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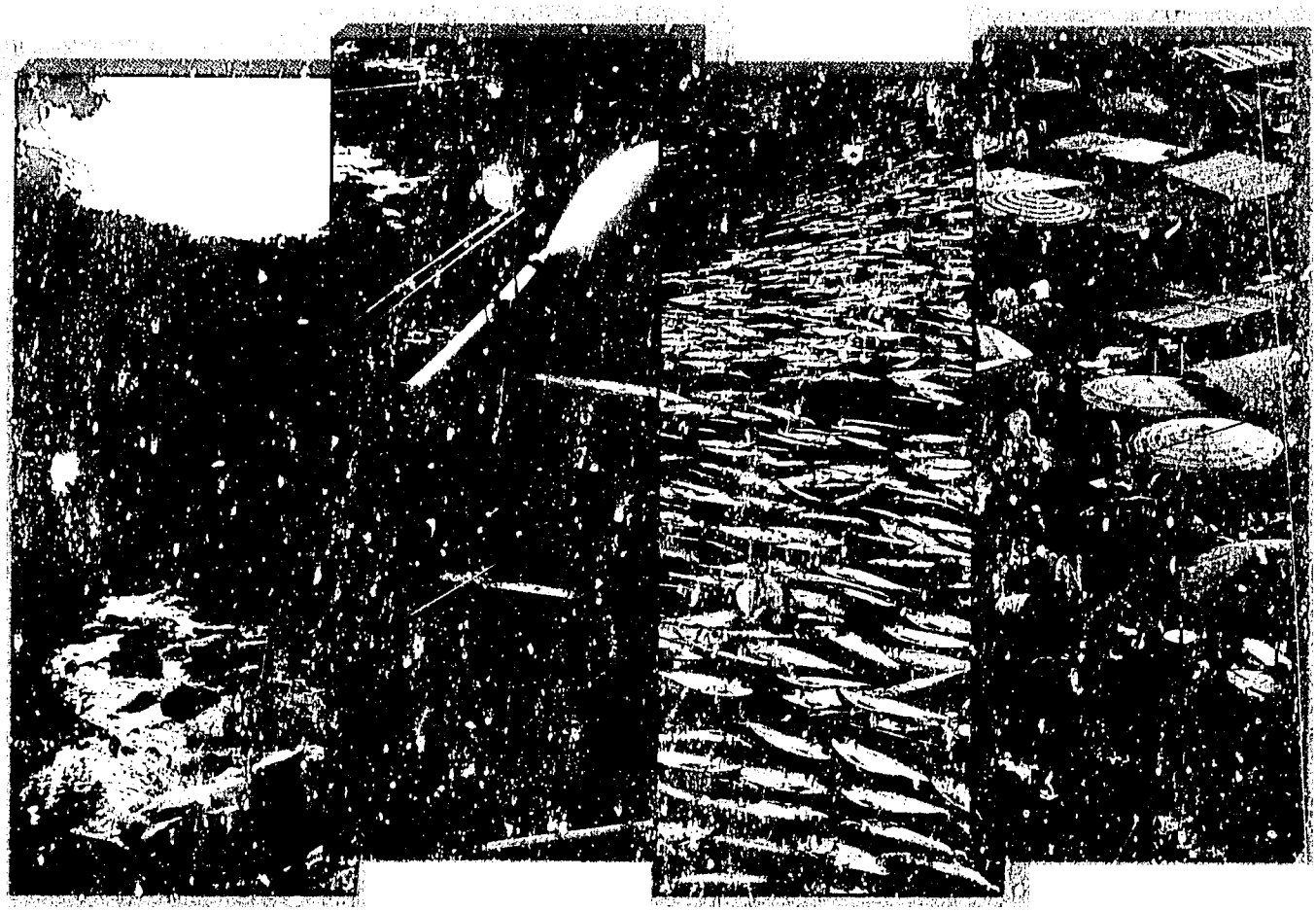
THAILAND
NATURAL RESOURCES PROFILE



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Thailand Natural Resources Profile

Is the resource base for Thailand's development sustainable?

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Foreword

Just over ten years ago, in 1976, the Royal Thai Government clearly stated its concern about the developing pressures on Thailand's natural resource base. *"The deterioration in the environmental condition of major natural resources, particularly our forest, land, water and mineral resources,"* the Third National Economic and Social Development Plan concluded, *"is a fundamental problem which has considerable consequences both for national survival and Thailand's future development potential."*

One reason for embarking on the present **Natural Resources Profile** was to clearly identify what those consequences are likely to be. This has been done, with the help of leading experts in the various fields. Successive chapters review the current status of our land, water, forest, nature conservation, mineral, mangrove and fishery resources. These chapters also look at the legal and institutional framework influencing resource management in each area, and highlight some of the most important emerging trends and issues. The environmental quality dimension is then explored in four further chapters, focusing on air and noise, water, wastes, and accident prevention.

Following this careful scrutiny of the current status of Thailand's natural resources and environment, the final section of the **Profile** considers the strategies that are now needed to begin the transition toward sustainable forms of development. But what is sustainable development? The basic idea is that natural resource management and development projects can be designed in such a way that the social, economic and ecological benefits which flow from those resources can be sustained into the foreseeable future. As for practical guidance on how to achieve sustainable development, there are many sources of advice to call upon, but in many areas Thailand will be pioneering approaches which will find much wider application around the world.

By building the resulting programs around local people in specific areas, we must not only convince them that development and conservation can go hand in hand, but

provide practical, working examples. People are more inclined to believe what they have seen with their own eyes and experienced in their own lives, rather than what they are told in massive public education programs.

The days of carefree exploitation and destruction of Thailand's natural resources are numbered. The ultimate test of the sustainability of Thai development, however, will be the extent to which a fair, equitable and acceptable balance can be struck between the needs of the country's urban populations, particularly the population of Bangkok, and the needs of the rural populations. This represents a most formidable challenge, but one we must face up to and tackle.

The most uncomfortable element is time. Our population growth, though slowing somewhat during the last decade, will not wait for us to catch up. Its momentum is strong and getting stronger. A growing population is demanding increased living standards and real hope for the future. We cannot return the babies born to us in order to enjoy more resources per capita. We can aim to implement more effective population control programs, but we also must investigate the potential for using technologies which are less polluting and more efficient in converting natural resources, whether they be energy, water or raw materials, into the goods and services we all need.

The following chapters underscore the fact that the challenge we now face is more serious than at any previous time in our country's history. We should not be overwhelmed by these problems, seeking instead to anticipate them and react in good time.

Our future is in our own hands. It can be a sustainable future, if that is what we decide we want. But it is vital that we are all committed to the transition that is clearly now needed. Only if sustainable development wins the support of the broad mass of the public will Thailand have a real chance of moving progressively into the twenty-first century and beyond.

Anat Arbhabhirama
President
Thailand Development Research Institute

Preface

This study was conceived based on the felt need that Thailand's natural resources are dwindling fast. We are crossing the thresholds beyond sustainable yields in the consumption of our natural resources. Such negative trends have to be reversed. Plans must be formulated and actions taken now to arrest the continuing erosion and depletion of our natural resources.

To be meaningful, such a study should serve as a reliable source of current information at least for the next 5 years. It is intended to be a major reference for those who would like to be familiar with the issues of the management of Thailand's natural resources as well as those who would like to understand the past and present trends in the consumption of our resources.

In undertaking this comprehensive study, we have relied on the contribution of 19 local specialists. It is evident that all resources are interrelated. Only through the careful illustration of the profile of each particular resource — land, water, forest, minerals, fisheries, and the impact of man's activities on the environment, can the total picture of Thailand natural resources emerge. In this context, the selection of topics for coverage in this volume was carefully conceived. In the present contents, energy resources are partially covered under "minerals", whereas the issues of Bangkok traffic, recurrent floods and urban housing are mentioned only in passing. This is intentional since there are other current master plans which already cover these issues in depth.

Thailand is a small but dynamic part of the world. Our share of the planet Earth in terms of tropical forests, minerals and fisheries is not insignificant. We hope that the information compiled and analysed in this report can be of interest to a broader audience beyond our national frontiers. Our successes and failures in managing our resources and conserving our environment may serve as examples to other countries facing similar problems. Only through the understanding of national profiles like ours can the international communities come to grips with global issues of sustainable resources management.

Thailand is still a fortunate land with history of plentiful natural resources. Use discreetly, our natural resources are for all of us to share and enough for generations to come. Use unsparingly, and competition for scarce resources will become the norm. It is our ultimate hope that this book will contribute towards the restoration of our natural resources so that all Thais can enjoy and benefit from the endowment of their motherland.

Dhira Phantumvanit
Editor
Bangkok, January 1987

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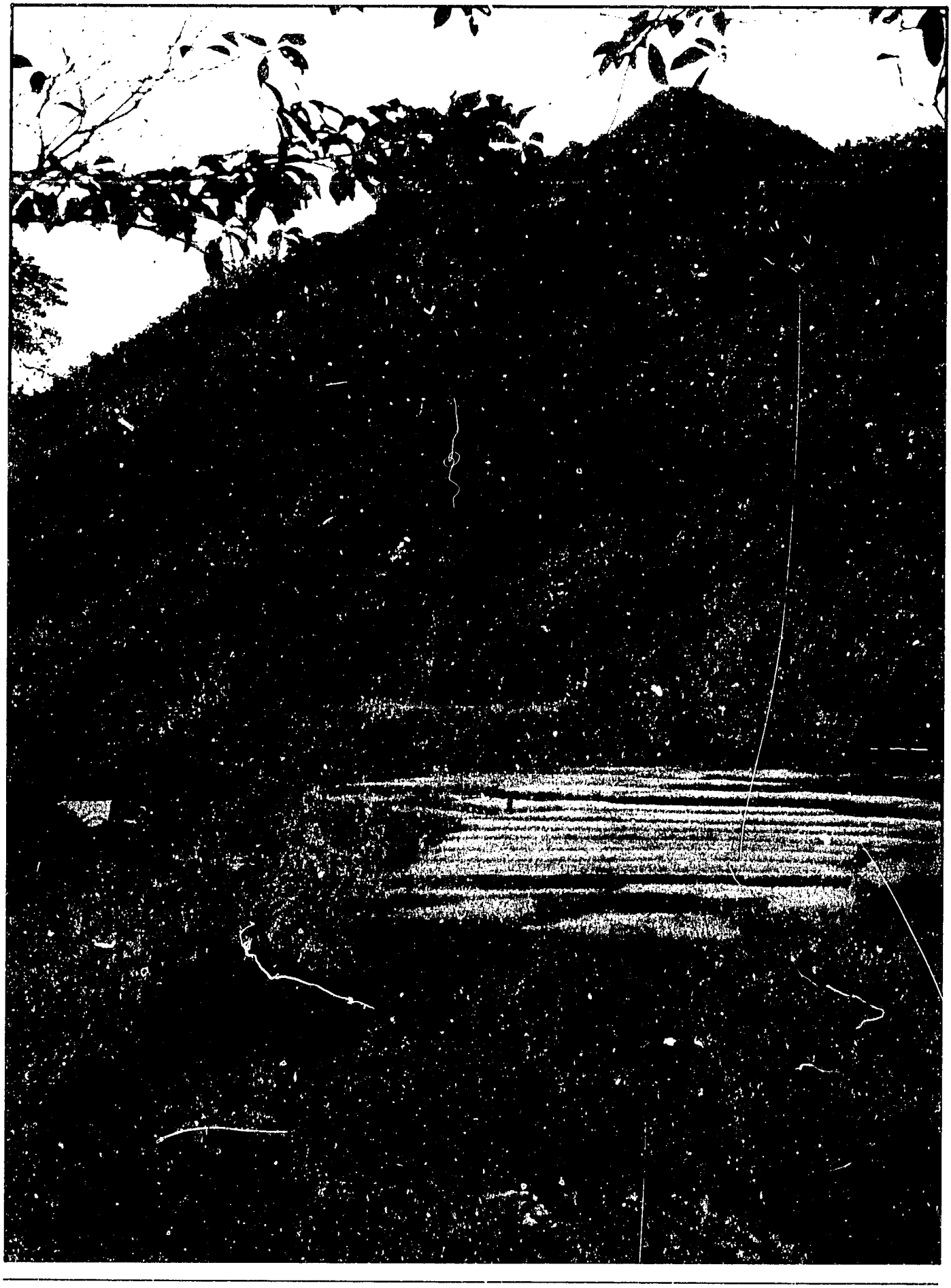
List of Abbreviations

ADAB	Australian Development Assistance Bureau
ADB	Asian Development Bank
AIT	Asian Institute of Technology
ALRO	Agricultural Land Reform Office
APT	ammonium paratungstate
ARD	Office of Accelerated Rural Development
ASEAN	Association of Southeast Asian Nations
ATPC	Association of Tin Producing Countries
B.E.	Buddhist Era
BHC	benzene hexachloride
BMA	Bangkok Metropolitan Administration
BOD	Biochemical Oxygen Demand
BOD_5	5-day Biochemical Oxygen Demand
°C	degree Celcius
CO	carbon monoxide
COD	chemical oxygen demand
COMECON	Council for Mutual Economic Assistance
CSO	Cold Storage Organization
CU	Chulalongkorn University
CUSRI	Chulalongkorn University Social Research Institute
$CaCO_3$	calcium carbonate
$CaSO_4 2H_2O$	gypsum or calcium sulfate dihydride
Ch-E	cholinesterase
DCP	Department of Cooperative Promotion
DIW	Department of Industrial Works
DLD	Department of Land Development
DMR	Department of Mineral Resources
DOA	Department of Agriculture
DOAE	Department of Agricultural Extension
DOF	Department of Fisheries
DOH	Department of Health
DOL	Department of Lands (in chapter 2)
DOL	Department of Labor (in chapter 12)
DOLA	Department of Local Administration
DPC	Department of Public Cleansing, BMA
DPW	Department of Public Welfare
DVCPF	double-vault composting pour-flush (latrines)
EEZ	Exclusive Economic Zone
EGAT	Electricity Generating Authority of Thailand
EIA	Environmental Impact Assessment
EPL	Exclusive Prospecting License
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization
FDA	U.S. Food and Drug Administration
FIO	Forest Industry Organization
FMO	Fish Marketing Organization
FY	Fiscal Year
GDP	Gross Domestic Product
GNP	Gross National Product
GSA	(United States) General Services Administration
GWh	Gigawatt-hour
HC	hydrocarbon
HD	The Harbour Department

HF	hydrofluoric acid
IEAT	Industrial Estate Authority of Thailand
IFC	International Finance Corporation
ILO	International Labor Organization
IMF	International Monetary Fund
ITC	International Tin Council
IUCN	International Union for Conservation of Nature and Natural Resources
JICA	Japan International Cooperation Agency
K	potassium
K_2O	potash or potassium oxide
K_2SO_4	potassium sulfate
LME	London Metal Exchange
LPG	liquefied petroleum gas
Leq	equivalent noise level
Leq(24)	24-hour equivalent noise level
M$	Malaysian Ringgit
MAI	Mean Annual Increment
MCM	Million Cubic Meters
MDL	maximum detectable limit
MIC	Mining Industry Council (in chapter 6)
MIC	methyl isocyanate
MMLCOE	million liters crude oil equivalent
MMscf	million standard cubic feet
MOAC	Ministry of Agriculture and Cooperatives
MOI	Ministry of Industry
MPH	Ministry of Public Health
MSTE	Ministry of Science, Technology and Energy
MSY	Maximum Sustainable Yield
MT	metric ton
MW	Megawatt
MWWA	Metropolitan Water Works Authority
MgO	dolomite or magnesium oxide
MnB	manganese in blood
MnU	mangenese in urine
N	nitrogen
N.S.2	Nor Sor 2 (preemptive certificate)
N.S.3	Nor Sor 3 (certificate of utilization)
N.S.4	Nor Sor 4 (title deed or Chanode)
NSC	National Security Command Headquarters
NEA	National Energy Administration
NEB	National Environment Board
NEC	National Executive Council
NESDB	National Economics and Social Development Board
NFLMD	National Forest Land Management Division, RFD
NHA	National Housing Authority
NICE	National Institute for the Improvement of Working Conditions and Environment
NO_x	nitrogen oxides
NO_2	nitrogen dioxide
NP	National Park
NPD	National Park Division, RFD
NRCT	National Research Council of Thailand
NSCT	National Safety Council of Thailand
NSO	National Statistics Office
NWRB	National Water Resources Board
NaCl	sodium chloride
O_3	ozone
OAE	Office of Agricultural Economics
OECD	Organization for Economic Cooperation and Development

OMO	Offshore Mining Organization
P	phosphorus
PCB	polychlorinated biphenyl
PEA	Provincial Electricity Authority
PF	pour flush (latrines)
PTA	Primary Tungsten Association
PVC	polyvinyle chloride
PWD	Public Works Department
PWWA	Provincial Water Works Authority
PbB	lead in blood
PbU	lead in urine
Pt-Co	platinum-cobalt color scale
RDCP	Regional Cities Development Project
RFD	Royal Forest Department
RID	Royal Irrigation Department
RTG	Royal Thai Government
S.K.1	Sor Kor 1 (claim certificate)
SEAFDEC	Southeast Asian Fisheries Development Center
SIC	Standard Industry Code
SO_2	sulfur dioxide
SPL	Special Prospecting License (in chapter 6)
SPL	sound pressure level
SPM	suspended particulate matter
STK	Sor Tor Kor (land use permit)
SiO_2	diatomite or silica sand
Sp.Gr.	specific gravity
TALDP	Thai-Australian Land Development Project
TAT	Tourist Authority of Thailand
TAWLD	Thai-Australian World Bank Land Development Project
TDRI	Thailand Development Research Institute
TEMCO	Thailand Exploration and Mining Co., Ltd.
TISTR	Thailand Institute for Scientific and Technological Research
TKN	total kjeldahl nitrogen
TOE	Tons of Oil Equivalent
TSP	total suspended particulates
TTIC	Thailand Tantalum Industry Corporation
TURA	Thai University Research Association
Ta_2O_5	tantalum pentoxide
TiO_2	titanium dioxide
U.K.	United Kingdom
UDN	Ulcerative Dermal Necrosis
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
W	Wolfram
WARPA	Wild Animals Reservation and Protection Act
WCD	Wildlife Conservation Division, RFD
WCF	Workmen's Compensation Fund
WHO	World Health Organization
WMD	Watershed Management Division, RFD
WRIST	Water Resources Information Systems for Thailand
WO_3	Wolframite: a tungsten ore
WVO	War Veterans Organization
WWF	World Wildlife Fund

cal/g	calorie per gram
cu.ft.	cubic foot
dB	decibel
dBA	decibel (A weighted)
dbh	diameter at breast height
g	gram
gC/m²/day	gram carbon per square meter per day
ha	nectare
hoi	Thai word for molluscs
ko	Thai word for island
kW	Kilowatt
kWh	Kilowatt-hour
kcal	kilo calorie
kcal/kg	kilocalorie per kilogram
kg	kilogram
kg/c/day	kilogram per capita per day
kg/ha	kilogram per hectare
kg/rai/day	kilogram per rai per day
khlong	Thai word for canal
km	kilometer
kung	Thai word for shrimp
l	liter
l/day	liters per day
m^2	square meters
m^3	cubic meters
m^3/rai	cubic meters per rai
m^3/rai/yr	cubic meters per rai per year
m^3/sec	cubic meters per second
mg/100ml	milligram per deciliter
mg/l	milligram per liter
mg/m^3	milligram per cubic meter
pla	Thai word for fish
pla muk	Thai word for squids or cuttlefish
ppm	parts per million
ppt	parts per thousand
pu	Thai word for crab
rai	Thai measure of land area, 1 rai = 1,600 square meters
spp	species
t/rai/yr	tons per rai per year
µg or ug	microgram
µg-at N/l	microgram atom nitrogen per liter
µg-at P/l	microgram atom phosphous per liter
µg/kg	microgram per kilogram
µg/l	microgram per liter
µg/m^3	microgram per cubic meter
µm	micron
wt	weight
yr	year



Overview and Perspective PART I

1 Introduction

1.1 OVERVIEW

Thais are proud of their heritage, of their land and their natural environment. Long before the age of the now infamous "Golden Triangle", this fertile country was known as the "Golden Land", in recognition of the high productivity of its farmlands and forests, and of its rich mineral wealth. A thirteenth century stone pillar inscription, dating from the Sukhothai period of King Ramkhamhaeng the Great, proclaims that:

"This Sukhothai is good. In the water there are fish, in the field there is rice. The King does not levy a tax on his people... Whoever wants to trade in elephants can do so. Whoever wants to trade in horses can do so. Whoever wants to trade in silver or gold can do so; people are contented..."

A succession of Siamese kingdoms saw the waxing and waning of a series of "golden ages", underpinned by agricultural and technological development, by commerce and the slow infusion and mixing of many peoples and cultures. This long cultural history, together with the interplay of technology and the country's natural resources, has molded today's Thailand with all its exciting economic potential and its undoubted social and environmental problems.

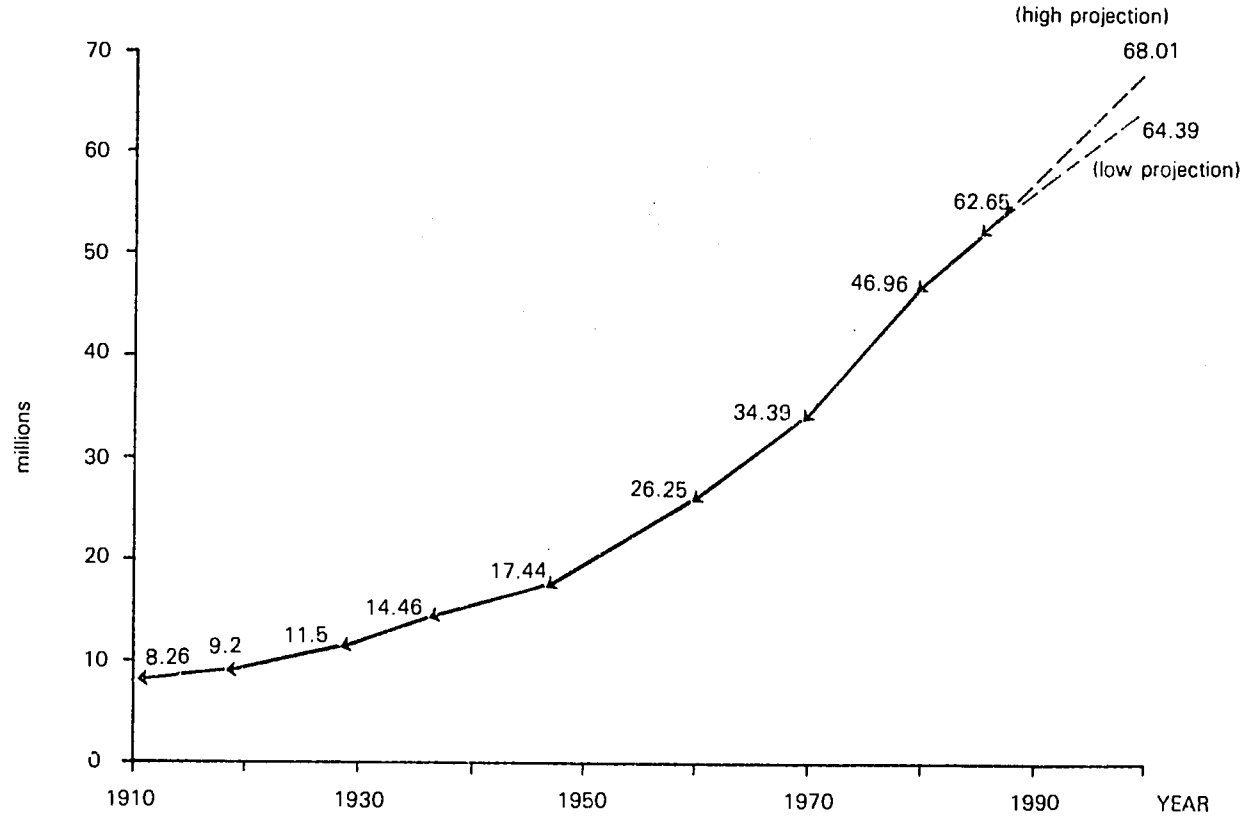
Modern Thailand can be proud of many achievements, whether in terms of its comparatively good transport and communication networks, its irrigation canals, its agricultural productivity, its commercial banking system or its manufacturing capability. But there are other features of today's scene which are worthy of comment.

Population growth, for example, continues apace. From a scant eight million in 1911, the country's population grew rapidly, surpassing the 50 million mark in 1984 (Figure 1.1). The pace of urbanization has also been very rapid. At least 10 percent of Thais live in a single urban concentration, the Bangkok Metropolis. This covers over 1,500 square kilometers, about 0.3 percent of Thailand's total surface area. Despite population control programs, the country's population continues to increase, imposing ever-growing pressures on its agricultural land and other natural resources.

Now, as the twenty-first century draws closer, there are warning signs that the present pattern of development may prove unsustainable. The fish catch per capita, from both inland and coastal waters, is falling. A few species are raised in aquaculture ponds or by mariculture methods, supplementing the catches from the sea and inland waters. This sector now accounts for about 2.5 percent of the total volume of fish consumed, with its share increasing steadily as the extension of unilateral exclusive economic zones exclude Thai fishermen from previously international waters. But even in the aquaculture sector, it is impossible to miss the signals of stress. As temperatures drop—and other factors converge—following the cool dry season, severe damage to pond fish recurs, resulting in crippling financial losses for some fish farmers.

As far as traditional agriculture is concerned, Thais regard yields of paddy rice as the primary index of food security. Many regions of the country are remarkably productive, with rice farmers now harvesting over one ton of rice per rai in several irrigated areas, compared with about one-fifth that figure in areas of traditional rainfed agriculture. Overall, the country's total annual rice harvest increased from less than

Figure 1.1 Population of Thailand, 1911-2000



10 million tons in 1966 to over 18 million tons in 1982. That is not to say, however, that Thai farmers are uniformly contented. Problems of farm debt and surplus production impose severe pressures in some quarters.

The country's water resources are under strain, too. The Bangkok Metropolis alone consumes over three million cubic meters of water daily, requiring an enormous investment in water treatment and distribution facilities. Irrigation water is costly to provide, although the users often do not pay for it. Industrial water users do pay, but release tremendous quantities of waste water, much of it inadequately treated. It is no longer possible to say, as the inscription writer did, that Thailand's river waters are *"as good to drink as Maekhong water in the dry season"*. Water conservation measures are increasingly needed to ensure a sustainable match between demand and supply, both in terms of quantity and quality.

On the health front, the statistics show marked progress, with major successes in the reduction of infant and adult mortality, and significant improvements in life expectancy and in industrial health and safety. At the same time, the statistics also show that a high proportion of children under five are suffering from protein and calorie malnutrition. It is distressing to note that the proportions for the North and Northeast are 54 percent and 60 percent respectively. Adults, too, are showing high levels of ill-health in these regions, with anemia a particular problem. Other regions report similar, if less severe, trends.

In these circumstances, it would be difficult to argue that *"people are contented"*. Many are, of course, but many more are hemmed in by increasing problems. So what happened to the Golden Land's bounty? How well have we managed our endowment of natural and human resources? How successful are we likely to be in marrying the twin objectives of conservation and development? And what changes are needed to ensure that Thailand increasingly achieves **sustainable** development?

Before attempting to answer these questions, and more, we need to have access to the latest information on our renewable and nonrenewable resources. We need an impartial assessment of the interactions between Thais and their natural environment, of our successes—and failures—in environmental management. The aim of this **Natural Resources Profile** is to supply much of the information needed to ensure that appropriate, integrated environment and development policies can be formulated and adopted nationally, regionally and locally.

1.2 NATURAL RESOURCES AND ENVIRONMENT

Our natural resources, diverse as they may appear, are always interrelated. Any exploitation effect related to one resource area may not be confined within that area alone, but may eventually affect the quality of nearby areas and resources. The main linkage is through man, the consumer, and the exploiter.

Man often admires the beauty of the sunrise, and of the sunset, without being aware of the enormous amount of energy that comes with it, an energy that sets everything in motion, the energy of life upon which mankind depends. There are oceans, the storehouse of water so essential to living systems, as well as many forms of marine life that benefit man. There are mountains, and hills; their formations were often bringing up mineral-rich veins within reach of miners. From these mountains, through slow and time-consuming processes, soils for the land resource are derived. The wind, and storms, play a key role in providing man with life-giving rainwater, which feeds the streams and rivers, fills ponds, lakes and underground aquifers, and replenishes air moisture. Without water, there would be no life.

Our covering of Rain Forests, lush and mighty as they appear, is very vulnerable to any disturbance of its many inter-relationships. Its nutrient cycle is all-important. Once burned over and cleared, it supports far less plant growth, nowhere comparable to the original biomass cover. If its soils are shallow on steep slopes, they will be eroded away in a very short time. The resulting silt's next destination is the alluvial plains downstream, or the reservoir bottom, or further down into the Gulf. Thailand's rich topsoil, accumulated over thousands of years, is eroding and depleting, being lost far faster than it was formed. It could still be saved for future generations, however, if we decide to do so, wisely and in good time.

The Soil and Land Use

Thailand is well endowed with cultivable land, which represents some 65 percent of the country's total area. This is a theoretical maximum, however, inclusive of land unutilized, not yet utilized or abandoned. Although not all arable land is available to private ownership and utilization, Thai citizens can buy and inherit land. Land is therefore an asset, property, as well as a place to work and earn a living.

Land use and land rights under population pressure

In past years, when population pressures were less intense, there seemed to be adequate land for every purpose — agriculture, human settlements, water bodies and so on. People felt that forest land was abundant, and could be cleared whenever and wherever needed. Presently, the per capita arable land is down to only 3.103 rai, plus some 0.958 rai of marginal land, and this area is getting smaller with each child born—almost two per minute. Our fertile arable land is also being converted into new urban settlements and industrial sites. Under mounting population pressure, we must produce more food and industrial crops for internal consumption, as well as for export, for an ever increasing and more demanding population.

Land rights

Thailand has long recognized and granted land rights to the citizen, yet the question of land rights remains unfinished business. Up to 1985 only 12 percent of the 152 million rai of agricultural land carried title deeds; some 48 percent was covered by a certificate of utilization or other papers; and 40 percent had no legal papers whatsoever. Yet the extent of "undocumented land" is in reality much larger due to an additional huge area of illegally occupied land carved out of the forest reserves, and pre-reserves, amounting to over 43 million rai in 1985. This is still expanding. The multitude of landless farm families will ensure that this remains a highly controversial area.

The Royal Thai Government recognizes this potential source of discontent and has been attempting to alleviate the problem through various programs of land allocation, land conservation, land consolidation, land reform and land use planning, in addition to accelerated land titling. Chapter 2 provides insight into the legal and institutional mechanisms underpinning such programs. Overall, it suggests that government efforts on the land right problems may have been handicapped by the lack of a coherent land policy framework, laying down coordinated guidelines for the 24 agencies and some 10 committees involved in this important area.

Land use planning

Of equal importance will be land use planning. It is imperative, with ever-increasing population pressures, to optimize the benefit from our diminishing per capita arable land. Land misuse is much more prevalent than is generally recognized, to an extent of some 28 million rai, not counting land which has been cleared and abandoned. Under-utilization, as well as unnecessary fallow land, are also evident. Several factors — human, economic, biological, climatic — are all involved. An initial key to the problem is information on land capability, to put this already limited land to its best use, for sustained maximum return.

To decide, agronomically, which land use is most appropriate, scientists need information about the soils, water and other climatic factors. The soil map provides soil classification for every parcel of land. The designation of soil unit helps to determine land suitability for various purposes, agricultural as well as nonagricultural. An accurate soil map, to scientists, is as necessary as a land title deed is to the ordinary Thai.

Most soil formations may have begun in similar ways,

but there are differences in quantity, as well as in physical and chemical quality, depending on the soil's precursors and the manner in which it was formed. Such differences give a basis for soil classifications, and guide the selection of the best possible plant types for any particular soil.

Soil scientists have developed soil classification systems over many years. For Thailand, the pioneer was Robert L. Pendleton, who produced the first general soil map (1946) of the country. The soil units used were "soil group", each being named after type and location, such as the Bangkok Dark Heavy Clay, Sithammarat Sandy and Coarse Sandy Loams, and so on. These are useful for a local reference, but present some difficulties for any universal reference system. A succeeding soil map, dating from 1967 and prepared by Moormann and Rojanasoonthon, utilized the soil unit that is based on the great soil groups of the world, or combinations thereof, in order to provide the required universal reference. This system, however, still does not quite meet the demand of scientists who need more comprehensive information from a soil designation.

A "soil taxonomy" classification system was adopted by the Department of Land Development. The system has been developed by the USDA scientists, and is regarded as the most suitable to facilitate technology transfer across different regions. A revised publication (1979) of the Thailand general soil map, which based its soil unit on the soil taxonomy classification, provides an improved basis for work on land suitability. This is a major consideration in land use planning, and details are provided in Chapter 2.

Land use planning will be based primarily on land suitability, and modified by relevant socioeconomic criteria. For example, paddy acreage is declining in the Central Plain, in contrast to a gradual expansion in other regions. Its conversion to more profitable uses such as industrial sites, new residential development, orchards, vegetable farms and aquafarms for shrimps and fishes, is responsible for the declining trend. The projected contraction of rural household numbers for the Central Plain may well accelerate this phenomenon. Land use planning in such circumstances will be difficult, but is likely to prove essential.

Forest Resources

Forests supply manking with many resources and services: wood, fuelwood, medicinal plants, animals, genetic resources, and so on. The ecosystem as a whole is sustained by forests. The air's oxygen supply is recycled constantly through the photosynthetic process in green leaves. The rainfall over the watershed, with adequate forest cover and grasslands, is partially infiltrated into the ground and released slowly to streamlets and headwaters. The plant nutrients to maintain natural soil fertility are supplied in part, by forest cover upstream. Man is sheltered and supported by forest products; yet now, man threatens to destroy that forest. Without forest cover, life could go on; but the hardship would be tremendous, both for rural and urban communities.

What is a forest?

Forest land, in its legal sense, could be a rangeland void of any tree, or having a few trees, or be crowded with trees and vegetation. Biologically, a forest is thought of as a stand of trees with not less than a certain tree population density. Ecologically, a forest is a community of living trees and associated organisms covering a considerable area, with productive characteristics as described in Chapters 4 and 5. Insects, birds, reptiles and mammals, plus myriad other living organisms make their home in the forest. Many of these are potential genetic resources for our domestic plants and animals.

A forest is subject to depletion, with an ecological deficit resulting where the amount of wood removed from it by whatever means, becomes greater than the new growth. If the deficit continues, the forest will shrink and, finally, disappear. Encroachment simply, and effectively, accelerates the shrinkage of the forest cover and its eventual disappearance. The loss of forest cover disrupts several basic cycles that provide and maintain the life supporting capacity of the land and water resources.

What about the mangrove?

The mangrove, by virtue of its unique position in a transitional zone, shelters a rather complex community of plants and animals that have adapted to the littoral environment. Yet the full development of the mangrove forest still depends on an adequate fresh water supply. At the same time, its ecosystem suffers if seawater circulation is obstructed. The right balance must be struck and maintained.

While good estimates exist for mangrove wood production, at some 0.75 million cubic meters annually of mostly "mai kongkang" *(Rhizophora spp.)* whose charcoal product is of a premium quality, the mangrove's economic contribution to offshore fishery resources is difficult to assess. It is known that the mangrove provides enough primary food source in the form of detritus, a decomposition product of mangrove forest litter, for primary consumers. They in turn attract the secondary consumer and tertiary consumer levels. A food web is thus generated, with extensive aquatic populations dependent upon the mangrove. There are over 300 resident mangrove species identified so far. Not all are of economic value, but every single one is part of our natural heritage.

A few of the species are rather important, economically. For example, mangroves feed and shelter, during a certain part of their life, "pla kapong-kao (white sea bass), "pla kao" (grouper), "pla ka-bok" (mullet) "pla nuan-chan-tha-le" (milk fish), "kung ku-la-dam" (jumbo shrimp), "kung chae-buay" (white shrimp), "hoi lai" (baby clam), and "pu tha-le" (mud crab). These are only some of the species of local importance, and their continued presence on the Thai table will partly hinge upon the proper management of the existing mangrove forest.

Considering the extent and pace of mangrove forest destruction, with some 0.62 million rai lost (over one-quarter

of the total area) during the period 1961-1986, and the evident damage by pollution to mollusc productivity within the last decade on mud flats adjacent to mangrove areas, it is urgent that proper management programs be agreed upon by concerned agencies. The Royal Forest Department has adopted a management system which involves franchising some 1.1 million rai of productive mangrove forest to private concessionaires, applying a logging system based on rotation zone clear-cutting and replanting, and initiating a programme designed to replant up to one-half of the degraded areas in six years. The Department of Fisheries has agreed that the areas taken out of the mangrove forest for shrimp farming, now amount to around 0.24 million rai, should be adequate to meet further expanded productivity requirements if intensive farming technologies are adopted. These technologies are available and should be used wherever possible.

