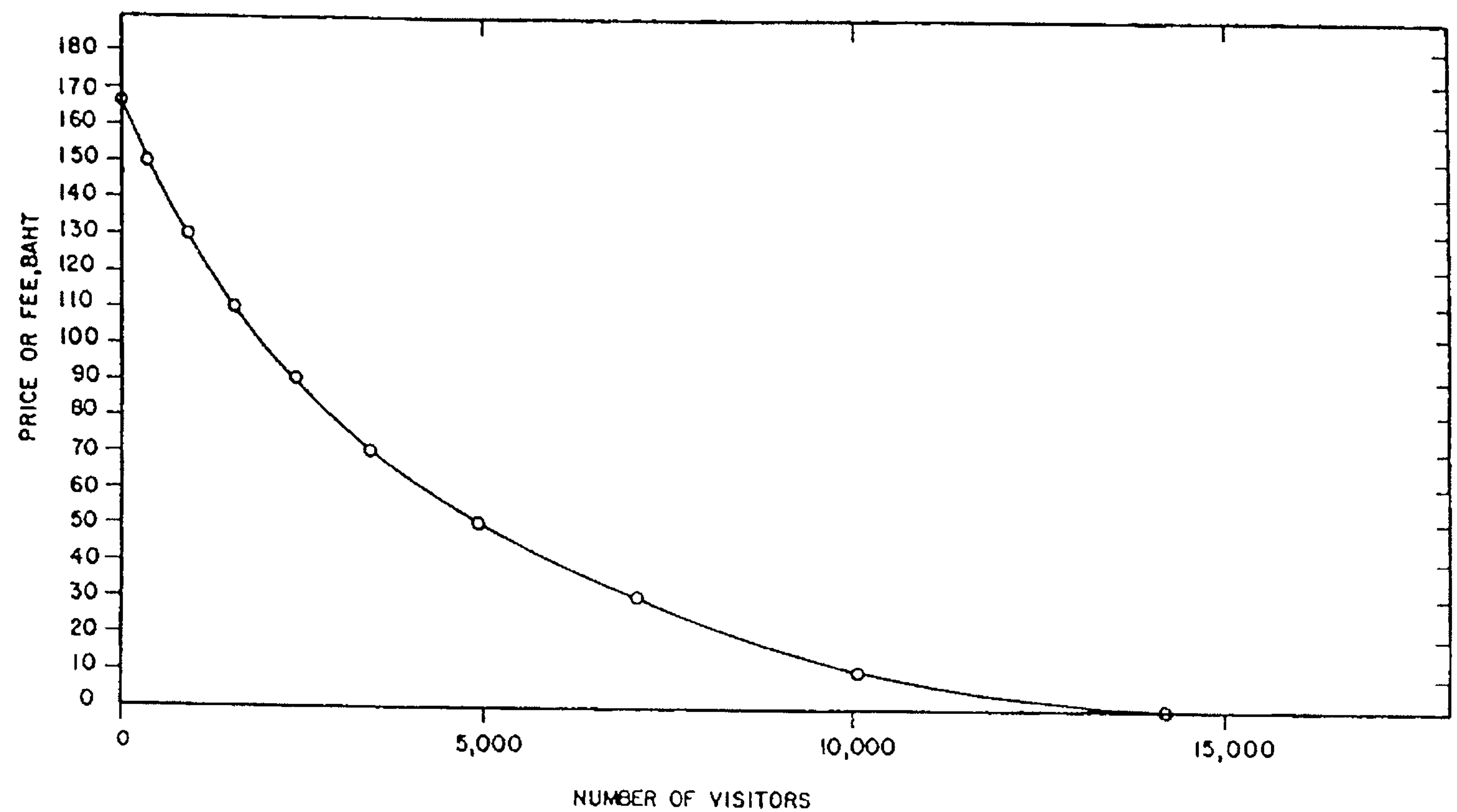


FIGURE 7.4

RECREATION DEMAND CURVE

TABLE 7.14

ESTIMATE OF AVERAGE ANNUAL TOTAL NUMBER OF VISITORS

Year	Total No. of visitors	Recreation group	OTHER Group	Assumed population growth rate	Assumed income growth rate
1995	78,070		14,196		
1996	88,048	73,509	14,539	2	3
2000	91,652	76,445	15,207	1.1*	3
2005	98,468	82559	15,909	1.1	3
2010	102,420	85,776	16,644	1.1	3
2015	114,870	97,455	17,415	1.1	3
2020	128,500	110,276	18,224	1.1	3
2025	146,480	120,085	26,395	1.1	3
2030	152,460	117,920	34,540	1.1	3

Note Growth rate according to the target set by the Eight National Economic and Social Development Plan.

(3) Benefit from the Dam Received by Recreation Type Visitors

The estimated relationship can be used to determine how the visitation rate would change if visitors were asked to pay for the experience of visiting Rajjaprabha dam. The analysis assumes that visitors would respond to a fee the same way they respond to travel costs. The analysis indicates how many visitors would be willing to pay for Rajjaprabha dam's recreation environment.

The number of visitors in 1996 as shown in Table 7.14 is used and the Equation determines points on the demand curve.

From Figure 7.4 visitors who come for recreation would be willing to pay up to the area under the demand curve. The area under the demand curve estimated in this analysis is approximately 5,246,660 bahts. However if visitors come from some distance, there may be other recreation sites.

Of assess that a trip to Rajjaprabha dam is not for a single purpose, then the travel costs should be divided between the different sites. In fact according to the questionnaire survey only 40 percent of the visitors visited the dam as a single destination. The remaining 60 percent visited a total of 3 or 4 places including the dam. Therefore if we divide the travel costs between the different sites then the results will be as follows:

(a) Benefit received by visitors who visited the dam only equal 5,246,660 x 0.4 = 2,098,664 bahts

(b) Benefit received by visitors who visited other places assuming Rajjaprabha is allocated 30 percent of the total equals 5,246,660 x 0.6 x 0.3 = 174,240 bahts;

(c) The total benefit therefore equals 2,098,664 + 174,240 = 2,272,904 bahts or 25.8 bahts per visitor

However this result is only for those visitors who came for the purpose of recreation.

(4) Benefit from the Dam Received by Non-recreation Type Visitors

For other visitors group, i.e., who come on official business, we can evaluate the benefit by asking directly about their willingness to pay. The result from this method is approximately 241,080 bahts or 14.7 bahts per visit. However this may well be an underestimation, as, rather than use the bidding game technique the study simply asked visitors how much they would be willing to pay. The bidding game technique, might have elicited a higher sum.

(5) Benefit from the Dam by Expenditure of Visitors

The average total expenditure of visitors who visited the dam using data from the questionnaire surveys works out to 147.5 bahts. The total benefit from visitors, based on the actual number of visitors in 1996 is approximately 12,987,080 bahts. The same principle of dividing travel costs between the various sites visited is adopted here. The total benefit from the visitors at Rajjaprabha dam in 1996 is approximately 3,698,540 bahts.

By summing up these benefits we can see that the total benefit from market and non-market sources is about 9,245,040 bahts, or 105 bahts/visitor in 1996. The benefits have also been calculated up to the year 2029 and are presented in the section on the evaluation of actual positive benefits.

5. ARCHAEOLOGICAL AND HISTORICAL VALUES

5.1 Introduction

In the pre-impoundment environmental and ecological study it was reported that places of cultural values are present in the reservoir area. In this post evaluation study, the archaeological and historical values are assessed for a much larger area, i.e., covering the whole Phum Duang river basin. This study identified altogether 5 sites of archaeological and historical values by field survey and field interview techniques. These sites include ancient settlement site; old palace, Buddhist monastery, and Royal Pavilion. These sites are assessed on their significance, existing condition, and development potential. Their original archaeological depositions have been severely destroyed by both natural and human causes.

From this investigation, the archaeological sites of historical times were found at the vicinity of project area. It can be concluded from the data that the Phum Duang river basin used to be inhabited by historic men who might have later migrated to the plains of Phum Duang river. In that period, men have moved into this area for tin mining. However, there has been no evidence of continuation of habitation until about 150 years ago, when a few families moved in this area once again, followed by many more and have stayed there until recently.

5.2 Historical Sites

Archaeological sites in the historic period are rarely found around Phum Duang basin and are not important as those belonging to the prehistoric period. Besides the artifacts found historical values are mostly small in site. The archaeological sites of the historic as well as the artifacts found during the survey are described below:

(1) Nai Mui village :

Ban Nai Mui village, there exists an abandoned monastery, which is about 150 years. The age of this monastery was estimated based on the information obtained from the local villages and on the age of the Buddha images, which used to be kept here, but have been removed to the new monastery at Bang Kaew village. Most of these images, with lap size ranging from 5 to 7 inches were highly decorated in the artistic styles of Ratanakosin during the reigns of King Rama III-IV. This monastery has been abandoned for more than 30 years as described previously. The reason for this move was said to be because of inconvenient communication with other villages, since the "Wat" was situated deep into Khlong Mui, which is a small canal. The built-up structure of the "Wat" is made of wood, which has mostly deteriorated, hence no permanent structure is left todays

(2) Pak Pae village :

There is a stone plate on which the royal signature of their Majestic the King and Queen were inscribed to commemorate their visit to this village in 1969. Today, the stone is placed in front of the flag staff at Ban Pak Pae School.

(3) Chiew Tae village :

In this village, here is an old silver coin. It is the coin of British currency, valued one rupee, with English inscription: "Victoria Queen" on one side and "East India Company one Rupee 1840" on the other side. This type of coin which is made of real silver, might have been used in trading of tin ore in this area, probably in the reign of King Rama V. Beside the said coins, other English, French, Spanish and Mexican silver coins were found to have been in antique collections of villagers who used to live along Khlong Saeng some of which to have been inherited from their ancestors. The age of these coins vary, the newest being an English coin made during the reign of King Edward VIII in 1906. Although many coins were reported to be found around Ban Chiew Tae, no other evidence of permanent settlement off historic were observed here.

(3) Chiew Tae village :

In this village, here is an old silver coin of the British with a value of rupee, with English inscription: "Victoria Queen" on one side and "East India Company one Rupee 1840" on the other side. This type of coin which is made of real silver, might have been used in trading of tin ore in this area, probably during the reign of King Rama V. Beside the said coins, other English, French, Spanish and Mexican silver coins were also found to have been in antique collections of villagers who used to live along Khlong Saeng some of which have been inherited from their ancestors. The age of these coins vary, the newest being an English coin made during the reign of King Edward VIII in 1906. Although many coins were reported to be found around Chiew Tae village, no other evidence of permanent settlement of historic were observed here.

(4) Pak Ka village :

Traces of a historic settlement was found at the average elevation of 60 m MSL, at Pak Ka village. These included British silver coin, which were found just like the one found at Chiew Tae village. A Chinese coin was also found here. All these items belong to the local people who said that they inherited them from the ancestors. This place might use to be a village where people traded tin ore about 100 years ago. In addition to these two coins, pieces of earthen-wares of historic times were also found around the mounds near the village.

(5) Wang Khon village:

Evidences of historic human settlement was found at this village at elevation of about 80m MSL at Wang Khon village, which included pieces of potsherds and Thai copper coins of the reign of King Rama V. These items show that this area used to be inhabited till around 100 years ago. The inscription on the front face of the coin (in Thai) is "Chulalongkorn" with the image of Phra Siam Dhevathirat and "one Solot" (in Thai) on the rear face.

(6) Plai Saeng village:

This site used to be a community, dwelling area which was deserted some 50 years ago. An old abandoned wat was found together with remains of an old village near the confluence of Khlong Khun and Khlong Saeng. Pieces of earthen-wares found here, show traces of historic human dwelling at this site. It is believed that this area used to be a large community since tin ores were reported to be present in large amount there.

The idea of using these archaeological sites in tourism promotion may need further planning and evaluation. Because their development may not be economically feasible. It may probably be more appropriate that the archaeological sites development be aimed at the conservation of cultural heritage. And the utilization of the sites for tourism promotion should be considered as the secondary objective.

Further archaeological and historical sites investigation and development should involve a more detailed study taking into consideration the historical meaning and significance of each site. Then only its real value and main attraction can be identified. Then systematic archaeological study, if found appropriate, should be carried out. Further site development attempt should be made to maintain the original condition of the sites in order to preserve their heritage values.

5.3 Conclusion

Investigation related the existence of some archaeological sites of historical importance at the vicinity of the project area. From this can be concluded that the Phum Duang basin used to be inhabited by historic men. They might have migrated to the plains of Phum Duang river. In that period men had moved into this area for tin mining. However, there has been no evidence of continuation off habitation until about 150 years ago, when a few families moved in this area once again, followed by many more and have stayed there until recently.

The archeological impact is not economically quantifiable for two main reasons. First, there are unknown sites suspected to be located under the reservoir. Since it is still unknown whether it is possible to make any economic evaluation. Second, for the number of known sites sunk under the reservoir there is no record of tourist visit upon which the tourists' willingness to pay might be estimated. Therefore, we do not have any database to assess the economic value of the archeological impact of Rajjaprabha dam at all.

CHAPTER VIII

ECONOMICS EVALUATION OF ENVIRONMENTAL CONSEQUENCES

CHAPTER VIII

ECONOMICS EVALUATION OF ENVIRONMENTAL CONSEQUENCES

The evaluation of environmental economics consists of three aspects: (i) the implication or regional economics which is the evaluation at the regional level (ii) the evaluation of actual positive benefits which is done at the project level and (ii) input-output analysis which indicates the effects of the project implementation on the regional economy of Surat Thani province.

1. Implication on Regional Economics

1.1 General Background

The macroeconomic impact of a project is evaluated to determine whether the project is consistent with overall national, regional, and sectional objectives, and whether the investment represents the best means of achieving the intended objectives. Hence, the framework adopted for economic analysis of the project should depend on policy objectives which include provision of basic needs of the people, provision of opportunities for gainful employment, achievement of rapid and sustained economic growth, and more equitable distribution of income among the various sections of the population. In other words, the purpose of macroeconomic analysis is to determine the importance and urgency of the project in relation to regional and sectional objectives.

The use of scarce resources for a sector reduces the resources available for other sectors. It is essential that the allocation of investment resources be well balanced among sectors. A proper allocation of scarce resources and the linkages among the various sectors of the economy is essential in achieving national objectives. For instance, continuous investment in industry would not be appropriate without additional investment for increasing electric power supply, and extra sustained agricultural production would require additional investment in transport to move the increased agricultural output to markets.

1.2 Objectives

The main objective of macroeconomic analysis of a project is to determine the extent to which a proposed project is consistent with contributing to the achievement of objectives and priorities enunciated in the national development program and downstream to the regional level.

1.3 Approach of Study

The study is organized in two stages: analysis of the overall context of the study and analysis of the specific study region.

To analyse the overall context, the task of trying to interpret the relationship of national policy goals to the stated specific objectives for the study areas seems to be necessary. Absence or presence of clearly defined national policies for developing a particular area is a major factor in designing the work plan. In Thailand, the government carries out regional planning mainly within the national planning objectives.

The following steps are followed in analyse of the specific study region.

(1) Determine the relationships in the designated study region and the large system of which it is a part. No sub-regional area is a closed system. So rarely do solutions to sub-region socio-economic problems exist solely within the sub-region itself. Likewise, a region's problems, including environmental constraints and opportunities may be part of a much larger fabric. Long-term solutions to development problems may involve the movement of people into or out of region, so a wide geographic view is essential. Similarly, a region's environmental problems may be better understood by viewing them in the context of the larger ecosystem in which they are occurring.

(2) Identify priority sectors and/or geographic areas within the project area.

(3) Consider the effects of ongoing projects or programs on the project and by means of inventory of existing plans and projects as a part of the regional development study.

1.4 Methodology of Study

The methodology adopted includes:

(1) Collecting basic data on natural resources at regional/sub regional levels.

(2) Collecting social and economic data on key regional/sub regional variables.

(3) Studying the relationship between region and project area.

(4) Defining preliminary regional/sub-regional strategies; and

(5) Assessing implication on regional economics of the project.

1.5 Sub-regional Development Framework

The economic and social development of the southern region of 1990-1995, which includes the project area, which was determined by the government in the Seventh National Economic and Social Development Plan. The main aim of this development plan was to readjust the local economic structure and to achieve greater diversification. Economic development of the southern region was integrated more completely into national economic development programme, which helped in solving social problems.