Whither the land forest?

The land forests are still huge and diverse, with some 93 million rai remaining. Their variability reflects the locality, altitude and local climatic conditions, giving Thailand four main forest types: Evergreen Forest, Mixed Deciduous Forest, Dry Dipterocarp Forest, and Pine Forest. The Evergreen Forest is the most productive in terms of tree volume per unit area and annual growth capacity.

The land forests are struggling to perform a number of tasks to meet man's expectations, under a very harsh and contradictory set of conditions. The forests are expected to meet an increasing demand for lumber and fuelwood that now stands at 1.25 cubic meters per capita, while the resource base is diminishing. Already, timber must be imported to meet this demand. We have turned from a longstanding net-exporter into a net-importer of timber. A projected demand for pulp and paper that rises rapidly with the new age of information—books, newsprint and myriad other paper products—will more than triple, from 0.79 to 2.80 million tons, between 1985 and 1990.

Meanwhile, satellite imagery registers the opposite trend in existing forest cover. The forested area of 171.02 million rai in 1961 had shrunk by over 32.45 million rai (18.9 percent) by 1973, and 45.40 million rai more (26.5 percent) by 1985. The average annual loss between 1961-1985 was about 3.24 million rai. The most damaging periods were between 1973-1976, and 1976-1978, when the annual rate of destruction reached 4.85 and 7.25 million rai respectively. This accelerated destruction is closely linked with the development of infrastructure, including the road network.

Environmental considerations

Equal in importance to economic considerations are several demands that can never be easily equated in terms of cost and benefit—since only the loss side would be felt in normal circumstances. Watershed quality and headwater management must be actively pursued to ensure water resource quality. We are losing annually an estimated 47.5 million tons of sediment into the Gulf, mostly topsoil, from the catchment areas of the North and Central regions, and from half of the South. This process cannot be prevented completely, but could be reduced.

Nature conservation also relates to the aesthetic and educational value of living organisms and of the living communities that can benefit humankind in so many ways. These communities need protection by the forests that, in turn, need protection by man against unwise use or misuse. This represents another high priority need which is being served by our protected forests—the national parks and wildlife preserves system. Altogether, the system covers an area of some 21.9 million rai, in 79 parcels. The Khao Yai National Park is a prime example of a protected area that stands to provide multiple benefits from the point of view of conservation as well as of recreation. But even Khao Yai is subject to regular encroachment and poaching. Details are given and discussed in Chapter 5.

The extent and status, of our land and mangrove forests are discussed in Chapter 4 and 7. Unless Thailand conserves these resources, ensuring sustainable development rather than ruthless destruction, Thais may experience "environmental bankruptcy" along the lines of Africa's Sahel and Ethiopian highlands.

Water Resources

Thailand receives a generous rainfall, at an average volume of some 800 billion cubic meters each year. That is enough water to keep a standing surface of 1.7 meter depth throughout Thailand, provided it is not absorbed or evaporated. But evaporation and infiltration are important factors, leading to about 171,206 million cubic meters of surface runoff, distributed unevenly among the regions and between seasons.

The surface water quantity for each river basin is determined as the annual runoff volume in million cubic meters at the river mouth, or expressed in terms of depth in millimeters of water over the basin area it covers. The Chao Phraya Basin of the Central Plain is Thailand's largest, with an annual runoff of 170 millimeters. The Maeklong Basin, west of Bangkok, has an annual runoff of 406 millimeters; the Mun Basin of the Northeast, 238 millimeters. These runoff figures provide a simple indicator that the runoff from Maeklong is very large indeed and could perhaps be diverted to the Central Plain, which needs more water for its growing economy.

Groundwater is another resource that exists throughout the country, but varies considerably in quantity and quality. Large and high yielding aquifers occur in alluvium and terrace deposits. This favors the Bangkok Plain. In the Northeast, the groundwater from most wells is salty. In the Bangkok area the abstraction rate of groundwater is exceedingly high, surpassing the estimated safe yield by at least 0.5 million m^3/day, or more, bringing the prospect of saltwater contamination, in addition to land subsidence.

Water resource development

The status of water resource development is indicated by the

land area covered by irrigation projects. The current figure stands at 25 million rai, out of 152 million rai of agricultural land. The actual irrigated acreage and the extent to which cropping under irrigation control can be practiced at different seasons are influenced by several factors, for there are other essential demands for the water.

Potable water from groundwater supplies the needs of those without access to piped water. The 1984 abstraction rate was estimated at 880 million cubic meters, about half of that used in the Metropolis.

Another important aspect is hydropower development, to satisfy increasing public demand for electricity. The 1985 status is a total of 1,998 MW in operation, and 240 MW under construction. In addition, there are several microhydropower projects, with a combined capacity of 1,123 kW, and more in progress. Hydropower meets only one-fifth of total electricity demand.

Our water resource development activities are implemented and supervised by no fewer than 30 agencies and 17 committees, at an estimated cost of 402,608.4 million baht over the 55 years between 1928 and 1983. Yet Thailand still does not have a national master plan, nor a national agency for water resources.

Regional differences

The North's rainfall pattern is fairly reliable and its lowland area is only 10 percent of the total. This makes for a very bountiful supply of surface water, and also for exaggerated flooding downstream from the slash-and-burned areas used for shifting cultivation. The region's irrigation system is well developed, and there is an intensive diversified cropping system. The North's water is also crucially needed to meet the water demand of the Central Plain, where economic activity and urban development are intense. A time will come when there must be a decision for fair appropriation of water, perhaps quite soon.

The Northeast receives comparable annual rainfall to the North, but with a somewhat unreliable pattern. Flooding alternates with water shortages. The regions's sandy soils hold water poorly and are also generally poor in plant nutrients. Cassava is the crop that best suits these conditions. Only about 8 percent of the area is in the river flood plains and has good alluvial soils. This smaller area provides the Northeast with a more diversified crop production. The annual water runoff from the Mun-Chi river system is higher than that of the Chao Phraya, but there are no extensive reservoirs and water distribution systems to improve water utilization.

The Central Plain has more farm land and the largest irrigated area, almost a quarter that has helped increase the rice production through dry season cropping. Its two major river basins—the Chao Phraya and Maeklong—represent a good water supply, but water demand is increasing rapidly. The increase is due mainly to industrial expansion, more dry season crop production, urban needs, and the extra supplies needed to combat saltwater intrusion.

What the future holds

In 1986, the question of whether or not to build the Nam Choan Project was highly controversial. The outcome will affect the public, either way. Yet there are larger questions ahead. The Central Plain, for example, requires an increasing supply of raw water for its essential activities, all important. The North, too, will find that it requires to keep more water for its own expanding economy. Will the North have first right to this precious water?

The Greater Chao Phraya Project supplies irrigation water to 7.5 million rai in the wet season, and some 3 million rai in the dry season. But when all factors are considered, there will be, at most, water enough for 2.5 million rai of dry season crops. When Bangkok demands a greater volume of raw water for its huge urban population, the dry season acreage could be clearly upset. There are many pressing issues, and certain ways in which they could be resolved. These are discussed in Chapter 3.

To resolve such issues peacefully and in good time, it would be to our benefit to prepare and adopt a master plan for water resource development under which multipurpose projects could be planned and implemented. Given the impending shortages of water, such multipurpose projects are the best choice. At the same time, the new concept of the rights and duties of water users cannot be put off. The days of free water are numbered.

Mineral Resources

Thailand lies within the metallogenic belt of Southeast Asia, containing a wide complement of mineral deposits, some 40 of which have been produced to date. Among them, the discovery and mining of large-scale tin deposits, both onshore and offshore in the Peninsular South, started the modern mining industry. Subsequently, exploration and extraction followed for other mineral ores, notably zinc, fluorite, gypsum, lead, barite, tungsten, columbite-tantalite, antimony, and some 30 others. Mineral developments brought this country a foreign exchange earning of some 14,934 million baht in 1980, about three-quarters of which was from tin. With the weakening of the world economy, however, 1985 earnings dropped to 7,779 million baht, a trend which seemed likely to continue through 1986. All key economic minerals seemed to be affected by this demand slowdown.

Local consumption

To soften any adverse effect of the world market on Thai commodities, a sound basic strategy would be to boost local consumption at the expense of the export of primary products. There is a bright prospect for minerals. The local consumption is becoming significant. Its share of value increased from 873 million baht in 1981 to 4,187 million baht in 1985, excluding petroleum products, but including lignite, which accounted for 60 percent of the domestic mineral consumption value. Generally, it can be anticipated that local consumption is indicative of a value-added utilization through the growth of

local manufacturing industries, encouraging the expansion of local employment.

Gas and oil

The natural gas, condensate (or natural gasoline) and crude oil industries are more recent in origin. At present, local energy production satisfies 40 percent of the country's needs. The combined value, from both offshore and onshore sites, rose from 6 billion baht in 1983 to 17 billion baht in 1985. The condensate is not utilized locally, for Thailand has a surplus from its refineries due, in part, to the national pricing policy. It must be exported at the moment, although a reassessment of national policy is needed.

The future for tin

Tin will continue to meet the needs of the tin-plate industry, which supplies the canned food manufacturers. There is as yet no efficient substitute for the tin-plate can. In the past, both supply and demand were "artificial", to the benefit of non-producing exporters. There are real possibilities for Thailand to adopt new marketing and trade strategies to give tin a continuing strong export role as well as an increasing role in local manufacturing industry.

...and tantalum

Thailand holds the largest share of tantalum production at 46 percent, unrefined. World production appears to be declining, but the electronics industry is the biggest consumer, and its appetite is growing. Tantalum is essential for space-age weapon systems. Barring another disaster, the prospects for Thailand in the tantalum market are good.

The environmental costs of mining

The mining industry possesses adequate technologies to make ore extraction, recovery and processing a "clean" business, legally and environmentally. Yet there are widespread cases of "dirty" operations that have damaged the environment, as well as honest citizens, or which have spoiled mineral reserves with the poor extraction that came with illegal operation. What is needed is a systems approach to mining, which safeguards both the health of the industry and of the environment. These issues are discussed in Chapter 6.

Fishery Resources

Thailand's fishery resources are harvested from the Gulf of Thailand, the Andaman Sea, rivers, lakes and reservoirs. The harvest includes fish, crustaceans, molluscs and other marine fauna and flora. Pond aquaculture, coastal brackish water culture, and mariculture are recent additions. Their market shares by weight are very small compared to fish capture by the established marine fisheries. However, in terms of value, the products of aquaculture and mariculture normally command premium prices, thereby encouraging further development. The new industry is vulnerable because of its close proximity to polluted water sources that could produce a real threat to its survival. The development and introduction of new technologies would assist aquaculture as it has done so with the marine fisheries.

Overall, the country's marine fisheries have demonstrated an impressive growth record of production in terms of fish capture—at a current annual rate of some 2 million tons, placing Thailand within the top eight countries worldwide. This achievement came with hard work during the past 24 years, with the credit to be shared by both the public and private sectors with equal attention to new technologies, new training and new investment. Details are provided in Chapter 8.

Fish utilization

Annual per capita consumption of fish is some 22.5 kg, leaving a sizable amount (roughly a million tons) for other purposes, including export. When the total captures were small, most of the catch went to the fresh fish markets, and almost none to the fishmeal factory. With greater capture tonnages, the fishmeal factories have taken a larger share, reaching 49 percent in 1980, but currently down to about 38 percent. The changing pattern also affected the post-harvest industry that manufactures traditional preserves, as well as newly introduced product lines. Shrimp, bivalves, squid and cuttlefish also share significantly in a new market structure. However, fish and fish product imports also show a small increasing trend, commensurate with the expanding economy.

The maximum sustainable yield (MSY)

Compilation of fish capture data, and of the effort and time expended in sea fishing over the years, provides a fair basis for the estimation of a maximum sustainable yield (MSY) for each area of water, such as the Gulf and the Andaman Sea. The estimated MSY provides a guide to a safe level of exploitation of fishery resources, whether pelagic (surface dwelling) or demersal (bottom dwelling) fishes. The past records indicate safe levels of exploitation in the Andaman Sea, but over-exploitation in the Gulf. It could be anticipated that, the effect of over-exploitation would show up in a diminishing return per unit of effort at sea—unless the trawlers add to their catch by fishing in international waters.

The human elements of technologies

The phenomenal growth of the fishery harvest since the 1960s reflects an efficiency improved by the introduction of new technology—such as trawl net fishing—with subsequent adaptation and modification of the techniques, more powerful trawlers, new training and the addition of needed infrastructures, plus growing consumer demand. But this great improvement through technology also creates a danger of over-exploitation, unless people's awareness of the need for resource conservation and self-control assist the legal meas-

ures. There are other areas of concern, such as the use of explosives underwater. New technologies entail important social, economic and ecological implications which need to be identified and evaluated.

The victims of pollution

The freshwater aquaculture industry's problems with polluted water and disease are widely recognized, but its growth pattern remains strong. The same is true of brackish water culture. The silent sufferer has been the mariculture of bivalves—oysters, mussels and blood cockles—in certain areas of the inner Gulf receiving water-flow through large urban and industrial centers. Much of this water is heavily contaminated with untreated wastewater (see Chapter 10). The problem can be corrected, not at the mollusc breeding site, but by investment in and proper operation of wastewater treatment plants.

The exclusive economic zone (EEZ)

The Thai fishing fleet has so far suffered damage estimated at 2 billion baht since neighboring countries enforced their EEZ. The other expenses incurred must also be sizable, not counting life and family loss. Although Thai trawlers are handicapped without modern navigation and international communication devices, they are still capable of venturing into the high seas. Certain international joint ventures have been suggested, and are being actively pursued by various agencies. Further appropriate training, equipment and other technology will be required for successful ventures outside Thai waters. This strategy may also help keep the level of exploitation in the Gulf within the MSY, ensuring a share of this wealth for future generations. Another approach would be further expansion of the aquaculture, brackish water culture and mariculture sectors, with investment, technology support and proper environmental studies linked into development planning.

Environment

The natural resource base of Thailand is considerable: its utilization, interacting with population trends and needs, influences environmental quality. Concerns about the degradation of forest, land and water resources has been increasingly evident and has accelerated with growing population pressure. Of more immediate concern is the deteriorating environmental quality around most urban centers and industrial sites, as discussed in Chapter 9, 10, 11 and 12.

Air

Air pollution may be familiar to urban residents because of their closeness to a major emission source, vehicles or factories burning petroleum products. Industry is now a minor contributor to air pollution and noise, compared to motor vehicles. Rural areas also have their problems, but the greater dispersion cuts down the nuisance. Lignite is a new energy source that threatens to contribute a relatively greater share of emissions with its projected increase for industrial uses—especially for power generation in the future (see Chapter 9).

Technologies are available to clean up or cut down polluting emissions and noise. The observed reduction of lead oxide in the air is a result of the decision to regulate and reduce the lead content in gasoline. The emissions from lignite burning also could be reduced significantly, at a cost. The airport noise problem could be made less of a nuisance, provided effective zoning discouraged new housing development near the established airport. Too often, however, the housing envelopes already established noise sources, such as Don Muang International Airport, or hazardous gas and chemical depots in the City's suburban area.

Water

The Bangkok Metropolis consumes a disproportionately large amount of water that must be taken from the Chao Phraya and from groundwater at a combined rate approaching one cubic meter per person daily, which is believed to be in excess of the safe limit. The problems are twofold: inadequate clean water supply and inappropriate waste treatment threatening the clean water supply—both surface waters and groundwater. Increased pumping capacity can be purchased, but naturally clean water supply cannot. The treatment cost of raw water prior to distribution is rising. Contamination of the aquifer by leachate from city garbage, and by high chloride content, forcing well closure, is increasing. Saltwater encroachment into freshwater aquifers is facilitated by over-pumping. Such aquifer pollution may not be reversible.

Wastes

Solid wastes and wastewater, created by urban consumers, are taxing environmental quality at an accelerated rate in heavily populated cities and towns. Technologies to treat them are available, at a cost to consumers—who are used to free resources. It is up to the public to decide how much they will pay—and how much they will put up with. The requirement of a wastewater treatment system for Bangkok Metropolis, and other urban centers, can be met in several ways. The major cost component is not the treatment plant itself, but the delivery or piping system needed to transport wastewater from the multitude of households, factories, hospitals, and so on. Meanwhile the detectable cases of acute diarrhea have increased eight-fold during the past decade, despite advancing public health care. This is but a small indicator of Thailand's changing environmental status, which requires contemplation and appropriate action.

Nontoxic solid waste output per capita ranges from 0.56 to 1.27 kg/day, increasing with income. The trend is for increasing output with further economic development, and for increasing treatment costs. Current treatment is minimal, certainly not adequate to safeguard the quality of rivers or aquifers. Solid waste and its leachate are pushing up the

oxygen demand level in river water, and crippling the life-support capacity of the water. Dumping of solid wastes from factories and drainage of agricultural wastes into the upstream flow, contribute to cumulative pollution problems, especially in the lower section of the Chao Phraya and Thachin rivers feeding into the upper Gulf.

Toxic substances

Some toxic substances from factories, farms and homes, including heavy metals, pesticides and toxic chemicals, are non-biodegradable under natural conditions, biologically accumulated and magnified, and lethal or capable of producing detrimental cumulative effects. These are being detected in variable concentrations. Though their concentrations in any particular commodity are regarded as being still within the safety limits, their accumulation in the sediment layers of major rivers and the Gulf needs regular monitoring and proper management.

There are suggestions for special precautions to be taken when locating chemical industry sites in order to cope with any inadvertent toxic pollution of major rivers. A city like Bangkok should not absorb any chemical pollution from upstream sources into its intake of raw water for potable water supply. The current effort of NEB and DIW to prohibit the establishment of certain factories north of Bangkok is a step in the right direction. But careful and frequent reassessment of this possible effect is needed especially after the Sandoz accident. There also is a need for a contingency plan to counter any possible accidental release of toxic chemicals from stockpiles and factory waste dumps.

Accidents and health

Accident prevention is also applicable to some 25 million workers who are now exposed to new dangers in industry and agriculture. Presently the rate of accidents and injuries is considerable, especially in industry (see Chapter 12). The death rate from accidents is in the region of 32 per 100,000 workers, with a disproportionately large share in the construction industry. The 1985 injury claims disbursed, that partly covered industrial workers, amounted to 232 million baht. There are recognized to be more unreported or nonregistered cases in industries not now covered by the Workmen's Compensation Fund, in certain agricultural sub-sectors with over reliance on pesticides, and also in certain high risk mining operations underground or underwater.

Some aspects of hazardous work conditions are being camouflaged by the quick turnover of workers and by the absence of continuing health surveillance. Those workers being exposed, for example, to lead or manganese poisoning in manufacturing factories, to toxic chemicals in certain farming operations, or to silicosis in the mines, generally do not die on the job. They succumb following "quick retirement", so that the impacts are difficult to assess accurately. Health surveillance on a continuing basis would help all parties.

The future

To safeguard the overall environment, including the working environment, in order to assure healthy living for every citizen, there is a need for a positive assessment of the legal controls and supervising agencies related to all the intermixed components of the environment and resource utilization. The public needs accurate information on the situation and on what can be done. A label displaying the same level of hazard warning for "Folidol", a lethal formula, and for "Sevin", an all-purpose formula, misleads the less informed into treating the lethal one too lightly, and they may pay dearly for it. The workforce needs appropriate training—for the job and for accident prevention. Integrated planning to realize such targets set within the national development plan, is essential.

Some Interrelationships

The foregoing brief reviews of Thailand's natural resources—soils and land use, forest resources, water resources, mineral resources, fishery resources, and environment —express a series of tangible interrelationships among resources, environment and man. Man exploits these resources, shapes the environment and either benefits or suffers, often both, because of his own activities. The benefits and costs are rarely shared equitably.

The country's natural resource base supports its citizens with wealth in food production and consumer goods. All production activities can be made sustainable with good management and effective cost control. The products, in turn, support the well-being of the population the production processes reshape the environment that affects man as well as the resource base. The resource base is at the mercy of man's habits and actions. With discipline, this base can be kept alive and well; without it, the ecological deficit begins to soar.

Why an ecological deficit?

An ecological deficit results from extracting more from a "living" system than can be replenished with new growth. The demand exceeds the "carrying capacity". The topsoil loss is greater than the new soil formation; the land becomes less and less productive, and without correction will ultimately become unproductive. Trees are harvested in larger numbers than new growth permits, outpacing the new trees planted; the forest diminishes in area and in its capacity to support other living plants and animals. The fish harvest is in excess of the maximum sustainable yield; the fish stocks decline, and in time collapse.

Such ecological deficits reduce the resource base upon which man depends. A reduced base supports less people, at the very same moment that the population is expanding and the average citizen is demanding a better standard of living.

1.3 KEY ISSUES

There are many important issues relating to the exploitation of natural resources, and to the degradation of the environment. The links with the potential for sustainable economic and human development are discussed in each chapter. But with their interrelated effects linking each of them to a common factor—population needs—there is in reality only one main issue: how to meet the population needs of 2001 A.D. and beyond.

Thailand's projected population in 2001 is likely to be between 65 and 69 million, depending on the outcome of predicted growth patterns. To supply barely enough energy to meet the minimum requirement just to keep people from hunger, the annual food needs in terms of all cereals and coarse grains (at approximately 180 kg per capita) will amount to 11.7 to 12.4 million tons. If an affluent standard for all is desired, the annual grain needs will amount to 50.7 to 53.8 million tons, half of which will be food grains, while the other half will be used to raise fish, poultry and livestock, and in certain industrial uses.

How will Thailand fare?

Future considerations

To provide for future population needs, assuming a mid-level standard of living, or better, for more people by 2001 and beyond, the following considerations among many others, require further scrutiny:

a) Land use planning and zoning to increase land productivity. There is a need to refine the agro-ecological zones based upon current land suitability work, agro-economic zones, conserved and protected forest area requirements, economic forest areas, freshwater and brackish water aquafarm areas, and potential water resource development for specific zones. Agro-ecological zoning can greatly assist in ensuring the required production volume, as well as sustainable production. The zoning for agricultural land, industrial sites, human settlements and recreational areas will become increasingly critical to future efforts to feed and house more people to improved standards.

b) Forest conservation and maintenance. A step beyond declaration of intent will be needed to demarcate the forest cover boundaries in addition to the parks and wildlife refuges, which need effective protection, replanting and maintenance (see Chapter 5). Watershed classification and protection, the practicable operation of economic forest, social forestry and agro-forestry programs—all these are essential contributors to successful land use planning and also contribute towards an acceptable environment. The package will have a greater chance of being successful if the sacrifices and benefits are well understood and accepted by the people who must participate. The current integrated management planning of the mangroves, parks and wildlife refuges, if fully implemented and expanded, can be adopted and tailored to fit other zones.

c) Water use and availability. The effort to achieve su tainable maximum productivity from the land depends heavil on the efficiency of water use. Water use technologies involv both technical and social considerations. Appropriate tec nologies need much development effort to achieve the desire sustainable productivity. The sharing out of water supplies- e.g., rural vs. urban needs; regional vs. subregional shares- needs attention and clear guidelines. Proper water econom awareness must be created among farmers as well as urba industries and dwellers to ensure a reasonably adequate distr bution and relieve the pressure on new supplies of water. Th public needs to be informed and convinced of the possibl disastrous effects arising from abuses, such as over-abstractio from artesian wells, or irrigation without adequate drainag systems in critical crop land.

d) Expanded employment. The noneconomic aspects c creating more jobs for the coming population are related t the necessary exploitation of natural resources—minerals water, fisheries, forests, mangrove forests, land, and so on— and, inevitably, to environmental quality. The fiber and foo industries influence, and are in turn influenced by, the lan use pattern. Diversification into livestock and fisheries, inclu sive of aquaculture, adds jobs and other benefits. The manufac turing industries are linked to better return from minera resource exploitation, providing more jobs. But expande employment, it is important to remember, also often add more pollutants.

Is it possible to optimize all these components in ar integrated package of area-oriented planning and implemen tation?

e) Environmental cleanup costs. Environmental quality affects human health and also the productivity of natura resources. And all processes, from exploitation through consumption to waste disposal, affect the environment. This effec could be prevented, corrected or minimized at a cost—the cos for environmental cleanliness—that will be both monetary and social.

The problems and needs of expanding urban centers, o more crowded rural settlements, can only increase with more industrial activities, more intensive farming, more consumers' wastes. Old and new pollutants demand management and control, at a cost that was never fully paid before.

The cost must be paid to ensure the survival of future generations, to ensure their health, and the longest possible benefits from all life-supporting resources.

Are we willing to pay this cost to provide a clean, healthy and sustainable future, or do we elect to pass on the deficits by taking no action?

To prepare to meet the demand of the future, we need to look into "sustainable development" that will assist the planners and implementers of Thailand's natural resource management programs in boosting the sustainable rate of exploitation and benefits, as well as keeping environmental quality within acceptance limits for us all. Key facts and thoughts are presented in the following chapters of this Profile.

They provide the facts needed to think about—and plan for—our future.

1.4 OVERVIEW OF THAILAND AND ITS REGIONS

People lived in and roamed the countryside of what is now Thailand long before written records began. There is extensive archaeological evidence of human activity and settlement, dating back to the earliest users of crude stone tools. One group of people lived in what is now Mae Tha, Lampang, some 700,000 years ago, while other, more recent sites have been found in the North and West, at Chiang Rai, Phrae and Kanchanaburi. Much later, some 10,000-12,000 years ago, hunters equipped with more sophisticated tools covered much more extensive territories which suggests a growing population.

A burial cave uncovered at Tham Phra, Kanchanaburi, provided clues that even 12 millennia ago at least one group was already burying food—but no pottery—with its dead. Then, some 8,000-10,000 years ago, the cave-dwellers of Mae Hong Son began to develop a more settled existence. They made pottery, with simple line decoration. They gathered, and may even have planted and harvested, a number of food crops. A millennium later, rice was added to their diet, with the first signs of rice culture dating from around 7,000 years ago. By 3,000 B.C., the archaeological record contains significant traces of settlement in the Northeast, together with increasingly elaborate practices for the burial of the dead.

The pace of development was beginning to accelerate, with improved pottery, the introduction of cast bronze technology, the evolution of an increasingly sophisticated division of labor and the devising of ever more elaborate rituals. By 1,000 B.C., village communities were scattered throughout the region, with growing evidence of contacts and exchanges between them. Iron, copper and salt became important trading commodities. Further, by the beginning of the Buddhist era, from about 500 B.C., maritime contacts began to broaden the scope of trade and migration. These contacts spurred both cultural and political evolution, with scattered villages beginning to assemble into increasingly powerful chiefdoms. These, in turn, developed into the cities and city-states of the Southern coast, the Chao Phraya Basin, the Northeast and then the North.

Throughout this period, new centers of power emerged, prospered and faded away, whether because of shifting trading patterns, the exhaustion of nearby natural resources, or the decimation of populations by war and famine. Over a period of some 2,000 years, however, these small kingdoms and city-states gradually evolved into the Kingdom of Siam.

With its current seat of power securely established in Bangkok, the Kingdom of Siam should continue to prosper, provided that the mistakes of the past are not repeated and that new problems are identified in time and effectively tackled. Developing regional strengths in the conservation and management of natural resources are likely to prove critical in ensuring sustainable development and overall security, both for current and future generations.

Regional Diversity

Thai society is generally considered to be fairly homogeneous, although it is recognized that there is considerable, healthy regional diversity. A short description of the country's major regions follows, to set the scene for the ensuing discussion of the current state of its natural resources and environment.

the North

The North, administratively speaking, covers two geographic regions—the northern mountains and valleys and the upper Central Plain—accounting for one third of the country's land area and 20 percent of its population. The 1984 regional population density was 57.44 per square kilometer, making it the least crowded of the four regions. The North also ranked last with regard to the proportion (estimated to be 14 percent up to 1981) of forest reserves suffering from encroachment. Shifting cultivation is causing significant forest destruction, but the rate of loss appears relatively small due to the very large base of forest cover—accounting for 68.54 percent of the region's total area in 1961, falling to 51.73 percent in 1982. That reduction represents a loss of some 17.81 million rai, equivalent to one-sixth of the region's total land cover in two decades.

The North's reputation for good forest cover is clearly already endangered. Another uncomfortable figure is that of encroachment on forest land with slope greater than 35 percent, amounting to 1.89 million rai by 1982. The implications for soil erosion are obvious—and worrying. There are already concerns about lower soil moisture. The quality and capacity of the northern forest watersheds will be reflected in surface and ground water supply in the valleys of the North, as well as in the Central Plain downstream.

Even with a comparatively low population density overall, the agricultural activities of the North are condensed into rather small intermontane basins and narrow river plains. As a result, the mean farm size is lower than the national average. The migration of people in search of better farming land, together with the natural population increase, is placing disproportionate pressure on the more fertile farmland of the northeastern areas of the region. Indeed, it seems to have been the target of migration from all directions since the earliest times right up to the present day.

While it is generally considered that the North enjoys good crop productivity, and has the potential to develop further, with crop diversification and rotation, and dairy production, in addition to mining for antimony, wolfram, fluorite, lignite, oil and other minerals, some areas of the North face a range of emerging problems. The forest depletion rate, for example, is extremely high, up to 84 percent during a 5-year period

following the population increases in certain provinces during the 1970s.

Another phenomenon requiring further investigation is suggested by the fact that the increase in the area of land under cultivation from 1965-1978 amounted to just one-fifth of the forest area lost in the period 1973-1977.

the Northeast

The Northeast is a unique area where the administrative demarcation readily fits the geographic pattern. The region's land area is also one-third of the country's total; adjusted figures rank it about equal with the North. Its population ranking remains undisputed, at 34.5 percent of the total, it is the most populous region, but its average population density in 1984 of 93.64 per square kilometer places it second to the Central region, on this count at least. This population is well distributed, such that no province has over 200 persons per square kilometer.

The share of agricultural land for this region runs above 40 percent of the national total, yet its agricultural output could account for only one-quarter of the national production. While the total rainfall, on average, is better than that of the North, the area is generally inadequately supplied with moisture at times of greatest need. Poor soil and erratic rainfall are cited as chief reasons for poor productivity and, hence, very poor per capita income, at some 40 percent of the national average.

As far as the Northeast's forest cover is concerned, it had been reduced by 1982 to some 15 percent of the region's total area. This is the lowest proportion for all the regions, and it continues to dwindle at a high rate; 13 percent remained by 1985. This is a dramatic decline, from 42 percent to 13 percent in 24 years, in the space of a single generation. What, if anything, will be left for the next generation As to why this is happening, research has shown that high population density is the chief factor leading to rapid deforestation. Accessibility by road, which is more extensive than in the North, also helps accelerate the process.

Vast areas of the Northeast regularly experience surplus water in the form of standing floods over the river terraces and basins, periods of excess which alternate with periods of too little soil moisture. This ensures a generally low productivity from the land. The resulting low incomes seem to have helped accelerate forest encroachment, whether to gain farm land or to gather forest products. In the process, more forest land on slopes greater than 35 percent was converted into crop land, before eroding away. By 1982, some 0.94 million rai on steep slopes had been encroached, removing an estimate 11 percent of the region's protected watersheds. The ensuing after-effects could be much more damaging than any anticipated in the North.

Subsistence farming largely depends on a single crop. Attempts to find and introduce appropriate systems based on multi-crops and/or crop-livestock combinations continue. Meanwhile, however, a significant number of people will continue to migrate to other areas in search of a better living, or a living of some sort. This is not a recent phenomenon. Northeasterners have been migrating, perhaps for centuries, to populate the North and the Central Plains. Accounts of mass migration during the tenth and eleventh centuries are beginning to be verified. Presently there are genuine concerns that the influx of new population into the lower North, the Southeast and the South, where local forests have been disappearing at a quicker pace, may be the continuation of a long-established trend. This, too, requires verification.

the Central

The Central is a conglomerate of three geographic regions, namely, the western mountains, the Bangkok Plain and the Southeast coast, plus an extension into the uppermost section of the Peninsular South. It covers one-fifth of the country, with some 22 percent of the population—or 32.5 percent if the capital is included. It has the highest population density, at 114.92 persons/km^2, not including the Bangkok Metropolis (at 3,306 persons/km^2). There are four provinces with over 300 persons/km^2, and five more over 200 persons/km^2. The rich soils of the Chao Phraya Basin have been a major factor attracting population to this region. Other activities, such as fisheries, commerce and industry, underpin several strong urban centers. The waterways provided the earliest reliable transportation network, which was later supplemented by railroads and roads. Developers continue to favor the Central, especially its urban centers.

Such induced differential growth of urban centers came with economic prosperity, and brought many environmental problems in its wake. Energy demand, water supply, housing shortages, waste disposal, pollution of all categories—all emerge into the modern scenario. These must—and can—be handled on a proper, integrated basis.

Surrounding the Central Plain are mountains to the west and east, and forests that provide additional water and moisture, soil replacement and fertility replenishment to the Bangkok Plain downstream. Granitic cores within the western mountains and basaltic cores in the eastern hills represent sources of several minerals and precious stones that are commercially exploitable. Nature has endowed the Central with excellent opportunities for agriculture, mining, industry and commerce.

Judging from the rate of forest encroachment in the region, the Central, though better provided with almost everything than its sister regions, is far from blameless. Estimates up to 1981, assessed encroachment of forest reserves at 51 percent in the eastern area and 19 percent in the upper part of the Bangkok Plain. Migration pressures and increasing population pressures, were often blamed. But, underlying it all, greed may be the real instigator of much deforestation.

the South

The South is the Peninsular South, minus the uppermost province, whose local dialect is closer to that of the Central region. Its area is approximately one-seventh of the country

total, and it has some 12.5 percent of the total population. On that basis, the population density is 80.62 per square kilometer. There are two provinces with population densities higher than 200 per square kilometer. However, the South also has one province with the distinction of being the least populated in the country, and also has the second lowest in density.

The South, in general, enjoys a real tropical climate that provides good moisture and humidity throughout the year. This could be one reason that despite the great rate of deforestation —up to 40 percent of the forest reserves were lost by 1981, and the depletion of forest cover generally from 42 percent to 22 percent within the past 24 years—there has been less protest than in some other regions. Another factor would be the pararubber plantations that have replaced most of the deforested areas in the lower South. Nearly 0.56 million rai of forest areas with slopes of more than 35 percent had been encroached upon up to 1982, again mostly in the lower South, where pararubber trees and good moisture combine to alleviate some of the erosional effects. The upper portion of the South, however, some areas of which are turned into upland crops, stands to suffer more from deforestation.

Tin mining has helped the South develop a modern economy. Pararubber plantations give it a unique landscape and considerable further wealth. Onshore and offshore mining in the South have produced riches for some, and imposed suffering on others. The winning of minerals and natural gas are well developed activities. But, as with the rubber, the major share of the resulting benefit may fall a little beyond the South itself. Horticultural crops, fisheries and trading are strong in the area, providing a good living for its people.

The region's tourism potential is considerable, and is being developed earnestly. However, both the development of tourism and that of mining and mineral processing require extreme care. Integrated planning needs to be adopted for both sectors. The same argument holds true for other areas and localities.

People generally welcome economic development. They may be concerned, however, even scared, about the environmental changes involved. Paradoxically, however, the same people who protest about a major development project, may well themselves pollute or damage the environment, perhaps unknowingly.

Geography and Physiography

Geographic location

Thailand is located in the middle of the Indochinese Peninsula, between latitudes 5°40' and 20°30'N, longitudes 97°20' and 105°45'E. Its total area is 513,115 square kilometers, of which some 84 percent falls within the mainland section and 16 percent within the Peninsular South. The extreme length from north to south measures 1,620 kilometers, while at its broadest Thailand is only 780 kilometers wide from east to west. The narrowest strip at about 11°43'N latitude on the Peninsular South is 10.6 kilometers. The Isthmus of Kra is some 64 kilometers wide, situated further south at about 10°N latitude. The form is therefore anything but compact, affording Thailand excellent access to the seas.

The "golden axe" shape, in fact, provides over 2,614 kilometers of shoreline, facing both the Pacific and Indian oceans, with several hundred islands. The seacoast bordering the Gulf of Thailand is 1,660 kilometers long; that bordering the Andaman Sea is 954 kilometers long. There are basic physical differences and variations in resources between these two coastlines. Pertinent details will be discussed in later sections.

The land boundary extends for some 3,400 kilometers, on the mainland and the peninsula. Politically, the land boundaries are shared with Malaysia in the Peninsular South, Socialist Republic of the Union of Burma to the west and northwest, the Democratic People's Republic of Laos to the northeast, and the Democratic Kampuchea to the southeast.