The development policies in the southern region made some important conclusions which are as follows:

(1) Readjustment of the economic structure and diversification of economic activities. Industrial and agricultural marketing development have been primarily stressed at Surat Thani and Nakhorn Sri Thammarat province, which is being developed as a regional growth center in the upper southern region.

(2) Social development has improved education services, and promotion of youth welfare. Improvement in the role of women's groups will help the people to feel more socially integrated and to identify the rich Thai heritage;

(3) Poverty alleviation in rural areas.

The Eighth National Plan also established the following development measures:

(1) To set up an industrial estate and an export processing zone at the regional urban center of Surat Thani so that it will become a center for the development of the

rubber and fishing industries. A study to establish a provincial industrial development zone at Surat Thani will also be undertaken.

(2) A Rubber Public Warehouse Organization will be set up and Cooperative groups will be encouraged to set up their own rubber smoking houses in order to dispense with middlemen's services. A central market for agricultural products will also be set up in Nakhorn Sri Thammarat province and Surat Thani province where expansion of basic urban infrastructure services has been given priority.

(3) Enhancement of compulsory education. Education will be a part of the course offered in all government education institutions. A center for Islamic studies at Prince Songkhla University in Song Khla province and Walailuk University in Nakhorn Si Thammarat province areas will also be created. Harmonious religious relations will be promoted together with Thai language and technical knowledge to raise agricultural and industrial productivity. Activities of women and youth will also be given priority.

(4) The poor fishing villages will be aided by establishing a career development project to increase their income. Coastal land management projects will be carried out to help fishing industries in the area. The irrigation system will be completed, particularly with regard to on-farm distribution canals, and complementary economic crops will be introduced on small-scale rubber plantations in order to raise additional farmer income.

1.6 Overall View of Economic Base

The project area is a part of the upper southern region, which in total covers 7 provinces, namely Surat Thani, Nakhorn Sri Thammarat, Khra Bi, Phang-Nga, Chumporn, Ranong and Phuket. The project area, consisting of only Surat Thani provinces, covers only 466,800 ha, representing 21.15 percent of the upper southern region, or 5.32 percent of the whole southern region.

Table 8.1 shows the distribution of the gross provincial product (GPP), the gross regional product (GRP), and the gross national product (GNP) in 1995, which was the terminal year of the Seventh National Economic and Social Development Plan (1991-1995).

A comparison of the project area with the upper southern, the southern, and the whole country is done. It is clear that the economic base of the project area was predominantly agriculture, which was similar to those of the upper southern region, and the southern region.

As for the project area itself, the GPP figure shows that the project area contributed around 2.7 percent of GRP of the southern region according to the constant 1992 price, but when comparing, with the market price, the GPP of the project area shared only 3.5 percent of GRP of the southern region. This implies that the inflation rate (or general price increase) in the project area was quite higher than that of the region. Besides, it can be seen, from the comparison of the GPP share of 2.7 percent (constant 1992 price), the area share is 5.3 percent and the population share of 2.3 percent, between the project area and the southern region, that the real per capita GPP of the project area was 11,980 bahts which was higher than the figure of 10,920 bahts of the southern region.

TABLE 8.1

GROSS NATIONAL PRODUCT GENERATED IN THE PROJECT AREA COMPARED WITH UPPER SOUTHERN, SOUTHERN REGION AND THE WHOLE COUNTRY (CONSTANT PRICE 1992)

Unit Million of Baht

Industrial origin	Project areal		Upper Southern		Southern Region		Whole Kingdom	
	Value	%	Value	%	Value	%	Value	%
Agriculture	1,429.40	40.10	34,330.92	38.60	54,166.28	40.80	139,146.89	23.80
Mining	3.56	0.10	1,245.16	1.40	9,957.04	7.50	99,39.06	1.70
Manufacturing	226.35	6.35	5,158.53	5.80	6,239.74	4.70	119,268.76	20.40
Construction	196.05	5.50	5,514.29	6.20	6,903.55	5.20	32,155.79	5.50
Electricity and water supply	149.71	4.20	3,379.73	3.80	3,451.77	2.60	14,031.62	2.40
Transportation, communication	169.32	4.75	4,713.83	5.30	6,239.74	4.70	38,002.30	6.50
Wholesale and retail trade	545.38	15.30	12,273.75	13.80	16,595.06	12.50	91,205.52	15.60
Banking insurance, real estate	149.71	4.20	4,002.31	4.50	4,779.38	3.60	43,264.16	7.40
Ownership of dwelling	74.86	2.10	3,201.85	3.60	4,513.86	3.40	9,939.06	1.70
Public administration, defence	163.97	4.60	3,023.97	3.40	6,903.55	5.20	22,216.73	3.80
Service	456.27	12.80	12,095.87	13.60	13,010.53	9.80	65,480.89	11.20
Total	**3,564.60**	**100**	**88,940.20**	**100**	**132,760.5**	**100**	**584,650.80**	**100**
GPP per capita (baht)	**11980.00**		**12,758.00**		**10,920.00**		**9,826.00**	

Source : National Accounts Division, Office off the National Economic and Social Development Board.

When compared with the upper southern region, the economic condition of the project area is below the average of the upper southern region. This conclusion is made on the fact that the GPP share of 4 percent (at constant 1992 price) of the project area was lower than the area share of 21.1 percent and population share of 4.3 percent. This also explains why the real per capita income of the upper southern region (12,758 bahts) was higher than the real per capita income (11,980 bahts) of the project area.

Table 8.2 compares the GPP of the project area in 1985 and 1990 with that of 1995. The three years being compared were the terminal years of the Fifth, Sixth, and the Seventh National Economic and Social Development Plans respectively. The GPP of various economic sectors generally increased except for the decrease of 64 percent for mining (annual growth rate decrease from -18.48 to –29.80). Since the annual growth rate changes for sectors were quite different, the economic base of the project area could be considered as under transition, as inferred from the relatively increase GPP share of agriculture (37.5 to 38.8 percent) throughout the period. During the period of the Seventh Plan also agriculture, which was still the most important production sector, indicated relatively constant GPP contribution (40.10 percent) to the total GPP, and other rapidly growing economic sectors were not able to overtake the agricultural sector. From this it can be concluded that the economy of the project area would depend on agriculture for a long time to come.

It was pointed out earlier that each economic sector had different rate of growth during the period of the Sixth and Seventh National Development Plans. In this contrast it should also be noted that the most consistently and rapidly growing sector was that of electricity and water supply.

TABLE 8.2

PERCENTAGE OF GROSS PROVINCIAL PRODUCT OF THE PROJECT AREA IN THE FINAL YEARS OF THE 5TH AND 6TH NATIONAL DEVELOPMENT PLAN COMPARED WITH THE 7TH PLAN

Unit Million of Baht

Industrial origin	1985		1990		1995		Annual Growth Rate	
	Value	%	Value	%	Value	%	1985-1990	1990-1995
Agriculture	1037.18	37.50	1158.76	38.80	1429.40	40.10	2.24	4.29
Mining	58.08	2.10	20.91	0.70	3.56	0.10	-18.48	-29.80
Manufacturing	182.54	6.60	191.14	6.40	226.35	6.35	0.92	3.44
Construction	196.37	7.10	206.07	6.90	196.05	5.50	0.97	-0.99
Electricity and water supply	89.89	3.25	104.53	3.50	149.71	4.20	3.06	7.45
Transportation, communication	147.97	5.35	161.27	5.40	169.32	4.75	1.74	0.98
Wholesale and retail trade	420.40	15.20	453.95	15.20	545.38	15.30	1.55	3.74
Banking insurance, real estate	107.87	3.90	119.46	4.00	149.71	4.20	2.06	4.62
Ownership of dwelling	52.55	1.90	59.73	2.00	74.86	2.10	2.59	4.62
Public administration, defence	121.70	4.40	131.41	4.40	163.97	4.60	1.55	4.53
Service	351.26	12.70	379.29	12.70	456.27	12.80	1.55	3.77
GPP	**2,765.8**	**100**	**2,986.5**	**100**	**3,564.6**	**100**	**1.55**	**3.60**
GPP per capita (baht)	**9,850**		**1,0750**		**11,980.00**		**1.76**	**2.19**

Source: National Accounts Division, Office off the National Economic and Social Development Board.

Table 8.3 breaks down in the total GPP of Surat Thani province for the year 1985 and 1996. Comparative analysis of the data reveals the following interesting points:

1. Agricultural sector of Surat Thani province contributed 33.80, 34.6 and 34.2 percent to the total GPP of the province in 1985, 1990 and 1995 respectively. This indicates that the agricultural sector plays a critical role in the economy of Surat Thani province. Moreover, comparison of the 1990 data with that of 1995 data disclose that, in spite of the increase in net GPP, the agricultural sector's contribution to the total GPP actually increased.

2. Growth of other economic sectors has slightly reduced the importance of the agricultural sector in Surat Thani. Electricity and water supply, public administration and defense, banking insurance and real estate, services, and wholesale and retail trade were the sectors which are growing at a higher rate than the previous year.

3. The results of analysis of the economic base of the province in the project area clearly indicate that Surat Thani had a stronger economy. It enjoyed higher economic growth in other non-agricultural sectors and attracted higher investment in wholesale, service and public physical infrastructures.

TABLE 8.3

PERCENTAGE OF GROSS PROVINCIAL PRODUCT OF SURAT THANI IN THE FINAL YEARS OF THE 5[TH] AND 6[TH] NATIONAL DEVELOPMENT PLAN COMPARED WITH THE 7[TH] PLAN

Unit : Million of Baht

Industrial origin	1985		1990		1995		Annual Growth Rate	
	Value	%	Value	%	Value	%	1985-1990	1990-1995
Agriculture	3228.91	33.80	4469.11	34.60	5,498.27	34.20	6.72	4.23
Mining	171.95	1.80	155.00	1.20	96.46	0.60	-2.05	-9.05
Manufacturing	630.50	6.60	826.66	6.40	1,028.92	6.40	5.57	4.47
Construction	649.60	6.80	800.82	6.20	932.45	5.80	4.27	3.09
Electricity and water supply	305.70	3.20	464.99	3.60	659.15	4.10	8.75	7.23
Transportation ,communication	640.05	6.70	749.16	5.80	755.61	4.70	3.20	0.17
Wholesale and retail trade	1,595.35	16.70	2,221.64	17.20	2,974.21	18.50	6.85	6.01
Banking insurance, real estate	448.99	4.70	619.99	4.80	723.46	4.50	6.67	3.13
Ownership of dwelling	171.95	1.80	245.41	1.90	337.61	2.10	7.37	6.59
Public administration, defence	448.99	4.70	619.99	4.80	835.99	5.20	6.67	6.16
Service	1,261.00	13.20	1,743.73	13.50	2,234.68	13.90	6.70	5.09
GPP	**9,553**	**100**	**12,916.5**	**100**	**16,076.8**	**100**	**6.22**	**4.47**
GPP per capita (baht)	**10,250**		**11,850**		**12,560.00**		**2.94**	**1.17**

Source : National Accounts Division, Office off the National Economic and Social Development Board.

2. Evaluation of Actual Positive Benefits

2.1 General Background

Evaluation of actual positive benefits involves assessing benefits of multipurpose components in various aspects, which are interrelated. Evaluation in this sense attempts to assess the overall impact of the project by means of benefit-cost analysis technique. The benefits of the project are the values of incremental outputs of goods and services made possible by the project.

2.2 Objectives

Objectives of this study aspect include the following:

(1) To estimate demand for electricity and damage due to electricity interruption.

(2) To evaluate the actual positive benefits after the project implementation and compare them with the estimated values before the project construction;

(3) To identify all significant changes in benefits from the previously estimated;

(4) To assess the multipurpose water resource development as previously estimated.

2.3 Methodology of Study

To fulfill the above objectives, the following methodologies are adopted.

For the first objective, data and information were collected from 12 selected industrial and service units utilizing pretested interview schedules. Information collected relate to number of workers per industrial unit, labour per hour, value of product produced per hour, cost of electricity per hour, damages due to electricity interruption per hour, ability to generate own electricity, and cost of fuel for generating own electricity per hour. Damages due to electricity interruption include two components; viz; direct damages and indirect damages. Direct damages consist of loss in quantity and quality of product outputs and storable inputs during electricity interruption. Indirect damage considered here is only labour cost, which is the cost of non-storable input.

In regard to the second objective, benefits from hydropower, irrigation, water supply, flood control, fisheries development, transportation and navigation, salinity and water pollution control, tourism, health improvement, and resettlement were evaluated. The data and information used in the evaluation of these benefits were obtained both from primary and secondary sources. The methods used in evaluating the various components were already described in Chapter I.

By such methods, all significant changes in benefits from the project after implementation from the previously estimated benefits can be identified. This fulfils the third objective. Then, the last objective involving assessment of the multipurpose water resource development as previously estimated can be achieved. The results of the study are presented in four parts in the following paragraphs.

2.4 Results of the study

2.4.1 Demand for Electricity and Damage Due to Electricity Interruption

A field survey was conducted in June 1997 to give general picture on demand for electricity as well as damages due to electricity interruption for selected industries and services. The results of the survey are presented in Table 8.4.

From the 12 types of industrial units and services surveyed, it was found that demand for electricity in terms of cost of electricity per hour ranged from 8 to 833 bahts per hour. Four out of 12 of them are able to generate their own electricity when there is an interruption of electricity supply from PEA. The cost of fuel for generating their own electricity ranges from 84 to 700 bahts per hour.

Value of product produced per hour for each industrial or service unit varies considerably, ranging from only 60 to 22,220 bahts. Utilizing the value of product produced per hour and cost of electricity per hour, factor share of electricity for each industrial or service unit can be computed. Ice making industry which uses only few and cheap inputs has a high factor share of electricity of about 82 percent while food canning industry which uses expensive inputs has very low factor share of electricity, approximately 1 percent. In general, factor share of electricity is about 6 percent, which means that for every 100 bahts of value of product produced 6 bahts will be for electricity cost.

Damages due to electricity interruption include two components: direct damage and indirect damages. Direct damages were found only for ice making industry at the rate of 3,000 bahts per hour. This damage was estimated from the fact that when there is no electricity for one hour, the temperature of water that is about to become ice rises and it takes about 3 hours for that water to resume the previous temperature. There is no direct damage for the other 11 industrial units since the inputs (except labour) used by them can be stored without much change quality until electricity is supplied again.

In this study, labour costs are considered as indirect damages. From worker's point of view, labour cost paid by the owners of industrial units is the worker's revenue. When there is an electricity interruption, the production process stops and workers cannot earn their income during that period of time. The reduction in this income (or labour cost from the point of view of the owner of industry) is, therefore, treated as indirect damage due to electricity interruption. It ranges from 15 to 2,580 bahts per hour per industrial unit.

Combining the direct and indirect damages together total damages due to electricity interruption are obtained and is presented in column 7 of Table 8.4. Ice making industry has the largest total damage of 3,079 bahts per hour compared with 15 bahts per hour for hair dressing service.

2.4.2 Evaluation of Actual Positive Benefits

As mentioned in section 2.3, eleven components of benefits are to be evaluated as shown in Table 8.5. Some prices used in the evaluation of actual positive benefits after the project implementation were not 1996 price, which was the price used in the estimation of benefits before project implementation. Therefore, to make them comparable, the post-evaluation benefits have to be converted to the benefits at 1987 price.

TABLE 8.4

DAMAGE DUE TO ELECTRICITY INTERRUPTION FOR SELECTED INDUSTRIES AND SERVICE

Type of industries and services	N0. Of worker per industrial Unit (1)	Labour cost per hour Baht (2)	Value of product producer per hour Baht (3)	Cost of electricity per hour Baht (4)	Factor share of electricity % (5) = (4) x100/ (3) (5)	Direct damage due to electricity interruption per hour baht (6)	Total damage due to electricity interruption per hour, baht (7) =(2)+(6) (7)	Ability to generate own electricity (8)	Cost of fuel for generating own electricity per hour Baht (9)
1. Fish meal	62	155	4,540	154	3.39	-	155	Yes	145
2. Saw mill	58	286	9,240	212	2.29	-	286	No	-
3. Rubber smokehouse	226	560	16,768	832	4.96	-	560	No.	-
4. Mining	20	215	4,720	265	5,61	-	255	No.	-
5. Ice making	30	79	1,015	833	82.0	3,000	3,079	No.	-
6. Cold storage	120	680	na	372	na	-	680	Yes	84
7. food canning	340	2,580	22,220	221	1.0	-	2,580	Yes	220
8. Coconut oil refinery	15	80	3,250	142	4.37	-	80	No	-
9. Welding shop	10	200	320	28	8.75	-	200	No.	-
10. Hair dressing	1	15	60	8	13.33	-	15	No.	-
11. Movie theatre	12	350	na	135	na	-	350	Yes.	700
12. Restaurant	10	80	na	60	na	-	80	No.	-

Notes : na denotes not available.