Physiographic characters

The location of Thailand straddles the area between two mountain systems—the Central Cordillera and the Cordillera of Annam—two of the four systems that fan out southwards from the Yunnan Knot, beginning at about 28°N latitude. The Central Cordillera gives Thailand its mountains in the North and West, and continues on into the Peninsular South and Malaysia. The Cordillera of Annam provides the mountains east of Thailand, on the boundary with Laos and beyond. The wide depression between these two mountain systems contains the alluvial plains of Chao Phraya and the Khorat Plain, known more familiarly as the Northeast Plateau.

Structural geology describes this depression on which Thailand is located as part of the Yunnan-Malayan geosyncline (also designated the Burma-Malaya geosyncline), which has undergone a long series of structural changes. The evidence suggests that such changes began in the Precambrian period (570 million years ago), again in the mid-Carboniferous epoch (220 million years ago), at the end of the Triassic epoch (190 million years ago), and toward the end of the Tertiary epoch (1.5 million years ago) for the latest round. Minor changes continue. Each change is believed to bring about the orogeny and/or epeirogeny, and metamorphism responsible for the rich mineral resources deposition in some areas.

Plate tectonic theory places Thailand on an inner perimeter of the Southeast Asia Plate, which is being compressed from opposite directions by the Indian Plate to its west and the Philippine Plate to its east. Continuing plate movements exert immense pressure and generate intense heat, capable of transfiguring our tranquil landscape—and the resources underneath. But on the scale of a single human lifetime, it will be Man himself that transforms these given resources for the better or for worse.

Based upon the precepts of structural geology, Thailand could be divided into four domains: the fold belt of mountains in the north, west and south of the country; the fold belt of mountains east of the Chao Phraya Plain, delimiting it against

the higher Khorat Plain and continuing eastward to delineate lower Kampuchea; the Khorat Plain with two major basins; and the Chao Phraya alluvial plain, with two major basins and a southerly continuation into the Gulf of Thailand.

Physiographic regions

There are six regions recognizable by their characteristic land forms: the northern ranges and valleys, the Central Plain, the western mountains, the Southeast coast, the Northeast Plateau or Khorat Plain, and the Peninsular South.

a) The northern ranges and valleys occupy the area above 18°N latitude. The five main parallel ranges running north-south and the valleys between them provide the catchment and headwaters of four major tributaries of the Chao Phraya River—the Ping, Wang, Yom and Nan rivers that drain southward. Above the Phipannam Divide are basins that drain northward into the Maekhong River—through the Mae Kok and Ing rivers. And to the northwest corner of the region are watersheds that feed into the Salween River of Burma. Between these ranges of the North are valleys and several intermontane plains at different altitudes that provide agricultural land and area for settlements. The forest cover is still closer to 50 percent of the land area, the best in all the regions. The North may not have the heaviest rainfall in the country, but with its physical landforms and good forest cover, the soil water is high and the soil productivity continues to be above average for the country.

b) The Central Plain extends southward from the ranges and valleys of the North to the Gulf of Thailand. It encompasses the alluvial plain of the Chao Phraya River, many tributaries and also distributaries, and the surrounding piedmont belts. The plain has a deep, fertile deposit of soil carried by water from the North and also from the mountains to its western and eastern boundaries. Other major rivers include the Maeklong and Sakae Krang from the west, and the Pa Sak, Lop Buri and Bang Pa Kong from the east. The plain is in effect a vast valley that extends 450 kilometers from the northern hills to the Gulf. It is some 150-200 kilometers in width, being widest at the Gulf end. Two basic subregions may be described according to their physical characteristics the upper plain and marginal plains, and the lower plain, Bangkok Plain or Deltaic Plain.

- The upper plain and marginal plains. The upper plain continues from the end of the northern ranges to where the Ping and Nan rivers merge into the Chao Phraya. For political reasons, this area is the lower part of the administrative Northern region. The marginal plains consist of a narrower strip of piedmont plains to the west and east. They share these common land forms: narrow plains of deposition along the rivers, low rock outcrops and higher elevation than the lower plain. The soil is fertile, but shallower.

- The lower plain, Bangkok Plain or Deltaic Plain. This plain is a true plain of aggradation, with deep soil formed by alluvation, and is slowly extending seawards through deposition of waterborne sediments into the Gulf.

The Chao Phraya River branches at about 15°15'N latitude to give rise to the Nakhon Chaisri River that runs in parallel with it to the Gulf. Two additional distributaries, the Noi and Lop Buri rivers, are formed further south. Both empty back into the main river, with the Lop Buri receiving water from the Pa Sak to the east. This river system gives the lower plain its outstanding soil fertility for agriculture, and provides a good transportation network since early human settlements. Bangkok's seaport still provides the main outlet for shipping.

c) The western mountains represent a continuation of the Central Cordillera from the north, between Thailand and Burma, to the west of the Central Plain. The valleys are small; the intermontane plains are also few and small, with the exception of the Mae Sot Basin. Human habitation is therefore sparse. Several tributaries of the Salween, Chao Phraya and Maeklong originate in these mountains. The Khwae Noi and Khwae Yai collect much water from the southwest monsoon rain over this mountain range, and latter join to form the Maeklong River.

d) The Southeast coast or East coast of the Gulf of Thailand is a rolling land with low hills to its north and mountains to its east, and with narrow coastal plains. It is drained by several streams and short rivers, all flowing south into the Gulf. Its coastline is much indented, exhibiting the character of a sinking coast, and is fringed with rocky forested islands. More prominent among some 80 islands are Srichang, Chang and Kut. The mountains and hills to the east are effective in trapping rainwater from the southwest monsoon, giving the southeast corner strip precipitation of over 4,000 millimeters, compared with the regional average of just over 2,100 millimeters. This makes the area's flora and agriculture distinct from those of the Central Plain. This region's position and terrain offer new potential for major ocean ports.

e) The Northeast Plateau, or Khorat Plain, is some 200 meters above mean sea level at its western edge, which is set apart from the Central Plain by the Phetchabun and Dong Phrayayen mountain ranges. These ranges extract much rainwater from the southwest monsoon and feed back to tributaries of the Chao Phraya and Bang Pakong. The Khorat Plain, with an expanse of some 153,600 square kilometers, tilts to the southeast and drains into the Maekhong. Its elevation does not make it a true plateau, and its "plain" is more saucer-shape, with two major basins—the lower and larger Khorat Basin and the upper and smaller Sakon Nakhon Basin, divided by the Phu Phan range.

The Northeast's major river system is the Mun, which drains into the Maekhong. Flooding during the wet season is normal, due to very slow runoff, and to high water from the Maekhong itself. During the dry season, many localities will develop salt crust, following the evaporation of saline water brought up through capillary action from deeper layers. A shallow sandy soil over rocks, in general, does not provide commensurate benefits from the reasonable rainfall that the area receives, which is slightly more than the North.

The upper basin, however, affords more freshwater bodies, such as the Nong Han, that are utilizable year-round. Small rivers drain into the Maekhong. The northeastern corner

strip of land receives greater precipitation, at 2,000 millimeters annually, and has good fertile soils. Another bright spot is the expanse of paddy land near the river-mouth of the Mun, on the Plain's southeast corner. Elsewhere, much hard work will be required if improvement is to be effected.

f) The Peninsular South is a continuation of the western mountains, affording a number of basins, and river and coastal plains which are fertile and habitable. Its northern limit begins at about 12°50'N, running south and southeast for some 750 kilometers. For administrative purposes, its northern limit is pushed southward by another 1° latitude. At its widest points, the peninsula is 150-250 kilometers in breadth. The mountain ranges form the backbone of this region, with the eastern coastline facing the Gulf of Thailand and the western coastline facing the Andaman Sea. More coastal plains and stretches of long beaches are found on the East coast, whereas the West coast appears to be a submerged coast, with a very irregular shoreline and many estuaries. The ridges of the Phuket range are closer to the West coast and contain more granitic cores, providing richer mineral deposits. Their location also helps them extract greater amounts of moisture from the southwest monsoon and produces a narrow belt of very high precipitation on the West coast, up in the range of 4,000 millimeters.

The east coast plains receive their rain more from the northeast monsoon that arrives later in the year. This difference also reflects the rather different vegetation and cropping cycles on the east and west coasts. There are several short rivers. The Pakchan River at the Isthmus of Kra drains into a "drowned valley" of the Andaman Sea. The Tapi river basin on the east coast is the most expansive in the area, and drains into the Bandon Bay. This, together with other shorter rivers, builds up the plains through the deposition of alluvium.

Even though there are over 275 islands off both shorelines, there are few bays or ship anchorages. The one inland sea, or "Songkhla Lake", is sizable and could be further developed. Ranong and Phuket offer similar potential on the west coast of the peninsula.

Climate

The climate of Thailand is tropical, and much influenced by the country's position. The Indochinese Peninsula is part of the Asian land mass that extrudes between two great ocean bodies—the South China Sea of the Pacific Ocean and the Andaman Sea of the Indian Ocean. While the Peninsular South is bounded by seas on both its east and west shores, the mainland part of the country is also in comparatively close proximity to two large bodies of water—the South China Sea to the east, and the Andaman Sea plus the Bay of Bengal to the West. The monsoons, resulting from the seasonal differences in temperatures between the land mass and the oceanic body, alternately blow southwesterly and northeasterly over Thailand. The South and Southeast Asia monsoons are the most powerful of all monsoons, dominating Thailand's climate. The surrounding water, as well as the physiographic terrain, again contribute much to modifying the monsoon effects on various localities of the country.

The following tropical climates, according to Koppen's classification, are applicable: Savanna Climate (Aw), for the area above the Peninsular South, excluding the eastern section of Southeast coast; Tropical Rain Forest (Af), for the lower east coast of the Peninsular South; and Tropical Monsoon Climate (Am) for the rest of the Peninsular South, and also the eastern section of the Southeast coast. In addition, the Humid Subtropical Climate (Cw) is applicable to the area in the far northeastern part of the North at higher elevations.

the seasons

As a tropical country, only the wet and dry seasons are succinctly differentiated. This is especially true in the Peninsular South and the lower mainland sections. For the upper mainland sections, however, a greater distinction between temperature differences during the dry season justifies a broad separation of "summer" and "winter". Such a seasonal change is the result of monsoon wind directions, interacting with the location and terrain

- The southwest monsoon carries moisture from the Indian Ocean, normally from May to mid-October; but for the upper mainland sections, it is effective from mid-May to September. Its initial strength correlates with that of the high pressure center over the Indian Ocean in the Southern hemisphere.

- The northeast monsoon brings in dry and cold air from China, and is normally active from mid-October to mid-February, sometimes extending into March. It causes a cool, dry season for the upper mainland section. The eastern shore of the lower South, however, receives this northeast monsoon after it has travelled across the South China Sea, picking up moisture and bringing more rain. Therefore, its wet season is in effect extended, with even higher precipitation, until January or later.

- The switch-over or pre-monsoon period, from mid-February to mid-May, coincides with the sun's position moving northward across the equator. Increased heat absorption by the land mass and much reduced rain produces a very hot climate, especially for the upper mainland sections. The wind can be very variable, with occasional storms. The lower section often receives southerly winds coming up from the Gulf, sometimes referred to as a southeast monsoon, making it generally cooler than the upper mainland section.

Precipitation

A general observation is that the further you go from the sea in Thailand, the less the precipitation. Interacting with the monsoons, location and terrain exert a considerable influence. Storms also provide additional precipitation inputs.

- Thailand's location creates two general effects. First, the upper mainland section is exposed to a shorter period of the southwest monsoon, by approximately one month. The total for the North is therefore no greater than for the North-

east. Second, the lower east coast of the South has an extended wet season, because the northeast monsoon that picks up moisture over the South China Sea well into January or February. The same northeast monsoon passing over the rest of the country will not have picked up that moisture and is therefore dry and cold.

● The terrain can add to or subtract from what would be considered the "normal" share of precipitation. There are at least four areas where pronounced orographic effects are evident: the west coast of the middle South; the southeast corner of the Southeast coast, the leeward area of the west mountains; and the leeward area of the Phetchabun and Dong Phrayayen ranges. The first two areas receive very heavy precipitation (near 4,000 millimeters), being on the windward side of high mountains with, perhaps, still very good forest cover. The latter two areas do not receive their fair share (around 1,000 millimeters or less), since much of the moisture has been trapped on the windward side of the mountains, and they are the areas whose soil is relatively fertile for a number of crops.

● There are two types of storms affecting the annual precipitation of certain areas.

i) The tropical or depression storm, downgraded from the typhoon of the Pacific Ocean while crossing the Annam Cordillera, can bring heavy rain, mostly to the upper Northeast and North during August to September. A full-scale typhoon could hit the exposed Peninsular South, but, fortunately, their occurrence close to the equator is infrequent. A rare depression storm may also originate in the Gulf or the sea nearby, and producing heavy rain, especially along the coastal areas.

ii) The cyclone from the Bay of Bengal could cross over Burma into Thailand, but rarely does so. When it does, its force has typically been much weakened. It could be expected in May, and again from October to December.

Temperatures

Two characteristic trends in temperature variation fit two broad areas of Thailand.

● The upper mainland section covers the North, Northeast, Southeast, West and Central, with the exception of areas adjacent to the seashore. The range of mean maximum temperatures will be 33-38°C. The highest-ever temperature in April between 1951 and 1980 was 44.5°C. Higher maximum temperatures normally occur in April due to greater solar absorption, less wind and less cloud cover. Cloud cover and rain seem to exert greater influence in depressing the maximum temperature. The Northeast benefits least from extensive cloud cover, and night radiation is strong. The daily range of temperatures will be 8°-12°C, but a wide range of as much as 20° during "winter" may be observed. Lower minimum temperatures occur in December and January, due to the northeast monsoon and heat radiation losses, with the mean minimum at 10°C. The upper North and upper Northeast normally will be exposed first to the very cold and dry northeast monsoon, and experience very low minimum temperatures. The coldest January temperature recorded between 1951 and 1980 was 0.1°C.

● The lower section covers the Peninsular South and mainland shoreline region. Temperatures are more uniform year-round, with a daily range of about 10°C. The mean maximum temperatures in December and in April differ by about 3°C in Bangkok, and by only 2°C in the lower South. The proximity to the sea helps alleviate the temperature extremes. The extreme maximum temperature registered between 1951 and 1980 was 40°C, while the minimum temperature was 8.9°C.

Atmospheric pressure

Any effect of the change in atmospheric pressure due to altitude is not readily observable in Thailand; only two effects may be cited. First, in the mountainous area above 1,350 meters, the Monsoon Forest will be replaced by Evergreen Mountain Forest, indicative of lower temperatures. Second, on a few higher elevation mountain slopes or intermontane basins the average temperature will be lower than at lower elevations.

The atmospheric pressure changes that considerably influence Thailand's climate are the high or low pressure centers built up over the distant oceans or the land mass, and the atmospheric disturbances that breed cyclones over the oceans.

● The high pressure center over the Indian Ocean, in the Southern hemisphere, affects the southwest monsoon strength, influencing the amount of precipitation.

● The high pressure center over China, in the Northern hemisphere, influences the northeast monsoon strength that, in turn, is related to dry weather and low temperatures over most of Thailand, and to additional precipitation over the lower east coast in the South.

● The high pressure center built up over the South China Sea influences the "southeast" monsoon, or southerly wind, in the Gulf of Thailand during the "switch-over" period from the northeast to southwest monsoons. It is moist and warm, so it raises some temperatures and brings occasional rain.

● The tropical cyclones that regularly form over the Pacific or the Indian Oceans at low latitudes, may pass through or pass by Thailand as a tropical depression, tropical storm or typhoon, from 3 to 4 times annually. Each can bring in precipitation over a wide area along its path, the amount varying from moderate to very heavy.

Tropical cyclones originating in the Indian Ocean can be expected in May, and again during October to December; those from the Pacific Ocean, may be expected during August and September over the upper section, and during October to December over the lower section of the country.

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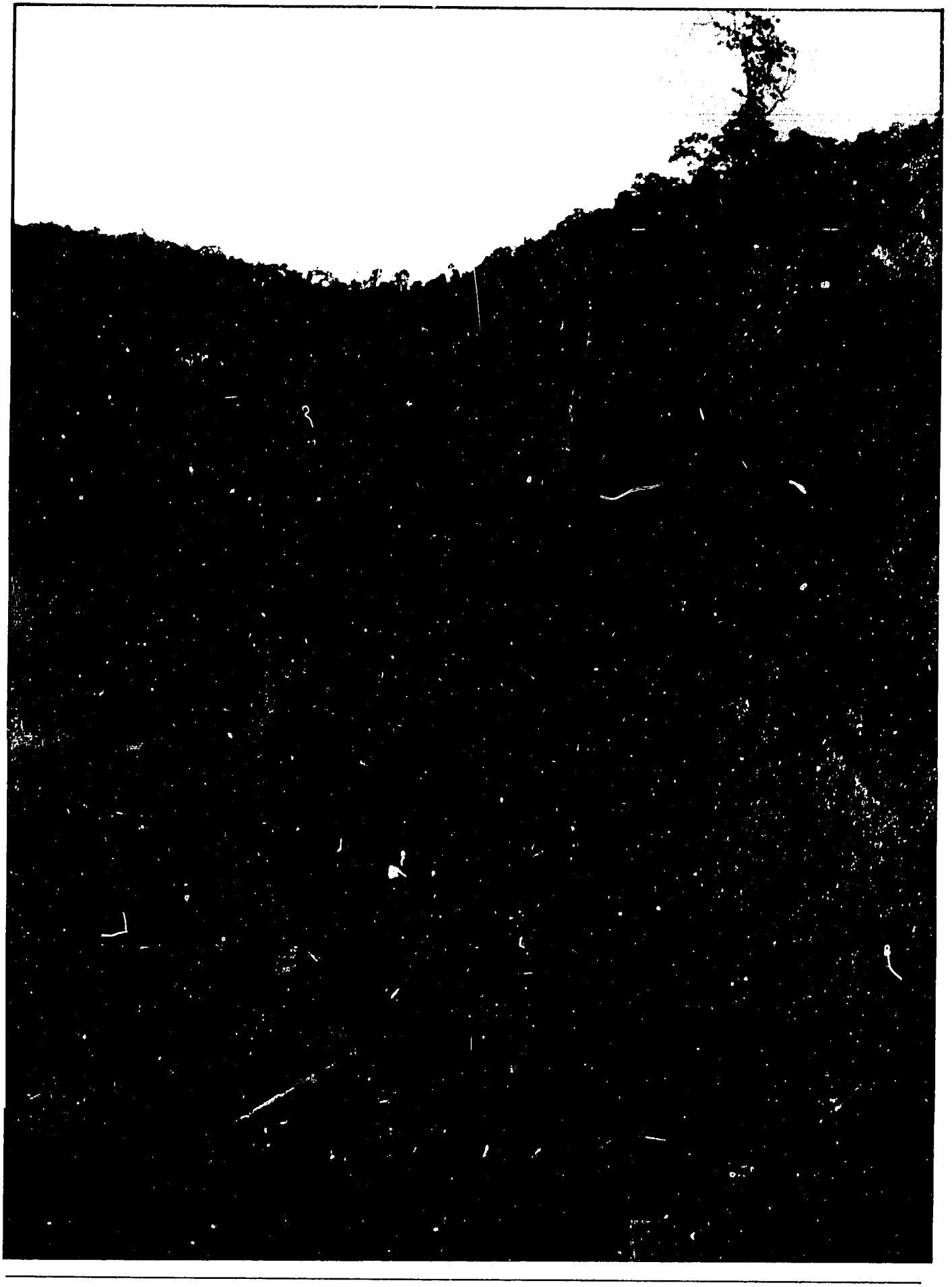


Natural Resources Management PART II

2 Land Resources

2.1 OVERVIEW

The word 'land' can be used to denote a specific area of the earth's surface. In this sense, land's characteristics may embrace all the reasonably stable or predictably cyclic attributes of the biosphere vertically above and below a particular area or site. These attributes may relate to the atmosphere, the soil and underlying geology, the topography, the hydrology, the plant and animal populations and the results of past and present human activities – wherever they exert a significant influence on present and future uses of the land by man (FAO, 1974).

According to Section 1 of Thailand's Land Code of 1954, *"Land means the earth's surface everywhere and including mountains, hills, streams, ponds, canals, swamps, marshes, waterways, lakes, islands and the sea coast."*

Soil

The soil is a three-dimensional natural body occupying the uppermost part of the earth's crust and having properties differing from the underlying rock material as a result of interactions between climate, living organisms (including human activity, the parent material and relief over periods of time. Any particular soil can be distinguished from other soils in terms of differences in its internal characteristics and/or in terms of the gradient, slope complexity, microtopography, stoniness or rockiness of its surface (FAO, 1974).

Significance of Land Resources

Thailand is no different from other countries in that its land resources have long been a key factor in the country's socioeconomic development. The increasing human population and the accelerating scope of human activities impact all natural resources. Since humans are basically terrestrial, their activities particularly affect the land resource. As land values and the diversity of land uses have increased, conflicts among competing land uses have multiplied. The sustaining base of land resources which supports us all has been damaged, or in some cases destroyed, by land uses which are inappropriate, exploitive, or inadequately planned.

During the past two decades, the problems of land availability, land use, and classification and titling, land development and soil conservation have become increasingly acute in Thailand. The immediate causes of these problems arise mainly from population pressure and the consequent shift in land use from forest to agriculture.

It is estimated that land suitable for agricultural use has now almost completely been utilized. In 1985, of the total land area of about 320.7 million rai, 136.2 million rai were accounted for by the national forest reserves (out of which 93.2 million rai remained intact while the rest were encroached forest lands). Another 26 million rai had been abandoned or were in use as pasture or rough grazing. The cultivated area represented about 152 million rai, of which

84 million rai were planted to rice, 51.5 million rai to upland crops and 16.5 million rai to perennial crops (TDRI, 1986).

Thailand is one of the leading exporters of agricultural products in Asia. Major export crops include rice, rubber, cassava, maize and sugar. Most of these crops are planted in the rainy season. Out of about 152 million rai of agricultural land only 21 million rai (14 percent) are irrigated with the remaining 86 percent still rainfed. In the dry season, however, about three million rai of rice can be grown, especially in the land consolidation areas, where irrigation facilities are well developed.

About 40 million of Thailand's 52 million people live in the rural areas and earn their livelihood principally from agriculture. There are about 4.7 million farm households and two million non-farm households in rural areas. In 1985, agriculture contributed about 70 percent of GDP, 60 percent of exports, and provided full or part-time employment for more than 70 percent of the country's labor force. Agricultural production (GDP in constant terms) in Thailand grew at an annual rate of about 5 percent during 1960-1980, an exceptional performance by international standards. However, the growth of agricultural production has been gradually falling off. Agricultural GDP in constant prices, which had grown at about 5.5 percent annually in the 1960s, slowed to 5.1 percent per annum in 1970-75, and 3 5 percent per annum in 1975-1980.

Although agricultural products have been the major export earner for Thailand in the past two decades, increases in production have come from the expansion of cultivated areas rather than increases in the yield per unit of land area. It is generally recognized that the limits of the nation's land resources are now being approached.

FAO (1984) reported that crop yields in Thailand showed a decreasing trend, both in irrigated and rainfed areas. Under the present farming system, crop yields have been reduced year by year, due to degradation of soils and poor management. Problems encountered might include the following: (1) irregular rainy seasons; (2) soil degradation, including physical, chemical and biological deterioration; (3) cultivation on steep slope land without soil conservation practices; (4) unsuitable farming systems; (5) lack of legal land title, resulting in a situation where many farmers are unable to obtain credit from commercial sources; (6) shortage of farm credit and (7) a lack of adequate agricultural infrastructure.

As a result of these existing problems, some of the older cultivated lands have been abandoned. Forest areas have been greatly encroached upon for cultivation. The most recent study by the Royal Forest Department (1985) indicated that there are only 93.2 million rai of forest area remaining and the clearing continues. A number of squatters have long illegally occupied and lived in the national forest reserves. Sporadic, unorganized migration has been the rule, resulting both in encroachment onto national forest reserves and indiscriminate deforestation generally. The present rate of deforestation is estimated to be about 1.52 million rai per year. This has resulted in the wastage of valuable national assets and has also been a cause of real social tension.

Land ownership security outside forest reserves also remains a serious problem. In 1985, only about 20 percent of the total area of private land had title deeds. This constitutes a basic obstacle to farm investment and rural development. Problems of tenancy and landlessness have been increasing in recent years and are expected to become more widespread with the intensification of agriculture. This is already quite evident in the Central Plain and the upper North.

An equally important factor responsible for the country's land-related problems is the lack of any coherent land policy combined with the proliferation of government agencies involved in land policy making. At present, there are 24 government agencies and several committees with overlapping responsibilities. There are eleven different laws, including revolutionary orders concerning land, various cabinet resolutions and several ministerial decrees.

In summary, without the framework of a coherent national land policy, Thailand's land problems cannot be solved. Many approaches have been tried and implemented for a period of time. Whenever the problems arose, such approaches were abandoned or allocated a lower priority. Since, land is the ultimate resource used for many activities by different groups of people, without consensus among those groups an efficient national land policy cannot be formulated.

The use of land are manifold: economic, social and political. Some people view land as a property asset, some view it as an agricultural resource or as a place to live, while others again may think of it in terms of its conservation potential. Inevitably, these differing perspectives, needs and preferences lead to tensions throughout Thailand, of a greater or lesser severity.

Background Information

The Kingdom of Thailand is located centrally in the Indochinese Peninsula of Southeast Asia, between 5°40' and 20°30'N latitude and 97°70' and 105°45'E longitude. The total area of the country is 320,696,950 rai or approximately 513,115 square kilometers. It shares the border with Laos in the north and east, Burma in the north and west, Kampuchea in the southeast, and Malaysia in the south. The country's longest north-south span is about 1,620 kilometers, while its widest east-west extent is 750 kilometers. Geographically, Thailand is open to the seas, having a 2,614 kilometers of coast line running through 23 out of 73 provinces.

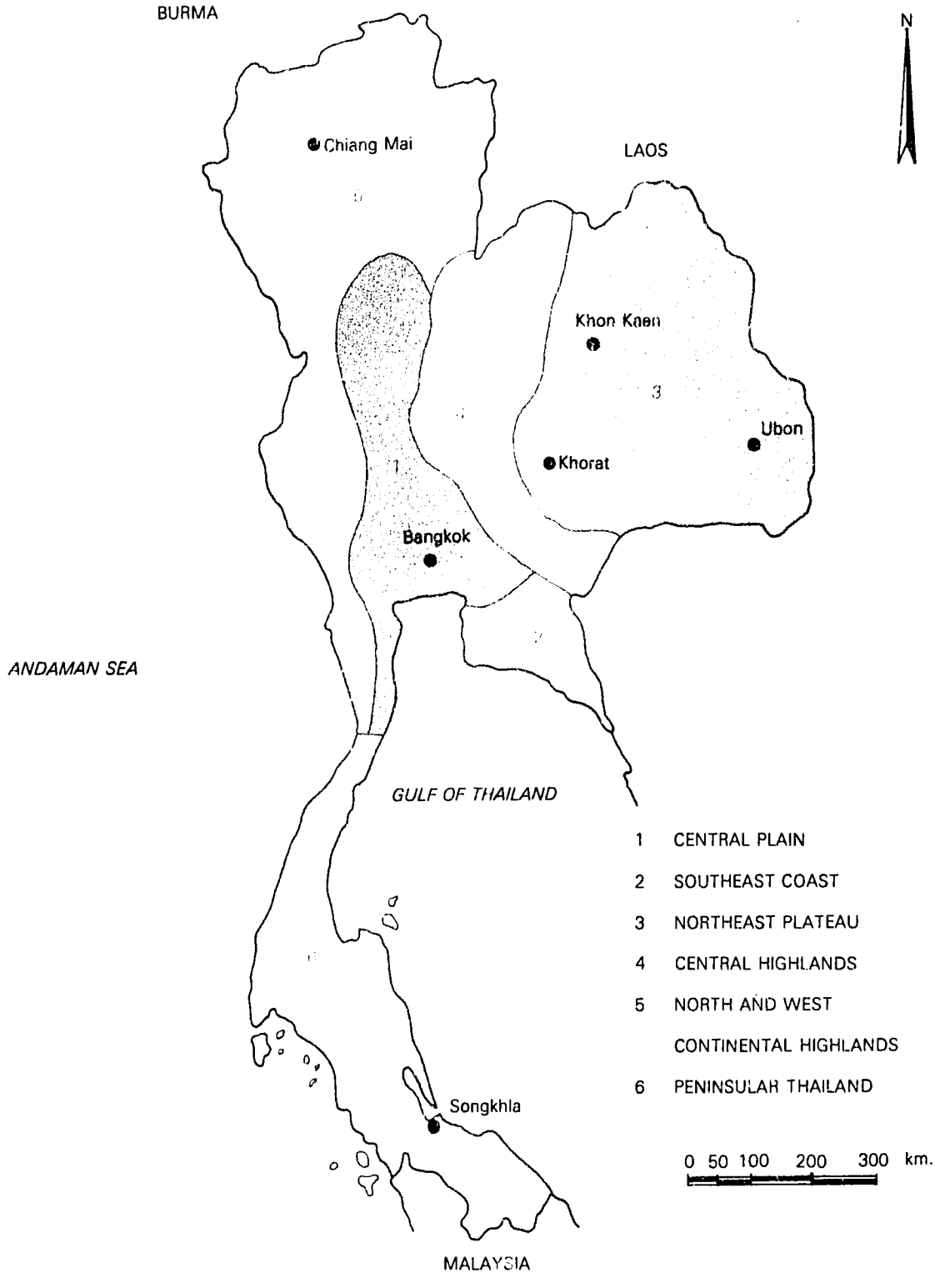
Physiography

Moormann and Rojanasoonthon (1968) divided Thailand into six principal physiographic regions (Figure 2.1). They described these regions as follows:

a) Central Plain

This region occupies the lower central part of Thailand it is

Figure 2.1 Physiographic Regions of Thailand



Source: Moormann, F.R, and S. Rojanasoonthon, "Soils of Thailand," SSR. No. 72, LTD., 1968

bordered by hilly areas to the east, north and west, and by the Gulf of Thailand to the south.

The south-central part of the region is occupied by the broad alluvial delta of the Mae Nam Chao Phraya system, and is known as the Bangkok Plain. Quaternary alluvial deposits in this Plain are considerable and reach to a depth of well over 300 meters in the Bangkok area. The surface layers of the Bangkok Plain are composed of recent and semi-recent alluvial deposits. Recent and semi-recent freshwater surface sediments dominate in the deltas of the major rivers, i.e., the Chao Phraya River system, the Maeklong and the Pa Sak. Marine sediments are found in the southern part of the Bangkok Plain. Sediments deposited in brackish water dominate a wide zone in the middle of the plain.

The Bangkok Plain and the alluvial valleys of the Ping, Yom and Nan rivers to the north are surrounded by alluvial terraces of different ages. In the southern zone of the Central Plain, at least the lower reaches of these terraces are found to be of marine origin, but farther north they appear to be mainly composed of overlapping alluvial fans from the surrounding highlands. Isolated hills are scattered through the marginal and northern parts of the Central Plain.

b) Southeast Coast

This region is bordered to the north by hills, to the south and west by the Gulf of Thailand and, to the east, by the Banthat Range, which marks the Thai-Kampuchean border. The east-central part of the region is formed by dissected highlands, which are a continuation of the Cardaman Mountains of southwest Kampuchea. Surrounding these highlands are quaternary terraces, mainly of marine origin, in the western and southern part of the region. Shallow terrace formations, probably river deposited, are found in the northern part of the region.

In the areas dominated by terrace formations, numerous separate hills and ranges are found, the rock formations mostly having a northwest-southeast orientation. Stream alluvial plains are insignificant. Along the coast, however, small non-connecting marine and brackish water alluvial plains occur. A minor, but nevertheless important landscape in this physiographic region is the volcanic plateau, west of Chanthaburi in the Tha Mai district.

c) Northeast Plateau

The Northeast Plateau is composed mainly of the broad river terraces of the Maekhong and its tributaries. This region is bordered to the west by the hills and plateaux of the Central Highlands, and to the north and east by the Maekhong River. The southern boundary along the Thai-Kampuchean border, is marked by the San Kamphaeng and Dong Rek scarps.

The main landscape features are the quaternary river terraces, of which three important levels have been recognized, i.e., the low, middle and high terraces. The low terrace is dominant in the catchment area of the Mun River system. The northern part of the plateau is predominantly occupied by middle terraces. Isolated remnants of high terrace are found in many places on the Northeast Plateau. Strings of these remnants seem to accompany the valleys of the Chi and Mun rivers. The largest high terrace areas occur south of Nakhon Ratchasima (Khorat).

River alluvium is found along all streams, although the width of these alluvial plains varies considerably. In the wider parts, shallow intermittent lakes are numerous. Isolated low hills and hill ranges occur on the margins of the basin of the Mun River system and in the northern part of the region. Volcanic outcrops and cones are found south of the Mun River.

d) Central Highlands

This region has a complex physiography, including diverging landscape elements such as hills, plateaux, peneplains and a number of valleys, of which the Pa Sak River Valley is the most important. The Central Highlands are bordered to the east by the Northeast Plateau and to the west by the North and West Continental Highlands, the Central Plain and the Southeast Coast. The boundary with the North and West Continental Highlands is somewhat arbitrary.

The northern portion of the region is mainly composed of hills and more or less strongly incised plateaux or peneplains, found at varying levels from approximately 1,200 to about 300 meters. The plateau areas are undulating to rolling; the intervening hilly areas are steep, with some very steep areas of craggy limestone buttes. The middle portion of the region is an area of low undulating peneplains, interrupted by steep limestone ridges and buttes. North of Chai Badan, an important volcanic area is found, the central hilly part of which is surrounded by rolling to undulating terrains. The southeastern portion of the Central Highlands includes mainly hilly land with incised plateaux.

e) North and West Continental Highlands

This region is usually subdivided into two subregions, i.e., the western mountains and the northern hills and valleys.

The western mountains consist of part of the rugged Central cordillera along the Thai-Burmese border from about 18°N in the north to 12°N, well into the Peninsula. Several subparallel ridges, divided by narrow and deep valleys are recognized. The westernmost of these ridges is the Tanaosi range, stretching south from approximately 15°N. East of this ridge, in the catchment area of the Maeklong, lies an extensive area of rugged limestone hills. An area of north-south oriented hill ranges and foothills is found between the limestones and the Central Plain.

The northern hills and valleys constitute a region of parallel north-south oriented hill ridges and high plateaux, alternating with elongated level-floored basins. In the western part of the subregion, most of the land is hilly to mountainous, with wide incised plateaux and with narrow intermontane valleys. To the east, the valleys are relatively more important; the main ones being those of Chiang Mai, Chiang Rai, Lam-

pang, Phrae and Nan. In these basins, several distinct river terraces can be found, of which the higher one usually is strongly eroded. Recent and subrecent alluvial plains occur in the basins and wider plains. Three larger steep limestone areas and a number of craggy limestone ridges are found in the hilly parts, whereas in Lampang and Phrae provinces, three larger volcanic plateaux are observed, with more or less weathered basalt generally at a very shallow depth.

f) Peninsular Thailand

This region is characterized by a number of distinct ranges of hills and mountains *en echelon*. The two principal ones are the Phuket range on the west of the peninsula, and the Nakhon Si Thammarat range, starting at about 10°N on Tao Island, and continuing into Malaysia, west of Padang Besar. The latter range is the backbone of the Peninsula.

The landscape between the main ranges is mainly made up of lower hills and of undulating terraces, principally of fluviatile origin. The widest and most pronounced of these depressions stretches from Surat Thani to Trang. On the west coast, the coastal terraces and plains are narrow, with the mountains extending down to the sea in many places. This coast is indented with many drowned estuaries. The east coast is smooth, with wider coastal terraces and plains. The largest coastal plain of Peninsular Thailand stretches from Nakhon Si Thammarat to Songkhla, including important elongated beaches and a large lagoon, the Thale Sap.

Landform

Based on the classification devised by Scholten and Siriphant (1973), the landform of Thailand can be classified into three major groups, according to their mode of formation: (1) landforms in transported materials; (2) landforms in organic materials and; (3) landforms in residual materials. These three major groupings have been further subdivided into eleven units:

Beach and dune formations are found along the shores of the present coastline in strips of varying width. Their elevations rarely exceed 10 meters above sea level and the relief is mainly undulating with slope ranging from 2 to 4 percent.

Active and former tidal flats of recent marine and brackish water deposits occur very extensively in the southern Central Plain, as a wide zone along the Gulf of Thailand from Cha-am in the west to Bang Pakong in the east. There is a large area of these deposits between Nakhon Si Thammarat and Songkhla. The relief is flat and slopes are less than 1 percent. The average elevation is 1 to 1.5 meters above sea level.