Source : Survey data

TABLE 8.5

SOURCE OF DATA AND INFORMATION AND PRICE USED IN THE VALUATION OF BENEFITS

Component off benefit to be evaluated	**Source of data & information used in the benefit**	**Price used in the evaluation of benefit**
Hydropower	Section 5.3 of Chapter VI	1996 price
Irrigation	Section 3.3.3 of Chapter VI	1995 price
Water supply	Section 3.3.2 of Chapter VI	1996 price
Flood protection	Section 6.3 of Chapter VI	1996 price
Fisheries development	Section 3 of Chapter V	1996 price
Transportation and Navigation	Section 4 of Chapter VI	1987 price
Salinity and water pollution control	Section 8.4 of Chapter IV	1996 price
Forestry	Section 4.5 of Chapter V	1987 price
Tourism	Section 4.9 of Chapter VII	1996 price
Health improvement	Section 3 of Chapter VII	1995 price
Resettlement	Section 2 of Chapter VII	1987 price

Twelve percent interest rate, which was adopted in estimation of benefits before project construction, and has been the dominant rate of interest of government bonds, is used in discounting the benefit stream. Since the construction of Rajjaprabha dam began in 1980, and its operation commenced in 1987 and with the assumption of 50 years project life, the stream of benefits at 1987 price from 1987 to 2037 are discounted to 1987 in this study.

The results of the evaluation of actual positive benefits are presented following the order listed in section 2.3 of this chapter.

(1) Benefits from Hydropower

From the data and information obtained from section 5.3 of Chapter VI. the hydropower benefit stream at 1996 price is computed and that is discounted at the rate of 12 percent. The discounted hydropower benefits are presented in Table 8.6. The present worth of hydropower benefits amounts to 1650.10 million bahts.

(2) Benefits from Irrigation

The computation of benefits from irrigation is based on the data and information from section 3.2.3 of Chapter VI. The estimated irrigation benefit stream at 1995 price is fint computed. Then it is discounted at the rate of 12 percent. The discounted benefits from 1987 to 2037 are presented in Table 8.7. The estimated present worth of benefits from irrigation 1,482.78 million bahts.

(3) Benefits from Water Supply

In this study costs of using groundwater as a substitute for raw water from Phum Duang river are considered as benefits from water supply. It is estimated in section 3.3.2 of Chapter VI. The results of the estimation are presented in Table 8.8. The water supply benefit stream, are converted to water supply benefit stream at 1987 price. Then it is discounted by 12 percent. Ths discounted benefits are calculated and that comes to approximately 131.21 million bahts.

(4) Benefits from Flood Protection

Flood protection benefit stream at 1996 price is assessed in section 6.3 of Chapter VI as presented in Table 8.9. As in the case of other benefit streams it is converted to benefits at 1987 price. This stream of benefits is discounted using 12 percent discounting factor. That forms the discounted flood protection benefits. The estimated present worth of flood protection benefits come to about 216.26 million bahts.

(5) Benefits from Fisheries Development

In 1980 it was estimated that the standing crops of fish in the proposed reservoir area and in the downstream area were 39.4 and 8.8 kilograms per rai, respectively. The standing crops of fish in 1996 as estimated in section 3 of Chapter V is 6.5 kilograms per rai in the reservoir area and 8.8 kilograms per rai in the downstream area. These standing crops in 1996 are assumed to represent the maximum sustainable yields. It was also assumed that the yields have increased linearly starting from 1988 when the reservoir had stored water for one year.

With these estimated increase in yield from an average reservoir surface area of 17,800 ha, average downstream water surface area of 15,000 ha, and average fish price of 35 bahts per kilogram in 1996, the fisheries development benefit stream at 1996 price is estimated and presented in Table 8.10. This benefit stream does not include downstream loss during the construction period and loss of migratory species since they are considered as negligible and insignificant from economic viewpoint. Benefits of aquaculture using water from the project are low in potential therefore; they are also excluded from computation of benefits.

The benefit stream at 1996 price is converted to benefit stream at 1987 price and presented in Table 8.10. From this benefit stream, the present worth of fisheries development benefits using 12 percent discount rate are estimated approximately 300.76 million bahts, 237.6 million bahts from the reservoir fisheries development and another 63.16 million bahts from the downstream fisheries development.

(6) Benefits from Transportation and Navigation

The study in section 4 of Chapter VI indicates that since the implementation of the project there has been no detectable change in land transportation, and the development potential for navigation. Therefore, estimation of benefits of this component involves only the cost of relocating road, the cost of using relocated road, the cost of using old road, and maintenance costs for the relocated road and the old road.

It is reported that cost of the construction work with respect to road relocation was 70,800,000 bahts. It was also indicated that the relocated road is 20 kilometers longer than the old one. With the data on average daily traffic volume from section 4 of Chapter VI, the estimated traffic volume per day is made as shown in Table 8.11. It should be noticed that the allowable maximum traffic volume per day is 8,000 (Team Consulting Co.Ltd 1980). Therefore, from year 2015 onwards the traffic volume is taken as 8,000 per day.

The data and information obtained from Highways Department reveal that (1) at the beginning of every eighth year there is a special road maintenance, and the maintenance cost is estimated at 60 bahts per square meter (1987 price) for highway No. 401, (2) routine maintenance costs in bahts per kilometer per year at 1987 price for this highway are 18,167+0.0828 average daily traffic volume (ADT) for good road condition; 14,522+0.0663 ADT for fair road condition; and 10,878+0.0497 ADT for poor road condition.

Based on total road user operating cost at the speed of 60 kilometers per hour which is 5.28 bahts per kilometer and the data mentioned above, transportation benefit stream at 1987 price is estimated as shown in Table 8.11. With 12 percent discount rate, therefore, the present worth of transportation benefit comes to -228.03 million bahts.

(7) Benefits from Salinity and Water Pollution Control

The benefits from salinity and water pollution control are negligible as mentioned in section 8.4 of Chapter IV.

(8) Benefits from Forestry

The results of the study of section 4.5 of Chapter V reveal that (1) Since the project was implemented, deforestation and illegal logging have decreased, and this decrease is estimated at 0.49 million bahts per year, (2) benefit from logging of vegetation in the resettlement area about 2.7 million bahts (1980). (3) benefits from timber logging in the overall reservoir about 324.4 million bahts. (4) damages from uncut forests about 18.01 million baths in the first year to about 72.53 million baths in the 50^{th} year.

These gain and losses are valued at 1987 price. With these results of the study, forestry benefit stream is estimated as shown in Table 8.12. Then, the present worth of forestry benefits is computed using 12 percent discount rate. It is approximately – 370.65 million bahts.

(9) Benefits from Tourism

The number of people who visited the Rajjaprabha dam was 20,519 in 1987, 61,662 in 1988, and 88,048 in 1996. The number of people who expected to visit the dam is also estimated to be about 92, 101, 112, and 120 thousands in, 2000, 2015, 2020 and 2030, respectively. With these data, the estimation of number of visitors is further made for the periods of 2000-2010, 2011-2020 and 2021-2030.

On the basis of a benefit of 105 bahts per visitor in 1996 (estimated in section 4.9 of Chapter VII), benefit from tourism at 1996 price is estimated and that is shown in Table 8.13. This benefit stream is then converted to the benefit stream at 1987 price. With 12 percent discount factor, the present worth of benefits from tourism is estimated to be approximately 176.75 million bahts.

(10) Benefits from Health Improvement

Benefits from health improvement include two components, i.e., increase in earning of person and decrease in cost of health care. The increase in earning is estimated by multiplying the increase in number of survivals of infants and children until they become adults by average income per adult. The decrease in cost of health care is the product of the decrease in number of patients and cost of medical care per person. It is indicated in section 3 of Chapter VII that:

(1) Total number of household in 1996 in Pattana village and Khoa Sok village, which is the control village were 386 and 225 respectively and the average number of person per household were 4.3 and 5.4 respectively.

(2) The percentage of infants, children, and adults were 20, 25, 55 in Pattana village and 19, 27, 54 in Ban Khoa Sok respectively

(3) Percentage of people who were sick during the last 12 months at the time of survey was 63 and 68 in Pattana village and Khoa Sok village, respectively.

Data and information in section 2 of Chapter VII that are relevant for estimation of benefits from health improvement reveal that:

(1) The average population growth rate in Pattana village and Khoa Sok village was 0.2 and 0.3 per cent per year respectively.

(2) The average annual income per household in 1996 was 54,210 bahts in Pattana village and 48,500 bahts in Khoa Sok village.

(3) The average costs of medical care per household in 1996 were 1,500 bahts for both the villages.

Based on the data and information mentioned above:

(1) It is estimated that the average earning per person, which is the average income per household divided by average number of adults per household, was 10,050 and 8,640 bahts per year at 1996 price in Pattana village and Khoa Sok village respectively.

(2) It is estimated that the average cost of medical care per person, which is the average cost of medical care per household divided by the number of person per household, are 250 bahts per year at 1996 price in both the villages.

(3) Estimation of population during 1987-1995 and 1997-2037 is made based on (i) the average population growth rate of 0.57 percent per year, (ii) the total population of 26 in Pattana village, 18 in Khoa Sok village in 1996. The children until they become adults is made based on (i) percentage of infants and children as indicated in section 3 of Chapter VII (ii) mortality rate as indicated in section 3 of Chapter VII. The results of the estimation are presented in Table 8.14

(4) Benefits from the decrease in cost of health care are estimated based on; (a) percentage of people who were sick as indicated in section 3 of Chapter VII (b) population as estimated (c) the average cost of medical care per person as mentioned above. The results of the estimation are presented in Table 8.15

(5) Benefits from increase in earning are estimated based on; (a) cumulative increase in survivals of infants and children until they become adults, and (b) the average earning per person mentioned above. The results of the estimation are presented in Table 8.16.

Thus, health improvement benefit stream at 1996 price can be derived by combining the stream of benefits from decrease in cost of health care with the stream of benefits from increase in earning as shown in Table 8.17. The health improvement benefit stream at 1996 price is converted to the benefit stream at 1987 price. With 12 percent discount rate, the present worth of benefits from health improvement is approximately 89.14 million bahts.

(11) Benefits from Resettlement

Benefit from resettlement is the difference between post-resettled household income and pre-resettled household income. The post-resettled income and pre-resettled income per household at 1996 price are already presented in section 2 of Chapter VII. The socio-economic study of farmers in resettlement areas also indicated that there were 385 households in Pattana village.

Considering the post-resettled and pre-resettled incomes, it is found that there are 4 sources of income. They are (i) rubber (inside and outside resettled area), (ii) fishery (iii) rubber tapping and (iv) hired labor. Benefits from resettlement originated from these 4 sources of income and they are estimated as follows.

(1) Rubber in resettled area: There are rubber plantations in the resettlement area in Pattana village. The average income from this rubber in 1996 was 36,400 bahts per household in Pattana village and 24,800 bahts per household in Khoa Sok village. Information from the Office of Rubber Replantation Fund indicates that latex can be tapped from rubber trees at the age of 7 to 20 years. The indices of yield are 28 at the age of 7 years, 44 at the age of 8 years, 66 at the age of 10 years, 78 at the age of 11-15 years, 85 at the ages of 16 to 20 years, and 83 at the ages of 23 to 25 years. Based on these data and the number of household mentioned earlier, stream of benefits from rubber in resettled area is estimated.

(2) Fishery: Only a part of the people in Pattana village earns their incomes from fishery. After they moved to stay in the resettlement area, income from fishery has increased by 6,800 bahts per household per year. Therefore, it is estimated that resettlement benefit derived from fishery is about 4.58 million bahts per year.

(3) Rubber tapping: After moving to the resettlement area, income from rubber tapping of the people in Pattana village has increased by 1,650 bahts per household per year, while in Khoa Sok village the increase was 1,705 bahts per household per year. Thus, resettlement benefit derived from rubber tapping is estimated at about -0.02 million bahts per year.

(4) Hired labor: With the same procedure used in estimating resettlement benefits originated from fishery and rubber tapping, resettlement benefits originated from hired labor is estimated. It is about 0.80 million bahts per year.

Combining all the 4 sources of benefit together the overall resettlement benefit stream at 1984 price is obtained as shown in Table 8.18. This stream of benefits is converted to benefit stream at 1987 price. With 12 percent discount rate, the present worth of resettlement benefit is estimated at about 152.25 million bahts.

TABLE 8.6

HYDRO POWER BENEFIT STREAM AT 1996 PRICE AND TWELVE PERCENT DISCOUNTED HYDRO POWER BENEFIT

Unit : Million of Baht

Year	Total Cost	Revenue	Total Benefit, At 1996 Price	Present Value 12 % Discounted	Year	Total Cost	Revenue	Total Benefit, At 1996 Price	Present Value 12 % Discounted
1981	56.000	0.000	-56.000	-306.520	2010	50.000	775.500	725.500	148.452
1982	76.000	0.000	-76.000	-371.421	2011	103.000	775.500	672.500	122.863
1983	396.000	0.000	-396.000	-1727.943	2012	50.000	775.500	725.500	118.345
1984	690.000	0.000	-690.000	-2688.223	2013	50.000	775.500	725.500	105.665
1985	1189.000	0.000	-1189.000	-4135.996	2014	50.000	775.500	725.500	94.344
1986	130.000	0.000	-130.000	-403.760	2015	50.000	775.500	725.500	84.235
1987	39.000	150.700	111.700	309.753	2016	50.000	775.500	725.500	75.210
1988	39.000	178.400	139.400	345.149	2017	50.000	775.500	725.500	67.152
1989	36.000	258.200	222.200	491.213	2018	62.000	775.500	713.500	58.965
1990	146.000	337.600	191.600	378.184	2019	58.000	775.500	717.500	52.943
1991	145.000	406.300	261.300	460.500	2020	105.000	775.500	670.500	44.174
1992	45.000	500.400	455.400	716.581	2021	100.000	775.500	675.500	39.735
1993	45.000	566.700	521.700	732.951	2022	62.000	775.500	713.500	37.474
1994	50.000	643.100	593.100	743.985	2023	50.000	775.500	725.500	34.021
1995	50.000	713.000	663.000	742.560	2024	50.000	775.500	725.500	30.376
1996	50.000	775.500	725.500	725.500	2025	50.000	775.500	725.500	27.122
1997	50.000	653.700	603.700	539.018	2026	50.000	775.500	725.500	24.216
1998	50.000	775.500	725.500	578.364	2027	50.000	775.500	725.500	21.621
1999	50.000	775.500	725.500	516.397	2028	50.000	775.500	725.500	19.305
2000	50.000	775.500	725.500	461.068	2029	50.000	775.500	725.500	17.236
2001	50.000	775.500	725.500	411.668	2030	50.000	775.500	725.500	15.390
2002	50.000	775.500	725.500	367.561	2031	50.000	775.500	725.500	13.741
2003	50.000	775.500	725.500	328.179	2032	50.000	775.500	725.500	12.268
2004	179.000	775.500	596.500	240.916	2033	50.000	775.500	725.500	10.954
2005	267.000	775.500	508.500	183.370	2034	50.000	775.500	725.500	9.780
2006	303.000	775.500	472.500	152.132	2035	50.000	775.500	725.500	8.732
2007	89.000	775.500	686.500	197.352	2036	50.000	775.500	725.500	7.797
2008	50.000	775.500	725.500	186.218	2037	50.000	775.500	725.500	6.961
2009	50.000	775.500	725.500	166.266	**SUM**	**6,060.0**	**36,203.6**	**29,943.6**	**1,650.1**

TABLE 8.7

IRRIGATION BENEFIT STREAM AT 1996 PRICE

AND TWELVE PERCENT DISCOUNTED IRRIGATION BENEFIT

Unit : Million of Baht

Year	Total Cost	Revenue	Total benefit At 1996 price	Present value 12 % Discounted	Year	Total Cost	Revenue	Total benefit At 1996 price	Present value 12 % Discounted
1980	26.000	0.000	-26.000	-142.313	2010	12.000	199.000	187.000	34.164
1981	59.000	0.000	-59.000	-288.340	2011	13.000	199.000	186.000	30.341
1982	86.000	0.000	-305.445	-305.445	2012	32.000	199.000	167.000	24.323
1983	226.000	5.000	-221.000	-861.011	2013	48.000	199.000	151.000	19.636
1984	94.000	14.000	-80.000	-278.284	2014	120.000	199.000	79.000	9.172
1985	62.000	34.000	-28.000	-86.964	2015	36.000	199.000	163.000	16.898
1986	86.000	60.000	-26.000	-72.100	2016	16.000	199.000	183.000	16.938
1987	28.000	91.000	63.000	155.986	2017	12.000	199.000	187.000	15.454
1988	12.000	126.000	114.000	252.018	2018	12.000	199.000	187.000	13.798
1989	12.000	150.000	138.000	272.388	2019	12.000	199.000	187.000	12.320
1990	12.000	176.000	164.000	289.024	2020	12.000	199.000	187.000	11.000
1991	12.000	178.000	166.000	261.204	2021	12.000	199.000	187.000	9.821
1992	12.000	180.000	168.000	236.028	2022	12.000	199.000	187.000	8.769
1993	12.000	186.000	174.000	218.266	2023	12.000	199.000	187.000	7.830
1994	12.000	197.000	185.000	207.200	2024	13.000	199.000	186.000	6.953
1995	12.000	195.000	183.000	183.000	2025	15.000	199.000	184.000	6.142
1996	13.000	199.000	186.000	166.071	2026	13.000	199.000	186.000	5.543
1997	14.000	199.000	185.000	147.481	2027	12.000	199.000	187.000	4.976
1998	15.000	199.000	184.000	130.968	2028	12.000	199.000	187.000	4.443
1999	14.000	199.000	185.000	117.571	2029	12.000	199.000	187.000	3.967
2000	16.000	199.000	183.000	103.839	2030	12.000	199.000	187.000	3.542
2001	15.000	199.000	184.000	93.220	2031	12.000	199.000	187.000	3.162
2002	12.000	199.000	187.000	84.589	2032	12.000	199.000	187.000	2.823
2003	12.000	199.000	187.000	75.526	2033	12.000	199.000	187.000	2.521
2004	12.000	199.000	187.000	67.434	2034	12.000	199.000	187.000	2.251
2005	12.000	199.000	187.000	60.209	2035	13.000	199.000	186.000	1.999
2006	12.000	199.000	187.000	53.758	2036	14.000	199.000	185.000	1.775
2007	12.000	199.000	187.000	47.998	2037	13.000	199.000	186.000	1.594
2010	12.000	199.000	187.000	34.164	**SUM**	**1,484.0**	**9,950.0**	**8,466.0**	**1482.78**

TABLE 8.8

WATER SUPPLY BENEFIT STREAM AT 1996,1987 PRICE AND TWELVE PERCENT DISCOUNTED WATER SUPPLY BENEFIT

Unit : Million of Baht

Year	Benefit at 1996 Price	Benefit at 1987 Price	Benefit 12 % Discounted	Year	Benefit At 1996 Price	Benefit At 1987 Price	Benefit 12 % Discounted
1987	4.493	2.202	4.012	2013	13.619	6.674	1.984
1988	4.915	2.408	3.918	2014	14.028	6.874	1.824
1989	5.496	2.693	3.912	2015	14.449	7.080	1.678
1990	5.842	2.863	3.713	2016	14.882	7.292	1.543
1991	5.990	2.935	3.399	2017	15.329	7.511	1.419
1992	5.933	2.907	3.006	2018	15.789	7.736	1.305
1993	6.250	3.063	2.827	2019	16.262	7.969	1.200
1994	6.865	3.364	2.773	2020	16.750	8.208	1.104
1995	7.512	3.681	2.709	2021	17.588	8.618	1.035
1996	8.240	4.038	8.240	2022	18.467	9.049	0.970
1997	8.487	4.159	7.578	2023	19.390	9.501	0.909
1998	8.742	4.283	6.969	2024	20.360	9.976	0.852
1999	9.004	4.412	6.409	2025	21.378	10.475	0.799
2000	9.274	4.544	5.894	2026	22.447	10.999	0.749
2001	9.552	4.681	5.420	2027	23.569	11.549	0.702
2002	9.839	4.821	4.985	2028	24.748	12.126	0.659
2003	10.134	4.966	4.584	2029	25.985	12.733	0.617
2004	10.438	5.115	4.216	2030	27.284	13.369	0.579
2005	10.751	5.268	3.877	2031	28.649	14.038	0.543
2006	11.074	5.426	3.565	2032	30.081	14.740	0.509
2007	11.406	5.589	3.279	2033	31.585	15.477	0.477
2008	11.748	5.757	3.015	2034	33.164	16.251	0.447
2009	12.101	5.929	2.773	2035	34.823	17.063	0.419
2010	12.464	6.107	2.550	2036	36.564	17.916	0.393
2011	12.838	6.290	2.345	2037	38.392	18.812	0.368
2012	13.223	6.479	2.157	**SUM**			**131.208**

TABLE 8.9

FLOOD PROTECTION BENEFIT STREAM AT 1996,1987 PRICE AND TWELVE PERCENT DISCOUNTED FLOOD PROTECTION BENEFIT

Unit Million of Baht

Year	Benefit at 1996 Price	Benefit at 1987 Price	Benefit 12 % Discounted	Year	Benefit At 1996 Price	Benefit At 1987 Price	Benefit 12 % Discounted
1987	3.200	1.568	8.874	2013	9.360	4.586	1.363
1988	6.060	2.969	15.004	2014	9.360	4.586	1.217
1989	9.360	4.586	20.692	2015	9.360	4.586	1.087
1990	9.360	4.586	18.475	2016	9.360	4.586	0.970
1991	9.360	4.586	16.496	2017	9.360	4.586	0.866
1992	9.360	4.586	14.728	2018	9.360	4.586	0.774
1993	9.360	4.586	13.150	2019	9.360	4.586	0.691
1994	9.360	4.586	11.741	2020	9.360	4.586	0.617
1995	9.360	4.586	10.483	2021	9.360	4.586	0.551
1996	9.360	4.586	9.360	2022	9.360	4.586	0.492
1997	9.360	4.586	8.357	2023	9.360	4.586	0.439
1998	9.360	4.586	7.462	2024	9.360	4.586	0.392
1999	9.360	4.586	6.662	2025	9.360	4.586	0.350
2000	9.360	4.586	5.948	2026	9.360	4.586	0.312
2001	9.360	4.586	5.311	2027	9.360	4.586	0.279
2002	9.360	4.586	4.742	2028	9.360	4.586	0.249
2003	9.360	4.586	4.234	2029	9.360	4.586	0.222
2004	9.360	4.586	3.780	2030	9.360	4.586	0.199
2005	9.360	4.586	3.375	2031	9.360	4.586	0.177
2006	9.360	4.586	3.014	2032	9.360	4.586	0.158
2007	9.360	4.586	2.691	2033	9.360	4.586	0.141
2008	9.360	4.586	2.402	2034	9.360	4.586	0.126
2009	9.360	4.586	2.145	2035	9.360	4.586	0.113
2010	9.360	4.586	1.915	2036	9.360	4.586	0.101
2011	9.360	4.586	1.710	2037	9.360	4.586	0.090
2012	9.360	4.586	1.527	**SUM**			**216.255**

TABLE 8.10

FISHERIES DEVELOPMENT BENEFIT STREAM AT 1996, 1987 AND TWELVE PERCENT DISCOUNTED FISHERIES DEVELOPMENT BENEFIT

Unit : Million of Baht

Year	Benefit at 1996 Price	Benefit at 1987 Price	Benefit 12 % Discounted	Year	Benefit At 1996 Price	Benefit At 1987 Price	Benefit 12 % Discounted
1990	0.000	0.000	0	2014	27.000	13.230	3.511
1991	0.000	0.000	0	2015	27.000	13.230	3.135
1992	3.000	1.470	4.721	2016	27.000	13.230	2.799
1993	7.000	3.430	9.834	2017	27.000	13.230	2.499
1994	14.000	6.860	17.562	2018	27.000	13.230	2.231
1995	21.000	10.290	23.520	2019	27.000	13.230	1.992
1996	27.000	13.230	27.000	2020	27.000	13.230	1.779
1997	27.000	13.230	24.107	2021	27.000	13.230	1.588
1998	27.000	13.230	21.524	2022	27.000	13.230	1.418
1999	27.000	13.230	19.218	2023	27.000	13.230	1.266
2000	27.000	13.230	17.159	2024	27.000	13.230	1.130
2001	27.000	13.230	15.321	2025	27.000	13.230	1.009
2002	27.000	13.230	13.679	2026	27.000	13.230	0.901
2003	27.000	13.230	12.213	2027	27.000	13.230	0.805
2004	27.000	13.230	10.905	2028	27.000	13.230	0.718
2005	27.000	13.230	9.736	2029	27.000	13.230	0.641
2006	27.000	13.230	8.693	2030	27.000	13.230	0.573
2007	27.000	13.230	7.762	2031	27.000	13.230	0.511
2008	27.000	13.230	6.930	2032	27.000	13.230	0.457
2009	27.000	13.230	6.188	2033	27.000	13.230	0.408
2010	27.000	13.230	5.525	2034	27.000	13.230	0.364
2011	27.000	13.230	4.933	2035	27.000	13.230	0.325
2012	27.000	13.230	4.404	2036	27.000	13.230	0.290
2013	27.000	13.230	3.932	2037	27.000	13.230	0.259
2014	27.000	13.230	3.511	**SUM**			**300.757**

TABLE 8.11

ESTIMATE TRAFFIC VOLUME AND BENEFIT STREAM AT 1987 PRICE AND TWELVE PERCENT DISCOUNTED TRANSPORTATION BENEFITS

Unit : Million of Baht

Year	Benefit at 1996 Price	Benefit at 1987 Price	Benefit 12 % Discounted	Year	Benefit At 1996 Price	Benefit At 1987 Price	Benefit 12 % Discounted
1987	740	-70.800	-70.800	2013	6663	-20.000	-1.050
1988	785	-7.850	-7.009	2014	7329	-20.000	-0.938
1989	832	-7.850	-6.258	2015	8000	-20.000	-0.837
1990	918	-7.850	-5.587	2016	8000	-20.000	-0.748
1991	974	-7.850	-4.989	2017	8000	-20.000	-0.668
1992	1033	-7.850	-4.454	2018	8000	-20.000	-0.596
1993	1096	-7.850	-3.977	2019	8000	-20.000	-0.532
1994	1163	-7.850	-3.551	2020	8000	-50.500	-1.200
1995	1234	-7.850	-3.170	2021	8000	-50.500	-1.071
1996	1309	-7.850	-2.831	2022	8000	-50.500	-0.956
1997	1450	-7.850	-2.527	2023	8000	-50.500	-0.854
1998	1595	-12.000	-3.450	2024	8000	-50.500	-0.762
1999	1755	-12.000	-3.080	2025	8000	-50.500	-0.681
2000	1930	-12.000	-2.750	2026	8000	-50.500	-0.608
2001	2123	-12.000	-2.455	2027	8000	-50.500	-0.543
2002	2335	-12.000	-2.192	2028	8000	-50.500	-0.485
2003	2569	-12.000	-1.957	2029	8000	-50.500	-0.433
2004	2826	-12.000	-1.748	2030	8000	-50.500	-0.386
2005	3108	-12.000	-1.560	2031	8000	-50.500	-0.345
2006	3419	-12.000	-1.393	2032	8000	-50.500	-0.308
2007	3761	-12.000	-1.244	2033	8000	-50.500	-0.275
2008	4137	-12.000	-1.111	2034	8000	-50.500	-0.245
2009	4551	-20.000	-1.653	2035	8000	-50.500	-0.219
2010	5006	-20.000	-1.476	2036	8000	-50.500	-0.196
2011	5506	-20.000	-1.318	2037	8000	-50.500	-0.175
2012	6057	-20.000	-1.176	**SUM**			**-147.729**

TABLE 8.12

FORESTRY BENEFIT STREAM AT 1987 PRICE AND TWELVE PERCENT DISCOUNTED FORESTRY BENEFIT

Unit Million of Baht

Year	Benefit at 1987 Price	Benefit 12 % Discounted	Year	Benefit at 1987 Price	Benefit 12 % Discounted
1982	324.400	571.704	2010	-106.930	-7.890
1983	9.360	14.728	2011	-106.930	-7.045
1984	9.360	13.150	2012	-106.930	-6.290
1985	9.360	11.741	2013	-106.930	-5.616
1986	9.360	10.483	2014	-106.930	-5.014
1987	-18.010	-18.010	2015	-106.930	-4.477
1988	-18.010	-16.080	2016	-98.880	-3.696
1989	-18.010	-14.357	2017	-98.880	-3.300
1990	-18.010	-12.819	2018	-98.880	-2.947
1991	-18.010	-11.446	2019	-98.880	-2.631
1992	-18.010	-10.219	2020	-98.880	-2.349
1993	-18.010	-9.124	2021	-98.880	-2.097
1994	-18.010	-8.147	2022	-98.880	-1.873
1995	-18.010	-7.274	2023	-98.880	-1.672
1996	-89.510	-32.278	2024	-98.880	-1.493
1997	-89.510	-28.820	2025	-98.880	-1.333
1998	-89.510	-25.732	2026	-85.650	-1.031
1999	-89.510	-22.975	2027	-85.650	-0.920
2000	-89.510	-20.513	2028	-85.650	-0.822
2001	-89.510	-18.316	2029	-85.650	-0.734
2002	-89.510	-16.353	2030	-85.650	-0.655
2003	-89.510	-14.601	2031	-85.650	-0.585
2004	-89.510	-13.037	2032	-85.650	-0.522
2005	-89.510	-11.640	2033	-85.650	-0.466
2006	-106.930	-12.415	2034	-85.650	-0.416
2007	-106.930	-11.085	2035	-85.650	-0.372
2008	-106.930	-9.897	2036	-72.530	-0.281
2009	-106.930	-8.837	2037	-72.530	-0.251
2010	-106.930	-7.890	-106.930	**SUM**	**-370.654**

TABLE 8.13

TOURISM BENEFIT STREAM AT 1996, 1987 PRICE AND TWELVE PERCENT DISCOUNTED TOURISM BENEFITS

Unit : million of Baht

Year	Benefit at 1996 Price	Benefit at 1987 Price	Benefit 12 % Discounted	Year	Benefit At 1996 Price	Benefit At 1987 Price	Benefit 12 % Discounted
1987	1.240	1.240	3.439	2013	10.754	5.269	1.566
1988	2.010	2.010	4.977	2014	10.754	5.269	1.398
1989	6.240	6.240	13.795	2015	12.061	5.910	1.400
1990	6.230	6.230	12.297	2016	12.061	5.910	1.250
1991	5.420	5.420	9.552	2017	12.061	5.910	1.116
1992	5.850	5.850	9.205	2018	12.061	5.910	0.997
1993	6.670	6.670	9.371	2019	12.061	5.910	0.890
1994	8.250	8.250	10.349	2020	13.492	6.611	0.889
1995	9.142	9.410	10.239	2021	13.492	6.611	0.794
1996	9.245	4.738	9.245	2022	13.492	6.611	0.709
1997	9.245	4.530	8.254	2023	13.492	6.611	0.633
1998	9.245	4.530	7.370	2024	13.492	6.611	0.565
1999	9.245	4.530	6.580	2025	15.380	7.536	0.575
2000	9.623	4.715	6.116	2026	15.380	7.536	0.513
2001	9.623	4.715	5.460	2027	15.380	7.536	0.458
2002	9.623	4.715	4.875	2028	15.380	7.536	0.409
2003	9.623	4.715	4.353	2029	15.380	7.536	0.365
2004	9.623	4.715	3.887	2030	16.008	7.844	0.340
2005	10.339	5.066	3.728	2031	16.008	7.844	0.303
2006	10.339	5.066	3.329	2032	16.008	7.844	0.271
2007	10.339	5.066	2.972	2033	16.008	7.844	0.242
2008	10.339	5.066	2.654	2034	16.008	7.844	0.216
2009	10.339	5.066	2.369	2035	16.008	7.844	0.193
2010	10.754	5.269	2.200	2036	16.008	7.844	0.172
2011	10.754	5.269	1.965	2037	16.008	7.844	0.154
2012	10.754	5.269	1.754	SUM			176.753