Former tidal flats of older brackish water deposits occupy a large area in the southern part of the Central Plain roughly extending between Ayutthaya in the north to Bangkhen in the south and from Kamphaeng Saen in the west to Prachinburi in the east. Small extents have been found in the Southeast and on the Peninsula. The relief is flat and slopes are less than 1 percent. The elevation ranges from 1 to 4 meters above sea level.

Flood plains of recent river alluvium occur along all main rivers and streams in the country. The wider plains show a distinct level-basin landscape, that has all the features of meandering river plains, such as levees, paint bars, oxbow lakes, and transitional zones between levees and basins. The levees are nearly flat to flat having slopes less than 2 percent, with undulating micro-relief where movement of stream channels has occurred. In large river plains, wide, nearly flat to flat transitions with slopes less than 1 percent exist between levees and basins. The basins or backswamps are flat and occupy depressed positions.

Low alluvial terraces of semi-recent and old alluvium occur extensively in all parts of the country. The terraces consist of higher-and lower-lying areas, but the lower-lying areas usually make up the greater part of the land form. The higher parts include old levees and areas with nearly flat to gently undulating relief and slopes that range from 1 to 3 percent. The lower-lying areas on low alluvial terraces have nearly flat relief with slopes that do not exceed 2 percent.

High alluvial terraces are found frequently in positions above low terraces. They have an undulating to rolling relief with slopes ranging from 2 to 16 percent. On the Peninsula, three different high terrace levels of old alluvium are distinguished. Coalescing alluvial fans have developed from the lower slopes of hills and mountains. Most terraces and fans have undulating relief, with slopes ranging from 2 to 8 percent. In Northeast Thailand, old alluvial terraces are very extensive and occupy a major part of the area. There is a major subdivision in middle and high terraces. Scattered along the borders of the southern Central Plain are high alluvial terraces and fans. Their relief is undulating and usually slopes range from 1 to 4 percent. In northern Thailand, high terraces and fans occur in all major alluvial basins.

Areas with peat and muck are restricted to those places in Peninsular Thailand where domed peat bogs have developed behind the fringe of sandy beach and dune formations, at elevations below 10 meters above sea level. The main occurrences are in Narathiwat province, although smaller areas of peat and muck are found in Pattani, Phatthalung and some other provinces.

Erosion surfaces occur in many parts of the country, usually in front of hills and mountains bordering the alluvial terrains of basins and valleys.

Lava plateaux are built up by successive interfingering flows of lava and layers of volcanic ash that in places may alternate with lake beds and stream deposits. They are not particularly widespread in the country and occurrences are scattered over North, Northeast and Southeast Thailand. The most extensive plateaux are located in the Central Highlands, along the Pa Sak River between Nongphai and Chaibadan. The plateaux are dissected and slopes may range from 2 to 16 percent. However, in most places they do not exceed 6 percent.

Steep-sided *limestone outcrops* are common topographic features in the hills and mountains of the Northern, Western and Central Highlands, and Peninsular Thailand. Limestone outcrops can also be found as islands amidst alluvial deposits of the Central Plain. The most extensive occurrences are in the area of the Khwae Yai and Khwae Noi rivers, to the northwest of Kanchanaburi, in the Phrabhudhabat-Pakchong area, and in the northern part of Mae Hong Son province. Slopes are steep to very steep and generally exceed 30 percent.

Hills and mountains occupy a considerable part of the country. They are arranged in approximately north-south trending ranges, with the exception of the hills in Northeast Thailand. They are formed in widely variable rocks of igneous and sedimentary origin that are more or less metamorphosed in places. The topography of the hills and mountains is sharply dissected and a high degree of relief exists. Slopes are steep to very steep and generally exceed 20 percent.

Climatology

Thailand has a monsoonal climate. In most of the country, three major seasons can be recognized: (1) the cool season from November through February; (2) the hot season from March to May; and (3) the rainy season from May through October. During the southwest monsoon, on the southeast coast of Peninsular Thailand, the rainy season lasts through December.

Most of Thailand has an average annual rainfall from 1,100 millimeters to 1,500 millimeters. Major high rainfall zones are Peninsular Thailand and the southeast coast, which has an average annual rainfall of more than 2,000 millimeters and up to 4,000 millimeters in some areas. The low rainfall zone is found in the rain shadow of the Western Continental Highlands, where the average annual rainfall is less than 1,100 millimeters. The peak of the rainy season in Thailand falls during August through early October.

Temperature in Thailand shows slight variations with the seasons. In the lower elevations, the minimum temperature occurs during the cool season, and mean monthly temperatures during January range from 26°C to 28°C for most of the country. In the hot season, during April, the temperature ranges from 28°C to 32°C. Southern Thailand shows even less variation, with mean monthly temperatures remaining between 26°C to 30°C throughout the year. Temperatures in the highlands of the North and Northeast are lower due to the altitude.

According to Koppens' climatic classification of the world, Thailand can be classified into two climatic types: (1) The Af climate or Tropical Rainforest. The areas under this type of climate are the south and southeast region. Some parts of this region experience Aw or Tropical monsoon climate. The Af climatic type has high rainfall throughout the year. The driest month has more than 60 millimeters of rainfall. (2) The Aw climate or Tropical Savanna. The rest of the country falls within this climatic type. It has high rainfall, with distinct wet and dry seasons. The driest month has less than 6 millimeters of rain.

Physical Supply of Land Resources

Based on the general soil map, at a scale of 1:1,000,000, the area coverage of soil in each order is summarized in Table 2.1. From the 10 soil orders, 38 great groups are classified in Thailand.

Land suitability classification

Information from soil surveys was interpreted and grouped into land suitability classes for upland crops, paddy rice, and other crops as required. Datails of land suitability classification are summarized in Table 2.2.

Land suitability for agriculture can be classified as follows: (1) suitable for upland crops, 67,683,529 rai (21.11 percent); (2) suitable for paddy, 84,469,300 rai (26.33 percent); (3) suitable for perennial crops, 16,359,806 rai (5.1 percent); (4) generally unsuitable for economic crops, but potentially suitable for cultivating special crops if appropriate measures are taken, 49,828,087 rai (15.53 percent); and (5) unsuitable for agriculture, 99,875,264 rai (31.14 percent).

Pressent land use

The land use of Thailand in 1985 is given in Table 2.3. As indicated, the total area of agricultural land is 152,041,555 rai. Agricultural land use can be classified by the following types of crops: (1) paddy, 84,250,816 rai (55.42 percent); upland crops, 51,411,432 rai (33.82 percent); vegetables, 101,262 rai (0.06 percent); para rubber, 10,541,957 rai (6.93 percent); oil palm, 386,421 rai (0.25 percent); and fruit and perennial crops, 5,349,667 rai (3.52 percent).

Changes in land use

Land use is a dynamic process. It changes over time due to a number of factors, including increasing population and changes in cropping system and technology. It is a well-known fact that prior to the mid-1950s agriculture in Thailand was characterized by mono-cropping, with rice as the only major crop. Indeed, in 1960, rice took almost 60 percent of the total cultivated area, compared to 12 percent and 1[illegible] percent for upland and tree crops, respectively, while forest covered almost 60 percent. During the period of 1960-1984, rice remained predominant as its share of acreage increased to 63.5 percent in 1975, then dropped slightly to 61.8 percent in 1980 and to 59.6 percent in 1984. Upland crops gained substantially in terms of cultivated area, increasing from 7.5 million rai in 1960 to 29.2 million rai in 1984. In terms of proportion, upland crops increased from 12 percent to 23 percent during the period. Tree crops (including fruit trees) dropped sharply during 1960 and 1975, then increased slightly

Table 2.1 Soils of Thailand

Soil Order	Area (km²)	(million rai)	%
Entisols	16,860	10.5	3.29
Vertisols	4,156	2.6	0.81
Inceptisols	48,253	30.2	9.40
Mollisols	6,003	3.9	1.17
Spodosols	615	0.4	0.12
Alfisols	46,991	29.4	9.16
Ultisols	216,192	135.1	42.13
Oxisols	153	0.1	0.03
Histosols	718	0.4	0.14
Unclassified[a]	173,174	108.2	33.75
Total	**513,115**	**320.7**	**100.00**

Note: a. Including slope complexes, water bodies, etc.
Source: Land Development Department, 1972. General Soil Map of Thailand, Scale 1:1,000,000

in later years. Forest land changed drastically, however, decreasing from 189.5 million rai (58.5 percent of the total area) to only 93.2 million rai (29.05 percent) between 1960 and 1985. Obviously, the great expansion of cultivated land during the period has been made possible due to the tremendous reduction in the forest area.

On a regional basis, during the past decade, a remarkable change in land use is observed in field crops in all regions, except the South, where fruit trees and tree crops are most important (see Table 2.4). It can also be seen that forest lands were heavily encroached in the Northeast. During this period (1975-1983) farm size remained rather stable (Table 2.5).

Soils and landforms

Soil and landform are closely related. Scholten and Siriphant (1973) have demonstrated clearly this relationship for Thailand. Soil characteristics vary according to the changing landform. This subsequently affects the vegetation and land use pattern. Soils on the lower lying landforms, such as tidal flat, flood plain, low terrace are normally poorly drained. Natural vegetations found on these soils are mainly salt—and inundation—tolerant families. Rice is an important crop. The yield of rice varies from 150-500 kilograms per rai, depending on soil quality, the amount of water and landscape. Lower land with flat topography and heavy texture soil normally gives higher yields.

Regional Differences

the North

Northern Thailand consists of 17 administrative provinces and lies between latitudes 15°N and 21.5°N, and longitudes 97.3°E and 102°E. It covers an area of about 106,027,680 rai. Topography divides the Northern region into two subregions, the upper and lower. The upper subregion consists of eight provinces. Mae Hong Son, Chiang Rai, Chiang Mai, Nan, Lampang, Lamphun, Phayao, and Phrae. The lower subregion consists of nine provinces: Tak, Kamphaeng Phet, Sukhothai, Phitsanulok, Uttaradit, Phichit, Phetchabun, Uthai Thani and Nakhon Sawan.

The original vegetation, which is made up of Mixed Deciduous and Dry Evergreen forest, and some pine forest above 1,000 meters in elevation, still covers the greatest part of the residual hills and mountains, but large parts are now cleared

Table 2.2 Land Suitability for Agriculture

(rai)

	North	Northeast	Central	East	South	Total
Area suitable for upland crops	20,036,318	30,694,340	11,485,471	5,306,758	160,642	67,683,529
Area suitable for paddy	16,434,526	40,520,643	14,873,477	5,583,579	7,057,075	84,469,300
No limitation	16,434,526	39,054,014	9,904,130	5,111,964	7,057,075	77,561,709
Acid sulfate soil	0	0	4,732,250	471,615	0	5,203,865
Saline soil	0	1,466,629	237,097	0	0	1,703,726
Area suitable for perennial crops	0	0	702,428	960,385	14,696,993	16,359,806
Area generally unsuitable for economic crops but can be suitable for cultivating special crops if there are appropriate measures	14,724,446	21,250,255	3,355,121	5,564,453	4,933,812	49,828,087
Area unsuitable for agriculture	54,241,443	12,092,402	12,845,747	3,988,102	16,707,570	99,875,264
Water body	590,947	976,323	188,259	84,535	640,900	2,480,964
Grand Total	**106,027,680**	**105,533,963**	**43,450,503**	**21,487,812**	**44,196,992**	**320,696,950**

Source: AIT, 1983

Table 2.3 Land Use of Thailand in 1985

(rai)

Land Use	North	Northeast	Central	East	South	Total	%
National Forest Reserve[a]	64,813,044	33,795,752	12,745,989	8,792,759	16,088,625	136,236,169	42.48
Agricultural Land	34,800,024	62,253,054	23,462,167	11,958,351	19,567,950	152,041,555	47.41
Rice	21,421,217	38,912,126	13,224,632	3,491,216	7,201,625	84,250,816	
Upland Crops	12,618,243	23,268,231	8,461,206	6,742,125	321,627	51,411,432	
Horticulture	37,644		63,618			101,262	
Para Rubber				1,011,352	9,530,605	10,541,957	
Oil Palm					386,421	386,421	
Perennial crops	722,920	72,697	1,712,711	713,658	2,127,681	5,349,667	
Urban	466,321	494,399	1,131,627	212,611	431,627	2,736,585	0.86
Water Bodies	601,249	992,113	632,616	181,661	651,617	3,059,256	0.95
Others (abandoned land, marsh,swamp,rock-outcrop, beach,pasture)	5,347,042	7,925,948	5,478,104	342,430	7,457,164	26,623,385	8.30
Total	**106,027,680**	**105,533,963**	**43,450,503**	**21,487,812**	**44,196,992**	**320,696,950**	**100.00**

Note: a. Including already encroached forest lands.
Source: TDRI, 1986.

for shifting cultivation. In the basins and valleys, transplanted rice is the main crop. Most of the transplanted rice is grown on soils which are well suited to very well suited for this crop. Some parts of these paddy soils, mostly recent or semi-recent alluvium, are used for tobacco, garden crops and soybeans as an irrigated second crop in the dry season. The level soils on recent and semi-recent alluvium are used for the cultivation of upland crops, including tobacco, corn, peanuts, soybeans, sugar cane, vegetables and fruit trees like longan and mandarin oranges.

Shifting cultivation is practiced on the old alluvial terraces and fans with such crops as upland rice, corn, groundnut and beans. The relative nutrient status is low (Charley and McGarity, 1970). Also a large part of the erosion-prone surfaces is in shifting cultivation with the same crop pattern. Scattered throughout the region, there are more fertile soils that are permanently cultivated, derived from basic rocks.

Based on a 1:1,000,000 regional soil map published by the Land Development Department, there is a wide range of

Table 2.4 Land Utilization by Region, 1975, 1980 and 1983

(1,000 rai)

Year	Region	Total Area	Forest Area	Farm Holdings					Unclassified Land
				Total	Paddy Land	Field Crops	Fruit Trees & Tree Crops	Others [a]	
1975	Northeast	105,534.0	28,823.7	47,497.2	34,090.3	7,526.7	467.2	5,413.1	29,213.0
	North	106,027.7	66,186.6	23,954.6	15,831.1	6,061.0	617.5	1,444.9	15,886.5
	Central	64,938.3	22,403.8	27,520.0	16,823.1	6,256.3	2,134.2	2,306.4	15,014.5
	South	44,197.0	13,348.2	13,239.6	4,494.8	108.5	7,193.7	1,442.6	17,609.2
	Whole Country	320,697.0	130,762.3	112,211.4	71,239.3	19,952.5	10,412.6	10,607.0	77,723.2
1980	Northeast	105,534.0	17,748.5	50,093.0	35,886.4	9,901.0	461.0	3,844.6	37,692.5
	North	106,027.7	57,028.2	26,025.2	16,783.0	7,182.0	757.8	1,302.4	22,974.3
	Central	64,938.3	18,010.8	29,063.0	16,054.7	8,571.6	2,280.1	2,156.5	17,864.4
	South	44,197.0	10,631.2	13,817.7	4,838.9	103.1	7,643.4	1,232.3	19,748.1
	Whole Country	320,697.0	103,418.7	118,998.9	73,563.0	25,757.7	11,142.3	8,538.8	98,279.3
1983	Northeast	105,534.0	15,822.3	53,270.1	36,576.1	11,477.2	614.6	4,602.1	36,441.6
	North	106,027.7	54,077.5	27,939.9	16,913.9	8,561.0	870.6	1,594.4	24,010.3
	Central	64,938.3	16,295.3	28,665.5	15,193.8	9,257.0	2,322.5	1,892.3	19,977.4
	South	44,197.0	10,072.3	14,354.7	9,450.8	132.9	8,098.8	1,172.2	19,769.9
	Whole Country	320,697.0	96,267.4	124,230.3	73,634.6	29,428.1	11,906.5	9,261.0	100,199.2

Note: a. Including lands for housing, vegetable and flowers, grass land, idle land and other lands.
Source: Center for Agricultural Statistics, "Agricultural Statistics of Thailand Crop Years 1983/84 and 1984/85."

Table 2.5 Average Farm Size and Number of Farms in 1975, 1980 and 1983

Year	Region	Farm Size (rai)	Number of Farms ('000)
1975	Northeast	28.3	1,675.7
	North	22.7	1,054.5
	Central	33.3	826.5
	South	23.5	563.4
	Whole Country	27.2	4,120.1
1980	Northeast	28.0	1,786.5
	North	22.4	1,162.2
	Central	32.6	891.6
	South	22.0	626.8
	Whole Country	26.6	4,467.1
1983	Northeast	27.4	1,944.3
	North	22.3	1,253.5
	Central	22.6	880.0
	South	22.6	635.3
	Whole Country	26.4	4,713.1

Source: Center for Agricultural Statistics, "Agricultural Statistics of Thailand Crop Years 1983-84 and 1984-85."

soils in the Northern region, the most common being Inceptisols, Alfisols and Ultisols.

In the northern region, there are about 20 million rai suitable for upland crops, 16 million rai suitable for paddy, representing a total of 36 million rai or 34 percent of the total regional area. Another 14.7 million rai are usually unsuitable for agriculture, but can be used for special crops if appropriate measures are taken. Agricultural land use in 1985 accounted for about 34.8 million rai, including about 21.4 million rai of paddy, 18.6 million rai of upland crops and about 0.7 million rai of perennial crops (TDRI, 1986).

the Northeast

Northeast Thailand lies between longitude 101° and 105°E and 14° and 18°N. It comprises an area of about 105,533,963 rai, or 32.9 percent of the country. It consists of 17 administrative provinces Nong Khai, Sakon Nakhon, Nakhon Phanom, Mukdahan, Ubon Ratchathani, Yasothon, Kalasin, Maha Sarakham, Surin, Si Sa Ket, Buri Ram, Roi Et, Udon Thani, Loei, Khon Kaen, Chaiyaphum and Nakhon Ratchasima.

The most important crop of the lowlands is transplanted rice, with both glutinous and non-glutinous varieties being grown. The soils of the flood plains are well suited for transplanted rice, the limitation being possible damage by flash floods. Transplanted rice is also grown on the low terraces and lower part of the middle terraces. They are only moderately suited for the purpose, however, because of low fertility and frequent droughts.

Upland crops are also grown on the levels of the alluvial flood plains on more fertile soils, but in places these soils have a high salt content. Cassava and kenaf are the main economic crops of the Northeast. Corn is grown in Si Sa Ket and Nakhon Ratchasima. Sugar cane is grown in Buri Ram, Khon Kaen and Udon Thani. Sorghum, castor bean, and peanuts are grown in several places. Important perennial crops are mulberry for silk production, mango and kapok. The Northeast region is one of the most important livestock production areas.

Soil fertility is moderate to low on nearly all soils, both of the uplands and lowlands. Water holding capacity is also low and serious crop damage from drought occurs frequently in the dry areas of the Northeast, from April through August. Because of the silt and very fine sand contents found in the surface soils, soil erosion is a serious problem on sloping cultivated soils during high intensity rainfall. Average yields of most crops are lower than in other regions.

The most common soils in the Northeast are Entisols, Inceptisoils, Alfisols and Ultisols. Data in Table 2.2 show that land suitable for paddy amounts to about 40.5 million rai, of which about one million rai are saline soils. There are about 30.7 million rai suitable for upland crops. Altogether there are about 71 million rai of land suitable for agriculture. In 1985, about 62.2 million rai were in agricultural use, including 39 million rai of paddy and 23 million rai of upland crops, with the rest given over to perennial crops (TDRI, 1986).

Central region

Central Thailand lies between longitude 98°10' and 101°30'E and latitude 11° and 15°20'N. It comprises an area of about 43,450,503 rai. It consists of 19 administrative provinces: Chai Nat, Singburi, Ang Thong, Lopburi, Saraburi, Nakhon Nayok, Suphanburi, Ayutthaya, Pathum Thani, Bangkok, Nonthaburi, Samut Sakhon, Samut Songkhram, Samut Prakan, Nakhon Pathom, Ratchaburi, Phetchaburi, Kanchanaburi, Prachuap Khiri Khan. The Central region can be divided into two subregions: the southern Central Plain and the western and northern Central Plain.

The southern Central Plain can be defined as the wide and flat lowland area around Bangkok that stretches from the Gulf of Thailand as far north as Chai Nat, and from the terrace landscape near Ratchaburi, Nakhon Pathom and Suphanburi in the west, to the uplands and mountains of Chonburi, Prachinburi and Saraburi in the east. The major part of the southern Central Plain consists of the delta of the Chao Phraya River and its distributaries and various smaller lateral deltas of the Maeklong River in the west and the Nakhon Nayok and Prachinburi rivers in the east.

The main crop in the region is wet land rice, as most of the soils are poorly drained, very fine textured and are flooded during the rainy season by either river or rain water. Both transplanting and broadcasting are used for rice cultivation.

Since, this area is covered by the Chao Phraya Irrigation Project, it can grow a second crop of rice in the dry season—about 2.5 million rai annually. The new high-yielding varieties are being used. Compared with most other regions production levels in the southern Central Plain are high, except for those

areas where yields are limited by deep, uncontrolled flooding or by extreme acidity of the soil.

Increasing areas are now also used for vegetables and fruit, some grown on land once used for rice. Vegetables and fruit trees are grown on raised beds, separated by deep ditches. The most widely grown fruits are citrus, papaya and mangoes. Snort-term vegetable crops are grown in quantity around Bangkok and in Damnoensaduak, Ratchaburi. The important vegetable crops are beans, eggplant, peas, tomato, sweet corn, baby corn, lettuce, cabbage, chinese kale and cucumber. The level of management of the farmers in Damnoensaduak is considered as the most sophisticated in Thailand.

In the tidal flat areas of Samut Sakhon and Samut Songkhram, attractive land use are saltwater shrimp and salt farming, and coconut gardening for sugar production.

In the western and northern Central Plain, the soils are more varied and the agriculture much more diversified. This subregion comprises the higher parts in the west and north of the Central Plain. It stretches from south of Phetchaburi as far north as Uttaradit.

The principal crops are transplanted rice, corn, soybeans, mungbeans, cotton and sugar cane. Transplanted rice is grown on the recent alluvial plains which are not deeply flooded by river water, but cultivation is most extensive on the low lying soils of the low terraces—composed of semi-recent alluvium—and on the nearly flat, coalescing old alluvial fans. These soils are mainly very well or well suited for transplanted rice. Generally, one crop a year is grown, but where irrigation water is available, a second crop of rice can be grown. Many of these soils are also suitable for one irrigated upland crop in the dry season. On the higher parts of the low terraces, which are composed of semi-recent alluvium, and on the levee soils of the flood plains, upland crops can be grown. In the western Central Plain, sugar cane is the most important upland crop, but it is often also grown on soils situated in somewhat lower positions than the freely drained levee soils of the flood plains and semi-recent terraces. Other important crops in the western Central Plain are corn, sorghum, castor bean, peanuts and mungbeans. Increasing areas of land once used for rice are now also used for shrimp pans and fish ponds.

The most common soils in the Central region are Inceptisols, Alfisols and Ultisols. Land suitability for agriculture can be classified as suitable for paddy (about 14.9 million rai), upland crops (11.5 million rai) and perennial crops (0.7 million rai). However, there are also about 4.7 million rai of acid sulfate soils in this region. In 1985, there are 23.5 million rai in agricultural use, including 13 million rai for paddy, 8.5 million rai for upland crops and about two million rai for perennial crops and horticulture (TDRI, 1985).

the East

Eastern Thailand lies between latitudes 12° and 14°N, and longitudes 101° and 103°E. It covers an area of about 21,487,812 rai. It consists of six administrative provinces: Chachoengsao, Prachinburi, Chonburi, Rayong, Chanthaburi and Trat.

Until recently the region was still under dry evergreen forest, but during the past two decades the region was largely cleared. Cassava, sugar cane, pineapple and corn are the most important upland crops. Coconut is also grown throughout the region. Transplanted rice is grown on poorly to somewhat poorly drained soils of recent riverine alluvium and on low lying nearly flat marine and alluvial terraces, e.g., in Chachoengsao and Prachinburi.

Rubber is another main crop in the region with area coverage of about one million rai. It is grown on soils, with a wide range of drainage conditions, that usually have low nutrient status and that occur on erosion surfaces and alluvial terraces. Rubber is grown in Rayong, Chanthaburi and Trat. Fruit crops are grown on similar soils to rubber. The main fruit growing areas, producing durian, rambutan and citrus, are Rayong and Chanthaburi.

The most common soils in the region are Inceptisols, Alfisols and Ultisols. Data in Table 2.2 show that land suitable for paddy amounts to about 5.6 million rai, with about 5.3 million rai for upland crops and about one million rai for perennial crops. In 1985, agricultural land totaled about 12 million rai, including 3.5 million rai of paddy, 6.7 million rai of upland crops and two million rai of rubber and perennial crops.

the South

Southern or Peninsular Thailand lies between latitudes 6° and 11°N, and longitudes 98° and 102°E. It covers an area of about 44,196,992 rai. It consists of 14 administrative provinces Chumphon, Ranong, Phangnga, Surat Thani, Krabi, Nakhon Si Thammarat, Trang, Phuket, Phatthalung, Satun, Songkhla, Pattani, Yala and Narathiwat.

The main crop in the Peninsula is rubber, which is grown mostly on sloping soils with good drainage. Rubber was introduced to Southern Thailand from Malaysia and substantial plantings were made in the 1930s. At present, about 9.5 million rai are grown. Fruit crops are grown in Chumphon, Surat Thani and Nakhon Si Thammarat. The main fruit is rambutan. Robusta coffee is grown in Krabi, Trang and Nakhon Si Thammarat. Coconut is grown on soils on erosion surfaces and alluvial and marine terraces, and on sandy beach formations. Cashew nuts are also grown on the eastern seaboard of the Peninsula.

The cultivation of upland crops such as corn and beans is mainly restricted to the deep and well-drained soils found on erosion surfaces and terraces on the east coast of the Peninsula, mainly Surat Thani, since climatic conditions in other parts of the region seem to be less favorable, due to excessive wetness during the greater part of the year.

Broadcast rice is grown in large areas on the east coast of the Peninsula, on recent marine brackish water and alluvial deposits that are subject to flooding during October-December. The tidal flats are mainly used for mangrove charcoal production and for the production of thatch from Nipa palm leaves.

Recently, an increasing area has been devoted to the cultivation of oil palm in Southern Thailand. Oil palm is grown on a few large estates and by small holders. Existing small holder oil palm plots suffer from poor management, with little use of fertilizer, poor weed control and inappropriate cultural practices that cause damage to the root systems of young palm trees.

The most common soils in the region are Entisols, Inceptisols and Ultisols. Data in Table 2.2 show that land suitable for agriculture totals about 21.9 million rai, with seven million rai suitable for paddy and 14.7 million rai for perennial crops. In 1985, land in agricultural use totaled about 19.6 million rai. There were 7.2 million rai of paddy, 9.5 million rai of rubber and 0.4 million rai of oil palm (TDRI, 1986).

Land Productivity

Productivity of some of the more important crops in Thailand are discussed in this section. It is generally known that land productivity in Thailand has been rather low and, in some cases, has been declining. For example, average yield per rai of major rice from 1982 to 1986 is only 302.8 kilograms per rai. This is about three times less than that of Japan, U.S.A. and Taiwan. Yield of rice also varies by region, ranging from 242, 272, 364 to 387 kilograms per rai in the Northeast, South, Central and North respectively (Table 2.6). As for the second (dry-season) rice, yield per rai is much greater. The average yield from 1982 to 1986 is 578 kilograms per rai. Most of these (80 percent) are produced in the Central Region, however.

On the otherhand, yields per rai of rubber have been increasing rapidly since 1966, i.e., from about 30 kilograms per rai in 1966 to almost 68 kilograms per in 1984. This trend might have been attributed to the rubber replanting scheme in the South (Table 2.7).

The case of maize is also similar to that of rubber. Maize yield is rather uniform in the three producing regions namely, Northeast, North and Central, averaging about 385 kilograms per rai during the period 1982-1986 (Table 2.7).

Yields of cassava (tapioca) show a declining trend. The yield was relatively high in the early 1960s, when cassava was planted in new and fertile lands then. The average yields from 1982 to 1986 are 2,301, 2,531 and 2,732 kilograms per rai in the Northeast, North and the Central regions respectively. While the Northeast, although the most important producing region, has the lowest yield (Table 2.8).

The yields of sugarcane, another important crop of Thailand, vary slightly between the regions. The average yields from 1982 to 1986 is 7,126 kilograms per rai. The Central is the most important region, producing 70 percent of sugarcane in the country (Table 2.8).

2.2 HISTORICAL DEVELOPMENT AND FUTURE TRENDS

Although a coherent national land policy has not been formulated during the past two decades, guidelines underpinning the administration of national land use have been formulated by various National Economic and Social Development Plans. The major focus of each Plan can be summarized as follows:

a) The First National Economic and Social Development Plan (1961-1966) emphasized land classification and land allocation.

Table 2.6 Harvest Area, Production, and Farm Value of Major Rice and Second Rice in Thailand, 1977 to 1986

Year	Major Rice[a]			Second Rice[b]		
	Harvest Area (10^6 rai)	Production (10^6 tons)	Farm Value (10^6 baht)	Harvest Area (10^6 rai)	Production (10^6 tons)	Farm Value (10^6 baht)
1977	48.3	13.7	25,218	2.7	1.4	2,644
1978	51.8	12.3	28,652	2.9	1.6	3,399
1979	51.9	15.2	33,256	3.9	2.3	4,898
1980	52.1	14.6	38,217	2.0	1.1	2,827
1981	54.3	15.4	47,263	3.2	2.0	6,270
1982	53.3	15.8	44,691	3.6	2.0	5,766
1983	52.0	14.8	43,378	3.9	2.1	6,108
1984	55.6	16.9	46,847	4.4	2.6	7,741
1985	55.8	17.3	42,842	4.4	2.6	6,572
1986	57.5	17.9	41,579	4.0	2.3	4,344

Notes: a. *Wet Season*
b *Dry Season*
Source: OAE, 1986, p.1-1-15

Table 2.7 Harvest Area, Production and Farm Value of Rubber and Maize in Thailand, 1976 to 1985

Year	Rubber			Maize		
	Harvest Area (10^6 rai)	Production (10^6 ton)	Farm Value (10^6 baht)	Harvest Area (10^6 rai)	Production (10^6 ton)	Farm Value (10^6 baht)
1976/77	6.8	0.394	3,591	7.0	2.7	4,468
1977/78	6.8	0.431	4,287	6.1	1.7	2,750
1978/79	6.8	0.467	5,889	8.2	2.8	4,493
1979/80	8.9	0.534	7,673	8.9	2.9	5,984
1980/81	7.8	0.465	7,434	8.4	3.0	7,285
1981/82	7.9	0.508	6,717	9.2	3.4	7,518
1982/83	8.9	0.576	9,567	8.2	3.0	6,125
1983/84	8.9	0.594	8,688	9.8	3.6	3,846
1984/85	8.6	0.617	9,109	10.9	4.2	9,846
1985/86	8.8	0.773	11,711	12.0	4.9	8,832

Source: OAE, 1986, p. 30 and 104.

b) The Second National Economic and Social Development Plan (1967-1971) emphasized the improvement of landownership for agriculture, land-leasing systems for agriculture and agricultural productivity.

c) The Third Plan (1972-1976) emphasized ownership, the need to prevent or eliminate the loss of landownership by farmers and to increase farmer land-holding, land productivity and, increasingly, land conservation.

d) The Fourth Plan (1977-1981) emphasized land reform as a primary component of agricultural development. Additionally, the appropriate land use regulations were to be made more responsive to economic, social, political and natural environment considerations.

e) The Fifth Plan (1982-1986) emphasized the following: (1)the need to accelerate land use policy formulation; (2)the holding limit not to exceed 50 rai for private individual landholders for agriculture and the establishment of the Land Bank; (3)the acceleration of land reform, emphasizing the Central and the lower Northern regions; (4)the surveying of fertile soils in deteriorating forest areas, to be allocated for settlement to farmers; (5)the upgrading of legislation to regulate the rate of land-leasing; (6)the improvement of special problem soils, e.g., saline and alkaline soils, acid sulfate soils; and (7)increased regulation for the protection and preservation of agricultural land.

(f) The Sixth Plan (1987-1991) focuses on: (1) improving efficiency in land use by means of preparing a land use development plan and land information system; (2) the speeding up of land ownership distribution by setting up a land bank and accelerating land reform program; (3) improving land taxation system and land valuation; (4) accelerating the classification of suitable land for agriculture from forest lands; and (5) accelerating land allocation and land titling programs.

Table 2.8 Harvest Area, Production and Farm Value of Cassava and Sugarcane in Thailand, 1976 to 1986

Year	Cassava			Sugarcane		
	Harvest Area (10^6 rai)	Production (10^6 ton)	Farm Value (10^6 baht)	Harvest Area (10^6 rai)	Production (10^6 ton)	Farm Value (10^6 baht)
1976/77	5.2	11.8	5,565	3.1	26.1	7,509
1977/78	6.6	16.4	6,052	3.5	18.9	5,453
1978/79	5.0	11.1	8,548	3.2	20.6	5,493
1979/80	7.0	16.5	12,405	2.7	12.8	4,968
1980/81	7.8	17.7	8,162	2.9	19.9	12,623
1981/82	6.8	17.8	9,072	3.8	30.2	14,427
1982/83	6.4	19.0	14,052	3.6	24.4	7,517
1983/84	8.3	20.0	13,190	3.3	23.9	8,282
1984/85	8.6	19.3	7,705	3.3	25.1	7,642
1985/86	7.5	15.3	11,899	3.4	24.1	5,710

Source: OAE, 1986, p. 38 and 46.

Land Administration

Land Administration in Thailand has long been established and gradually developed as follows:

a) Sukhothai Period (1238-1350)

A part of King Ramkhamhaeng's stone inscription of 1292 says:

"This Sukhothai is good. In the water there are fish, in the field there is rice. The King does not levy a tax on his people... Whoever wants to trade in elephants can do so. Whoever wants to trade in horses can do so. Whoever wants to trade in silver or gold can do so; people are contented..."

The policy of land management was also implicitly stated on the first inscribed stone, a part of which says:

"...everywhere in this Kingdom there are betel vine and betel nut forests. There are also in this Kingdom many coconut, jackfruit, mango, and tamarind forests. Whoever plants them, unto him they shall belong..."

From this inscription, it is clear that there was a policy encouraging people to utilize the vacant and unused land by granting ownership rights. It is assumed that there was no land for sale at that time.

b) Ayutthaya Period (1350-1767)

In 1360, due to disputes in land ownership, the Land Code of 1360 of the Comprehensive Law (Kod Mai Beth Seth) was issued. All land now belonged to the King. A private land holder was entitled to possession, not ownership. He could neither alienate his land nor did his heirs inherit it after him. Towards the end of the Ayutthya period, however, land holders were absolute owners and land became alienable quite freely. There was no issuance of land right documents at that time.

c) Rattanakosin Period (1782-present)

Early Rattanakosin Period (1782-1932)

Before 1899, most of the forest land in the country belonged to the feudal chiefs. The forests in the northern part of the country were divided up among the five feudal chiefs of Chiang Mai, Lampoon, Lampang, Phrae and Nan. They were recognized as properties to be maintained by these chiefs and passed on to their heirs (RFD, 1968).

In 1896, the Royal Forest Department was established by King Chulalongkorn and was attached to the Ministry of Interior. It was entrusted with the function of dealing with forest activities in the Kingdom (RFD, 1968). Three years later, in 1899, ownership and control of all forest were transferred from the feudal chiefs to the Government.

In 1901, the Department of Lands was established in the Ministry of Agriculture, and undertook a national land survey on which a new system of land registration was based. The Torrens System, the system for land tenure and transfer, was introduced into Thailand. The major procedures of the Torrens System are as follows: the government staff would examine claims, register the documents, issue the land titles, and the government would subsequently guarantee the accuracy of them. In 1908, the Land Title Deed Issuance Act was promulgated.

1932-Present

On 24 June 1932 there was a revolution and Thailand changed from an absolute monarchy to a constitutional monarchy. A constitution was adopted in March 1933. The new Government tried to modernize the country in social, economic, political, educational, and other ways. An economic plan was prepared and it was intended that the Government should decide how the nation's land should be classified (Vella, 1955). But such plans were not implemented until 1961.

Between 1932 and 1960, there were many new laws and regulations relating directly or indirectly to land resources. In 1954, for example, the government issued a Land Code by collating several land laws. It covered land survey, registration, issuance of land right documents, land allocation, control of state land and land preservation. The enactment of the Land Code provided the Government with an effective legal framework to control land uses, determine ownership and generate revenues from land. The Department of Lands has the prime responsibility for execution of the Code.