TABLE 8.14

ESTIMATION OF POPULATION DURING 1987-2037

Unit : in person

Year	Khao Sok village At 1996	Pattana village at 1987	Year	Khao Sok village at 1996	Pattana village at 1987
1987	1226	1568	2013	1307	1647
1988	1230	1571	2014	1310	1650
1989	1233	1574	2015	1312	1653
1990	1237	1577	2016	1315	1656
1991	1241	1581	2017	1317	1659
1992	1245	1584	2018	1320	1662
1993	1248	1587	2019	1323	1665
1994	1252	1590	2020	1325	1668
1995	1256	1593	2021	1328	1671
1996	1260	1596	2022	1331	1674
1997	1263	1600	2023	1333	1677
1998	1267	1603	2024	1336	1680
1999	1271	1606	2025	1339	1683
2000	1273	1609	2026	1341	1686
2001	1276	1612	2027	1344	1689
2002	1279	1615	2028	1347	1692
2003	1281	1618	2029	1349	1695
2004	1284	1621	2030	1352	1698
2005	1286	1623	2031	1355	1701
2006	1289	1626	2032	1357	1704
2007	1291	1629	2033	1360	1707
2008	1294	1632	2034	1363	1710
2009	1297	1635	2035	1366	1713
2010	1299	1638	2036	1368	1717
2011	1302	1641	2037	1371	1720
2012	1304	1644			

TABLE 8.15

BENEFIT FROM DECREASE IN COST OF HEALTH CARE

Unit Million of Baht

Year	Khao Sok village	Pattana village	Year	Khao Sok village	Pattana village
1987	-6.616	-9.340	2013	-7.060	-9.825
1988	-6.642	-9.373	2014	-7.074	-9.843
1989	-6.662	-9.391	2015	-7.088	-9.861
1990	-6.682	-9.410	2016	-7.102	-9.878
1991	-6.702	-9.429	2017	-7.116	-9.896
1992	-6.723	-9.448	2018	-7.131	-9.914
1993	-6.743	-9.467	2019	-7.145	-9.932
1994	-6.763	-9.486	2020	-7.159	-9.950
1995	-6.783	-9.505	2021	-7.173	-9.968
1996	-6.804	-9.524	2022	-7.188	-9.986
1997	-6.824	-9.543	2023	-7.202	-10.004
1998	-6.844	-9.562	2024	-7.217	-10.022
1999	-6.865	-9.581	2025	-7.231	-10.040
2000	-6.879	-9.598	2026	-7.245	-10.058
2001	-6.892	-9.615	2027	-7.260	-10.076
2002	-6.906	-9.633	2028	-7.275	-10.094
2003	-6.920	-9.650	2029	-7.289	-10.112
2004	-6.934	-9.668	2030	-7.304	-10.130
2005	-6.948	-9.685	2031	-7.318	-10.149
2006	-6.962	-9.702	2032	-7.333	-10.167
2007	-6.976	-9.720	2033	-7.348	-10.185
2008	-6.990	-9.737	2034	-7.362	-10.203
2009	-7.004	-9.755	2035	-7.377	-10.222
2010	-7.018	-9.772	2036	-7.392	-10.240
2011	-7.032	-9.790	2037	-7.406	-10.259

TABLE 8.16

BENEFIT FROM INCREASE IN EARNING OF PERSON

Unit : in baht

Year	Ban Khao Sok	Ban Pattana	Year	Ban Khao Sok	Ban Pattana
1987	0.000	0.000	2013	502,462	1,205,480
1988	0.000	0.000	2014	502,462	1,205,480
1989	0.000	0.000	2015	502,462	1,205,480
1990	0.000	0.000	2016	502,462	1,205,480
1991	0.000	0.000	2017	502,462	1,205,480
1992	0.000	0.000	2018	502,462	1,205,480
1993	0.000	0.000	2019	502,462	1,205,480
1994	0.000	0.000	2020	502,462	1,205,480
1995	0.000	0.000	2021	502,462	1,205,480
1996	556,268	155,417	2022	502,462	1,205,480
1997	108,412	304,514	2023	502,462	1,205,480
1998	162,471	452,132	2024	502,462	1,205,480
1999	212,563	596,475	2025	502,462	1,205,480
2000	278,653	742,592	2026	502,462	1,205,480
2001	335,261	864,921	2027	502,462	1,205,480
2002	395,643	996,437	2028	502,462	1,205,480
2003	407,125	1,185,634	2029	502,462	1,205,480
2004	502,462	1,205,480	2030	502,462	1,205,480
2005	502,462	1,205,480	2031	502,462	1,205,480
2006	502,462	1,205,480	2032	502,462	1,205,480
2007	502,462	1,205,480	2033	502,462	1,205,480
2008	502,462	1,205,480	2034	502,462	1,205,480
2009	502,462	1,205,480	2035	502,462	1,205,480
2010	502,462	1,205,480	2036	502,462	1,205,480
2011	502,462	1,205,480	2037	502,462	1,205,480
2012	502,462	1,205,480			

TABLE 8.17

HEALTH IMPROVEMENT BENEFIT STREAM AT 1995, 1987 PRICE AND TWELVE PERCENT DISCOUNTED HEALTH IMPROVEMENT BENEFITS

Unit Million of Baht

Year	Benefit at 1996 Price	Benefit at 1987 Price	Benefit 12 % Discounted	Year	Benefit At 1996 Price	Benefit At 1987 Price	Benefit 12 % Discounted
1987	0.680	0.333	1.684	2013	5.600	2.744	0.728
1988	1.360	0.666	3.007	2014	5.600	2.744	0.650
1989	2.040	1.000	4.027	2015	5.600	2.744	0.581
1990	3.420	1.676	6.027	2016	5.600	2.744	0.518
1991	3.650	1.789	5.743	2017	5.600	2.744	0.463
1992	4.210	2.063	5.915	2018	5.600	2.744	0.413
1993	4.970	2.435	6.234	2019	5.800	2.842	0.382
1994	5.340	2.617	5.981	2020	5.800	2.842	0.341
1995	5.380	2.636	5.380	2021	5.800	2.842	0.305
1996	5.400	2.646	4.821	2022	5.800	2.842	0.272
1997	5.400	2.646	4.305	2023	5.800	2.842	0.243
1998	5.400	2.646	3.844	2024	5.800	2.842	0.217
1999	5.400	2.646	3.432	2025	5.800	2.842	0.194
2000	5.400	2.646	3.064	2026	5.800	2.842	0.173
2001	5.400	2.646	2.736	2027	5.800	2.842	0.154
2002	5.400	2.646	2.443	2028	5.800	2.842	0.138
2003	5.400	2.646	2.181	2029	5.800	2.842	0.123
2004	5.400	2.646	1.947	2030	5.860	2.871	0.111
2005	5.400	2.646	1.739	2031	5.860	2.871	0.099
2006	5.400	2.646	1.552	2032	5.860	2.871	0.088
2007	5.400	2.646	1.386	2033	5.860	2.871	0.079
2008	5.600	2.744	1.283	2034	5.860	2.871	0.071
2009	5.600	2.744	1.146	2035	5.860	2.871	0.063
2010	5.600	2.744	1.023	2036	5.860	2.871	0.056
2011	5.600	2.744	0.913	2037	5.860	2.871	0.050
2012	5.600	2.744	0.816	**SUM**			**89.140**

TABLE 8.18

RESETTLEMENT BENEFIT STREAM AT 1987, PRICE AND TWELVE PERCENT DISCOUNTED RESETTLEMENT BENEFITS

Unit : Million of Baht

Year	Benefit at 1987 Price	Benefit 12 % Discounted	Year	Benefit At 1987 Price	Benefit 12 % Discounted
1984	7.850	11.029	2011	12.800	11.029
1985	8.260	10.361	2012	12.800	10.361
1986	10.500	11.760	2013	12.800	11.760
1987	12.800	12.800	2014	12.800	12.800
1988	12.800	11.429	2015	12.800	11.429
1989	12.800	10.204	2016	12.800	10.204
1990	12.800	9.111	2017	12.800	9.111
1991	12.800	8.135	2018	12.800	8.135
1992	12.800	7.263	2019	12.800	7.263
1993	12.800	6.485	2020	12.800	6.485
1994	12.800	5.790	2021	12.800	5.790
1995	12.800	5.170	2022	12.800	5.170
1996	12.800	4.616	2023	12.800	4.616
1997	12.800	4.121	2024	12.800	4.121
1998	12.800	3.680	2025	12.800	3.680
1999	12.800	3.285	2026	12.800	3.285
2000	12.800	2.933	2027	12.800	2.933
2001	12.800	2.619	2028	12.800	2.619
2002	12.800	2.339	2029	12.800	2.339
2003	12.800	2.088	2030	12.800	2.088
2004	12.800	1.864	2031	12.800	1.864
2005	12.800	1.665	2032	12.800	1.665
2006	12.800	1.486	2033	12.800	1.486
2007	12.800	1.327	2034	12.800	1.327
2008	12.800	1.185	2035	12.800	1.185
2009	12.800	1.058	2036	12.800	1.058
2010	12.800	0.944	2037	12.800	0.944
			SUM		**152.248**

2.4.3 Comparison of Benefits Estimated before and after Project Implementation

In this section the benefits of various components estimated in section 2.4.2. are compared with those estimated before project implementation. Table 8.19 show benefits estimated before and after project implementation. Benefits from water supply, salinity and water pollution control, health improvement, and health improvement was not estimated in monetary value before project implementation.

The present worth of hydropower benefits estimated before project implementation was 1,853.68 million bahts, while the one estimated after project implementation is 1650.10 million bahts. This difference is due to the computation of benefit is based on different sources of power generation. The benefit estimated before project implementation was based on 80 MW oil-fired plant plus 40 gas turbine plant, which was the most competitive alternative source of electricity equivalent characteristics during that period (EEI Report) while the benefit estimated after project implementation is based on 240 MW gas-fired plant, which is presently the least cost equivalent system. Moreover, due to oil crisis the cost of fuel for power generation during the period before project implementation was very high. But during this post evaluation study the oil crisis is over, and the cost of fuel particularly the cost of gas planed to be used for the 240 MW gas-fired plant is rather inexpensive sine it can be produced domestically. Therefore, the present worth of hydropower benefits estimated before project implementation was much higher than the one estimated after project implementation.

The present worth of irrigation benefits estimated before and after project implementation are 1,562.48 and 1,482.78 million bahts, respectively.

The present worth of flood protection benefits was not estimated before project implementation. It was only indicated that the benefit would be 23.57 million bahts per year. From Table 8.9 flood protection benefits estimated after project implementation is about 216.55 million bahts, higher than the previously estimated one.

The present worth of fisheries development benefits was also not estimated before project implementation. However, it was estimated that the benefit would be about 27.0 million bahts per year as compared to the average of about 300.76 million bahts estimated after project implementation.

Again, the present worth of transportation benefits was not estimated before project implementation. It was only revealed that the road relocation cost was estimated to be 120 million bahts and the benefit from transportation was about -266.08 million bahts. The estimation made after project implementation indicated that the cost of road relocation was about 70.8 million bahts and the benefit from transportation was about −147.73 million bahts per year.

The present worth of forestry benefits estimated before and after project implementation is about 324.4 and −370.65 million bahts, respectively. The difference, which is relatively small, is due to the different discount rates adopted in the two estimations. It was 10 percent in the previous estimation while it is 12 percent in this updated estimation.

Tourism benefits estimated before project implementation gave the present worth of about 206.26 million bahts as compared to approximately 176.75 million bahts estimated after project implementation.

TABLE 8.19

COMPARISON OF BENEFITS ESTIMATED BEFORE AND AFTER PROJECT IMPLEMENTATION (1987 PRICE)

Items of benefit (1)	**Estimated benefit, Million bahts**	
	Before project Implementation (2)	**After project Implementation (3)**
1. Hydropower	1,853.68	1,650.10
2. Irrigation	1562.48	1,482.78
3. Water supply	not estimated	131.21
4. Flood protection	23.57year	216.25
5. Fisheries development	27.0/year	300.76
6. Transportation and navigation	-16/year, and -266.08 for road relocation	-147.73
7. Salinity and water pollution control	not estimated	negligible
8. Forestry	324.4	-370.65
9. Tourism	206.26	176.75
10. Health improvement	not estimated	89.19
11. Resettlement	154.50	152.25

All benefits, except those of items 4, 5 and 6 in column 2, are in terms of present worth.

2.4.4 Project Assessment

Based on Table 8-19, the overall benefit of the project is lower than it was previously estimated. However, this should not result in the conclusion that the overall benefit from the project is lower. This was due to external factors. These factors are, for example, the costs of fuel used in the power generation as already described in section 2.4.3 of this chapter. The less expensive cost of natural gas, which can be produced locally makes the cost of alternative source of electricity lower. Hence the benefit of the hydropower generation declines.

Another factor that causes a component of the benefits to be delayed is right-of-way problem. The right-of-way problem makes irrigation component progresses slower than it was anticipated. Thus, its benefit during the overall project life is smaller than it was previously estimated.

Besides, some of the actual benefits derived from the project are greater while some others are smaller than those previously estimated. However, these differences seem to be rather insignificant. Therefore, it can be concluded that the overall actual positive benefit of the project is lower than it was anticipated, and it is caused by external factors.

2.5 Conclusion and Recommendation

The study with regard to demand for electricity of industrial and service units reveals that the cost of electricity ranges from 8 to 833 bahts per hour. Factor share of electricity varies from only 1 percent for food canning industry to 82 percent for ice making factory. Damage due to electricity interruption is estimated to be in the range of 15 bahts per hour for hair dressing service to 3,079 bahts per hour for ice making business.

The present worth of benefits, at 1987 and 12 percent discount rate, of hydropower production, irrigation, water supply, flood protection, fisheries development, transportation and navigation, forestry, tourism, health improvement, and resettlement are made. They are approximately 1650.10, 1482.78, 131.21, 300.76, -147.73, -370.65, 176.75, 89.14 and 152.25 million bahts, respectively.

Comparison of benefits estimated before and after project implementation has been made. It is found that the differences in present worth are tremendous for forestry, hydropower production and irrigation. The ones estimated after project implementation are about 695, 203 and 79 million bahts, respectively, lower than those estimated before project implementation. The changes in input and output prices and unexpected delay in work implementation of irrigation project mainly caused these differences. The differences between benefits estimated before and after project implementation for forestry and tourism are rather small. The comparisons of other components of benefits could not be made directly either because their present worth was not estimated before the project implementation, or because their benefits were not estimated at all.

3. Input-Output Analysis

3.1 Introduction

Like most investment projects, Rajjaprabha dam also produces not only direct effects, but also indirect effects on output and income in the regional economy Rajjaprabha dam essentially produces two products: electricity and water. Electricity is supplied to producing activities, particularly manufacturing as intermediate input, and to households as consumption goods. Water is distributed mainly for irrigation for agricultural production. In addition, the construction of the dam also changed the natural structure of the area. It improves navigation facilities, changes structure of forestry resources, fisheries resources, etc. Thus, in one way or the another, it affects production structure of the economy.

The dam affects environment as well. The project improves flood control system in the region, reduces salinity damages in the basin, and eliminates or reduces pollution generated by economic activities, etc. On the other hand, economic expansion (that generated by the dam) produces by-product as pollution that affects quality of life in the region.

These are direct and indirect effects generated by Rajjaprabha dam should be included in project evaluation but usually not captured. The purpose of this study is to analyse direct and indirect effects on output, income and pollution generated by the dam in the region. Indirect effects are also emphasized.

3.2 Objective and Scope

The main objective of this study is to analyse direct and indirect effects of Rajjaprabha dam on output, income and environment in Surat Thani. So the administrative boundary of Surat Thani province is defined as a region specific economic system. Production sectors within the area are "domestic" production sectors and those outside the area are aggregated as "the rest of the world". Inflows of goods and services from the rest of the world are considered as "imports" while outflows of goods and services from the region, "exports".

3.3 Methodology

(1) Model : In addition to the usual input-output matrix, household income consumption matrices and pollution row are included in the model. The model is described in details in section methodology chapter 1.