In the Rattanakosin period, several government agencies involved with land administration have been established. The First National Economic Development Plan began in 1961. In this Plan, a policy for land classification was stated for the first time. A program of land allocation to the landless farmers was also launched by the Government.

Land Classification

Article 7 of the Land Code of 1954, states that all land will be classified by soil fertility and land suitability. In order to ensure that the forests will be protected for the national benefit, the First Plan (1960-1964) stated explicitly that it would be necessary to reserve 256,000 square kilometers (or 50 percent) of Thailand as national forest. At that time there were about 300,000 square kilometers (58 percent) of forest lands. The plan allowed for a possible decrease of forest area to 200,000 square kilometers (40 percent). These targets for forest land have remained unchanged since the first Five-year Plan.

In 1960, the Government established the National Land Classification Committee to carry out soil surveys and subsequent land classification. It started the implementation of land classification by establishing a center attached to the Department of Lands in 1961. Since 1964, this task has been trans-

Box 2.1 Responsibilities of the Main Land Agencies

A profusion of agencies and committees have responsibilities for, or interests in, land. Table 2.13 hints at some of the inevitable areas of overlap between the activities of these agencies, and what follows is a brief description of the roles of some of the key organizations in this field.

The Department of Lands (DOL) was established in 1901. Under the Land Code of 1954, it has four main functions: (1) to register land holdings and maintain an efficient system of land transfer; (2) to conduct cadastral surveys and prepare maps; (3) to issue land related documents, particularly land titles and land use certificates; and (4) general land administration. For the land allocation program, public lands other than reserved forests are already under the jurisdiction of the DOL, and the Department is authorized to allocate unutilized land to landless farmers. The program distinguishes between large projects of over 10,000 rai, for which supporting services are provided, and small projects of under 10,000 rai, in which land is simply allocated. Plot sizes, determined by provincial committees are small, but farmers are appreciative because they eventually receive a formal land certificate (Nor Sor 3). Services provided in so-called large projects are primarily land clearance, domestic water supply and roads. Unlike the other agency programs, the DOL integrates its operations into the normal local administration system. They are administered by the provincial governors, who frequently enlist support from other agencies.

The Department of Public Welfare (DPW) is one of the departments within the Ministry of Interior, which was established on 1 September, 1940. Among its responsibilities are social security, general welfare, hilltribe welfare, community services and settlement. Self-help land settlement is one of the social welfare programs implemented by the DPW. The principle governing the establishment of selfhelp land settlements was originally stipulated in the Land Allocation for Livelihood Act of 1968. The main objective was to permanently settle landless farmers by providing government assistance for land clearance, land development and public services. The aim was to help the farmers become self-supporting. When a self-help land settlement became sufficiently developed in economic, social and cultural aspects, the status of self-help land settlement would be phased out and the settlement would be turned over to the local authorities. Land title deeds would eventually be issued to the land holders. Currently, there are 47 land settlements in the program; 12 settlements have been turned over to provincial authorities.

The Hilltribe Welfare Division is charged with the responsibility of promoting the development and welfare of members of hilltribes, with the aim of enabling them to become citizens and full participants in Thai society. It also operates the Tribal Research Center, which undertakes demographic, economic, social and anthropological studies of the hilltribes.

The Royal Forest Department (RFD) was established by a Royal Decree on September 18, 1896, to oversee logging activities.

Two divisions of the Department are involved in a land allocation program; the National Forest Land Management Division (NFLMD) and Watershed Management Division (WMD). The NFLMD is responsible for the protection, utilization and improvement of national forest reserves. Its main task is to relocate illegal settlements in national forest reserves through the "Forest Village Program" and "STK Program", and to carry out the rehabilitation of forest lands through forest plantation activities. The WMD is responsible for the management, protection, and rehabilitation of the country's watershed areas. The forest village program seeks to consolidate squatters from forest reserves into villages, where they are provided with permanent living quarters, domestic water supply, schools, health care and access roads. They may supplement their farm income by working for the Department as laborers in replanting work.

The Agricultural Land Reform Office (ALRO) was established in 1975. Its main function is to improve land distribution and security of tenure in specified land reform areas on public and private lands. It aims to bring about a more equitable income distribution and an increase in both production and incomes by: (1) providing security of tenure, which encourages greater investment; and (2) improving infrastructure, which raises productivity and also directly affects living standards. At present, 73 land reform areas have been established, including 39 (700,000 ha) on encroached public lands suitable for agriculture and 34 (300,000 ha) on private lands. The ALRO is initially concentrating on developing the public lands under its jurisdiction, but has a plan to increase its involvement on private lands in the future. It currently has about 1,700 employees.

The Land Development Department (LDD) was established as an agency in the Ministry of National Development in May, 1963, with responsibilities for land assessment and development. In 1973, the LDD was transferred to the present Ministry of Agriculture and Cooperatives, where it performs the same function.

According to the Land Development Act, which dates from 1983, the LDD has a duty to survey land and to analyse the soil in order to determine its fertility, the land class and the area's suitability for utilization and development; to prepare land censuses; to conduct economic surveys of the land; and to perform other tasks assigned to it by the Board of Land Development.

Box 2.1 (contd.)

The Department of Cooperatives Promotion (DCP) implements land programs through its Land Cooperative Division. It aims to help the landless and tenants become land owners through land settlement and land hire-purchase schemes using the cooperative mechanism and to help tenants to rent land under long-term leases with low rental rates through tenants' cooperative schemes; and to assist farmer-owners to increase farm production through land improvement or irrigation cooperative schemes. Development expenditures go mostly for a rather dense network of farm roads and canals. DCP assigned Cooperative Officers to be based in the settlements to perform administrative, credit and extension functions.

Commissions, Committees, and Boards

A number of other Thai Government boards, committees, and commissions have some responsibility for making land policy. They include:

The National Land Allocation Commission, which operates under Article 14 of the Land Code of 1954. The powers and duties of the Commission include: (1) the formulation of land allocation policy such that people are provided with sufficient land to be self-subsistent; (2) the formulation of plans related to land tenure; (3) to preserve and develop land in order to allocate it to the people; (4) to preserve unoccupied public lands for common use; (5) to review land allocation projects of public bodies; (6) to supervise land allocation carried out under the 1954 Land Code and other appropriate laws; (7) to implement land policies as entrusted by the Council of Ministers; (8) to delegate authority to appropriate public bodies regarding matters related to the Commission's duties under the Land Code; (9) to carry out other duties as provided by the 1954 Land Code or other laws; and (10) to establish rules, regulations, procedures, or conditions related to land allocation and land valuation for the purpose of local taxation.

The Land Consolidation Commission operates under Section 6 of the Land Consolidation Act of 1974. Its powers and duties include: (1) the control of the operations of the Central Land Consolidation Office and Provincial Land Consolidation Offices; (2) the design of land consolidation projects in various areas; (3) the identification of project areas to be proposed to the Minister of Agriculture and Cooperatives for designation in accordance with Section 25, d; (4) the giving of advice to the Minister of Agriculture and Cooperatives on the sale of land or transfer of land rights in land consolidation project areas in accordance with Section 32; (5) the approval of plans for land consolidation for irrigation, drainage, road building, exchange or transfer of rights in land, hire-purchase, or other activities proposed by provincial land consolidation offices; (6) the development of rules and procedures on the valuation of land and properties on land in project areas; . (7) the approval of budgets for land consolidation in project areas proposed by the Provincial Land Consolidation Offices; and (8) the determination of the status of land as public property for common use or state use, in accordance with Section 43.

The Agricultural Land Reform Committee operates under Section 12 of the Agricultural Land Reform Act of 1975. Under Section 19, the Committee has responsibility for establishing policies, measures, bylaws or regulations concerning the ALRO land reform programs, as well as the supervision of ALRO's administration.

The Land Development Board operates under Section 4 of the Land Development Act. The Act gives the Board the following powers and duties: (1) to formulate the criteria for land classification, land use planning, and land development, and to specify areas for land utilization, for consideration by the Council of Ministers, so that they may be carried out by the state agencies concerned; (2) to prescribe areas for land survey under Section 11 of the Land Development Act; (3) to specify measures for the improvement of soil or land or measures for the conservation of soil and water, so that the state agencies concerned may employ them and promote them among farmers; (4) to approve the establishment of land development agencies at various levels in any area, in order to provide technical assistance, demonstrations and advice directly to farmers in relation to the improvement of land or the conservation of soil and water; (5) to formulate regulations, terms or conditions relating to the processing of applications for analysis of soil samples, of soil improvement or individual land development operations under Section 14 of the Act; (6) to formulate regulations relating to the performance of duties by subcommittees; and (7) to carry out any other assignments prescribed by the law or assigned to it by the Council of Ministers.

In the performance of its duties, the Board may direct the Land Development Department to prepare and submit proposals to the Board for its consideration.

The Land Subcommittee is a subcommittee of the National Rural Development Committee established on 29 September 1981. It has been delegated the authority to implement land policies approved by the Committee through the preparation of plans to be followed by RTG agencies.

The Land Subcommittee's mission is to: (1) prepare operational and financial plans, including the establishment of financial institutions, such as a land bank; (2) prepare plans related to land administration structures, and plans for effective coordination among organizations concerned with land policy; (3) prepare plans for the distribution of land title documents in areas such as land settlements; (4) prepare plans related to manpower development; (5) appoint specific task groups as necessary; (6) carry out assignments made by the National Rural Development Com-

Box 2.1 (contd.)

mittee; and (7) to exercise other duties and powers authorized by the National Rural Development Committee.

The Property Valuation Committee was established by the Ministry of the Interior in 1984, as a joint committee of 19 members representing agencies within the Ministries of the Interior and Finance. Its mission is to: (1) formulate a policy on property valuation for economic, financial, taxation, and administrative purposes; (2) give advice and support to the efficient operation of the National Valuation Authority; (3) consider, approve and endorse proposals of subcommittees appointed by the Committee; (4) propose and suggest amendments to the property valuation law to the Council of Ministers in order to make it more appropriate; (5) carry out other duties assigned by the Council of Ministers; and (6) appoint sub-committees to perform duties on its behalf.

The National Economic and Social Development Board (NESDB) is the Government's main planning body. It prepares national level and macroeconomic plans and is primarily responsible for preparing, monitoring, and evaluating the five-year national economic and social development plans. It is responsible for defining national development priorities as well as for preparing both long-term and short-term planning documents. The NESDB also prepares and establishes policy guidelines for government units responsible for program development and implementation.

The NESDB is the central point in the planning system. It has two principal functions: (1) to act as the principal resource for the government in proposing, analyzing, evaluating and advising on economic and social policy and national development; and (2) to aid and assist in translating national development strategy into programs and projects. All of the NESDB's activities relate directly to one or both of these roles. In the first, the primary constituency is the office of the Prime Minister and the Cabinet. In the second, the constituencies are broader—the ministries, departments and other agencies, the private economic sector, and the public at large.

It is in this context that the NESDB has become involved in the management of land policy and land use planning. Through its interaction with the multitude of RTG agencies operating land development programs, the NESDB has come to see the need to adopt a more comprehensive approach to land use management and development in Thailand. Through the project mechanism, NESDB feels it can begin the process of understanding land policy issues, improving coordination among land development and land management agencies, and establishing procedures and processes for more efficient land use planning and program implementation.

ferred to the Land Development Department by a Cabinet resolution.

During the period 1962 to 1966, a total area of 162,209,668 rai or 259,535 square kilometers was classified as permanent forest (LDD, 1977). The permanent forests were to be gazetted by royal decree as forest reserves under the National Reserve Forest Act of 1964. By the end of December 1985, about 136,236,169 rai or 218,156 square kilometers had been declared as forest reserves (RFD, 1986).

The growth of population at a relatively high rate during the 1960-1975 period put considerable pressure on the limited amount of available land. The Land Development Department estimates that only 168 million rai or 268,800 square kilometers (52 percent of total land area) are suitable for agriculture, and most of that land has already been utilized (AIT, 1983).

In 1960, the structure of agriculture in Thailand changed from subsistence to commercial farming. Rice is the most important crop with the planted area increasing from 40 million rai or 64,000 square kilometers in 1960 (OAE, 1984), to 83 million rai or 132,800 square kilometers in 1983 (AIT, 1983). The planted area of other export-oriented upland crops, such as cassava, sugar cane and corn, has also increased. Cassava and sugarcane have had a very high growth rate in terms of area cultivated and quantity produced because of the high returns.

Since the First Plan, the Government has used the land classification systems as a basis for issuing land titles to private individuals. However, the granting of land titles has not kept pace with the demand generated by a rapidly expanding population over the last two decades. As a result, the land occupant often lacks a legal title and, thus, the opportunity and incentive to use his land for investment. Rather, the search for new land becomes the principal method of raising income. As a result of the uncontrolled expansion of cultivation and encroachment upon forest reserves, the forest area of the country decreased from 50 percent in 1960, to 29 percent in 1985 (RFD, 1985).

Land Reclassification

The forest areas have been encroached for agriculture both in the national forest reserves and the pre-reserve forest areas (areas to be surveyed and mapped prior to gazetting). But the policy of the Government on the national forest reserve did not change until June, 1982. Land suitable for agriculture in the national forest reserve and pre-reserve areas is still considered forest land. The degazetting of national forest reserves for other activities could be done through complicated procedures under the National Forest Reserve Act, of 1964. For the pre-reserve areas, land reclassified for other activities has to be approved by the Land Classification Committee and the Cabinet.

In June 1982, the Cabinet approved a land use and ownership policy as a first step towards consolidating and rationalizing land use related activities. This policy was prepared by the Land Subcommittee of the National Rural Development Committee. The main objective was to legalize squatters. Land unsuitable for agriculture will remain gazetted as part of the national forest reserves.

Land originally classified as pre-reserve or permanent forest which is now being degazetted will be reclassified. If the land is for agriculture, a form of land ownership would be issued to the squatters. Land unsuitable for agriculture will remain gazetted as part of the national forest reserve. In gazetted national forest reserves, about 30 million rai (encroached figure in 1980) of the encroached land will be reclassified. Land suitable for agriculture will be distributed to the farmer by issuing a STK certificate. Unlike the situation in the pre-reserve areas, full ownership titles would not be readily provided to the farmers. Instead, they would receive the privilege to legally utilize the land which they already held. If land is reclassified as unsuitable for agriculture, a reforestation program will be implemented.

Beginning in 1982, the LDD engaged a private firm to prepare new aerial photographs of the forest areas in Northern Thailand. NESDB also allocated funds to the Royal Thai Survey Department to prepare new aerial photographs of the forest areas in the Northeast, East, Central and Southern regions of Thailand, covering a total area of about 200,000 square kilometers. The aerial photograph operations were completed in 1985, and were used for the land reclassification program. At the end of September 1985, 20 million rai of pre-reserve forest had been classified and 75,806 rai had been documented by issuing Nor Sor 3 Kor certificates to farmers by DOL.

Soil Survey and Classification

Soil survey and classification techniques were first introduced into Thailand in 1935. To begin with, soil survey activity was scattered among different departments of the Ministry of Agriculture and Cooperatives. Later, soil survey and classification were transferred to the Land Development Department, following its establishment in 1963.

The first general soil map of Thailand was prepared and published in 1953, at a scale of 1:2,500,000, by R.L. Pendleton, an American soil scientist who was the agriculture and soil technology advisor to the Department of Agriculture and Fisheries. The soil units, commonly called "soil series," shown on the map were limited. These soil units were by no means as sophisticated as today's "soil series," as defined in the Soil Survey Manual (USDA, 1951). Rather, they were broad generalizations, usually on the level of the great soil group, or of the association of two or more such groups.

In 1968, the second general soil map of Thailand was prepared and published, at a scale of 1:1,2500,000, by Moormann and Rojanasoonthon (1968). The map units were based on the soil classification outlined by Dudal and Moormann (1964). Twenty-three basic map units were distinguished. The elements used in defining the map units were threefold: the dominant soil or association of soils; the broad group of parent material; and the land form, as expressed by the general topography of the unit area.

Since 1970, the Soil Survey Division of the Department of Land Development has adopted the "Soil Taxonomy of the National Cooperative Soil Survey" developed by the soil survey staff of the U.S. Department of Agriculture. All soil series established in the country were placed into soil families using this classification system. A revision of the general soil map by Moormann and Rojanasoonthon (1968) was carried out by the Soil Survey Division and was published, at a scale of 1:1,000,000, in 1979. The soil units shown on the map were great groups and associations of great groups. A total of 3 great groups were recognized in Thailand in 1983 (Changprai, 1983).

At the same time, the Land Development Department published a number of soil maps at different scales, such as 1:500,000 for the regional soil maps, 1:100,000 for the provincial soil maps and 1:10,000-20,000 for specific projects. At present, the Land Development Department has completed detailed reconnaissance soil surveys of the whole country. Fifty eight provincial soil maps at a scale of 1:100,000 were published, with maps of a further 1 provinces under preparation.

Land Allocation and Land Reform

The Government has supported land allocation programs on public land since 1938. These were designed to establish new villages on virgin lands, primarily to settle landless families or to resettle those displaced from sensitive areas by flood, dam inundation or other factors. In 1975, the Agricultural Land Reform Office was established to improve land distribution and security of tenure on both public and private land. At the same time, the Royal Forest Department has been implementing its forest village program, aiming to reforest denuded uplands which have been encroached upon by squatters. A key feature of the program is the regrouping of farmers into villages on the borders of forest reserves. Moreover, there are other projects on land allocation which are undertaken by a number of other government agencies. Land allocation is empowered by the Land Code (1954) the Land Allocation for Livelihood Act (1968) the Land Reform Act (1975) and Cabinet Resolutions.

At present there are 14 government agencies involved with land allocation. The various programs have not been well coordinated and differ widely in terms of their objectives, scale, management and benefits to settlers. The land-related agencies can be separated into two groups. There are five key agencies: the Department of Lands, the Department of Public Welfare, the Department of Cooperatives Promotion, the Office of Agricultural Land Reform, and the Royal Forest Department

Nine other agencies also play a lesser role: the Office of Accelerated Rural Development; the Office of Policy and Planning, Ministry of the Interior; the Provincial Committee; the Land Development Department; the Forest Industry Organization; the Royal Irrigation Department; the Electricity Generating Authority of Thailand; the National Security Command; and the War Veterans' Organization. Since 1938, some 16.3

million rai have been allocated, and the number of beneficiaries was 1.2 million families. The results of land settlement, land reform and other activities by major agencies are given in Table 2.9.

Land Tenure

In Thailand, land may be divided into land owned privately and land owned by the state. The status of land tenure indicates the rights of the land holder. The extent and conditions of these rights depend on ownership rights, holding rights, laws and regulations, as well as local custom.

Privately-owned land can be issued with land titles. The Land Code 1954 recognizes four forms of private ownership document. A **Title Deed** (Nor Sor 4 or Chanode) indicates full ownership, and is supported by a deed plan showing the position of boundary mark stones. A **Certificate of Utilization** (Nor Sor 3 or Nor Sor 3 Kor) proves that the person named as owner has put the land to use. A **Pre-emptive Certificate** (Bai Chong-or Nor Sor 2) authorizes temporary occupation of land. And a **Claim Certificate** (Sor Kor 1 or S.K. 1) indicates a claim lodged by a person who was in possession and had made use of the land prior to 1954, the effective date of the Land Code.

The most recent study by TDRI (1986) found that the cultivated area in Thailand totals about 152 million rai or 47.5 percent of the country area, suggesting that about half of the country is now permanently occupied by private individuals. Only about 23.7 million rai of this total are covered by title deeds (Nor Sor 4 or Chanode), while a further 70.9 million rai are covered by certificates of utilization (Nor Sor 3 and Nor Sor 3 Kor). The rest are "undocumented" private lands.

In the area where the government agencies are implementing land allocation projects, there are many forms of land documentation. The Department of Public Welfare, which carries out self-help land settlement projects, issues Nor Kor certificates to settlers. The Department of Cooperatives Promotion, which develops cooperative settlements, issues Kor Sor Nor certificates to the settlers.

Since these two Departments carry out the land allocation program under the Land Settlement Act 1968, after a period of time the settlers and the members can apply for certificates of utilization—and later title deeds—from the Department of Lands. The land allocation program of the Department of Lands is carried out under the Land Code of 1954. Since the Department of Lands is the authorized agency to issue land documents, therefore the Nor Sor 3 has been issued to the farmers at the end of the project.

The other form of land tenure for private land is land tenancy. The control of land tenancy is governed by the Agricultural Land Rent Control Act of 1981 and the Agricultural Land Reform Act of 1975. In the public or state land, especially in the national forest reserves, land rights have been given to squatters in the form of land use permits. There are two major government agencies which carry out the land allocation program in this area.

In accordance with the cabinet resolution on 28 August 1979, the Royal Forest Department began the Sor Tor Kor (STK) program in the encroached national forest reserve areas. The program permits squatters occupying land in national forest reserves to claim cultivation rights to 1 rai of land, and to lease from the Royal Forest Department any additional area, up to a combined total area of 50 rai. The Royal Forest Department issues the STK certificate to squatters, but this type of document cannot be used as collateral for a loan or as a guarantee.

In the public land sector, the land document Sor Por Kor 4-01, issued by the Agricultural Land Reform Office, is a land use permit similar to STK. It takes at least two years to issue after land is distributed. This land document, like STK cannot be used as collateral for a loan. Because of these differences in land ownership security, problems arise with regard to the degree of inequity and inequality among holders of land documents issued by different government agencies. This is an important policy issue which should be of concern to the government.

Table 2.9 Land Allocation by Major Settlement Programs, 1984

Name of Program	Agencies	Source of Authority	Total	
			Area (ha)	Families
Self-help land settlement	DPW	Land Allocation Act 1968	2,097,382	128,972
Land co-operatives	DCP	Land Allocation Act 1968	2,029,886	69,485
Land reform	ALRO	Land Reform Act 1975	1,812,131	81,257
Land allocation	DOL	Land Code 1954	3,281,471	274,100
War veterans	WVO	Cabinet resolution	32,221	1,633
Land development projects	LDD	Cabinet resolution	178,962	14,359
Forest villages	RFD	Cabinet resolution	334,493	2,089
Forest community development	RFD	Cabinet resolution	199,918	23,129
Sor Tor Kor (Cultivation rights)	RFD	Cabinet resolution	6,360,449	624,048
		Total	**16,327,413**	**1,219,072**

Source: Division of Research and Planning, Agricultural Land Reform Office, Ministry of Agriculture and Cooperatives, 1986.

Land Consolidation

Land consolidation is an integrated, technical method of land development at the inter-farm and farm level, with emphasis on water management. Typical activities in land consolidation are: (1) construction of a minor irrigation system to supply water to each farm; (2) construction of a minor drainage system to evacuate excess water from each field; (3) construction of farm roads along the irrigation ditches to improve the accessibility of the farmer's fields; (4) rearrangement of farm holdings in between the newly constructed irrigation ditches and drains; and (5) clearance and levelling of arable land to improve the on-field water control.

After completion of land consolidation, every holding has an irrigation inlet, a drainage outlet and access to a farm road. The plots are levelled and have a rectangular shape to allow for modern agricultural practices, such as the mechanization of land preparation. In summary, land consolidation results in improved physical production conditions which are needed to achieve the agricultural development objectives of increasing the wet season rice production, initiating dry season cultivation and creating additional rural employment opportunities.

Land consolidation began in Thailand in 1968 as a pilot project in the Central Plain at Amphur Bang Rachan, Singburi. An area of 7,400 rai in the Chanasutr Irrigation Project, which is one area of the Greater Chao Phraya Project, was selected as a pilot project with another 4,200 rai in a nearby area. In 1972, the pilot stage of the land consolidation program came to an end.

Based on the encouraging results in the land consolidation pilot area, the Royal Thai Government decided to continue the land consolidation program on a large scale. In 1974, it launched a Land Consolidation Act as a tool to support the implementation of land consolidation. To implement the Act, the Central Land Consolidation Office was established in 1975. In 1986, land consolidation projects cover an area of about one million rai throughout the country. Therefore, much remains to be done, with about 20 million rai of irrigated areas potentially needing similar arrangements.

Soil Conservation

Soil and water conservation policies were included in the Second National Economic and Social Development Plan in 1967 Prior to the establishment of the Land Development Department in 1963, soil and water conservation was carried out by several agencies. Later, the Land Development Department's Soil Conservation Division became responsible for the task. In 1984, after the reorganization of the Department, its name was changed to the Soil and Water Conservation Division.

Since its inception, the LDD has emphasized research and experiment on the causes of soil erosion and protection measures. At the same time, the transfer of technology to farmers has been achieved by several methods, including demonstration, training, general meetings and public relations.

During 1966 to 1971, soil and water conservation programs assisted by USAID were implemented in the Northeast. A prime objective was to train local technicians to use soil information in conservation planning and to show farmers how to practice soil and water conservation. Eight land development centers were established during 1963 to 1967 in the Northeast. Mobile units were also set up to work closely with the farmers.

Soil and water conservation have been carried out by the LDD since 1963. Fifty-three Land Development Centres, located in different provinces of the country representing different agro-climatic regions, have been established. The major responsibility of land development stations is soil and water conservation. In fiscal year 1986, the LDD was allocated 114.7 million baht for soil and water conservation activity.

At present, the LDD emphasizes three approaches for the implementation of soil and water conservation.

a) Technology transfer: This includes six activities, namely public relations, training of local government officers, training of farmer leaders, farmers' meetings, demonstration, regular visiting and communications.

b) Services: Four activities are involved here, namely land use planning, soil and water conservation system survey and design, distribution of cover crop seeds and tree crop seedlings, and mechanical control structure construction.

c) Establishment of local groups: In order to insure greater farmer participation in soil and water conservation, including the maintenance of the mechanical structures after the withdrawal of government agencies, local support groups should be established.

Land Use Planning

The Royal Thai Government has long realized the importance of land use planning. The First Plan (1960-1966) stated that half the country should be kept as forest or preservation areas, the rest being progressively developed for agriculture and other activities. Forest preservation has been carried forward since 1960 under the following Acts: the National Forest Reserves Act of 1964, the Wildlife Reserves and Conservation Act of 1960 and the National Parks Act of 1961.

Land use planning for agriculture has been the responsibility of the LDD since 1973. Currently, three regional land use plans have been published, for the Northeast, East and Central regions. At the provincial level, 49 provincial land use plans have been published. The main objective of land use plans is to recommend suitable crops so that land can be better utilized.

However, the implementation procedures are weak. To overcome this problem, the Land Use Planning Subcommittee was established in 1984 by the Land Development Board. After the completion of the regional or provincial land use plan by

the LDD, the plan is submitted to the Land Use Planning Subcommittee, Land Development Board and to the Cabinet for approval. Even so, there may still be problems in implementing such plans. Without strong support from the government, it seems that land use planning will not be a priority. Land use for town planning is carried out by the Office of Town and Country Planning. Under the Town and Country Planning Act of 1975, several town plans have been prepared and implemented.

Soil Degradation and Erosion

There is evidence both of degradation and erosion of Thai soils. The degradation of soils can be caused by physical, chemical, biological, socioeconomic and institutional factors. In isolation or in combination, directly or indirectly, such factors alter the soil's potential for sustained or increased agricultural production.

Soils supporting undisturbed tropical forests are characterized by low soil bulk density and high macro-porosity, partly due to the relatively high activity of the soil fauna. Once the forest cover is removed, however, the soil characteristics begin to change. Their bulk density increases in the wake of deforestation and cultivation, as do a number of their other physical and chemical properties. Norman (1984) compared the physical properties of new and old development areas and showed a gradual process of change. The total infiltration capacity of soils in the older development areas had fallen by 62 percent, when compared with the original forest values. The soil chemistry had also changed. The organic carbon content of the soils in the older areas had dropped by 18 percent, while their calcium, magnesium and potassium tended to be lower, too.

These changes can have a significant influence on the erodability of soils. Soil erosion, in fact, is one of the most pressing natural resource problems in Thailand. A theoretical study by Srikhajon, et al., (1980) indicated that about 107 million rai nationwide suffer from a medium or high degree of soil erosion, particularly upland areas where slopes are greater than 5 percent (Table 2.10). Data from three years of small plot experimentation at the Sa Land Development Station, in Nan Province, indicated that in many areas the average soil loss may exceed 16 tons per rai per annum (Marston, 1984). This, it is worth pointing out, is at least 20 times the recommended tolerable annual soil loss (Arnoldus, 1977).

In Phetchabun province, on Ultic Paleustalfs with a 9 percent slope. soil losses of 162.6 tons per hectare of soil were reported for 1983 (Chaisiri et al., 1984). 110 tons of soil per hectare per year were being lost from 3 percent slope bare soil in Chonburi province in 1983 (Lekakul, 1984). By contrast, in the Northeast's Kalasin province', on 6 percent slope bare soil, a lower figure of 20.8 tons per hectare was reported (Pairintra, et al., 1982).

A study on cumulative soil loss on various land management plots at Rong Kwang, Phrae and at Chiang Rai, showed that soil loss from forest management is less than from swiddening and continuous rice cultivation. The effect of producing one crop of rice every ten years was to increase soil loss by 1.5 to 1.7 times the losses typical in a Dry Dipterocarp Forest (Attaviroj, 1986). The effect of shortening the swiddening rotation from once in 10 years to once in 2 years, was a 1.6-fold increase in soil loss at Rong Kwang and a 1.8 fold increase at Chiang Rai.

Chomchan and Panichapong (1986) reported that soil loss in the Ping and Nan river basins is averaging about 2 to 10 ton/rai/year. If land use changes from forest to row crop cultivation without soil and water conservation measures, soil loss will increase about 6 to 10 times.

Soil erosion and soil degradation inevitably result in declining yields. Norman (1984) indicated that in the NADP areas, grain yields of corn on newly cleared areas ranged between 130 to 423 kg/rai and averaged 262 kg/rai, while those in old development areas averaged 166 kg/rai. In the same area, grain yield of upland rice average 221 kg/rai on newly cleared areas but only 114 kg/rai on old development areas.

Attaviroj (1986) made the assumption that in Northern

Table 2.10 Areas Affected by Soil Erosion in Thailand

Category	Soil Loss (ton/rai/year)	Area (million rai)	Land Use
Very slight	0.01-1.00	119	forest, paddy
Slight	1.01-5.00	90	forest, rubber, orchards, paddy
Moderate	5.01-20.00	26	rubber, orchards, field crops, forest + field crops
Severe	20.01-100.00	43	rubber, orchards, field crops, forest + field crops, shifting cultivation
Very severe	100.01-966.65	39	field crops, forest + shifting cultivation
Others		4	coastal area, mangrove forest, shrimp farms etc.
Total		**321**	

Source: Srikhajon et al. 1980.

Thailand, of a total area of 1.4 million rai of encroached forest each year, about 0.2 million rai per year are used to replace land that is seriously eroded and degraded. These degraded areas will be allowed to revert to bush fallow.

The effects of siltation from soil erosion on dams and from sedimentation along water courses result in a sediment load at the mouth of the Chao Phraya River of about 104 tons, per square kilometer. This represents 11 million tons, or about 8.5 million cubic meters of sediment (El-Swaify, 1982; quoted by Attaviroj, 1986).

The LDD (1985) reported that plant nutrients were leached by runoff water in Thailand, representing a total nutrient loss of about 27.4 million tons per year. These losses might include 24.1 million tons per year of potassium (K), 3.1 million tons per year of nitrogen (N) and 0.2 million tons per year of phosphorus (P).

Another type of soil degradation is salinization. There are two hypotheses on the causes of dry land salinization in Northeast Thailand. The first suggests that the salt originates in deep rock salt beds, with deep groundwater circulation bringing the salt up to or near the soil surface. The second, hypothesis proposed by Sinanuwong and Takaya (1974), suggests an origin of the salt in the weathered zone of the shales and siltstones beneath upland areas. It is believed that salt was distributed to lowland areas by interflow. In this view, salt not only occurs in the rock salt, but also in the shales and siltstone of the Maha Sarakham Formation.

Forest clearing for agriculture is commonly identified as a prime cause of soil salinization (ADAB, 1977; Moormann and van Bremen, 1978). In the past decade, upland areas in the Northeast have been cleared for major crops such as cassava, corn and kenaf. This might be expected to cause an increase in upland groundwater recharge and a rise in groundwater levels in lowland areas. At present, there is no information to indicate which of these two hypotheses is right, but studies are in progress in several provinces of the Northeast to test them.

Currently, the Royal Thai Government's human and financial resources are insufficient to deal with the scale of these problems—and will probably remain insufficient The implication is that soil degradation and erosion problems will become even more pressing in the future.

Landlessness

It was estimated a few years ago that the landless amounted to 500,000 households in Thailand (NESDB). The problem is serious in the Central Plain and the North. While the data on this aspect of land are very limited and incomplete, it is expected that the situation will deteriorate further as the potential for land expansion is constrained and population pressures increase.

Since 1979, the problem of landlessness has received considerable attention in Thailand. The first survey was conducted in selected provinces of the North, Northeast and Central Plain. Other surveys were undertaken in other provinces in 1981, 1982 and 1983. The results from these surveys shed some light on the seriousness of the problem (see Table 2.11).

In all the surveys, landlessness accounted for over 10 percent of total households. The problem is particularly serious in the upper North, where the percentage of the landless is the highest. Almost 60 percent of those studied were near-landless or small farmers. The main reason given for having no land, or less land than before, is also reported in the surveys. Most landless farmers sold and/or lost their lands through mortgages. Landlessness has aggravated the poverty

Table 2.11 Percentage of the Landless, Near-landless and Small Farmers

Area	Type of Farmers				
	Landless[a]	Near-landless[b]	Small[c]	Other[d]	Total
Selected Provinces[e]	10.59	3.25	4.53	81.63	100
	(92,034)	(28,287)	(39,354)	(709,469)	(869,144)
Upper North[f]	13,48	31.37	27.51	27.64	100
	(12,245)	(28,511)	(25,002)	(25,116)	(90,874)
Lower North and Some[g]	10.11	8.16	9.61	72.12	100
Parts of Central Plain	(74,977)	(60,503)	(71,275)	(534,948)	(741,723)
East and Some Parts[h]	13.03	7.4	7.86	71.71	100
of Central Plain	(39,802)	(22,593)	(24,006)	(218,973)	(305,374)

Figures in parentheses are the estimated number of farms from the survey.

Notes: a. Those who do not own any land (excluding homelot) and do not rent any land from other people. They are mainly farm labourers.
b. Those who own less than 5 rai of land and have a net cultivated area of not more than 5 rai (including own land and rented land).
c. Those who own less than 10 rai and have a net cultivated area of not more than 10 rai.
d. Other means those holding over 10 rai of land.
e. The survey, conducted in 1979, covered 3 provinces in lower North, one in the Northeast (Khorat), and 8 provinces in the Central Plain.
f. 1981, covered 8 provinces.
g. 1982, covered 13 provinces (3 in lower North).
h. 1983, covered 9 provinces (6 in Central Plain).

Source: Agricultural Land Reform Office.

Box 2.2 Competing Titles to Land

"Everywhere in this Kingdom there are betel vine and betel nut forests," declared a stone inscription of 1292, "There are also in this Kingdom many coconut, jackfruit, mango, and tamarind forests. Whoever plants them, unto him they shall belong..."

Property rights clearly extend far back into Thailand's history, although the Land Code of 1360 subsequently made all land the property of the king. Private land holders were entitled to possession, but not to ownership. They could not transfer property to another person nor pass it on to their descendents. Later, however, this position changed, and in the early 1900s new systems of land tenure and transfer were introduced, under which land titles were granted to private individuals and guaranteed by the government.

A profusion of laws and regulations was issued following 1932, when the era of constitutional monarchy began. In 1954, however, a new Land Code was enacted, providing a much more effective legal framework for controling land use, determining ownership and generating revenues from land. The Department of Land (DOL) has the prime responsibility for ensuring that the Land Code is implemented.

But, because the pace of land titling has not kept up with the growth in Thailand's population, land occupants today often lack any effective legal title to the land they use. This means that there is little incentive to invest in the land, while the main method of raising income becomes the acquisition of new land. In addition, there are the landless, estimated several years ago to number 500,000 households, or over 10 percent of total households. The government has supported land allocation programs on public land since 1938, whether to settle such landless families or to resettle those displaced by major projects like reservoirs.

In recent years, a growing number of other agencies have become involved in land allocation, including the Agricultural Land Reform Office (ALRO), the Department of Public Welfare (DPW) and the Royal Forest Department (RFD). The different agencies involved in allocation have tended to give different types of document to those allocated land.

The Land Code of 1954 recognized four different types of private land ownership documents confirming legal title. These were a title deed (Nor Sor 4, or Chanode), indicating full ownership; a certificate of utilization (Nor Sor 3, or Nor Sor 3 Kor), proving that the holder has put the land to use; a pre-emptive certificate (Bai Chong, or Nor Sor 2), authorizing the temporary occupation of land; and a claim certificate (Sor Kor 1 or S.K.1), indicating that the holder had used the land prior to 1954.

There are currently some 14 government agencies involved in land allocation programs. The DOL is the only one which can give full title, in the form of Nor Sor 4, The DPW, which carries out self-help land settlement projects, issues Nor Kor certificates to settlers, while the Department of Cooperative Promotion (DCP) issues Kor Sor Nor certificates. Only about 16 percent of the cultivated area in Thailand is covered by such title deeds, while a further 47 percent is covered by certificates of utilization.

The other major form of land tenure for private land is tenancy. On public or state land, especially in the forest reserves, squatters have been given land use permits by two different government agencies. The Royal Forest Department (RFD) began its Sor Tor Kor (STK) program in 1979, which allows squatters in encroached national forest reserves to claim not more than 15 rai of land, and to lease any additional land from the RFD, up to a total of 50 rai. The STK permit cannot be used as collateral for a loan, however, or as a guarantee. And the ALRO issues the Sor Por Kor 4-01 land use permit, which is similar to the STK permit.

In such circumstances, overlaps of jurisdiction, administrative conflicts and lack of coordination are unavoidable. Overall, one must conclude, land allocation, as currently practised, is ineffective, inefficient and inequitable. If Thailand's land-based natural resources are to be properly managed, these problems will need to be recognized and tackled. The obvious solution — if politically problematic — would be to pull all land allocation activities together under a single bureau.

problem which is widespread in the upper North, where land and population pressures have been acute.

Intensity of Land Use

Land use in Thailand is traditionally extensive rather than intensive. Mono-cropping is very common, especially in rainfed areas. Land use has been less intensive mainly due to the lack of irrigation facilities. Even though there has been considerable investment in irrigation, only about 15 percent of the total cultivated area is under irrigation. Furthermore, the area is concentrated in the Central Plain, where the larger projects are located. Extensive agriculture has also been possible because, over the past two decades, the rate of expansion of agricultural land was higher than that of the population growth. However, this cannot long continue into the future. If agricultural production is to be increased, improvements in land productivity are essential. As the Fifth Plan recognized, this implies that land must be used more intensively.

As regards future trends, it is likely that cropping intensity will increase, albeit gradually to begin with. The major potential for increased cropping intensity will be in irrigated areas in the Central Plain and in the North. Another factor influencing land use intensity is the farm-gate prices of major crops, such as rice, soybean, and vegetables. As for rainfed areas, particularly in the Northeast, new cropping systems are required if increased cropping intensity is to be realized. Research on this area has been intensified in the Northeast.

2.3 LEGAL AND INSTITUTIONAL FRAMEWORK

Land laws dated from 1360, during the Ayutthaya period. At present there are 11 laws that directly or indirectly touch upon land resources in Thailand. They are: the Forestry Act, 1941; the Land Code, 1954; the Wildlife Reserves and Conservation Act, 1960; the National Parks Act, 1961; the National Forest Reserves Act, 1964; the Land Settlement Act, 1968; the Land Consolidation Act, 1974; the Improvement and Conservation of National Environmental Quality Act, 1975; the Town and Country Planning Act, 1975; the Agricultural Land Reform Act, 1975; and the Land Development Act, 1983.

Despite all these acts, the classic example of the difficulties in law enforcement can be illustrated by the continuing encroachment of forest lands.

At the end of December 1985, the Royal Forest Department (RFD) announced that 136.2 million rai had been gazetted as the national forest reserve. This area has to be protected under the National Forest Reserve Act, 1968. However, in November 1985, the RFD reported that only 93.2 million rai are actually forested. This means that more than 40 million rai of national forest reserve had been encroached upon. Between 1982 and 1985, the average rate of destruction was about 1.6 million rai per year. It is estimated that there are about one million squatter families in Thailand's forest areas at the present time.

The presence of squatters in the national forest reserves has been accepted as a fact of life. The question is how to solve the problem at hand with least hardship to the people as well as minimum threat to the existence of the forests of the country. Enforcing the law against squatters is virtually impossible, because of their great number.

Land Administration

As we have seen, there are many government agencies dealing with land administration in Thailand. They operate under several ministries. In fact, there are 24 agencies under six ministries and several land committees. Furthermore, there are also 11 laws on land, including Revolutionary Orders concerning land and Cabinet Resolutions, as well as several ministerial decrees.

Due to the lack of a national land policy, these government land agencies, at times have been operating without adequate coordination.

Most of these agencies are facing similar problems in administration, e.g., lack of funds, manpower and government support. Most land projects have not reached their specified goals. Some do not even have a clear project duration or a work plan. Therefore, the project is implemented monotonously, year by year, depending on the budget obtained annually.

More attention is required in the monitoring and supervising of land projects. The evaluation of land projects is not carried out regularly by the government, with the exception of those funded through loans or foreign assistance. This has resulted in inefficiency in the administration of land projects which are financed by regular budgets.

Given the problems just mentioned, there is a need for the reorganization and/or the restructuring of the land administration system in Thailand. To obtain efficiency in administration with better coordination among agencies concerned, a national level land resources committee may be necessary to formulate land policy, and to coordinate, evaluate and monitor the implementation of the land projects. Finally, given that land allocation faces serious administrative problems (e.g., overlapping, lack of funds and manpower), change in the present complicated and duplicative administrative structure is unquestionably needed.

2.4 KEY ISSUES

Land Reclassification

In the past decade, considerable attention has been focused on the encroached forest areas. In August 1979, the Cabinet approved the STK program, which permits illegal squatters to live and continue to cultivate in such areas. The Royal Forest Department issues a land use permit document to squatters, but critics of the Department's approach have argued that the government should degazette such areas and issue the legal land right document (Nor Sor 3 or Nor Sor 4).

The Royal Thai Government was adamant that immediate degazetting was not feasible, but was willing to support an accelerated reclassification program in the forest reserve areas. This may help influence land policy and may be a transitional step in the process of providing security of tenure and supporting services to farmers on agriculturally suitable land.

The RTG also recognizes land use planning as a prerequisite for the improvement of forest utilization. In June 1982, the Cabinet approved the land use and ownership policy. The thrust of this policy is to reclassify 30 million rai of pre-reserve forests into areas suitable and unsuitable for agriculture. Similarly, in the gazetted national forest reserves, an encroached area of about 30 million rai would be reclassified.

Box 2.3 When Soils Turn to Salt

Travel through the Middle East's "Fertile Crescent", where the early Sumerian, Babylonian, Assyrian, Phoenician and Hebrew civilizations flourished, and you will find entire landscapes turned to salt. The use of irrigation without adequate drainage encouraged evaporation and salt crystallization, sterilizing the soil for all time. Thailand may not have produced the shining white saltscapes you can see in some parts of the world, but Thai soil scientists argue that the problem of saline soils is increasingly urgent.

Saline soils may be found in some southern coastal areas, but these tend to be caused by seawater flooding, rather than by irrigation. According to data published by the Department of Land Development (DLD), the problem of saline soils is worst in the Northeast of Thailand. Here, an estimated 17.8 million rai of land, or around 17 percent of the total Northeastern region, have been affected to some extent. Of this affected area, about a third (5.8 million rai) is considered to be "worryingly" saline. Some four million rai are considered "mildly" saline, with salt crusts affecting up to 10 percent of their surface area; 1.3 million rai are classified as "moderately" salty, with salt crust coverage of 10-50 percent; and nearly 210,000 rai are "severely" saline, with salt crust coverage of more than 50 percent.

Two-thirds of the 17.8 million rai of saline soils can still produce quantities of a salt-tolerant crop like rice, but the farmer typically achieves much lower yields than on non-saline soils. Yields on moderately saline soils tend to be halved. The evidence suggests that the problem is likely to get worse.

Apart from the linkage between irrigation, poor drainage and salinization, a number of other factors may also be at work in Thailand. For example, it is now recognized that the construction of dams can raise the water table in downstream areas. Where there are deeper saline layers, the result may be to flush the salt up into the surface soils.

Another possible contributor is salt production, an important economic activity in the Northeast. Wastewater from salt production operations may either be discharged directly to paddy fields, or discharged to rivers and extracted lower down. Either way, the problem of saline soils is aggravated. More tentatively, some researchers suspect a link between the deforestation of major watershed areas, which may influence the rate at which salts leach out of upland deposits.

Whatever the causes of salinization in particular areas, however, the evidence of depressed crop yields signals the need to carefully consider the suitability of land proposed for irrigation. If a decision is made to invest in irrigation, then sufficient funds will need to be made available to ensure that poor drainage does not raise soil salinity to unacceptable levels. The farmer should be aware that this is a cumulative problem, with each generation leaving an increased salt burden in the soil it passes on to the next.

On 20 December 1985, the Land Subcommittee of the National Rural Development Committee agreed that the issuance of STK certificates would be done following land reclassification.

Furthermore, on 3 December 1985, a national forest policy was approved by the Cabinet. According to the policy, 40 percent of the country area is to be kept as forest. It is generally accepted that land unsuitable for agricultural purposes in upland areas (i.e., areas of shallow soil or with a slope of more than 35 percent) should be kept as forest. Soil survey and classification will need to be employed to implement such a policy.

Land suitable for agriculture has now been almost completely utilized. Therefore, attention has to be paid to encroached forest areas in which production efficiencies and economic returns are very low. The goal must be to insure maximum value-added consistent with sustained yield. This would be achieved through land reclassification, evaluation and land use planning. These activities would serve as a prerequisite leading to degazetting, settlement improvement and the legitimatization of farm families on suitable lands, which for the most part are already utilized for subsistent agriculture. Land classified as unsuitable for agriculture would be designated for reforestation.

Soil Conservation

Soil degradation problems, including declining soil fertility, soil compaction, soil erosion and salinization, threaten to become more prominent. More attention must be given to soil conservation since past programs have rarely been successful.

The limited success of past soil and water conservation projects has been due to three factors. There has been a lack of support from the government and the responsible organizations were not prepared to tackle the problems effectively. Another negative factor has been the social and economic conditions of the farmers. Thirdly, the conservation techniques were difficult to use and no immediate return could be expected.

Future soil and water conservation projects should have the following characteristics: (1) they should be simple enough for individual farmers to apply; (2) the cost should be low; (3) the project should be farm-based; (4) less construction should be required; and (5) the project should be easily replicable. These, though they seem rather simple, require some changes in the current programs. Moreover, there is also a need for new and simple techniques of conservation which must be adopted and tested carefully before introducing to the farmers.

Misuse of Land Resource

It has been found that a substantial amount of agricultural land has been misused. The cultivation of paddy on unsuitable soils alone amounts to 13.48 million rai, and the growing of upland crops on unsuitable soils accounts for a further 14.58 million rai (TURA, 1980).

Another type of misuse of land is the encroachment and destruction of forests on steep slopes, especially those that exceed 35 percent. It was found that the total area nationwide covers 3,949,392 rai, of which 1,895,712 rai are in the North (CUSRI, 1983). Most of the encroachment is for cultivating upland crops without any soil and water conservation practices, thus creating severe erosion problems. The Water Management Division of the Royal Forest Department (1984) reported that about 9.4 million rai of watershed area has been encroached.

Land Use Planning

After land reclassification has been achieved, land use planning is essential to ensure an efficient allocation of land resources. To insure that a land use plan can be implemented, supporting measures must be carefully designed.

As regards watershed classification, broad land use planning or zoning has been done. However, in each zone, more detailed work will be needed to insure effective implementation.

In preparing a land use plan, a number of problems will be encountered. A way must be found to solve them. Land use planning must be set up at different levels; national, regional and provincial. Supporting measures including law enforcement must be provided if the plans are to be effectively implemented. Close cooperation and coordination among agencies concerned are required.

Land Rights

On privately owned land where people have legally settled, steps are being taken to expedite the issuance of title deeds through the Land Titling Project, implemented by the Department of Lands. In due course, all documents will be converted to title deeds (Nor Sor 4 or Chanode).

The Land Titling Project has two overriding objectives. The first is to extend the benefits of secure land ownership to a larger proportion of the public. This will be achieved by increasing the capability of the Department of Lands to accelerate its rate of issuance of title deeds and improve the quality of its service to the public in the area of land administration. The second objective is to rationalize cadastral mapping and documentation in a timely manner in order to compile a complete national cadastre. The project will accomplish this by integrating cadastral mapping into the national topographic grid and by converting land documentation into one uniform and simplified system. The Department of Lands has a plan to complete the exercise within 20 years.

On public land, especially that covered by the government land allocation projects operated by the Department of Lands, Department of Public Welfare and Department of Cooperatives Promotion, the situation of land rights differs between these agencies. In the land allocation project areas under the Department of Public Welfare and Department of Cooperative Promotion, settlers can apply for a legal land right document as defined in the Land Settlement Act. These two departments should accelerate the issuance of their documents (Nor Kor of the Department of Public Welfare and Kor Sor Nor of the Department of Cooperative Promotion). With these documents the settlers can apply for a legal land right document from the Department of Lands.

In the encroached forest areas where land allocation projects are operated by the Royal Forest Department and the Agricultural Land Reform Office, land rights still represent a major problem. The Royal Forest Department issues a land use permit (STK certificate) to illegal settlers in the national forest reserve. The Agricultural Land Reform Office also issues a land use permit (Sor Por Kor 4-01). These two documents cannot be used as collateral for a loan. A change in this type of document to Nor Sor 3 or Nor Sor 4 will have a significant economic impact to the local farmers. On the other land, it may facilitate the transfer of ownership leading to the loss of land by poor farmers and eventully more encroachment of forest lands.

Land Allocation

At present, there are 14 government agencies involved in land allocation, and the programs under each agency differ widely in terms of objectives, scale, management and benefits to settlers. Based on the Cabinet resolution on 22 June 1982, land allocation projects cannot be extended in other areas and the ongoing programs have to be completed first. The land reform program is, however, an exception.

Due to the fact that the work on land allocation and settlement is administered by several governmental organizations, the overlapping of jurisdiction, administrative conflicts, and lack of coordination are unavoidable. These administrative defects have caused ineffectiveness, inefficiency, waste of land and waste of budget. Since all of these governmental organizations are undertaking activities of a similar nature and the relative scope of their responsibilities have not yet been clearly defined, the formulation of consistent policies and their close coordination are greatly needed. This should include a possible reorganization or consolidation of these related organizations under a single umbrella organization.

Land Valuation

Since 1932 a complex system of property-value-based taxation has evolved in Thailand which is a vital source of revenue to local and central governments. Until recently, there were no qualified and experienced property valuers in the Government. In November 1981, however, the Cabinet approved the establishment of a National Valuation Authority within the Technical Division of the Department of Lands,

Table 2.12 Extent of Problem Soils in Thailand

Problem Soils	Name of Great Group	Area (km²)	Area (rai)
Saline and Sodic soils	Natraqualfs Sulfaquents Hydraquents Halaquepts	2,096	1,310,000
Acid Sulfate	Sulfic Tropaquepts	8,404	5,252,500
Sandy Texture soils	Quartzipsamment	9,454	5,908,750
Ground Water Podzols	Tropohumods	894	558,750
Vertisols soils	Chromuderts Pelluderts Chromusterts Pellusterts	3,368	2,105,000
Organic soils	Tropofibrists	808	505,000
Skeletal soils	Ustorthents Troporthents Dystropepts Haplustalfs Plinthaquults Paleaquult Plinthustults Paleustults Haplustults Plinthudults Paleudults Tropudults	83,822	52,388,750
	Total	**108,846**	**68,028,750**

Source: Panichapong, S. 1982. "Distribution, Characteristics and Utilization of Problem Soils in Thailand." Tropical Agriculture Research Series, No. 15, p. 83-96.

Under the Land Titling Project, the National Valuation Authority would revise the valuation basis for land property taxation. By improving valuation techniques and completing the cadastral survey, government revenue, especially for local municipalities, should increase substantially. Valuation on a consistent and professional basis should reduce inequities among tax payers arising from omissions and distortions in property tax.

In addition to generating government revenue, accurate valuation can serve as a disincentive to land ownership for speculative purposes if the property tax structure is progressive. Though a good start has been made by the Lands Department in this area, much technical works remains to be done. This will require a considerable number of well-trained personnel, and other resources—including financial. As matters stand, it appears that land valuation will be an important issue for years to come.

Special Problem Soils

The expansion of cultivated land is likely to be limited in the future, due to the fact that land suitable for agriculture is almost completely utilized. Existing cultivable and abandoned lands will need to be developed to meet the future land requirement. There are about 68,028,750 rai classified as special problem soils (Panichapong, 1982). They are saline and sodic soils, acid sulfate soils, sandy texture soils, ground water podzal soils, vertisols soils, organic soils and skeletal soils (Table 2.12). Some of these problem soils have already been in use, including saline and sodic soils, acid sulfate soils and Vertisols soils, but their productivity is very low.

With regard to research work on these special problem soils, only saline and sodic soils and acid sulfate soils have been intensively covered to date. In order to develop these areas for better utilization, the research program on each type of soil should be accelerated.

Table 2.13 Government Agencies Related to Land Administration

Implementing Agencies:

Bank of Agriculture and Agricultural Cooperatives
Department of Agriculture
Department of Cooperative Promotion
Department of Lands
Department of Land Development
Department of Public Welfare
Department of Religious Affairs
Department of Treasury
Electricity Generating Authority of Thailand
Forest Industry Organization
Government Housing Bank
National Housing Authority
National Security Command
Office of Accelerated Rural Development
Office of Agricultural Land Reform
Office of Agricultural Economics
Office of Policy and Planning
Office of Land Consolidation
Office of Town and Country Planning
Provincial Committees
Royal Forest Department
Royal Irrigation Department
War Veterans Organization

Policy Agencies:

Agricultural Land Reform Executive Committee
Board of Land Development
Land Allotment Control Committee, Ministry of Interior
Land Consolidation Committee
Land Subcommittee of the National Rural Development Committee
National Environment Board
National Land Allocation Committee
The Committee on the Leasing of Land for Agriculture
The Committee on Real Property (Rachaphatsadu Land)
The Land Allotment Control Committee

Source: TDRI, 1986.

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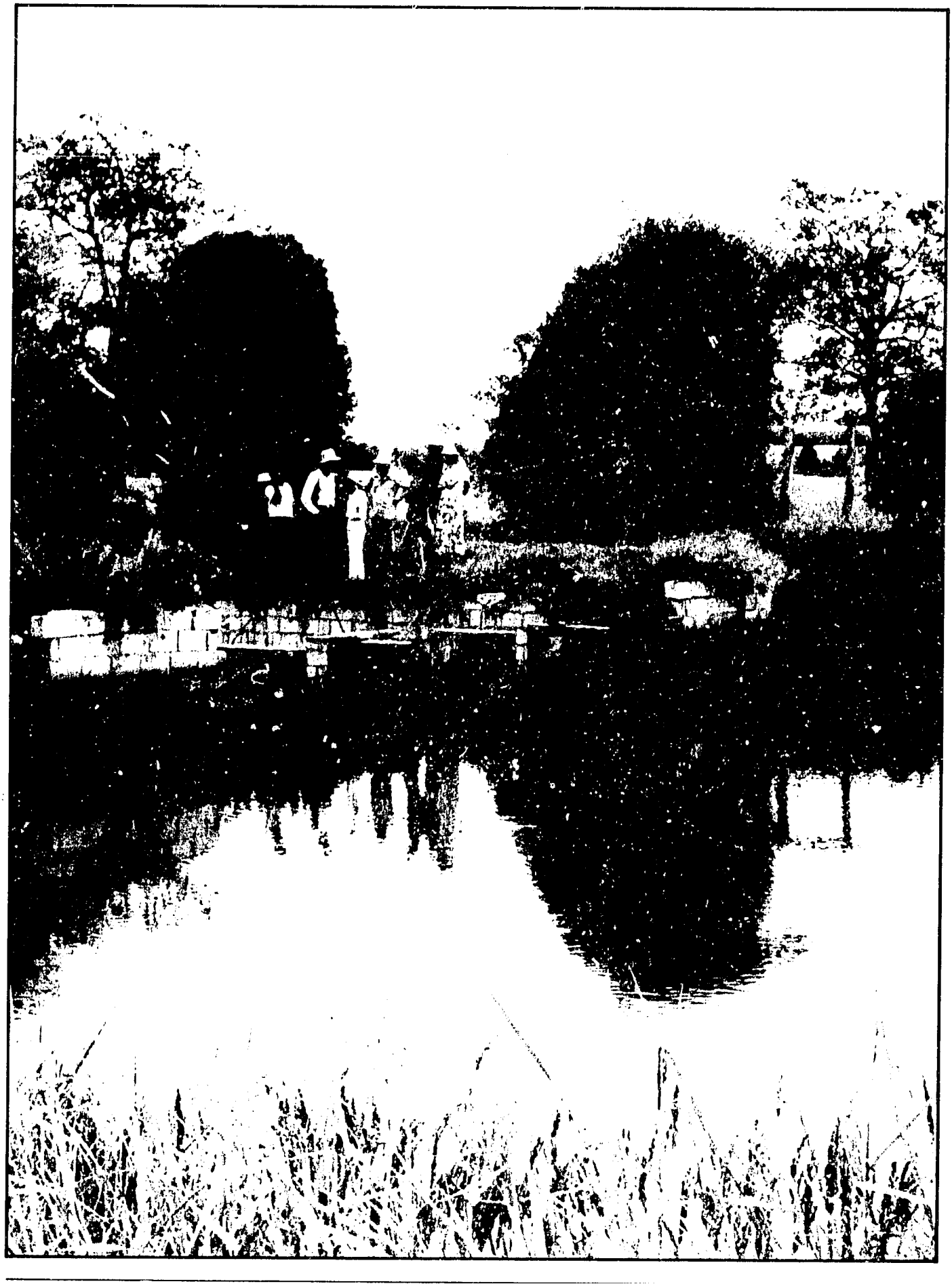


3 Water Resources

Water resources are vital assets in the development of Thailand. Water is essential for human consumption, sanitation, the production of food and fiber, as well as for the production of many industrial goods. But rainfed agriculture alone cannot provide sufficient products for the growing population and development of the country; therefore, irrigation is assuming an increasingly important role in the agricultural sector.

Once water was considered a non-marketable human necessity. Nowadays, by contrast, it is regarded as a resource to be allocated among different users. Some uses, however, degrade the quality of the water resource for downstream users. The increasing use of water by urban and industrial consumers has resulted in the pollution of some of the available fresh water.

The most striking characteristic of the water resource is its uneven and inequitable spatial and temporal distribution. Some areas have too little water, others have too much, suffering from floods which can cause substantial loss of life and damage to property. One of the main objectives of water resources development is to even out this inequity. This chapter discusses the status of water resources development in Thailand and highlights a number of major issues that require attention.

3.1 OVERVIEW

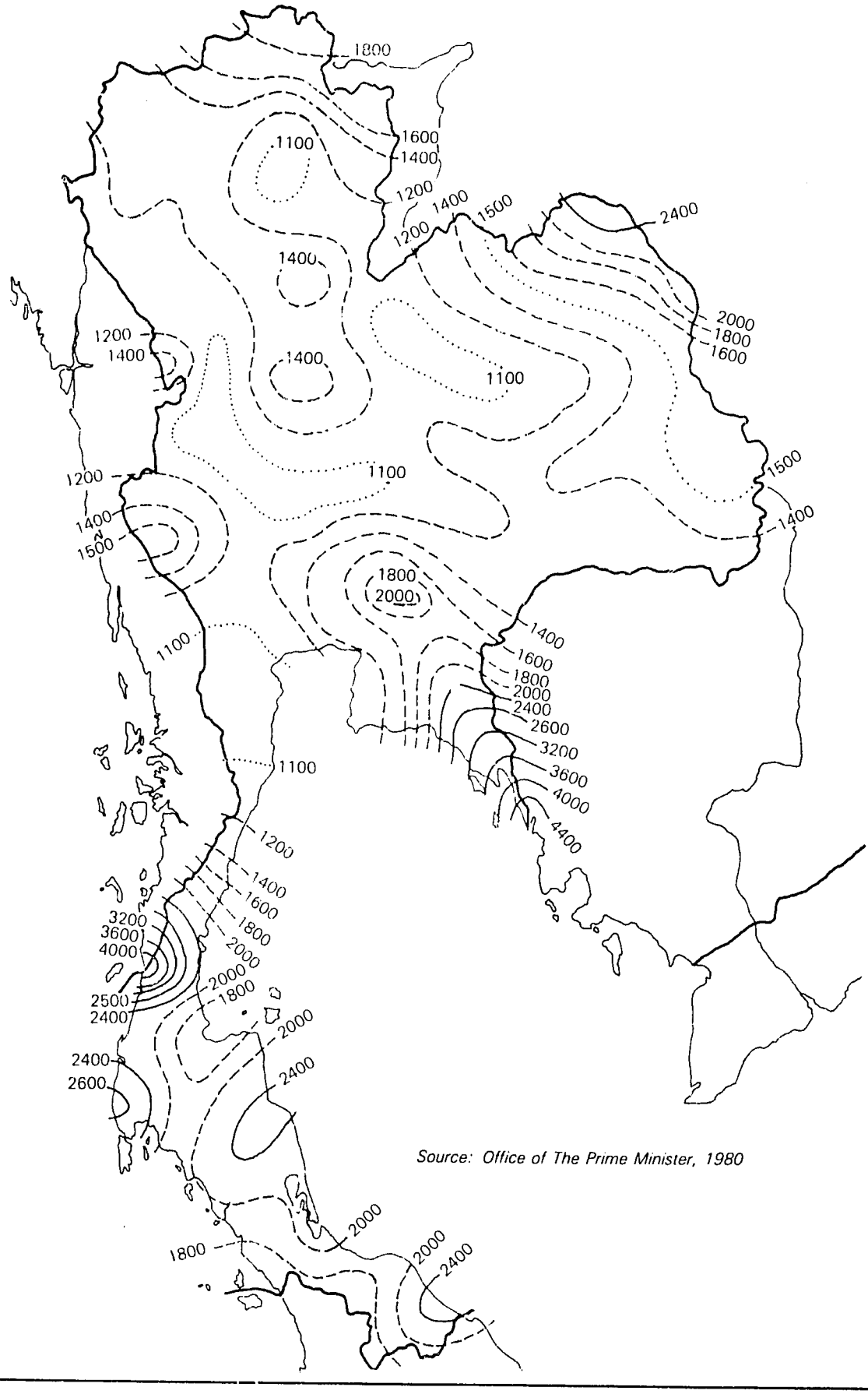
This first section presents an inventory of Thailand's water resources, including the amount and availability of surface water and groundwater, and discusses the present status of water resources development in Thailand. The characteristics of major regions of the country are presented along with a discussion of the significance of water resources to the regional economy.

Surface Water

Thailand has a total area of 513,115 square kilometers. The average annual rainfall is about 1,550 millimeters. The average volume of rainfall is about 800 billion cubic meters annually. However, the rainfall is not evenly distributed throughout the country (see Figure 3.1). The Southern region receives the highest rainfall while the Northern and Central regions receive the lowest. The distribution of rainfall for each region is shown in Table 3.1. After subtracting losses, such as evaporation and infiltration, the average total surface runoff is about 171,206 million cubic meters (MCM). The regional distribution of surface runoff is shown in Table 3.2.

With the exception of the Southern region, approximately 85 percent of the rain falls during the rainy season, i.e., from May to October. During this period, the Northeastern, Northern and Central regions are under the influence of the southwest monsoon. In general, September is the month with the highest rainfall. In the Southern region, the influence of the northeast monsoon is more important because it causes high intensity rainfall from October to January. Over 50 percent of the annual rainfall may occur in this period. Between May and September the southwest monsoon has only a weak influence on the Southern region, particularly on the eastern side of the peninsula.

Figure 3.1 Average Rainfall Distribution from 1951 to 1975



Source: Office of The Prime Minister, 1980

Table 3.1 Annual Rainfall Volume in Each Region of Thailand

Region[a]	Average Annual Precipitation (mm)	Area (km^2)	Rainfall Volume (MCM)
Northeast	1,400	168,854	236,400
North	1,300	169,644	220,500
East	2,100	36,503	76,700
Central	1,350	67,399	91,000
South	2,400	70,715	169,700
Total		**513,115**	**794,300**

Note a The categorization of different regions is based on compiled statistics on water resources available in related governmental agencies.

The most important and the largest river basin in Thailand is the Chao Phraya Basin. It originates in the mountain ranges in the north and covers nearly all the areas in the Northern and Central regions. The major tributaries are the Ping, Wang, Yom and Nan rivers. Their confluence occurs at Nakhon Sawan, about 200 kilometers north of Bangkok, forming the Chao Phraya. The Pa Sak joins the Chao Phraya River at about 55 kilometers north of Bangkok. The basin has a drainage area of 178,000 square kilometers. The average annual runoff at the river mouth is 30,300 million cubic meters, or 170 millimeters in terms of depth. (The volume of water is sometimes expressed as depth of water over the basin area it covers.) The majority of agricultural products are produced in this basin.

The second important river basin is the Maeklong Basin. The two main tributaries, the Quae Yai and the Quae Noi, originate in the mountain range in the west, near the Burmese border, and join together to form the Maeklong River some 80 kilometers from the Gulf of Thailand. The drainage area is 33,000 square kilometers. The average annual runoff is 13,400 million cubic meters, or 406 millimeters of depth. This basin has the highest potential in terms of water resources development, since it has much more water than would ever be needed by the land resources in the basin.

In the Northeastern region, the major river basin is the Mun Basin. There are two major rivers in the basin, the Nam Chi and Nam Mun. Both rivers originate in the mountain range separating the Central and Northeastern regions. The Nam Chi joins the Nam Mun at Ubon Ratchathani, flowing eastward into the Maekhong River. The total drainage area is 119,573 square kilometers. The average annual runoff is 28,575 million cubic meters, or the equivalent of 238 millimeters of depth.

In the other regions, the major river basins are the Bang Pakong Basin in the East, the Maekhong and the Salawin basins in the North, and the Tapi and Pattani basins in the South. Table 3.3 shows the typical flows of some of the major rivers in the country. Recently, there has been an attempt to standardize the classification and delineation of the river basins into major basins and sub-basins. This is being carried out by the Project Planning and Investigation Department of the Electricity Generating Authority of Thailand (EGAT) as part of the Water Resources Information Systems for Thailand (WRIST) project. There are 25 major river basins in the country, as listed in Table 3.4. The basin codes in the table are ordered from north to south.

Groundwater

Groundwater resources exist throughout the country. However, the quantity and quality of groundwater vary according to local hydrogeological conditions. Usually, large and high-yielding aquifers occur in alluvium and terrace deposits. To a lesser extent, groundwater also exists within crack formations in limestone, sandstone and some types of shale. According to Piancharoen (1982),the groundwater resource in each physiographic province of Thailand can be summarized as follows:

a) The Northern Highlands

Major aquifers are the alluvium and older terrace deposits of the basins of Chiang Mai, Lampang, Mae Chan and Phrae. Generally groundwater is shallow in alluvium deposits. Typical yields from shallow drilled wells are in excess of 25m³/hrs, with no more than 10 meters of drawdown. Deeper wells

Table 3.2 Number and Amount of Surface Water Sources in Thailand

Region	River		Reservoir		Natural Storage	
	Number	Volume (MCM)	Number	Volume (MCM)	Number	Volume (MCM)
Northeast	3	26,558.00	552	6,230.69	1	193.00
North	6	23,175.00	44	48,723.00	1	34.00
East	6	29,720.00	27	18,780.85	1	156.00
Central	3	3,747.00	19	332.68	-	
South	2	6,795.00	6	6,708.00	1	53.20
Total	**20**	**89,995.0**	**648**	**80,775.22**	**4**	**436.20**

Note Total volume of water 171,206.42 MCM
Source: Kiravanich (1983), p. 5.

drilled to a depth of 50 meters can yield up to 50 m^3/hr. Wells penetrating older terraces, at depths exceeding 200 meters, yield 150-200 m^3/hr with about 30 meters of draw-down. The quality of groundwater is good both for drinking and agricultural purposes.

b) The Upper Central Plain

The alluvium aquifers in the upper Central Plain are situated under the flood plains of the Ping, Yom and Nan rivers. The aquifers can be located up to a maximum depth of 60 meters and yield about 10-70 m^3/hr of potable water. The older terrace aquifer is the most potentially significant groundwater resource in this area. It is concealed under the lower terrace deposits in the northern and western sides of the plain, and under the alluvium deposits in the plain's central area. The thickness of the aquifers ranges from 200 to 300 meters. Wells drilled in the valleys of minor streams in the northwest and the west yield less than 30 m^3/hr, while those in the many productive zones in the north, central area and west yield in excess of 250 m^3/hr of good quality water.

c) The Lower Central Plain

This region consists of flood plains of the Chao Phraya River, the Tha Chin River and their tributaries. It also includes the Bang Pakong River Basin. The area is about 150 kilometers in width and 200 kilometers in length. There are eight principal artesian aquifers in the upper 650 meters, with the upper two aquifers extending to a depth of about 120 meters. All aquifers are productive. Yields of 300 to 400 m^3/hr are quite common. However, the amount of groundwater being extracted far exceeds the safe yield in Bangkok and adjacent provinces. As a consequence, these areas experience land subsidence and flooding problems.

d) The Khorat Plateau

The Khorat Plateau in the Northeast is the most arid region in Thailand. There is a shortage of water for agriculture and domestic purposes for at least six months of every year. The upper Khorat aquifer lies under the highly populated areas. More than 90 percent of wells drilled in the flood plain yield salty water. In areas of higher elevation, yields of 5-50 m^3/hr of fresh water may be obtained from wells about 60 meters deep. Most of the wells produce water with a high sulfate content.

In the vicinity of the Phu Phan Range, the lower Khorat aquifer can produce good quality groundwater from a depth of 30-60 meters at a pumping rate of 5-25 m^3/hr. On the western side of the plateau, the yield from a carbonate aquifer is in the range of 10-100 m^3/hr of good quality water. In some areas in the northwest, a yield of up to 20 m^3/hr can be expected. The alluviums of the rivers Chi and Mun are small in size and no more than 50 meters in thickness, yielding less than 25 m^3/hr. The alluvium of the Maekhong River can extend 5-10 kilometers from the river bank and normally yields up to 100 m^3/hr, at an average depth to bedrock of about 40 meters

e) The Maeklong Basin

The upper part of the basin is mountainous and is traversed by the Quae Yai and Quae Noi rivers. The flood plain, from the confluence of the two rivers to the Gulf of Thailand, forms the lower part. Groundwater in the lower part of the basin is similar to that in the lower Central Plain. There is an alluvial plain along the Maeklong River which forms a shallow unconfined aquifer. Villagers have been able to construct jetted wells (wells which are "jetted" into the ground as opposed to "drilled") for agriculture for about two decades. The pumping rate from the jetted wells can be as high as 40 m^3/hr.

Table 3.3 Mean Annual Flow of Some Major Rivers

River	Gauging Station[a]	Catchment Area (km^2)	Flow Volume (MCM)
Mae Kok	Ban Tha Kok, Chiang Rai	10,300	5,500
Mae Ing	Therng, Chiang Rai	5,400	2,200
Chao Phraya	Nakhon Sawan	110,570	24,200
Sakaerung	Uthai Thani	3,250	550
Pa Sak	Saraburi	14,500	2,400
Mun	Phibulmungsahan, Ubon	115,690	28,500
Songkhram	Seka, Nong Khai	4,650	500
Maeklong	Kanchanaburi	26,450	12,300
Phetchaburi	Phetchaburi	4,190	1,050
Bang Pakong	Kabinburi, Prachinburi	7,500	3,900
Rayong	Ban Khai, Rayong	1,255	470
Khlong Yai	Trad	920	1,560
Lang Suan	Chumpon	1,240	1,780
Ta Pi	Surat Thani	6,200	11,000
Trung	Trung	1,800	1,330
Pattani	Yala	3,300	2,450

Note: a. Guaging station does not necessarily cover the whole basin area.
Source: Unpublished data from EGAT.

Table 3.4 Major Basins and Their Standard Codes

Basin code	Basin Name
01	Mae Nam Salawin
02	Mae Nam Khong
03	Mae Nam Kok
04	Mae Nam Chi
05	Mae Nam Mun
06	Mae Nam Ping
07	Mae Nam Wang
08	Mae Nam Yom
09	Mae Nam Nan
10	Mae Nam Chao Phraya
11	Mae Nam Sakae Krung
12	Mae Nam Pasak
13	Mae Nam Tha Chin
14	Mae Nam Maeklong
15	Mae Nam Prachin Buri
16	Mae Nam Bang Pakong
17	Tonle Sap
18	East Coast Gulf
19	Mae Nam Petchaburi
20	West Coast Gulf
21	Peninsula-East Coast
22	Mae Nam Tapi
23	Thale Sap Songkhla
24	Mae Nam Pattani
25	Peninsula-West Coast

f) The Peninsula

The principal groundwater resources of the coastal plain occur on the eastern side of the peninsula. The plain is about 450 kilometers long, from Nakhon Si Thammarat to Narathiwat, and about 22 kilometers in average width. The yield from production wells is in the range of 10 - 200 m^3/hr.

g) The Eastern Provinces

The Eastern provinces have the least groundwater potential of all the regions in the country. Wells drilled in alluvium and terrace deposits yield only 7-10 m^3/hr of potable water. The limestone aquifer near the Kampuchean border yields about 10-20 m^3/hr.