(2) Data : The 1975 national input-output transaction table is used as a basis to derive regional technical coefficient matrix. Based on economic profile of the region, important production activities are identified. Production activities are aggregated into 36 sectors. Households are differentiated between agricultural and non-agricultural households. The adapted transaction table is used to derive technical coefficient matrix for the regional economy (Table 8.20). Technical coefficients for households (income and consumption) are derived from the social account matrix for Thailand. Primary data from survey, spot check and secondary data from various sources are used to cross check the technical coefficient matrix. Certain cells have been adjusted. Observation in the area suggested that air pollution is not important here. Hence, only water pollution is emphasized. As suggested from water quality study, only few industries have more potential to be pollutant generators. Their pollution coefficients are obtained from water quality study. Each row represents supply of goods and services from a row sector to various column sectors while each column represents demand for goods and services from various row sectors. Row households refer to value added to households while column households refer to consumption of households.

The technical coefficient in Table 8.20, reading along the column, represent the production function of a column production sector. For example, the value of 0.0318557 of row 1 column 1 indicates that to produce a unit of paddy, the paddy production sector (column) requires o.0318557 units of output from paddy sector itself (row) as input. Similarly, the value of 0.004224 means that to produce one unit of paddy, the paddy sector needs 0.004224 units of output from forestry sector as input in the same manner. The value of 0.858128 in row 37, column 1 shows that to produce one unit of paddy, the sector requires 0.858128 units of value added agricultural households. Column 26 of Table 8.20 hence shows the inputs (as outputs from various rows sectors) required for electricity production. As can be seen, only marginal proportion of inputs from the regional economy issued in the production process. More than 60% of inputs is supplied from outside the region (imports).

TABLE 8.20

TECHNICAL COEFFICIENTS FOR REGIONAL ECONOMY

Item		1	2	3	4	5	6	7
Paddy	1	0.0318557	0	0.0012471	0	0.0066329	0.0281027	0
Beans and Nuts	2	0	0.0124866	0.0007008	0	0	0	0
Vegatable and Fruit	3	0	0	0.0326292	0	0	0.0072246	0
Rubber	4	0	0	0	0	0	0	0
Other Crops	5	0.0254730	0.0524014	0.0105930	0.0136359	0.02223520	0	0.0161915
Livestock	6	0	0	0	0	0	0.0013552	0
Forestries	7	0.0004224	0	0.0009008	0	0.0157243	0.0012462	0.0392260
Fisheries	8	0	0	0	0	0	0.0128238	0
Mining and Quarrying	9	0	0	0	0	0	0	0
Slaughtering	10	0	0	0	0	0	0	0
Oil from Crop or Animal	11	0	0	0	0	0	0	0
Other processing of food	12	0	0	0	0	0	0	0
Rice Mill	13	0	0	0	0	0	0.0658043	0
Ice	14	0	0	0	0	0	0	0
Other food	15	0	0	0	0	0	0	0
Animal feed	16	0	0	0	0	0	0.2646912	0
Softdrink and Carbonate wat	17	0	0	0	0	0	0	0
Printing and Publishing	18	0	0	0	0	0	0.0000236	0.0000005
Rubber Sheel and Black	19	0	0	0	0	0	0	0
Concrete and Cement Produc	20	0	0	0	0	0	0	0.0036250
Others	21	0	0	0	0	0	0	0.0016081
Motor Vehicle and Repair	22	0.0012898	0.0006722	0.0015695	0.0006838	0.0019193	0.0009403	0.0007747
Saw mill	23	0.0000954	0	0	0	0.0003651	0.0000807	0
Wood product	24	0.0007049	0.0031391	0.0063901	0.0005778	0.0074544	0.0003249	0.0012633
Other Manufacturing Goods	25	0	0	0	0	0	0.0000598	0.0000217
Electricity	26	0	0	0	0	0	0.0007761	0
Water work and supplies	27	0	0	0	0	0	0.0022058	0
Building Construction	28	0.0008743	0.0018651	0.0007805	0.0015234	0.001527	0.0073584	0.0036286
Public work and construction	29	0	0	0	0	0	0	0
Trade	30	0.0095992	0.0056619	0.0196759	0.0074052	0.0141387	0.0542165	0.0064295
Restaurant and Hotel	31	0	0	0	0	0	0	0
Road transportation	32	0.0012135	0.0013258	0.0040037	0.0013791	0.0019729	0.0085740	0.0013868
Water transportation	33	0.0005163	0.0003366	0.0013718	0.0003799	0.0007711	0.0038053	0.0003726
Air transportation	34	0	0	0.0000039	0	0.0000177	0.0000033	0
Post and other communicatio	35	0	0	0	0	0	0	0
Services	36	0.0191152	0.0072192	0.0075901	0.0049575	0.0016195	0.0090666	0.0027965
Agricultural household	37	0.8581280	0.3513223	0.8533162	0.9252000	0.8669900	0.4745680	0.8276400
Nonagricultural household	38	0	0	0	0	0	0	0
Imports	39	0.0517225	0.0235709	0.0583223	0.0442573	0.5862600	0.5684970	0.3329780
Pollution	40	0	0	0	0	0	0	0
Sum raw		1	1	1	1	1	1	1

TABLE 8.20 (CONT'D)

Item	-	22	23	24	25	26	27	28	
Paddy	1	0	0	0	0.0132154	0	0	0	
Beans and Nuts	2	0	0	0	0	0	0	0	
Vegatable and Fruit	3	0	0	0	0	0	0	0	
Rubber	4	0	0	0	0	0	0	0	
Other Crops	5	0	0	0.0000053	0.0001106	0	0	0.0000477	0
Livestock	6	0	0	0	0.0211245	0	0	0	
Forestries	7	0	0.4551523	0.0828155	0.0110157	0	0	0.0083317	0
Fisheries	8	0	0	0	0	0	0	0	
Mining and Quarrying	9	0	0	0	0	0	0	0	
Slaughtering	10	0	0	0	0	0	0	0	
Oil from Crop or Animal	11	0	0	0	0	0	0	0	
Other processing of food	12	0	0	0	0	0	0	0	
Rice Mill	13	0	0	0	0	0	0	0	
Ice	14	0	0	0	0	0	0	0	
Other food	15	0	0	0	0	0	0	0	
Animal feed	16	0	0	0	0	0	0	0	
Softdrink and Carbonate wat	17	0	0	0	0	0	0	0	
Printing and Publishing	18	0.0003659	0	0	0.0003133	0.0005150	0.0002402	0.0001150	0.
Rubber Sheel and Black	19	0	0	0	0	0	0	0	
Concrete and Cement Produc	20	0	0	0	0	0	0	0	
Others	21	0	0	0	0	0	0	0.0069997	0.
Motor Vehicle and Repair	22	0	0.0118776	0.0073021	0.0011096	0.0014464	0.0006763	0.0018334	0.
Saw mill	23	0	0	0.2055461	0.0308814	0	0	0.7832610	0.
Wood product	24	0	0	0.0016607	0.0043684	0.0005078	0.0002371	0.0029519	
Other Manufacturing Goods	25	0.0000307	0.0001035	0.0000925	0.0007684	0.0000847	0.0000400	0.0000114	0.
Electricity	26	0.0055782	0.0182010	0.0127534	0.0055456	0.0236003	0.1550101	0.0042419	0.
Water work and supplies	27	0	0.0004569	0.0005872	0.0001508	0.0014464	0.0023687	0.0001105	0
Building Construction	28	0.0010512	0.0033436	0.0062330	0.0033171	0.0026033	0.0063072	0.0003667	0.
Public work and construction	29	0.0001892	0	0.0011613	0.0011258	0.0003328	0.0015066	0	
Trade	30	0.7667880	0.3784480	0.1028118	0.8941570	0.0787164	0.0257336	0.0874981	0.
Restaurant and Hotel	31	0	0.0030870	0.0057141	0	0	0	0.0063252	0
Road transportation	32	0.0129337	0.0184167	0.0145858	0.0083438	0.0148873	0.0040617	0.003509	0.
Water transportation	33	0.0025053	0.0021706	0.0049356	0	0.0028161	0.0007933	0.0187963	0.
Air transportation	34	0.0000741	0	0	0.0000005	0.0010324	0.000732	0.0000001	0.
Post and other communicatio	35	0.0005282	0.0008082	0.0024230	0.0001214	0.0007231	0.0006657	0.0005788	0.
Services	36	0.0011654	0.0118434	0.0091193	0.0040038	0.0221406	0.0072525	0.0178769	0.
Agricultural household	37	0	0	0	0	0	0	0.0169430	
Non-agricultural household	38	0.2771530	0.4093380	0.4047850	0.5448830	0.3853920	0.5954770	0.3561440	0.
Imports	39	0.6217463	0.0273565	0.1374673	0.2601804	0.4637553	0.1998979	0.3890923	0.
Pollution	40	0	0	0	0	0	0	0	
Sum Raw		1	1	1	1	1	1	1	

3.4 Analysis Results

The results of the study are presented in two parts. One is the analysis of structural linkages in the regional economy. The other is the analysis of impacts generated in the economy by the Rajjaprabha dam.

3.4.1 Structural Linkages

One of the advantages of input-output analysis is that it provides a full picture of inter-industry relationship in the economy, i.e. direct and indirect relationship. Table 8.21 shows direct and indirect effects on various row sectors that are generated by an exogenous change in final demand (including household demand), while Table 8.22 shows the effects generated by other final demand (excluding household demand). Table 8.23 summarizes total effects on production from Table 8.21 and Table 8.22. In addition, total effects on imports, pollution, and income generated by other final demand are also presented.

Thus, 1.093124 of fisheries sector means that a unit increase of fisheries final demand generates 1.6808 units of output in the economy. The distribution of these 1.6808 units are distributed can be seen in fisheries column of Table 8.21. The same interpretation is applied to others. As can be seen, figures along column 1 (paddy sector) of Table 8.21 shows output (directly and indirectly) demanded from various row sectors due to unit increase in final demand for output of the paddy sector. Each element of the diagonal matrices in Tables 8.21 and Table 8.22 has a value of 1 for the exogenous final demand added, while other elements of the matrices refer to direct and indirect demand generated. For instance, the value of 0.000046 of row 6 column 1 in Table 8.21 means that the amount of 0.000046 units of output from livestock are indirectly generated due to an increase in one unit of final demand for output of paddy sector. It should be noted that this amount is not directly demanded in paddy production (see the respective cell in table 8.20). Similarly, along column 26 of Table 8.21, all row sectors have received direct and/or indirect demand from a unit increase in final demand for electricity. Thus, a unit of final demands for electricity indirectly generates 0.000078 units of output from paddy sector, and so on.

Total effects from Table 8.21 are conventional input-output inverse, which have been argued to be inappropriate particularly for rural economy. It has been assessed that direct and indirect effects are generated not only through production linkages, but also through income consumption linkages. Through income-consumption linkages, the increased income (generated due to increase production) must be either spent or saved depending on behaviours of the resource owners. In Surat Thani province, where more than 70 percent of household are engaged in agriculture, income-consumption effects cannot be neglected. The analysis here concentrates on the income-consumption effects. As shown in Table 8.22, much higher direct and indirect effects are generated in the economy when income-consumption effects are included. Without income-consumption effects, a unit increase in final demand for paddy production generates 1.1015 units of total output in the regional economy (the last row of column 1 in Table 8.21). With such effects, the total outputs of 3.3618 unit are generated. Similarly, an increase in other demand of electricity generated 2.21347 units of total output compared to 1.17685 units of the case without income consumption effects.

TABLE 8.21

TOTAL EFFECTS IN THE ECONOMY DUE TO AN EXOGENOUS CHANGE IN FINAL DEMAND

Item		1	2	3	4	5	6	7	8
Paddy	1	1.033104	0.000596	0.001431	0.000105	0.007032	0.110020	0.000135	0.000379
Beans and Nuts	2	0.000004	1.012646	0.000737	0.000001	0.000002	0.000014	0.000001	0.000004
Vegetable and Fruit	3	0.000018	0.000011	1.033752	0.000009	0.000014	0.007551	0.000008	0.000033
Rubber	4	0	0	0	1	0	0	0	0
Other Croops	5	0.026944	0.085397	0.011345	0.013960	1.023233	0.003138	0.017256	0.000037
Livestock	6	0.000046	0.000026	0.000052	0.000022	0.000033	1.001525	0.000020	0.000092
Forestries	7	0.001236	0.002252	0.002400	0.000463	0.018461	0.002231	1.041741	0.001111
Fisheries	8	0.000020	0.000011	0.000022	0.000009	0.000014	0.032352	0.000008	1.001161
Mining and Quarrying	9	0	0	0	0	0	0	0	0
Slaughtering	10	0.000035	0.000021	0.000043	0.000018	0.000029	0.000142	0.000016	0.000065
Oil from Crop or Animal	11	0.000006	0.000003	0.000006	0.000002	0.000003	0.000017	0.000002	0.000008
Other processing of food	12	0.000027	0.000014	0.000024	0.000011	0.000014	0.000070	0.000009	0.000031
Rice Mill	13	0.000019	0.000012	0.000027	0.000011	0.000019	0.106998	0.000022	0.000495
Ice	14	0.000035	0.000026	0.000069	0.000026	0.000050	0.001624	0.000025	0.042489
Other food	15	0.000014	0.000008	0.000018	0.000007	0.000012	0.00006	0.000007	0.000028
	16	0.000012	0.000007	0.000014	0.000006	0.000009	0.265189	0.000005	0.002938
Softdrink and Carbonate wate	17	0.000015	0.000009	0.000020	0.000008	0.000013	0.000078	0.000009	0.000037
Printing and Publishing	18	0.000243	0.000102	0.000135	0.000073	0.000052	0.000444	0.000052	0.000217
Rubber Sheet and Block	19	0	0	0	0	0	0	0	0
Concrete and Cement Product	20	0	0.000001	0.000001	0	0.000007	0.000007	0.000377	0.000187
Others	21	0.000013	0.000020	0.000013	0.000013	0.000043	0.000071	0.001703	0.000005
Motor Vehicle and Repair	22	0.001636	0.001140	0.002280	0.000919	0.002372	0.002993	0.001092	0.001574
Saw mill	23	0.000457	0.001029	0.001553	0.000311	0.002145	0.001253	0.000643	0.001253
Wood product	24	0.001032	0.003881	0.006809	0.000731	0.007732	0.001049	0.001494	0.005345
Other manufacturing Goods	25	0.000043	0.000018	0.000021	0.000012	0.000008	0.000177	0.000031	0.000819
Electricity	26	0.000234	0.000182	0.00030	0.000103	0.000249	0.004083	0.000130	0.004624
Water work and supplies	27	0.000650	0.000037	0.000071	0.000029	0.000045	0.002617	0.000030	0.001672
Building Construction	28	0.001459	0.002275	0.00120	0.001784	0.001831	0.009411	0.003946	0.000459
Public work and construction	29	0.000077	0.000035	0.000044	0.000022	0.000021	0.000342	0.000018	0.000057
Trade	30	0.010467	0.008156	0.022521	0.008302	0.016402	0.094988	0.008004	0.039609
Restaurant	31	0.000681	0.000461	0.001057	0.000412	0.000747	0.003658	0.000395	0.001692
Road transportation	32	0.001555	0.001727	0.004566	0.001537	0.002382	0.014090	0.001739	0.007128
Water transportation	33	0.000643	0.000510	0.001577	0.000460	0.000935	0.006056	0.000532	0.001767
Air transportation	34	0.000102	0.000057	0.000117	0.000048	0.000089	0.000384	0.000042	0.000175
Post and other communication	35	0.000139	0.000084	0.000161	0.000064	0.000108	0.000599	0.000059	0.000284
Services	36	0.021130	0.005229	0.009303	0.005586	0.002727	0.017476	0.003525	0.006640
Sum		1.101513	1.128957	1.101625	1.034993	1.086832	1.680764	1.093124	1.122412

TABLE 8.21 (CONT'D)

Item		20	21	22	23	24	25	26	27	2
Paddy	1	0.000105	0.005090	0.000066	0.000164	0.000252	0.002613	0.000078	0.000039	0.00025
Beans and Nuts	2	0.000011	0.000004	0.000006	0.000011	0.000022	0.000008	0.000010	0.000005	0.00002
Vegetable and Fruit	3	0.00010	0.000039	0.000061	0.000100	0.000214	0.000236	0.000076	0.000037	0.00020
Rubber	4	0	0	0	0	0	0	0	0	
Other Croops	5	0.000038	0.001667	0.000018	0.007881	0.003109	0.000651	0.000031	0.000021	0.00087
Livestock	6	0.000245	0.000111	0.000138	0.000230	0.000471	0.021343	0.000179	0.000088	0.00044
Forestries	7	0.000667	0.092019	0.000248	0.474490	0.184756	0.027401	0.000495	0.000522	0.04737
Fisheries	8	0.000096	0.000037	0.000057	0.000095	0.000201	0.000756	0.000075	0.000037	0.00019
Mining and Quarrying	9	0	0	0	0	0	0	0	0	[illegible]
Slaughtering	10	0.000193	0.000070	0.000121	0.000198	0.000426	0.000154	0.000149	0.000073	0.00040
Oil from Crop or Animal	11	0.000023	0.000009	0.000013	0.000023	0.000047	0.000017	0.000019	0.000009	0.00004
Other processing of food	12	0.000096	0.000036	0.000054	0.000093	0.000190	0.000070	0.000079	0.000039	0.00018
Rice Mill	13	0.000128	0.006706	0.000081	0.000136	0.000286	0.002363	0.000096	0.000047	0.00031
Ice	14	0.000354	0.000126	0.000239	0.000182	0.000439	0.000321	0.000258	0.000125	0.00037
Other food	15	0.000092	0.000044	0.000052	0.000083	0.000173	0.000064	0.000065	0.000033	0.00016
Animal feed	16	0.000065	0.000030	0.000037	0.000061	0.000125	0.005651	0.000048	0.000023	0.00011
Softdrink and Carbonate wate	17	0.000110	0.000061	0.000057	0.000091	0.000186	0.000069	0.000072	0.000036	0.00017
Printing and Publishing	18	0.000753	0.000314	0.000540	0.000312	0.000430	0.000539	0.000963	0.000539	0.00051
Rubber Sheet and Block	19	0	0	0	0	0	0	0	0	[illegible]
Concrete and Cement Product	20	1	0.000033	0	0.000172	0.000067	0.000010	0	0	0.00001
Others	21	0.000056	1.000181	0.000012	0.000805	0.000361	0.000077	0.000029	0.000055	0.007091
Motor Vehicle and Repair	22	0.016072	0.011305	1.001694	0.014669	0.012527	0.002946	0.003532	0.001856	0.00386
Saw mill	23	0.000968	0.000524	0.000365	1.000761	0.207021	0.032472	0.000683	0.000795	0.07940
Wood product	24	0.004650	0.000315	0.000268	0.000888	1.002389	0.004773	0.000677	0.000507	0.00341
Other manufacturing Goods	25	0.000116	0.000088	0.000046	0.000155	0.000166	1.000800	0.000148	0.000083	0.00007
Electricity	26	0.010065	0.006880	0.006113	0.019276	0.017946	0.006922	0.025046	0.159532	0.006638
Water work and supplies	27	0.000488	0.002577	0.000180	0.000642	0.001024	0.000435	0.001717	1.002718	0.000447
Building Construction	28	0.007498	0.004270	0.001565	0.005827	0.008680	0.004377	0.003703	0.007239	1.001889
Public work and construction	29	0.000643	0.001629	0.000217	0.000080	0.001254	0.001182	0.000452	0.001616	0.000115
Trade	30	0.116589	0.041089	0.079859	0.047208	0.119945	0.096788	0.084695	0.040859	0.096300
Restaurant	31	0.004980	0.001791	0.003247	0.005209	0.011427	0.004116	0.003726	0.001842	0.010724
Road transportation	32	0.052807	0.056664	0.013722	0.020340	0.020506	0.010239	0.016246	0.007062	0.006554
Water transportation	33	0.029985	0.032495	0.002778	0.002793	0.006157	0.000576	0.003242	0.001564	0.019819
Air transportation	34	0.001042	0.000606	0.000413	0.000294	0.000654	0.000399	0.001496	0.001135	0.000501
Post and other communication	35	0.001543	0.000743	0.000929	0.001157	0.003319	0.000634	0.001278	0.001063	0.001243
Services	36	0.023981	0.009965	0.004598	0.016602	0.018326	0.008898	0.027285	0.013155	0.024456
Sum		**1.270375**	**1.277516**	**1.117794**	**1.621035**	**1.621035**	**1.337690**	**1.176848**	**1.242757**	**1.314203**

TABLE 8.22

TOTAL PRODUCTION AND INCOME EFFECTS IN THE ECONOMY DUE TO A EXOGENOUS CHANGE IN OTHER DEMAND

Item		1	2	3	4	5	6
Paddy	1	1.203084	0.279393	0.266664	0.275280	0.274903	0.313052
Beans & Nuts	2	0.004079	1.016851	0.004766	0.004145	0.004052	0.003372
Vegetable and Fruit	3	0.040661	0.041928	1.073947	0.041315	0.040405	0.041232
Rubber	4	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
Other crops	5	0.462017	0.533996	0.441687	0.455968	1.455548	0.365324
Lirestact	6	0.101747	0.104973	0.100595	0.103455	0.101121	1.084936
Forestries	7	0.066558	0.069534	0.067452	0.066733	0.083340	0.057633
Fisheries	8	0.073694	0.075945	0.072912	0.074818	0.073209	0.094124
Mining and Quarrying	9	0	0	0	0	0	0
Slaughtering	10	0.024176	0.024381	0.024223	0.023847	0.023799	0.027891
Oil from crop or animal	11	0.000334	0.000339	0.000331	0.000333	0.000328	0.000314
Ther processing of food	12	0.001452	0.001475	0.001437	0.001449	0.001426	0.001359
Rice mill	13	0.347524	0.360241	0.342669	0.355572	0.346107	0.368657
Ice	14	0.014608	0.015012	0.014508	0.014778	0.014515	0.014342
Other food	15	0.033827	0.034762	0.033527	0.034214	0.033565	0.029814
Animal feed	16	0.027145	0.028006	0.026839	0.027601	0.026979	0.287447
Softdrink and Carbonate water	17	0.012261	0.012594	0.012156	0.012394	0.012164	0.010877
Printing and Publishing	18	0.003389	0.003335	0.003253	0.003255	0.003174	0.003220
Rubber Sheet and Block	19	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
Concrete and Cement Product	20	0.024305	0.025044	0.024051	0.024670	0.024150	0.020491
Others	21	0.009484	0.008747	0.008395	0.009610	0.009457	0.007215
Motor Vehicle and Repair	22	0.026981	0.271440	0.027406	0.026534	0.027514	0.025560
Saw mill	23	0.023473	0.024739	0.024330	0.023666	0.025006	0.020714
Wood Product	24	0.102894	0.108835	0.107604	0.104120	0.108916	0.086905
Other Manufacturing Goods	25	0.000463	0.000449	0.000437	0.000437	0.000425	0.000544
Electricity	26	0.031296	0.032135	0.031066	0.031563	0.031084	0.031006
Water work and supplies	27	0.003600	0.003639	0.003591	0.003565	0.003540	0.006170
Building Construction	28	0.018745	0.020052	0.018324	0.019215	0.018988	0.004466
Public work and construction	29	0.001208	0.001201	0.001163	0.001171	0.001145	0.001205
Trade	30	0.212842	0.215923	0.223206	0.212723	0.217125	0.266424
Restaurant and Hotel	31	0.058440	0.059673	0.058381	0.058642	0.057999	0.056672
Road transportation	32	0.076290	0.078624	0.078580	0.077251	0.076577	0.078629
Water transportation	33	0.027145	0.027781	0.027820	0.027314	0.027246	0.028892
Air transportation	34	0.008596	0.008726	0.008570	0.008561	0.008493	0.008740
Post and other communication	35	0.079753	0.082054	0.078977	0.090792	0.079169	0.068584
Services	36	0.141726	0.131946	0.128941	0.127281	0.122300	0.126899
Agricultural household	37	1.800688	1.866965	1.775290	1.842990	1.793490	1.350849
Non agricultural household	38	0.557327	0.561483	0.558713	0.548948	0.548396	0.653479
Imports	39	1.000173	1.000180	1.000171	1.000179	1.000174	1.000128
Pollutions	40	0.003080	0.003154	0.003059	0.003101	0.003052	0.002922
Total production effects.	41	3.361796	3.459491	3.337411	3.331272	3.322775	3.562792
Total income effects	42	2.359015	2.428449	2.334003	2.391837	2.341988	2.004327

TABLE 8.22 (CONT'D)

Item		20	21	22	23	24	25	
Paddy	1	0.053803	0.086655	0.036039	0.173927	0.112759	0.079111	0.050
Beans & Nuts	2	0.001736	0.001587	0.001167	0.003457	0.002809	0.002298	0.001
Vegetable and Fruit	3	0.017915	0.026455	0.012051	0.035020	0.028744	0.023929	0.0169
Rubber	4	0.000001	0.000001	0	0.000001	0.000001	0.000001	0.0000
Other crops	5	0.196017	0.226484	0.131935	0.386404	0.314783	0.259740	0.1841
Lirestact	6	0.042030	0.042676	0.028254	0.095109	0.068542	0.076925	0.0394
Forestries	7	0.038387	0.128694	0.022281	0.534270	0.235468	0.070378	0.0312
Fisheries	8	0.034701	0.039260	0.023354	0.065462	0.054664	0.046384	0.0325
Mining and Quarrying	9	0	0	0	0	0	0	
Slaughtering	10	0.035715	0.035460	0.024094	0.043252	0.047014	0.045030	0.0335
Oil from crop or animal	11	0.000249	0.000250	0.000166	0.000378	0.000375	0.000310	0.0002
Ther processing of food	12	0.001071	0.001078	0.000711	0.001631	0.001607	0.001331	0.0009
Rice mill	13	0.067674	0.102541	0.045321	0.222862	0.143464	0.099189	0.0633
Ice	14	0.005806	0.009383	0.005934	0.014550	0.031220	0.011336	0.08204
Other food	15	0.020493	0.022257	0.013798	0.034127	0.030541	0.026598	0.01924
Animal feed	16	0.011226	0.012999	0.007547	0.022718	0.018301	0.020496	0.01053
Softdrink and Carbonate water	17	0.007576	0.009177	0.005087	0.012489	0.011276	0.009774	0.00709
Printing and Publishing	18	0.002676	0.002403	0.001835	0.003501	0.003285	0.003037	0.00277
Rubber Sheet and Block	19	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.00000
Concrete and Cement Product	20	1.011758	0.013291	0.007917	0.022040	0.018441	0.015486	0.01105
Others	21	0.004168	1.004915	0.002781	0.008440	0.006782	0.005489	0.00389
Motor Vehicle and Repair	22	0.032215	0.028749	1.012573	0.040949	0.036302	0.023889	0.01871
Saw mill	23	0.012306	0.013268	0.007999	1.021653	0.224662	0.047378	0.01133
Wood Product	24	0.049759	0.055894	0.033457	0.092561	1.079413	0.069652	0.047201
Other Manufacturing Goods	25	0.000362	0.000356	0.000212	0.000571	0.000534	1.001121	0.00038
Electricity	26	0.027489	0.026058	0.017850	0.049370	0.044276	0.029666	1.041423
Water work and supplies	27	0.004048	0.006229	0.002581	0.005484	0.005895	0.004976	0.005066
Building Construction	28	0.017424	0.015135	0.008252	0.022779	0.023605	0.017318	0.013037
Public work and construction	29	0.001156	0.002212	0.005630	0.001068	0.002069	0.001860	0.000934
Trade	30	0.249501	0.184110	0.169431	0.260631	0.314545	0.268969	0.209662
Restaurant and Hotel	31	0.048881	0.046307	0.031492	0.069676	0.071681	0.058166	0.043127
Road transportation	32	0.093957	0.102036	0.041439	0.092058	0.008294	0.064005	0.054925
Water transportation	33	0.044430	0.048452	0.012498	0.029088	0.028105	0.019443	0.016806
Air transportation	34	0.009006	0.008833	0.005785	0.011386	0.011658	0.010587	0.009988
Post and other communication	35	0.042909	0.046728	0.029787	0.005347	0.066893	0.054855	0.040156
Services	36	0.102368	0.099110	0.060915	0.147543	0.139286	0.116705	0.104713
Agricultural household	37	0.333881	0.481566	0.223525	1.139695	0.722745	0.481774	0.312762
Non agricultural household	38	0.861455	0.855585	0.581419	1.030971	1.124742	1.087222	0.810641
Imports	39	1.000030	1.000014	1.000019	1.000109	1.000064	0.986819	1.000024
Pollutions	40	0.002397	0.002525	0.001616	0.003583	0.003406	0.003084	0.002254
Total production effects.	41	**2.289821**	**2.441197**	**1.804007**	**3.599692**	**3.243943**	**2.585312**	**2.134721**
Total income effects	42	**1.195336**	**1.237152**	**0.804944**	**2.170656**	**1.847487**	**1.568996**	**1.123402**

TABLE 8.23

TOTAL EFFECTS GENERATED ON PRODUCTION, IMPORT POLLUTION AND INCOME IN THE ECONOMY, WITH AND WITHOUT INCOME-CONSUMPTION LINKAGES

Sectors	Without income consumption linkages	With income-consumption linkages			
	Production	Production	Imports	Pollution	Income
1. Paddy	1.1015	3.3618	1.0002	0.0031	2.3380
2. Beans and nut	1.1291	3.4595	1.0002	0.0031	2.4281
3. Vegetable and fruit	1.1017	3.3374	1.0002	0.0031	2.3341
4. Rubber	1.0351	3..3313	1.0002	0.0031	2.3910
5. Other crops	1.0868	3.3328	1.0001	0.0030	2.3410
6. Livestock	1.6808	3.5628	1.0002	0.0029	2.0043
7. Forestry	1.0831	3.3849	1.0001	0.0031	2.3977
8. Fisheries	1.1224	3.1660	1.0001	0.0024	2.1461
9. Mining and quarrying	1.0873	2.7828	1.0001	0.0038	1.9681
10. Slaughtering	2.3794	4.2322	1.0001	0.0032	2.0186
11. Oil from crop/animal	1.4863	3.0497	1.0001	0.0030	1.7432
12. Other processing of food	1.5117	3.1882	1.0002	0.0034	1.8743
13. Rice mill	1.8667	4.0717	1.0000	0.0031	2.3084
14. Ice	1.1831	2.7399	1.0000	0.0037	1.8272
15. Other food	1.2533	2.3030	1.0001	0.0024	1.2259
16. Animal feed	1.5041	2.7794	1.0000	0.0027	1.4297
17. Soft drink, carbonate water	1.2591	2.5086	1.0000	0.0029	1.4657
18. Printing and publishing	1.2159	2.2047	1.0001	0.0023	1.1593

TABLE 8.23 (CONT'D)

Sectors	With out income consumption linkages	With income-consumption linkages			
	Pro-duction	Pro-duction	Imports	Pollution	Income
19. Rubber sheet and block	1.698	3.6674	1.0000	0.0037	2.1309
20. Concrete and cement product	1.2704	2.2898	1.0000	0.0024	1.1958
21. Other	1.2775	2.4415	1.0000	0.0025	1.3371
22. Motor vehicle and repair	1.1178	1.8040	1.0001	0.0016	0.8049
23. Saw mill	1.6210	3.5887	1.0001	0.0036	2.1706
24. Wood product	1.6231	2.2438	0.9868	0.0034	1.8475
25. Manufacturing product	1.2377	2.5853	1.0000	0.0031	1.5690
26. Electricity	1.1768	2.1347	1.0000	0.0022	1.1234
27. Water work and supplies	1.2428	2.5937	1.0000	0.0032	1.5853
28. Building construction	1.3142	2.4464	1.0000	0.0025	1.3087
29. Public work/construction	1.2320	2.1940	1.0000	0.0022	1.1251
30. Trade	1.1483	2.9009	1.0000	0.0041	2.0500
31. Restaurant and hotel	1.4344	2.9318	1.0000	0.0033	1.7259
32. Road transportation	1.2480	2.3976	1.0000	0.0027	1.3465
33. Water transportation	1.1135	1.6033	1.0000	0.0035	1.7454
34. Air transportation	1.1805	2.4187	1.0000	0.0029	1.4524
35. Post and other communication	1.3218	2.9322	1.0000	0.0038	1.8894
36. Service	1.1742	2.9109	1.0000	0.0040	2.0214

As shown in Table 8.23, with income-consumption effects, agriculture generates relatively larger multiplier effects than non-agriculture. This is because higher value added per unit output in agriculture as well as higher marginal propensity for the consumption of farm households. Most indirect effects are absorbed by paddy, other crops, rice mill and trade sectors (Table 8.22). Among non-agriculture, agriculture based industries also produce larger multiplier effects than nonagricultural-based industries and services. This implies that an investment that increases output in agriculture or agricultural based industries produces larger benefits to the economy as a whole. Hence, a multi-purpose dam like Rajjaprabha dam with improved agriculture in the region has potential to produce more benefit to the society.