Present Status

The present status of water resources development in Thailand can be gauged from the data for existing projects. According to the Royal Irrigation Department (RID), there were 4,039,595 hectares of irrigation projects that were either completed or under construction in 1984, and 3,464,979 hectares of irrigated area (large, medium and small-scale projects) throughout the country. Table 3.5 lists details for each river basin. Table 3.6 provides a summary of large and medium-scale irrigation projects completed and under construction by the RID in 1984, while Figure 3.2 shows the main areas of irrigation in Thailand.

On the hydropower front, as of January 1985, a total generating capacity of 1,998 MW was operational, with an additional 240 MW under construction. The completed projects and those under construction are shown in Figure 3.3. The National Energy Administration (NEA) has, to date, constructed 23 microhydropower projects throughout the country. Their total capacity is 1,123 kW. Twelve more projects were to be completed in 1985.

Under the National Potable Water Scheme, a total of 22,361 serviceable wells had been drilled up to September 1985 (information from the Groundwater Section of the Department of Mineral Resources). It is estimated that about 880 million m^3/yr of groundwater was abstracted in 1984. Of that amount, approximately 475 million m^3/yr was used for domestic and industrial water supply in Bangkok and adjacent provinces. The budget for groundwater development during the Fifth National Economic and Social Development Plan (1981 - 1986) totaled 1.3 billion baht. The National Economic and Social Development Board (NESDB) has estimated that 6 billion baht was spent on small-scale water resources development by various authorities in 1985. For the same period, 12.7 billion baht were allocated for large and medium-scale water resources development projects.

At present, 17 committees plus 31 agencies from eight ministries are involved in water resources development projects. The majority of the projects, however, are carried out independently. It is therefore difficult to determine the exact status of development. The NESDB has estimated that from 1928 to 1983 the government invested 402.6 billion baht in large and medium-scale projects alone. The figure is based on the 1984 present worth value, with a 10 percent interest rate.

Regional Characteristics

The Northern region of Thailand contains about 26 percent of the population of the country. It consists of mountain ranges with flat plains, interspersed between mountains and hills. It includes the Chiang Mai, Maekhong , Lampang, Phrae and Uttaradit basins. The lowlands constitute only 10 percent of the total area. The regional rainfall is dominated by the southwest monsoon, and is quite reliable compared to other regions, averaging 1,300 millimeters per annum. The temperature is influenced by the altitude, but is low enough for growing temperate fruits and vegetables in the highlands. The soils have good internal drainage and can facilitate irrigated upland crop production. Slash and burn shifting cultivation has increased the flooding in the wet season and there are water shortages in some areas in the dry season. It can be said that the water resources of the region would be most abundant if they did not have to be used to provide water for the Central region, the most important region in terms of economic development. The ever-increasing water requirement in the Central region puts a major constraint on the expansion of irrigated areas in the Northern region.

The Northeastern region covers about 30 percent of the total area of Thailand, and also contains 30 percent of the population. The river basins of the Mun and Chi occupy two-thirds of the region. The bulk of this area is a raised

Table 3.5 Irrigation Projects in Thailand Completed in 1983 and Under Construction in 1984 by River Basin

River Basin	Completed and under Construction (hectare)	Completed area (hectare)	Completed area %
Salween	14,726	12,798	0.37
Maekhong			
Mun	266,797	200,192	5.78
Chi	217,488	161,253	4.65
Other tributaries	219,790	186,101	5.37
Maekhong Subtotal	718,801	560,344	15.80
Chao Phraya			
Ping (upstream of Bhumiphol)	180,102	158,406	4.57
Ping (downstream of Bhumiphol)	123,424	98,448	2.84
Wang	44,088	39,680	1.15
Yom	112,149	93,805	2.71
Nan	242,284	217,076	6.26
Pa Sak	22,816	20,336	0.59
Sakae Krung	75,392	59,296	1.71
Chao Phraya project	1,165,280	1,159,040	33.45
Lower Chao Phraya tributaries	116,504	105,704	3.05
Chao Phraya Subtotal	2,082,039	1,951,791	56.33
Bang Pakong	230,030	221,790	6.40
Maeklong	451,008	277,344	8.00
Petchaburi	57,942	57,030	1.65
Pranburi	43,902	41,902	1.21
Southern Region			
East Coast	376,978	294,178	8.49
West Coast	29,248	24,693	0.71
Southern Region Subtotal	406,226	318,871	9.20
Eastern Coast	40,316	31,360	0.91
Khmer Lake	9,331	4,547	0.13
Grand Total	**4,039,595**	**3,464,979**	**100.0**

Source: RID. 1985. "Water Resources Development in Thailand (completed to the end of 1983 and under construction in 1984)." Program Coordination and Budget Division, Statistics and Progress Report Section, April.

plateau, some 100-200 meters above sea level. The topography is moderately rolling. Though the region has an annual average rainfall comparable to other regions, there is a severe shortage of water during the dry season and the rainfall pattern is the least reliable of all the regions. Flooding in the wet season and water shortages in the dry season are common phenomena. To aggravate the water shortage situation, the majority of groundwater wells yield either brackish or salty water. The soils of the region have poor water-holding capacity and lack plant nutrients. The heavy alluvial soils in the flood plain of the major rivers account for only 8 percent of the total area. The water resources in this region are not well regulated, due to an inadequate number of storage reservoirs and distribution systems.

The Central region is both the most populous and most prosperous region of Thailand. Nearly all the areas are flood plains and lowlands suitable for rice production. It is estimated that there are about 4.4 million hectares of agricultural land in this region and the irrigation systems, which are the most extensive in Thailand, constitute almost 25 percent of the total irrigated area in the country. There are two major river basins, the Chao Phraya and the Maeklong. Most of Thailand's industry is also located in this region. The water requirement for the Central region is increasing rapidly, due to industrialization and the increase of dry season crop production. Because of the flat terrain in the southern part of the region, the Central region is subject to regular flooding, especially in Bangkok and adjacent provinces. Furthermore, saltwater intrusion in the coastal areas and the abstraction of groundwater in excess of the safe yield also aggravate the problems of this region.

The Eastern region consists of provinces along the eastern shore of the Gulf of Thailand, between Chonburi province and the Kampuchean border. The Khao Yai National Park constitutes the northern border of the region. The average annual rainfall is high, at 2,100 millimeters. The important basins here are the Bang Pakong and the Rayong basins. Large flat plains form the eastern part of the region. Generally there is no shortage of water, except in some coastal areas where there

Figure 3.2 Irrigation and Water Resources Development in Thailand

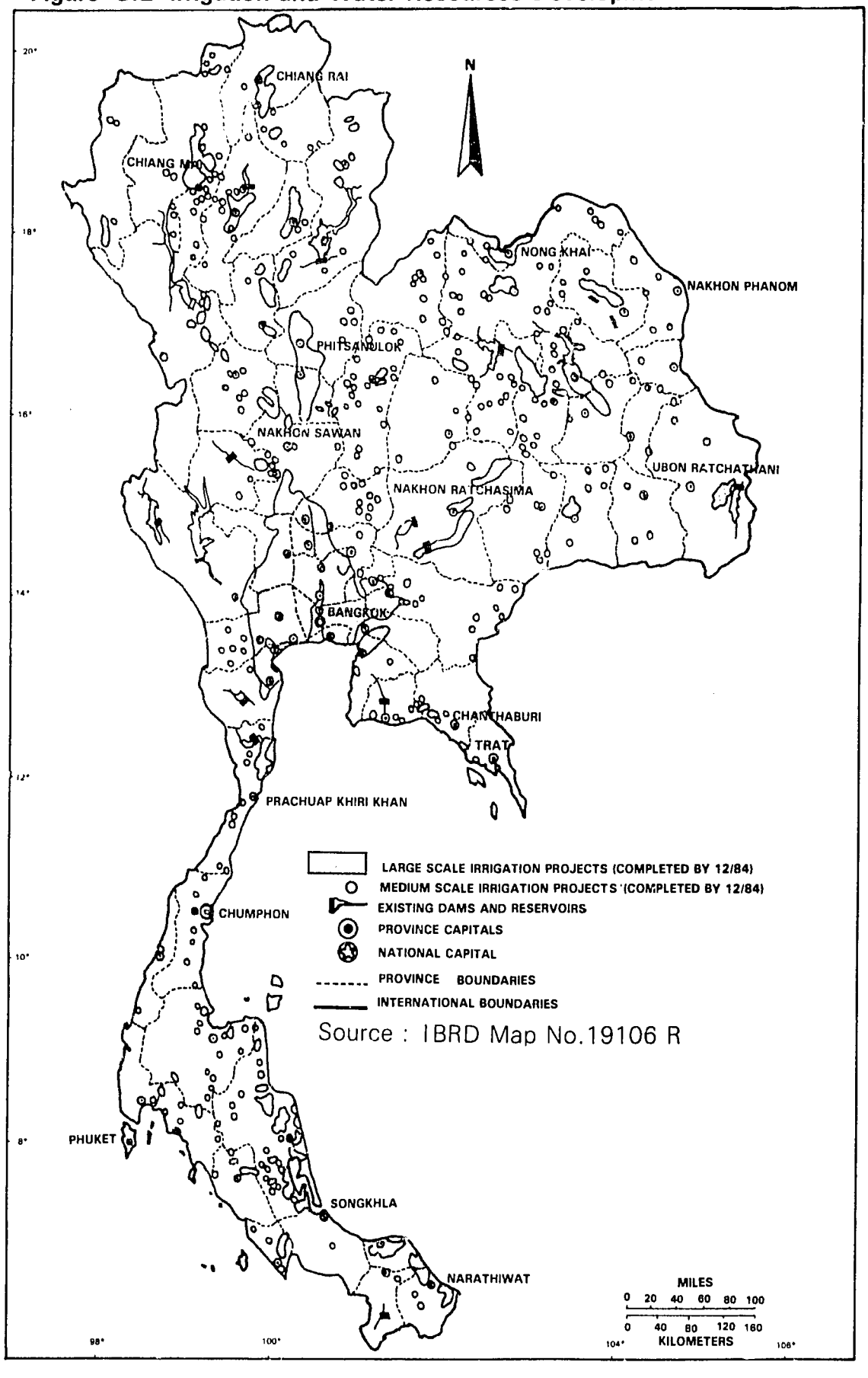


Figure 3.3 Hydropower Potential in Thailand

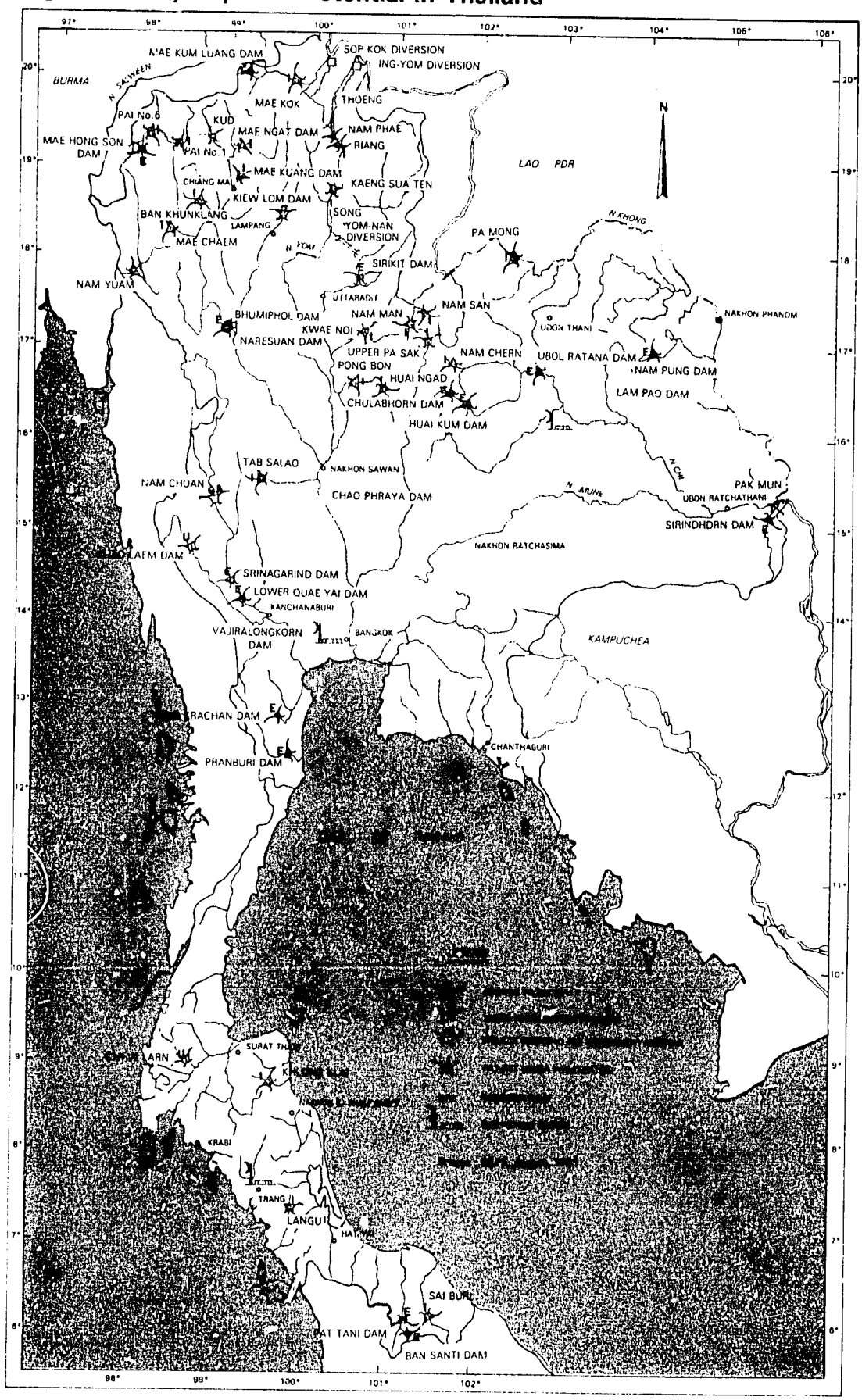


Table 3.6 Summary of Large and Medium-Scale Irrigation Projects Completed and Under Construction in 1984

Type of Projects	Unit	Completed	Under Construction
Storage by dams and reservoirs	$10^6 m^3$	27,772.20	1,631.40
Irrigation, drainage, flood protection, land reclamation	ha	2,918,378	471,303
Ditch/Dike structures	ha	1,241,177	75,696
Land consolidation	ha	118,889	14,727
Pumping for rice paddy in 1983			
Wet season crop	ha	99,349	
Dry season crop	ha	107,518	
River works	km	543	

Source: RID 1985 "Water Resources Development in Thailand (completed to the end of 1983 and under construction in 1984)." Program Coordination and Budget Division, Statistics and Progress Report Section, April.

have been rapid increases in industrialization, in addition to a high population density.

The Southern region is a peninsula, bounded by the Andaman Sea on the west and the Gulf of Thailand on the east. There is a series of mountain ranges stretching north to south over the entire peninsula. The rivers in this region are short and steep. The average annual rainfall is about 2,400 millimeters. The rainfall intensity tends to be on the high side, which causes drainage problems, and flooding occurs frequently. The river basins of significance are the Tapi, Phum Duang and Pattani basins, which have all been well developed. The coastal plains consist of beaches, swamps, or brackish alluvium unsuitable for crop production.

Significance of Water Resources to the Regional Economy

Agriculture plays the most important role in the economy of all regions, except Bangkok. The World Bank (1984) estimated that, in 1980, 45 percent of the GDP of the North and Northeast regions came from agriculture, compared to the national average of 26 percent. There are many suitable sites for the development of medium and small-scale hydropower projects in the North. In some areas in the upper North, double cropping or even triple cropping is practiced. Because of the intensity and diversity of cropping in the North, there are many irrigation projects which are well developed and organized. Groundnut, soybean, tobacco and garlic are major crops in the North, where irrigation is dependable. Upland crops, such as fruit and vegetables, also significantly contribute to the regional income of the North.

As in the Northern region, the value added in agriculture of the Northeastern region is about 45 percent. However, the Northeast has the lowest rice yield per unit area (1.2 ton/ha for rainfed paddy and 2.6 ton/ha for irrigated paddy). Out of the total cultivated area of four million hectares, only 190,000 hectares are served by the seven largest reservoirs in the region (Plusquellec and Wickham, 1985, p.32); thus, the majority of paddies are rainfed. The sandy soils and difficult terrain put a serious constraint on the performance of irrigation systems. Since they can only serve a small proportion of the cultivated area, usually near the reservoir and along the banks of rivers, groundwater is an important resource for agriculture and water supply. At present there are 24,566 usable boreholes, supplying a total of around 310,000 m^3/day (Ramnarong, 1985b). Land used for cassava production now accounts for two-thirds of the region's farm cash income.

The heavy clay soils and the flat terrain of the Central Plain are favorable factors for extensive rice production. The region has the largest irrigated area, approximately 25 percent of the total irrigated area of the country, and the highest yield for irrigated rice (3.9 ton/ha). For comparison, the 1983 yields reported for other countries were 3.09 ton/ha for Burma, 3.77 for Indonesia, 2.47 for the Philippines, 2.86 for Malaysia, 6.19 for South Korea and 5.70 ton/ha for Japan. The average yield for Thailand in 1983 was 2.04 ton/ha (MOAC, 1986). The increased rice production in the Central Plain has resulted from farmers switching to high yield dry season cropping, especially in irrigated areas. Sugar cane is also grown extensively in this region.

The importance of water to the Central Plain is paramount. In the rainy season, the region is usually affected by

too much water. Nearly all areas are inundated to some degree, due to the flat terrain and inefficient drainage capacity. In the dry season, the region depends on water received from the Northern region. Almost all farmers in the southern part of the region grow dry season rice, which is more profitable than wet season rice. However, because of the limited water resource, only 35 percent of the irrigable area in the Greater Chao Phraya Project has adequate water for irrigation in the dry season. This is in great contrast to the Maeklong project, where water resources are in excess of demand; about 70 percent of irrigable land has adequate irrigation in the Maeklong Basin. According to the NESDB, the 1983 GDP per capita in this region, excluding Bangkok, was 24,002 baht compared to 12,441 baht in the North; 7,146 baht in the Northeast; 16,148 baht in the South; 51,441 baht in the Bangkok Metropolitan Area; and 18,770 baht for the country as a whole.

The Southern region has the highest average rainfall. The availability of water is not a problem in this region, except in a few isolated pockets. On the contrary, the most striking problem related to water resources is flooding. This is caused by the steep slopes, the short streams and the high rainfall intensity. The region is not a major rice producing area, due to unsuitable soils and topography. According to the Agricultural Statistics of Thailand, Crop Year 1984/85 (MOAC, 1986), rice paddy constitutes only 34.5 percent of the total farm holding land, while fruit tree and tree crops make up 56.4 percent (1983 data). About 23 percent of the land of the region is forest. This region ranked third in terms of GDP per capita in 1983, behind Bangkok and the Central region. The bulk of its income comes from rubber, timber and tin mining. Water resources play a less important role in the regional economy compared with other regions. The primary goals of water resources development here are hydropower production, flood prevention, domestic water supply and the prevention of saltwater intrusion. Major water resources development projects include the Pattani Dam, Ban Santi Dam and Chiew Larn Dam.

Bangkok is the center of commerce and industry. The population has grown from one million in 1953 to about six million today. The total urbanized area is about 500 square kilometers. This represents more than half the urban population and 10 percent of the total population of the country. Bangkok faces problems of both too much and too little water. Flooding occurs frequently in the wet season due to low average ground level, high tide and inadequate drainage (See Box 3.1). The Metropolitan Water Works Authority (MWWA) is unable to supply water to meet all domestic and industrial demand. As a result, in the outskirts of Bangkok, and especially on the city's eastern side, private and industrial abstraction of groundwater exceeds the safe yield of the aquifer. This accelerates the rate of land subsidence which, in turn, aggravates the problem of flooding. NESDB has estimated that the damage to property caused by the 1983 flood alone was 6.6 billion baht. It is difficult to estimate the damage to intangible items, such as loss of business, loss of working hours, and human stress and hardship, but it can be said that its magnitude is very high.

3.2 HISTORICAL DEVELOPMENT AND EMERGING TRENDS

It is not clear when water resources development actually began in Thailand. However, characteristically, Thailand's water resources development can be divided into three main categories, namely, irrigation, hydropower and groundwater.

Irrigation

Evidence exists to indicate that the first reservoir was built about 700 years ago, during the reign of King Ramkhamhaeng in Sukhothai. Systems of diversion weirs and canals were also built in the state of Lanna Thai in the North, under the suzerainty of Phraya Mengrai, the founder of Chiang Mai. The first storage irrigation system in the Central region was built around 1633, in the Ayutthaya Dynasty.

In modern times, water resources development can be said to have begun about 80 years ago, during the reign of H.M. King Rama V. His Majesty gave concessions to a private company, called Khu Na Siam, to build canals, locks and gates in Thung Rangsit. The purpose was to keep water in the canals and to drain the paddy in times of flood, specially towards the end of the cropping season. In addition, the canals also served as inland waterways for transportation. This network is still being maintained by the Royal Irrigation Department (RID).

The RID was established in 1903 by H.M. King Rama V. It was first called the Khlong (Canal) Department. Its main responsibility was to maintain inland waterway transportation and to plan irrigation projects to aid cropping in the Central Plain. The first Director- General of the RID was a Dutch irrigation engineer named J. Howan van de Heide, from Indonesia. The project to build a barrage across the Chao Phraya River at Chai Nat, to divert water for irrigation, was first suggested during this period. But the project was deferred indefinitely, due to its high cost. In 1912, the name of the department was changed to Thang (Passage Way) Department.

Two severe droughts occurred in 1911 and 1914, early in the reign of H.M. King Rama VI. Sir Thomas Ward, an irrigation engineer from India, was commissioned to review the Chai Nat project. It was concluded that the original proposal was appropriate, but nothing further happened. The name of the department was later changed to Thod Nam (Water Diversion) Department and finally it became the Royal Irrigation Department (RID) on 21 March 1927, during the reign of H.M. King Rama VII. In the early days, the RID was responsible for water conservation, irrigation, drainage, land reclamation, flood control, hydropower, inland navigation and river training.

The first project carried out in modern times by the RID involved the construction of a diversion dam, called the Rama

Box 3.1 Water: An Abundant Resource?

The fact that Thailand receives something like 800 billion cubic meters of rainfall a year suggests that water is unlikely to be in short supply. However, some 85 percent of that rainfall comes in the rainy season, from May to October. In the south of the country, meanwhile, over 50 percent of the annual rainfall may come between October and January. The main problem here is not a shortage of water, but flooding. So Thailand's relatively abundant rainfall is concentrated both in time and in space. Some regions of the country, in short, get more than others.

The Southern region receives the highest rainfall, while the Northern and Central regions receive the lowest. Indeed, the South receives almost twice as much rain as do either the North or Central regions. Nonetheless, Thailand's largest river basin, the Chao Phraya Basin, originates in the north and covers virtually all of the North and Central regions, draining a total of some 178,000 square kilometers. Most of Thailand's agricultural products are grown in this one basin.

Thailand has made increasing use of its water resources. The country's first reservoir was built some 700 years ago and irrigation has since become an essential component of the country's agricultural economy. Even so, there are significant water shortages in some regions. The Central region, for example, suffers from a paradox: many areas are inundated in the rainy season, but in the dry season very considerable volumes of water have to be imported from the Northern region. Only 30 percent of the irrigable area covered by the Greater Chao Phraya Project has adequate irrigation in the dry season, in contrast to the situation in the Maeklong Basin, also part of this region, where about 70 percent of potentially irrigable land is adequately irrigated.

Water demand is increasing rapidly in the Central region, which is the most populous and prosperous region in Thailand, due to the pace of industrialization and the growing area devoted to dry season crop production.

Inevitably, there is growing competition for water resources, both within and between regions. Water demand grows constantly, while the actual amount of water available is relatively static. Agricultural, industrial, urban and inland waterway transportation users all want more water and increasingly compete for existing water resources. Unfortunately, most of the obvious reservoir sites have already been used, with many of the remaining sites either found in densely populated areas or in environmental conservation areas.

Clearly, Thailand needs to adopt a more coordinated approach to water resources management. Yet, as this chapter shows, a very considerable number of different government agencies have overlapping—and in some cases competing—objectives in this area. Increasing friction between water users will only be avoided if Thailand can move towards comprehensive planning and the integrated management of its water resources.

There is an increasingly urgent need, for example, for master plans covering groundwater exploitation and interbasin water transfers. More also needs to be done to transfer responsibility for the maintenance of irrigation systems from the Irrigation Department to the farmers who use—and sometimes abuse—these systems. The developing water shortages in certain regions will need to be tackled, with growing interest in groundwater resources and further interbasin transfers, but there is also a need for more work designed to improve the efficiency of water use in various sectors of the economy. Many farmers, for example, continue to think of water as a free, virtually unlimited resource, whereas the facts increasingly suggest otherwise.

VI Dam, on the Pa Sak River, at Tha Luang in Saraburi province, and the excavation of the Rapheephat canal. Its purpose was to divert water for rice paddy in the provinces of Saraburi and Ayutthaya, and thence to Thung Rangsit, to join the canal system. Construction began in 1915 and was completed in 1924. After that, 20 more irrigation projects were constructed during the period of the Great Depression and World War II. The Chai Nat project was reconsidered once again after the war. This time, the construction of the project went ahead in 1952, financed by a US $18 million loan from the World Bank. The project was completed in 1957 and was the largest irrigation project in east Asia at that time. The barrage at Chai Nat was named the Chao Phraya Dam.

The RID was also responsible for the construction of the Bhumiphol Dam, on the Ping River in Tak province. It was the first multipurpose dam with large-scale hydropower generation in Thailand. The dam was completed in 1964. Another similar project, the Sirikit Dam on the Nan River, was completed in 1971. These two projects enabled the RID to control about 22 percent of the flow into the Chao Phraya Basin. It should be noted that the Electricity Generation Authority of Thailand (EGAT) took over the responsibility for hydropower development from the RID in 1969.

Throughout the Fourth and the Fifth National Economic and Social Development Plans (1977-1981, 1982-1986) the emphasis of water resources development by the RID has shifted towards small-scale projects, to spread the benefit over all areas of the country, as a greater priority has been given to water development in low income areas.

Hydropower

Since the beginning of the First National Economic and Social Development Plan in 1960, the country's energy requirements have increased tremendously, from 1.6 million tons of oil equivalent (TOE) in 1960 to 18 million TOE in 1983. Approximately 75 percent of Thailand's energy currently comes from petroleum products.

Hydropower, meanwhile, has also played an important role. EGAT was entrusted with the responsibility for power production, and in 1969 became responsible for nearly all hydropower development in the country. Although hydropower requires a costly investment (about 7,400 baht/kw compared to 3,500 baht/kw for thermal generation or 2,300 baht/kw for gas turbine and diesel generation), the operating cost is much lower. It is estimated (based on 1985 prices) that hydropower costs 0.50 baht/kWh, while thermal power costs 1.10 baht/kWh. Another benefit is that hydropower is a renewable energy resource.

Large hydropower projects have been constructed continuously since the completion of the Bhumiphol Dam, which has an installed capacity of 535 MW. Examples of other projects are the Sirikit Dam, with an installed capacity of 375 MW, and the Srinagarind Dam, with an installed capacity of 360 MW. The latest large-scale project, which has been operational since mid-1985, is the Khao Laem Dam. This has an installed capacity of 300 MW. At present, hydropower accounts for approximately 22 percent of EGAT's total power output.

In addition to EGAT, the National Energy Administration (NEA) and the Provincial Electricity Authority (PEA) have been active in carrying out minihydropower and microhydropower projects. These are projects which have an installed capacity of less than 6 MW per project. The rationale for these projects is to provide electricity to outlying areas in the country. In general, the construction of transmission lines to small communities which are far away from the power grid network involves very costly capital investment. In some geographically suitable areas, the provision of a small weir and a generator with a capacity of 10-200 kW costs much less than a transmission line, while the hydropower generated is sufficient for domestic use in the community. This is an important avenue through which development can reach people who are remote from urban areas. In most cases, the community participates in the construction and maintenance of such projects.

Groundwater

The utilization of groundwater for domestic water supply began in Bangkok as early as 1914. At that time, bamboo rigs were used for drilling and were operated by the private sector. Government involvement in groundwater development at a national scale started in 1955. The Department of Mineral Resources (DMR), through its Groundwater Division, started a groundwater investigation program with the help of the United States Geological Survey (USGS). The goal was to provide groundwater for domestic water supply and sanitation for the Northeastern region, where a shortage of water is always critical for at least six months of the year. In 1965 the investigation was expanded to cover all regions of the country. In 1969, the Metropolitan Water Works Authority (MWWA) began a study focusing on the groundwater resources of the Bangkok Metropolitan Area. The RID has also frequently commissioned consulting firms to undertake studies of groundwater resources for irrigation projects, with the most significant study being that of the Yom Basin, carried out in 1971.

The DMR began using geophysical survey techniques in its groundwater investigation program in 1962. The results of these investigations have been compiled and hydrogeological maps have been published, e.g., the *Hydrogeological Map of Northeastern Thailand*, published in 1975. Maps for other regions have also been published. The *Hydrogeological Map of Thailand was* published by the DMR in 1983. The enormous amount of data collected is being computerized in order to establish a groundwater data center.

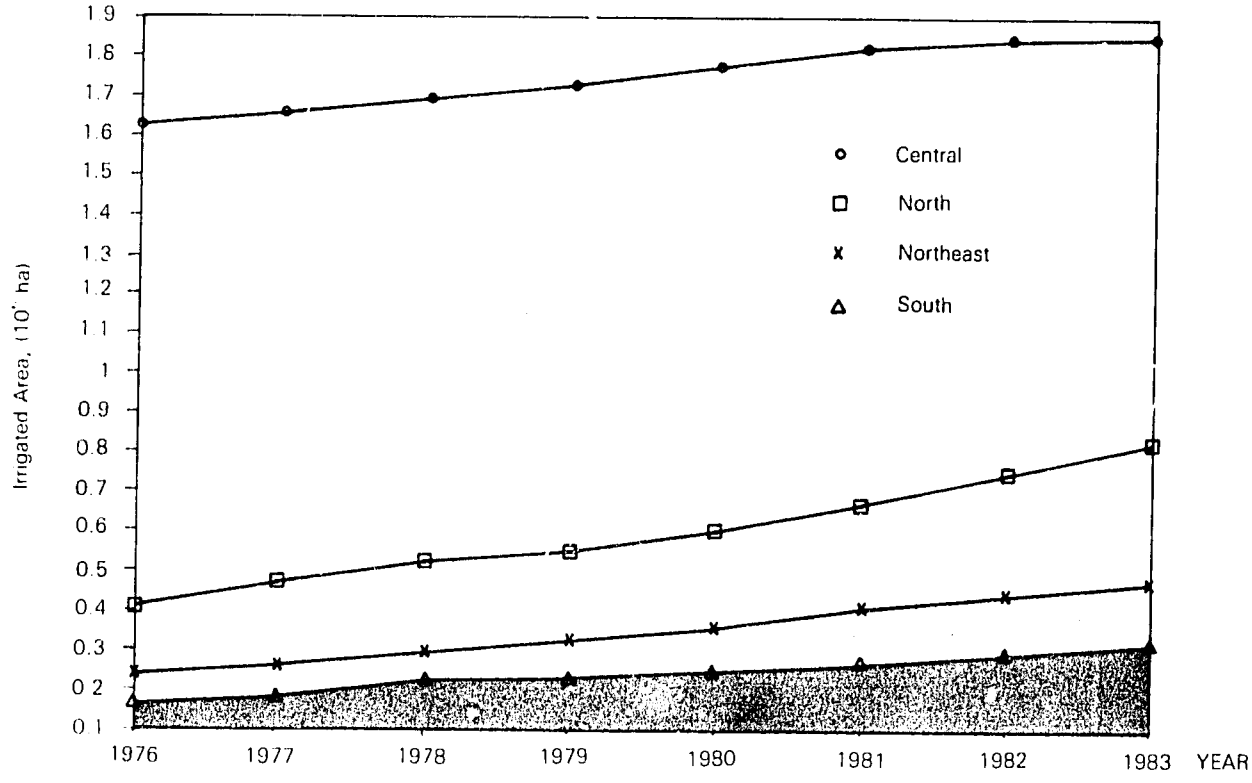
Projected Future Trends

Up until recently, water resources in Thailand have been abundant and in excess of the need for water utilization. Development in the past has gone full steam ahead, subject only to limitations of budget. Since the country has become more industrialized and the population has increased rapidly, the need for water has grown, while the amount of water available has remained roughly constant. This has given rise to problems resulting from conflicts over water use between various sectors, such as agriculture, domestic consumption, hydropower, flood protection and inland waterway transportation. Another noticeable problem is that nearly all the suitable sites for large scale projects, especially storage reservoirs, have already been exploited. The remaining undeveloped potential sites are either in the heavily populated areas or in the national park reserves. This poses difficulties for the development of large-scale projects, either in terms of population resettlement or environmental conservation. A prime example is the proposed Nam Choan project (See Box 5.3, Chapter 5), which has been the center of conflict between developers and conservationists. It is increasingly obvious that there will be less scope for the development of such large-scale projects in the future.

Irrigation

From the agricultural sector's point of view, the most developed irrigation systems are found in the Central Plain. The irrigated area in the Central region in 1983 covered 1,854,965 hectares, compared to 823,994 hectares in the North, 473,950 hectares in the Northeast, and 318,742 hectares in the South (MOAC, 1986). Figure 3.4 shows the increase in irrigated area for all regions from 1976 to 1983. It is most interesting to compare the Northern and the Central regions, since the latter relies on water that flows from the former. The irrigated area is increasing at a greater rate in the Northern region than in the Central region. Assuming that this trend continues, a point will be reached in the near future where water released from the Northern region, after satisfying its own require-

Figure 3.4 Accumulated Irrigated Area in Various Regions



ments, will be less than at present. As a consequence, the demand for irrigation water in the Central region will not be fulfilled.

In fact, the shortage of water for irrigation in the dry season is quite evident in the Greater Chao Phraya Project (i.e. area under the control of the Chao Phraya Dam). According to the RID Division of Operation and Maintenance, the irrigated area in the Greater Chao Phraya Project in the wet season is about 1.2 million hectares. In the dry season (February to May), the area of suitable land for dry season paddy is about 0.5 million hectares. To irrigate 0.5 million hectares in the dry season requires 6 billion cubic meters of water. In 1986, EGAT set a target release from the Bhumiphol and Sirikit dams of 5 billion cubic meters from February to May. Of this amount, approximately 1.5 billion cubic meters are required for water supply in Bangkok and to prevent saltwater intrusion into the Chao Phraya River. From these data, the RID estimated that about 3.5 - 4 billion cubic meters of water would be available for irrigation during February to May in 1986 (RID, 1986). This amount of water permitted the target for dry season paddy area to be set at only 0.4 million hectares, instead of the full potential of 0.5 million hectares.

The water deficiency which prevents dry season irrigation from operating at its full potential and the ever-decreasing market price for rice are forcing farmers in the Central Plain to switch from paddy to field crops. This trend is clearly shown in Figure 3.5. Although field crops use less water (e.g., 6,200 m^3/ha for soybean and 12,200 m^3/ha for dry season transplanted rice), they require much better water control and drainage than rice. Most of the present irrigation systems cannot provide such control, since they have been designed specifically to irrigate rice paddy.

Figure 3.6 also shows the increasing trend for dry season rice crops. This is because the higher yield of dry season rice crops is more attractive to farmers. Figure 3.7 shows the approximate total inflows (i.e. total outflows + changes in storage) of the Bhumiphol and Sirikit dams between 1975 and 1984. It shows that the approximate inflows of the two dams are roughly constant in recent years. This means that the two dams cannot supply additional water to meet the increasing demand of the Central region. The problem of water deficiency will inevitably worsen, with increasing population and cultivation generating increasing demands. Transbasin projects, such as the diversion of water from the Maeklong Basin to the Chao Phraya Basin, and the diversion of water from the Mae Kok and Mae Ing to the Yom and Nan will inevitably aggravate the water deficit in the Central Plain.