The two products from Rajjaprabha dam, viz., electricity and water, are quite different in nature. While electricity is a sufficient condition in production structure, irrigation water is close to necessary condition. Electricity, a service to the economy, produces relatively small multiplier effects of 2.13. It is not possible to value irrigation water from the dam directly. From paddy producing sector, it is observed that a much larger multiplier effects of 3.362 are induced.

Production sectors in the economy tend to produce similar effects on imports and pollution. Regardless of direct structural linkages (Table 8.21), sectors in the economy eventually induce certain amount of pollution to the system (Table 8.23). Similar to production effects, high income is directly and indirectly generated by agriculture or agriculture based industries. Lower income is generated by non-agriculture-based industries or services (Table 8.23).

3.4.2 The Impacts

Rajjaprabha dam affects producing sectors in the economy in various magnitudes, both positively and negatively, as well as measurable and non-measurable forms. In addition to increasing electricity supply, the main effects of the dam are increasing irrigated area and hence crop production; improving flood protection and hence higher returns to the producer; improving land use and water supply through salinity control; increasing forestry and fishery resources, and improving navigation facilities. These are primary effects that have to be quantified in order to fit into the model.

Irrigation water from Rajjaprabha dam increase-cropping intensity gradually. It was estimated that in 1996 the project would increase paddy production by 9,100 metric tons. If full development occurred, paddy production due to the dam could be as high as 264,900 metric tons. Because the estimates are based on yields under normal conditions, the values here are considered to include benefits from flood protection. Flood protection also reduces damages to public utilities. Comparing flood damage between 1985 and 1990, it is expected that at least 10 million bahts of repair and maintenance expenditure were saved annually. Considering limited budget of government, the amount saved can be utilized on other public utilities project. Hence, the amount is used to impute an exogenous expansion of public construction sector. Similarly, benefits from protection of salinity intrusion on water supply are estimated as 4.6 million bahts. The increased catch of fish due to the project is estimated as 0.754 million bahts. Effects of the project on forestry are difficult to be estimated, and hence neglected from the analysis.

Table 8.24 shows total impacts of Rajjaprabha dam on output and income generated in Surat Thani provinces under present irrigation capacity. Direct benefit of the dam of less than 45 million bahts generates additional 61.5 million bahts, or about 1.4 times of output in the economy. Benefits to agriculture constitute only about one-third of total benefits. The remaining benefits are shared between manufacturing and services.

Agricultural households (44 million bahts) mostly capture income generated in the economy. Non-agricultural households receive about 38% of total income (27 million bahts). Increase in output and income in the economy also generates additional imports. About one-third of output is imported. Pollution generated in the economy is 108,000 kg of BOD equivalent.

Table 8.25 shows output and income generated by the dam with full development of the irrigation project. Given about 30 times higher output of paddy, the dam generates more than 20 times of output than the first case. The total output generated is 1,296 million bahts. Agriculture receives about 37% of total output. of the 1,547 million bahts of income generated in the economy, agricultural households receive about 73 percent. The remainder is distributed to nonagricultural households. Hence, the larger the irrigation effects, the higher is the share of total income directed toward agricultural households than nonagricultural households. Similarly, higher income generates higher imports (6.90 million bahts). It should be noted that high irrigation benefit also generates high share of imports to total output. It generates more than 50 percent of output in the economy. As indicated in Table 8.25, pollution generated in the economy is 2,095 million kg of BOD equivalent, almost 20 times higher than in the first case.

In general, increased irrigated area is likely to contribute more benefits to the agricultural sector compared to non-agricultural sector. It also tends to generate higher share to agricultural households than non-agricultural households do. The only drawback of such increase is that it is also likely to generate larger share of imports to total output. Considering Surat Thani as a part of the national economy, imports to Surat Thani are supplied from other regions of the economy as well as from over-seas. Effects on balance of payments depend on composition of such imports.

TABLE 8.24

DIRECT AND INDIRECT IMPACT ON OUTPUT AND INCOME

OF EXISTING BENEFIT

No	Sector	Value	No	Sector	Value
1	Paddy*	27.300	21	Other	0.514
2	Beans and nut	14.719	22	Motor vehicle and repair	3.001
3	Vegetable and fruit	2.098	23	Saw mill	0.013
4	Rubber	1.408	24	Wood product	1.622
5	Other crops	2.164	25	Manufacturing product	0.128
6	Livestock	0.000	26	Electricity	0.573
7	Forestry*	1.353	27	Water work and supplies *	4.600
8	Fisheries	0.751	28	Building construction	0.032
9	Mining and quarrying	0.010	29	Public work and	
10	Slaughtering	0.040		construction*	10.000
11	Oil from crop/animal	8.264	30	Trade	7.953
12	Other processing of		31	Restaurant and hotel	2.053
	food	0.403	32	Road transportation	2.915
13	Rice mill	1.076	33	Water transportation	1.176
14	Ice	0.002	34.	Air transportation	0.332
15	Other food	0.358	35	Post and communication	4.441
16	Animal feed	0.118	36	Services	4.782
17	Soft drink, carbonate		37	Agricultural household	44.031
	water	0.002	38	Non agricultural	27.461
18	Printing and publishing	0.722		Household	27.461
19	Rubber sheet and block	0.264	39	Imports	38.041
20	Concrete and cement		40	Pollution	0.109
	product	1.026			

* **Notes** : denotes sectors primarily affected

TABLE 8.25

DIRECT AND INDIRECT IMPACT ON OUTPUT AND INCOME OF FULL BENEFIT

No	Sector	Value	No	Sector	Value
1	Paddy*	794.700	21	Other	4.588
2	Beans and nut	334.949	22	Motor vehicle and repair	66.187
3	Vegetable and fruit	53.447	23	Saw mill	0.243
4	Rubber	27.731	24	Wood product	18.869
5	Other crops	47.552	25	Manufacturing product	1.941
6	Livestock	0.000	26	Electricity	11.150
7	Forestry*	23.205	27	Water work and supplies *	4.600
8	Fisheries	0.754	28	Building construction	0.486
9	Mining and quarrying	0.189	29	Public work and	
10	Slaughtering	0.773		construction*	10.000
11	Oil from crop/animal	211.780	30	Trade	150.194
12	Other processing of food	7.697	31	Restaurant and hotel	39.4100
13	Rice mill	22.417	32	Road transportation	51.743
14	Ice	0.002	33	Water transportation	18.342
15	Other food	7.430	34.	Air transportation	5.991
16	Animal feed	2.346	35	Post and communication	52.532
17	Soft drink, carbonate		36	Services	95.350
	water	0.033	37	Agricultural household	1130.61
18	Printing and publishing	15.882	38	Non agricultural	416.549
19	Rubber sheet and block	5.449		household	
20	Concrete and cement		39	Imports	698.687
	product	17.684	40	Pollution	2.095

* **Notes** : denotes sectors primarily affected

CHAPTER IX

CONCLUSION AND RECOMMENDATIONS

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1. INTRODUCTION

This post evaluation of environmental consequences of Rajjaprabha dam is conducted ten years after its commencement.

The Rajjaprabha dam project was planned and implemented as a multipurpose project, mainly for hydropower production, flood protection, fisheries, recreation and irrigation. The project includes the dam and reservoir with a 240 MW hydropower plant located about 90 km upstream from Surat Thani province, and irrigation systems covering the coastal plain in Surat Thani. The upstream storage reservoir (with about 5,639 mcm storage) and the hydropower plant had already been implemented. The first phase of irrigation system covers an area of 23,100 hectares. The second phase is envisaged to cover about 50,000 hectares. But this has not yet been implemented. When the project was completed it was expected to provide the following benefits: (1) generation of about 554 GWh power per year from the 240 MW installed capacity plant, (2) irrigation of about 50,000 ha, of land, and (3) flood protection and drainage for the towns of Surat Thani and other downstream communities including the paddy areas in the coastal plain.

2. OBJECTIVES OF THE STUDY

This study was conducted with the following objectives: (1) to assess all existing environmental resources and their values with the help of input-output analysis (2) to findout the beneficial impacts of the project (3) to evaluate the actual positive effects vis-a-vis the estimated effects before the project was implemented and (4) to identify all significant changes in relatives to the impacts previously assessed.

3. HYPOTHESES

The following hypotheses were formulated for the study (i) adverse effects of the dam are not significant on the physical resources in the project area (ii) negative impacts on the ecological resources caused by the project will be confined to the project area alone and (iii) the dam has positive impacts on the economy and especilaly the standard of living of the people in the Phum Duang river basin.

4. SCOPE OF THE STUDY

The study area includes the Phum Duang river basin of about 4,668 km^2 (placed on the areas that are upstream and downstream to the damsite), The duration of study is limited to 10 years after the dam has become operational i.e. from 1987-1997.

5. METHODOLOGY

Both primary and secondary data were collected for the study. Primary data were collected through field studies that were carried out during the dry as well as wet seasons. Data were collected using a pre-tested schedule from a sample population, which was selected on the basis of random tables. The secondary data were collected from various reports and studies.

Analysis of the collected data was done by using the Percentile method, Chi-Square test and Likert method. The three types of economic analysis employed for valuation of environmental values are: (i) market value (ii) travel cost method and (iii) survey techniques.

The economic evaluation of environmental consequence consists of three aspects: (i) the implication at the regional level (ii) the evaluation of actual positive benefits at the project level and (iii) input-output analysis to ascertain the effects of the project implementation on the regional economy of Surat Thani province.

6. MAJOR FINDINGS OF THE STUDY

The major finding of the study are presented below:

6.1 Physical resources

The results of the study reveal that there is no significant changes in climatic and ground water resources, with respect to the study area inspte of the fact that the physical and chemical properties of the soil have slightly changed. Sedimentation in the reservoir does not have much effect on the function of the dam. But it is seen that water quality in the reservoir has changed significantly. On the basis of this the first hypothesis is rejected.

6.2 Ecological resources

No change has occurred in the amount of plankton in the reservoir. But the composition of fish has changed. Earlier it was the herbivorous variety, which was more in the catches. But now the carnivorous variety is grown in the dam, which is more beneficial to fisherman. This is a man made change. Before construction of the dam there was large scale illegal logging but after completion of the dam, this has come down. But construction of the dam has caused loss of at least 165 km^2 of forest area, i.e. submerged under water. Before construction of the dam there were 179 species of animals and other fauna in the area. Those have been reduced to 152 after construction of the dam. On the basis of this finding the second hypothesis is rejected.

6.3 Implication on Regional Economics

The main objective of the macroeconomic analysis of the project is to determine the extent to which the development project is consistent with and contributory to the achievement of objectives and priorities enunciated in the national development program.

The economic base of the project area is predominantly agriculture. The real per capita Gross Provincial Product (GPP) of the project area is lower than the average of the southern region, and also lower than the average of the upper southern region. Although the economic base of the project area is under transition i.e. moving away from agriculture, the area would depend on agriculture for a long time to come. The decline in importance of agriculture in Surat Thani is due to growth of other sectors. Surat Thani has a very strong economy. It enjoys higher economic growth in other non-agriculture sectors and higher investment in construction and public physical infrastructure. Even through the province used to be confronted with economic fluctuations, it maintained a positive growth of 5 percent in crops production.

6.4 Actual Positive Benefits

Evaluation of actual positive benefits involves assessing benefits of various interrelated multipurpose components of the project. Hence a benefit-cost analysis is done to evaluate the overall impact.

The cost of electricity ranges from 8 bahts/hour for hair dressing to 833 bahts/hour for ice making. Factor share of electricity, or electricity cost per product value, varies from 1 percent for food canning industry to 82 percent for ice making factory. Damage due to electricity interruption is estimated to be in the range of 15 bahts/hour for hair dressing to 3,079 bahts/hour for ice making business.

The present worth of benefits was estimated at 1987 price. Comparison of the benefits estimate before and after the project implementation reveals that the difference in present worth are not significant for forestry, irrigation and hydropower production The values estimated after project implementation are about 356, 210 and 68 million bahts, respectively, and they are lower than those estimated before project implementation. The differences in benefit estimation are mainly caused by the changes in input and output prices, and also by unexpected delay in the implementation of the downstream irrigation project. Discrepancies in benefits for other project components are comparatively smaller.

6.5 Input-Output Analysis

The direct and indirect impacts of Rajjaprabha dam with respect to the regional economy are also assessed. Rajjaprabha project as already mentioned is a multipurpose development project. It is important not only in producing electricity, but also in supplying water for agriculture as well as protecting environment of the region. Such investments generate direct and indirect effects on the regional economy. The investment on the dam and the expansion of the economy, due to the dam, also affect environment system in the region.

Positive and negative effects of the project are analyzed based on structural relationships between economic activities and households in the economy. Evaluation of the total impacts of the project on the regional economy is also emphasized.

By allowing full multiplier effects (i.e., including production and income-consumption effects), the analysis of structural linkages of economic activities in the regional economy indicates that agriculture generates larger multiplier effects than non-agriculture. This is largely because of the higher value added per unit of output in agriculture than that in non-agriculture, and a higher marginal propensity to consume in the case of agricultural households than that of non-agricultural households. An increase in one baht worth of other demand for agricultural products in the economy will generate more than three bahts of total output in the economy. Similarly, any increase in one baht of other demand for most non-agricultural products will generate about two bahts worth of total output in the economy. The increase in one baht of other demand increase household income ranging from less than one to more than two bahts, imports by about one baht, and water pollution by 0.0016 to 0.004 kg of BOD. Thus the results show that agriculture is a more important multiplier effect generator than non-agriculture, on both output and income.

Excluding electricity produced, primary effects of the Rajjaprabha dam in the regional economy are defined as higher paddy and fish production, improvement of flood protection, and better control of salinity intrusion. Under the existing irrigation capacity, it is estimated that total indirect effects generated by the dam was about 62 million bahts or about 1.4 times of its primary effects. Hence, the total effects on output in the economy as generated by the dam were more than 104 million bahts. Rajjaprapha dam contributed 71 million bahts to gross regional product, increased 38 million bahts of imports and 108 thousand kilograms of BOD.

If full development of the irrigation project is realised, the dam will indirectly generate more than 20 times higher output in the first case. Total output generated is estimated at 2,016 million bahts. It is likely to contribute about 1,547 million bahts to gross regional product. Similarly, it is also expected to generate larger imports and intensity pollution in the region than in the first case.

In sum, the total effects of Rajjaprabha dam on the regional economy are enormous. The indirect benefits of economic activities from the project vary from sector to sector, depending on their inter-relationships with the primarily affected sectors. In aggregate, agricultural households receive larger shares of benefits than non-agricultural households. Distribution of benefits, however, depends on the weight of each household class to the total population. So the third hypothesis is accepted.

From the above findings, the following recommendations are made:

General criteria for watershed management to serve multiple purposes while sustaining desirable ecological balance should be done as follows.

(1) Land should be used in accordance with its potential, i.e., land of high agricultural potential should be used for crop production. Other lands of low agricultural potential should be assessed for their suitable was such as agro-forestry or wildlife management.

(2) Consideration should be given to prevailing environment in the planning and development. Local environment should be regarded as an already functioning ecosystem, and within which agricultural and other land use development are to take place in harmony with the prevailing environment;

(3) More attention should be paid to efficiency and long term stability of agricultural and silvicultural systems. They should be regarded as ecosystems, particularly regarding the resources depletion and environment deterioration;

(4) Land use planning should consider both increased productivity and soil and water conservation;

(5) Comprehensive ecosystem analysis, including such aspects as energy flow, nutrient cycling, population dynamics, and others crucial to successful land management should be a prerequisite for watershed management; and

(6) Industrial development may create serious adverse impact on renewable resources. Hence such development should be carefully planned and located in the watershed with adequate control, and also with properly planned monitoring program.

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