In the Northeastern and the Southern regions, water shortages usually result from inadequate water regulation, rather than from insufficient rainfall input. Figure 3.8 shows the water inflows to the Ubonratana Dam From 1975 to 1984. It does not show any trend of decrease, apart from fluctuations due to annual rainfall variation. The small-scale water resources development projects initiated by the government in the Fourth Five-year National Development Plan have improved water regulation in the Northeast to a considerable

Figure 3.5 Crop Types in Central Region

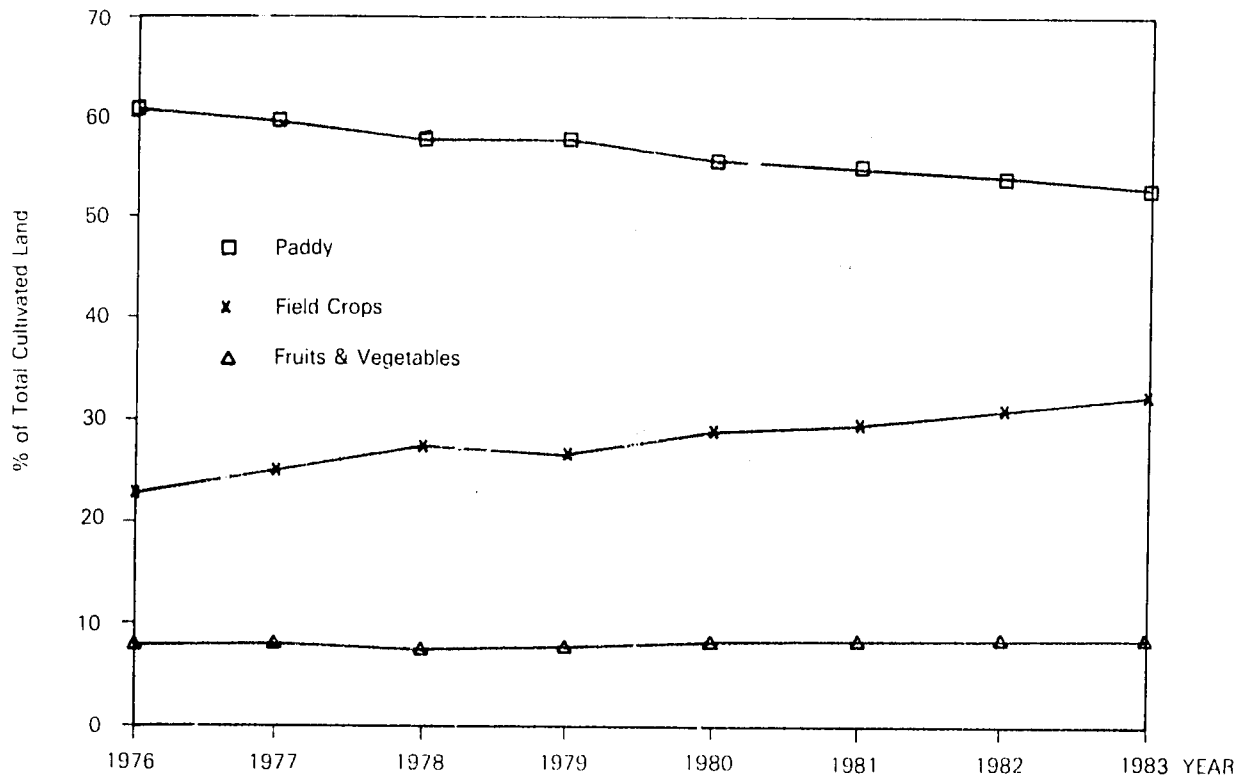


Figure 3.6 Dry Season Paddy Area

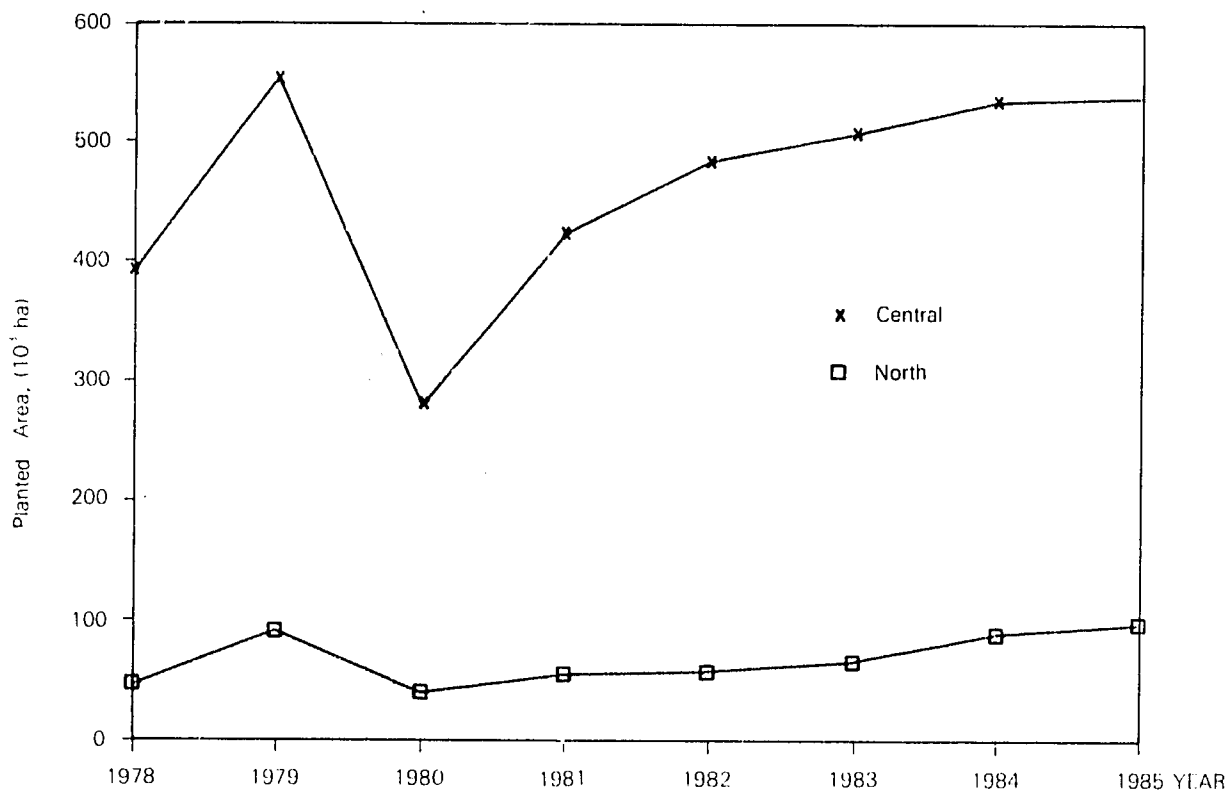


Figure 3.7 Approximate Inflows to Sirikit and Bhumiphol Dams

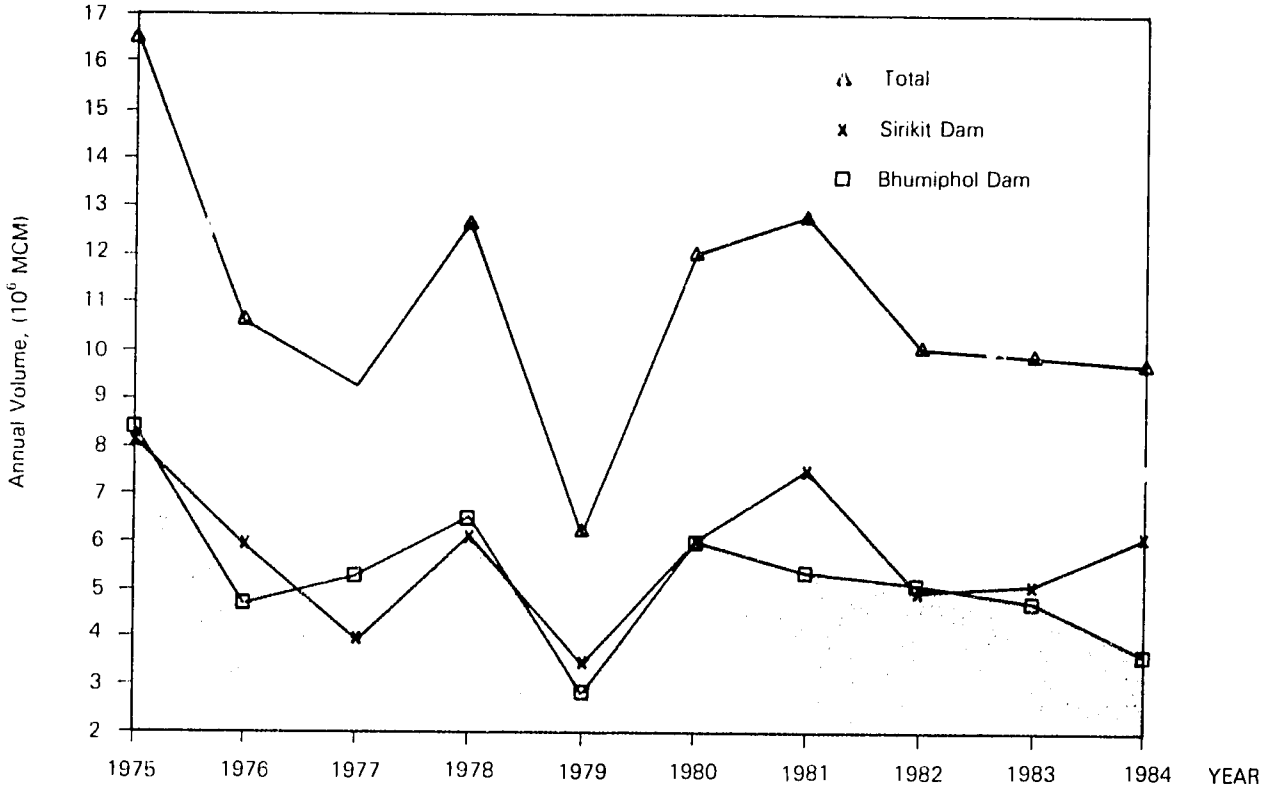
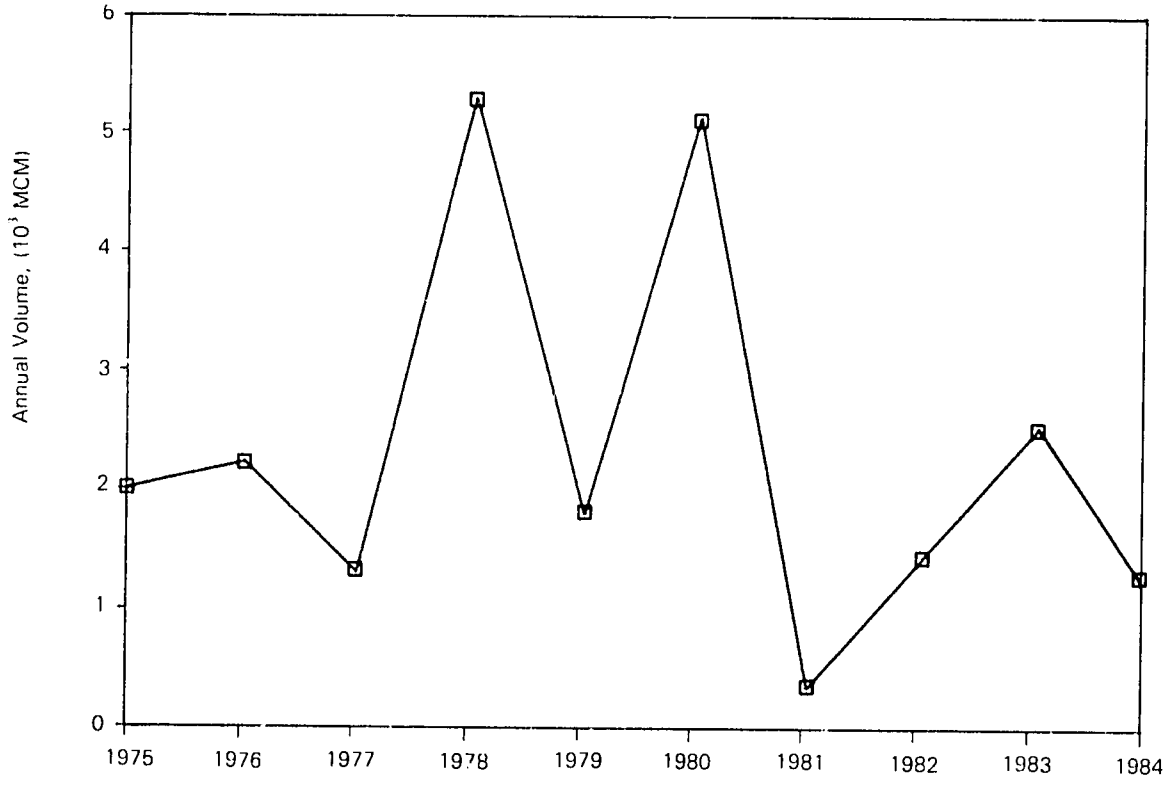


Figure 3.8 Approximate Inflows to Ubon Ratana Dam



extent. Stream flows in the Northeast are characterized by rapid rises and falls. The construction of large storage reservoirs is appropriate in these circumstances. However, the cost of resettling large communities does not make such projects feasible. The development trend in the future will probably shift more towards regulating and maintaining water levels in rivers, to facilitate pumped irrigation. The Nam Mong project under construction at Nong Khai is the first such project. When completed, it should provide water for pumped irrigation for areas far away from the banks of the Maekhong River.

Hydropower

Hydropower development will continue to play an important part in national development. The present electricity requirement is about 3,800 MW and is expected to increase at an estimated rate of 10 percent annually. Figure 3.9 shows the power requirement forecast by EGAT and the NESDB. At present, hydropower contributes about 22 percent of the total electricity requirement. To at least maintain this portion of hydropower contribution, hydropower development must continue, despite the diminishing number of sites for large-scale projects. EGAT (1984) estimates the total hydropower potential of the country, excluding international projects, to be 10,626.2 MW, as shown in Table 3.7. It can be concluded that future hydropower development will focus on pumped storage from existing dams, and on small hydropower plants at irrigation dams.

Groundwater

As for groundwater development, drilling will continue. However, more attention will need to be paid to the quantitative aspects of groundwater, such as the establishment of an appropriate hydrogeological network to monitor groundwater movement, flow direction and water level fluctuation. When better quantitative data are available, it can be expected that more areas will be designated as groundwater areas under the 1977 Groundwater Act. Groundwater will play an increasing role as a water resource for domestic consumption, small-scale irrigation and industrial water supply.

The key water resource-related problems in the Bangkok Metropolitan Area (BMA) are insufficient piped water supply, flooding and land subsidence (see Box 3.2). These problems are very much interrelated. The MWWA is responsible for providing piped water to the BMA, Samut Prakan and Nonthaburi. It draws about 2.1 million m^3/day from the Chao Phraya River for its water treatment plants. The MWWA also abstracts groundwater for its plants. In 1982, it abstracted 447,000 m^3/day of groundwater. In the same year, private abstraction of groundwater was estimated at 944,305 m^3/day. Since then, the MWWA has decreased its abstraction of groundwater, as shown in Table 3.8. However, Table 3.8 also shows that private sector abstraction has increased keeping total abstraction roughly constant at 1.3 million m^3/day. The increase in groundwater abstraction by the private sector is a result of the inability of the MWWA to meet the demand for piped water, especially in the eastern suburbs, where housing estates and industrial plants are growing at a very rapid rate. This groundwater abstraction rate far exceeds the estimated safe yield of 0.8 million m^3/day. Furthermore, unlicensed abstraction of groundwater may be as high as 50 percent of the legal licensed total of 1.3 million m^3/day.

Various studies have indicated that the major cause of land subsidence in the BMA is excessive groundwater abstraction. The Army Department of Survey has found that the subsidence rate in the eastern suburbs is 10 cm/year, while that of the inner city is 5-10 cm/year and that of the western suburbs is less than 5 cm/year. The area of Hua Mark subsided 1.4 meters between 1940 and 1980 (Ramnarong, 1985a). The subsidence has caused some parts of the drainage systems to be below normal water level and has rendered them ineffective. These factors, together with high intensity rainfall, result in the frequent flooding of the BMA.

The policy guidelines of the MWWA for the Sixth National Development Plan (NESDB, 1985) are to reduce groundwater abstraction by both public and private users to a level below

Table 3.7 Estimated Hydropower Potential

Type of Hydropower	Estimated Total Potential (MW)	Annual Energy (GWh)
1 Conventional hydropower projects	6,536.4	16,559.0
2 Power plants at irrigation dams	66.8	293.8
3 Small hydropower projects	291.0	1,600.0
4 Transbasin projects	508.0	1,750.0
5 Pumped storage projects	3,224.0	
Sub-total	10,626.2	19,762.8
6 International projects	16,895.0	111,685.0
Total	**27,521.2**	**131,447.8**

Source: EGAT, 1984.

Box 3.2 Bangkok is Sinking

Like Venice, Thailand's capital is sinking into the sea, to use a phrase often on the lips of Bangkok residents. Located on alluvial soils near the mouth of the Chao Phraya River, Bangkok is a city of some 6 million people and covers some 1,500 square kilometers. Its name, literally translated, means The City of Angels. All the evidence suggests, however, that the city is going down, not up.

The combination of a sinking city located almost at sea level and heavy monsoon rains, which frequently overtax the capacity of the Chao Phraya River, has resulted in frequent flooding. The 1982 flood caused damage valued at 6,600 million baht (roughly US$253 million), while the damage caused by the flood in May 1986 is still being calculated.

When flooding occurs, the citizens of Bangkok tend to blame the authorities, and particularly the Bangkok Metropolitan Administration (BMA). But the real cause of flooding, apart from meteorological and geological factors, is the land subsidence caused by the over-pumping of groundwater in the region.

Groundwater has been used in Bangkok for over 70 years. Early on, there were only private wells, which tended to be very shallow since the water table was high. The Metropolitan Water Works Authority (MWWA) began pumping groundwater for its piped water supply in 1954, at a rate of about 8,000 cubic meters a day. The MWWA's daily water usage increased to 370,000 cubic meters in 1974 and to 447,000 cubic meters in 1982. Private industry was also using ever-increasing quantities of groundwater. It was estimated, for example, that large hotels, factories and housing estates were using about 350,000 cubic meters a day by 1974, and this figure increased to 944,000 cubic meters a day in 1982.

This 1982 figure, however, was collected from licensed users of groundwater, whereas it is thought that the unlicensed use of groundwater could run as high as 50 percent of the licensed usage. Total groundwater abstraction by the private sector and the MWWA was running at around 1.4 million cubic meters a day by 1982, which was almost double the estimated safe aquifer yield of 0.8 million cubic metres a day. Although the MWWA has since tried to cut its groundwater pumping, the evidence suggests that the private sector's pumping rate has increased. Preliminary estimates of groundwater usage in 1985 suggest that the MWWA used about 0.26 million cubic metres a day, while the private sector used 1.03 million cubic meters. The total figure of 1.3 million cubic meters a day still exceeds the safe extraction rate by over 60 percent.

One symptom of this over-pumping is the falling level of the aquifers which underlie the city. On average, the water table lay 12 meters under the surface of central Bangkok in 1968, and 4 meters beneath the eastern suburbs. By 1979, the corresponding levels were 45 meters and 54 meters.

As the level of the water table slumps, a series of problems emerge. Apart from the obvious fact that wells have to be dug deeper and more effort has to be expended in pumping up water from the aquifer using ever-larger pumps, saline water begins to intrude into the freshwater aquifers, and the land surface begins to subside.

Land subsidence has been a feature of Bangkok life since 1968. The most obvious evidence comes in the form of the ubiquitous cracks between the steps of tall buildings and the footpaths with which the steps were meant to connect. Subsidence is also certainly caused by soil compaction resulting from the growing weight of tall buildings, vibration from pile, the sheer volume of traffic in the city's streets, and so on. But groundwater pumping is the real culprit.

Surveys conducted by the Army Survey Department, together with a four-year (1978-1982) monitoring program by the Asian Institute of Technology, have indicated that land subsidence has reached a critical stage in Bangkok. For example, between 1930 and 1940 the district of Bangkapi was 1.6 meters above mean sea level. The area subsided 50-85 centimeters between 1940 and 1978, and the center of Bangkok has also subsided 20-85 centimeters during the same period.

The worst subsidence rates are found in the areas of greatest groundwater usage, the eastern suburbs. The areas of Ladprao, Hua Mark, Phrakhanong and Bang Na all have land subsidence rates exceeding 10 centimeters a year. The inner districts of Bangkok have been subsiding at a rate of 5 to 10 centimeters a year. The worst subsidence has been around Ramkhamhaeng University, an area which the Army Survey Department has shown is now below mean sea level. It has not been flooded so far simply because the surrounding areas are still above mean sea level.

The situation is aggravated by the fact that Bangkok's drainage system has not kept pace with the city's rapid development. Existing drains are meant to work by means of gravity, but the combination of flat land and further subsidence means that many of them are fully submerged for most of the time. As the city spreads, so greater quantities of water are collected by its impervious surfaces and discharged into the already overtaxed drainage system.

Studies using mathematical models suggest that unless the use of groundwater is greatly reduced in the Bangkok area, the city will subside by at least a further two meters

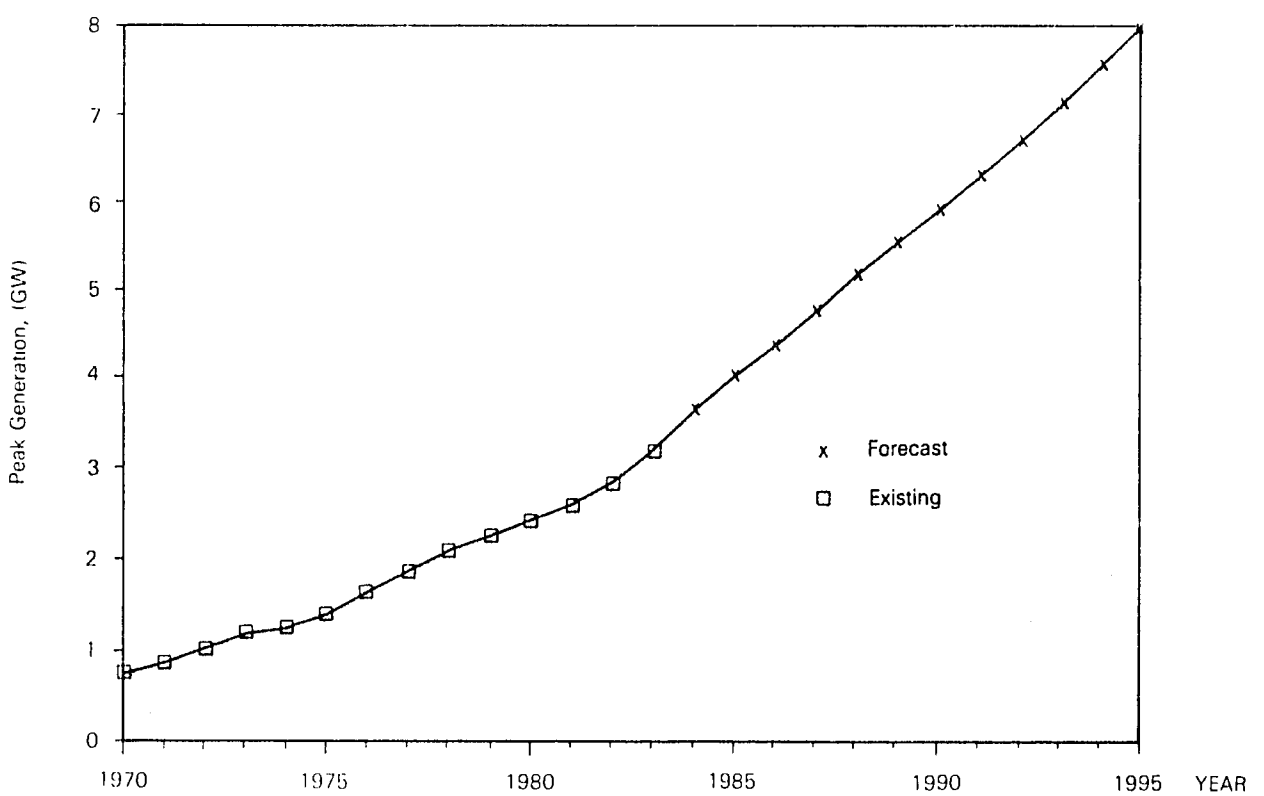
Box 3.2 (contd.)

by the year 2000. Flood prevention schemes are being considered for the eastern suburbs and some inner areas of Bangkok, with a new canal proposed from Pak Kred to Samut Prakan, to accelerate the flow of water into the sea. But the only real long-term solution is to cut the rate of groundwater extraction.

A study carried out back in the 1960s concluded that to implement a master plan covering sewerage, drainage and flood protection could cost approximately US$110 million for the first stage of the plan, serving 1.5 million people at a cost of US$17 per capita for sewerage and US$31 per capita for drainage and flood protection. This plan was not carried forward.

Another study was carried out in 1983 by the Bangkok Flood Control and Drainage Joint Venture (BFCD), to design a new master plan. Despite the fact that the internal rate of return on the new plan would be high, equalling the opportunity cost of capital in Bangkok even on pessimistic assumptions, the complete plan will not be carried forward. BMA is planning to implement one part of the original, broader program, costing about 2 billion baht. The costs will be borne equally by the BMA and the central government. About 57 percent of the project's cost has been secured in the form of loans from the World Bank. The MWWA is also pushing ahead with plans to extend piped-water supplies to more areas of the city, to cut the pressure on groundwater. But it is still anyone's guess as to what the eventual outcome will be.

Figure 3.9 EGAT Generation Requirements



the natural aquifer recharge rate to cut losses in the water supply from 40 to 30 percent by the end of the Sixth National Development Plan and to increase water production capacity by 0.5 million m^3/day. Considering the past record, it is doubtful if such a goal can be achieved within the time specified. As a consequence, private abstraction of groundwater will continue, though at a reduced rate. Therefore, it may not be possible to arrest land subsidence completely in the near future. Even with the optimistic assumption that the MWWA can increase its production by 0.5 million m^3/day over the present 2.2 million m^3/day, the MWWA will require 2.7 million m^3/day from the Chao Phraya River in order to eliminate groundwater abstraction from its wells. To supply 2.7 million m^3/day to the MWWA and to prevent saltwater intrusion, the Bhumiphol and the Sirikit dams will have to release more water. This, as we have seen, is very

Table 3.8 Groundwater Usage in BMA and Adjacent Provinces

(m^3/day)

Year	MWWA	% decrease	Private	% change	Total	% decrease
1982	447,000		944,305		1,391,305	
1983	350,000	21.7	993,842	+5.2	1,343,842	4.3
1984	272,365	22.3	1,034,511	+4.1	1,306,876	2.7
1985[a]	269,410	1.0	1,026,032[a]	-0.8	1,295,442	0.9

Note: a. Record up to May.
Source: Ramnarong, 1985a.

unlikely. Therefore, it can be predicted that the interrelated problems of water supply, flooding, and land subsidence will not be totally eradicated unless some drastic remedial actions are undertaken in the near future.

3.3 LEGAL AND INSTITUTIONAL FRAMEWORK

Water law is probably the most important facet of water resources development and management. In the absence of a legal framework, resource management cannot be implemented without confusion and conflict. However, legislation directly related to water resources management in Thailand has been limited. Some of the existing laws that are related to surface water management are as follows: the People's Irrigation Act, 1941 the Public Irrigation Act, 1942 (Fourth Amendment, 1975); the Ditch and Dike Act, 1962; the Land Consolidation for Agriculture Act, 1974; and the Land Reform for Agriculture Act, 1975.

In none of these laws is there a clause that clearly defines the rights and duties of irrigation users, or the authority and duties of irrigators (Surarerks, 1985, p. 238). In 1978, the Royal Irrigation Department (RID) put forward a draft Irrigation Act, but it failed to reach the legislative assembly. However, the RID has also proposed a draft for the Fifth Amendment to the 1942 Act, which defines the role of water user groups and the collection of water charges. Because of the increasing water demand by various sectors, the lack of a law which clearly defines the rights and duties of riparian users may lead to future conflicts resulting from competitive uses of water.

Groundwater Act of 1977

The Groundwater Act of 1977 empowers governmental control of groundwater development and management. Under the provisions of the Act, one must obtain an official permit to utilize groundwater from designated Groundwater Areas. The Act governs drilling and the use of groundwater as well as the disposal of wastewater into an aquifer through a well. At present, the Act is being implemented in some areas where over-exploitation and groundwater quality have been critical problems. The Director General of the Department of Mineral Resources (DMR) is the chief executive administering the Act, under the direction of the Minister of Industry.

The Minister has issued directives on the technical principles of groundwater management (Piancharoen, 1982, p. 47) as follows: (1) Bangkok and the five adjacent provinces have been designated as the Bangkok Groundwater Area. Groundwater occurring at depths exceeding 1 meters below the surface in this area is subject to control under the Act; (2) specifications for drilling and the construction of wells are provided under the Act. Standard forms for daily drilling reports, well records and other information are prescribed; (3) methods of groundwater extraction and conservation are outlined; (4) technical measures to protect groundwater from pollution are described and drinking standards have been issued; and (5) technical principles are given for the disposal or injection of water or liquids into an aquifer through a well. Emphasis is placed on the monitoring of water quality in the affected aquifer and neighboring aquifers through a network of observation wells.

Those who violate the Act or ministerial directives are punishable by fine or imprisonment. It is worth noting that the area designated as the Groundwater Area only covers Bangkok and adjacent provinces with a total area of 700 square kilometers. Though land subsidence and saltwater encroachment problems due to groundwater pumping in Bangkok are well recognized, drilling and pumping of groundwater cannot be totally eliminated. This is due to the inability of the Metropolitan Water Works Authority (MWWA) to meet water demand. Nevertheless, the implementation of the Act serves to reduce the severity of the problem.

Government Agencies

At present, there are 31 agencies and 17 committees under eight ministries responsible for various aspects of the administration of water resources development (NESDB, 1982). Each agency has its own allocated budget and program to develop water resources for its own specific purposes. The agencies at the departmental level involved in water resources development are listed in Table 3.9.

It is widely accepted that water resources can be most effectively developed by means of multipurpose projects.

Table 3.9 Government Agencies Involved in Water Resources Development

Ministry of Agriculture and Cooperatives

Office of the Permanent Secretary
Royal Irrigation Department
Department of Agricultural Extension
Department of Agriculture
Royal Forest Department
Land Development Department
Cooperatives Promotion Department
Department of Fisheries
Department of Livestock Development
Agricultural Land Reform Office
Royal Rain Making Research and Development Institute

Ministry of the Interior

Local Administration Department
Department of Public Works
Department of Public Welfare
Office of Accelerated Rural Development
Department of Community Development
Department of Lands
Metropolitan Water Works Authority
Provincial Water Works Authority

Ministry of Public Health

Department of Health

Office of the Prime Minister

Electricity Generating Authority of Thailand
Rural Employment Generating Committee

Ministry of Industry

Department of Mineral Resources
Department of Industrial Works

Ministry of Communications

Department of Harbor
Meteorological Department

Ministry of Defence

Naval Hydrographic Department
National Security Command Headquarters

Ministry of Science, Technology and Energy

National Energy Administration
National Environment Board
National Research Council of Thailand

Independent development by government agencies, by contrast, can result in inefficient use of resources and even conflicts between upstream and downstream users. In some projects, several government agencies are responsible for different aspects. The roles of various government agencies in the development of a typical river basin can be illustrated by the following example. The Electricity Generating Authority of Thailand (EGAT), the Royal Forest Department and the Local Administration Department are all responsible for the headwater area. In the irrigated area, the Local Administration Department is responsible for People's Irrigation while the Royal Irrigation Department (RID) and the Harbor Department are responsible for Public Irrigation. The Harbor Department is also responsible for the river outlet and estuary area. Lack of coordination among the agencies can lead to project delays. One example is provided by the prolonged delays in implementing irrigation in the Nam Pong project, following the completion of the dam (Ludwig, 1979).

Irrigation alone cannot improve the quantity of products and efficiency of production in terms of agricultural development. There are other aspects involved, such as land development, modern crop production technology and post-harvest marketing. The integrated planning of such aspects of development requires full coordination of all the government agencies involved. Without this, water resources cannot be utilized to their maximum potential.

It is apparent, however, that water resources development in Thailand lacks comprehensive planning. The emphasis is often on the construction of dams and reservoirs, which is just one aspect of overall development. Also, little effort is put into stimulating the government agencies involved into concurrently carrying out other relevant aspects of development.

3.4 KEY ISSUES

There are many important issues that require attention when discussing Thailand's water resources, such as the maintenance of irrigation systems; the efficient use of existing water; the adoption of measures to prevent flood and drought; the development of future water supplies for the Central Plain and other regions; the supply of water to rural areas; the implementation and enforcement of new and existing water laws; the establishment of a national agency for water resources development; the formulation of a master plan for river basin development; and the formulation of a master plan for groundwater development. These issues are discussed below.

Maintenance of Irrigation Systems

One reason for the failure of irrigation projects to live up to their design potential is the lack of adequate maintenance. The most common, severe maintenance problems are the siltation of canals, the failure of canal linings, the incursion of aquatic weeds, and damage to minor control structures. These problems seem to be prevalent among medium and small-scale projects. The Royal Irrigation Department (RID) has insufficient manpower, equipment and funds to properly maintain all its irrigation systems. To make matters worse, farmers sometimes intentionally damage irrigation structures, as a protest against the inability of the systems to deliver water in times of need. The government's involvement in the past has led farmers to take it for granted that the government

must provide for all irrigation needs. It is practically impossible for the RID, with its limited resources, to carry out all maintenance work required at all levels in the system.

To date, the RID has not been successful in the task of preventive maintenance. Preventive maintenance requires a systematic program of inspection of facilities and routine maintenance, so that breakdowns will not occur too frequently. With a good preventive maintenance program, breakdowns will still occur, but less often. The RID has no comprehensive preventive maintenance program, nor a system of regular inspection of facilities. Consequently, the RID Operation and Maintenance Division constantly has to carry out work on breakdowns and failures. The RID budget and the Bureau of Budget norms for maintenance work should be reviewed with particular emphasis on preventive maintenance, as well as on breakdown maintenance.

Perhaps some of these maintenance problems can be partially solved at the tertiary level, such as farm turnouts. Farmers could be encouraged to form user groups or user associations to look after the maintenance of tertiary structures at the farm level. User groups can be educated and guided on maintenance matters. Efforts could be made to convince farmers that they stand to benefit greatly from this action. Regular maintenance, both preventive and breakdown-related, carried out by user groups, with periodic supervision from officials, would emancipate the RID from having to maintain systems at farm level. This concept of user group maintenance for some parts of the system is not new. It has been practiced for a long time in the North, in People's Irrigation projects (Surarerks, 1985). Farmer cooperatives in pumped irrigation systems along the bank of the Maekhong River are another example of user's responsibility towards the maintenance of the systems. Widespread implementation of this scheme would benefit farmer and official alike.

Efficient Use of Water

Given a constant supply of water and increasing demand for water resources, inefficiency in the usage of water resources is one of the most important issues. The efficiency of irrigation systems leaves a good deal to be desired. This is the result of incomplete systems, unregulated flow, inadequate or outdated control structures, and wasteful use of water for irrigation. Many incomplete systems have resulted from insufficient budget allocation to provide conveyance and distribution systems. This is particularly true for medium and small- scale projects. The unregulated flow problem is the result of damage to—or removal of—control gates at farm turnouts. In addition, some farmers have installed their own farm turnout gates. These factors make the control of flow impossible and result in irregular supply. Consequently, some farmers protect themselves by hoarding water. Another cause of the problem is the inequity of supply. Areas near the head regulator receive an excess of water most of the time, while those at the end of the delivery system face shortages.

In the past, the RID has concentrated on building large and medium-scale projects. Considering the uncertain future, the present low price of rice in the international market, and the increasing scarcity of good vacant land for agriculture, new investment, especially in large-scale projects, may not be economical. On the other hand, making better use of the potential of existing projects by means of modernization and/or rehabilitation of the infrastructure is definitely a better alternative. Some of the main and lateral canal systems were originally designed to provide supplemental wet season irrigation. The majority of control structures from the water source to the farm level are manually operated. This puts a great burden on RID operations staff. The present staffing level of RID can manage the routine operation of the head and main regulators in the Chao Phraya projects quite successfully, but this is not the case in other projects.

In addition, the early systems were designed to operate at full capacity only in the wet season. The canal capacities and control regulators are inadequate for today's increasing demand for dry season irrigation. Most turnouts are unable to deliver adequate water supply in the dry season because the water levels are often too low. The On-Farm Development, Ditches and Dikes, and Land Consolidation projects have improved the efficiency of water usage to a certain degree, but they do not solve the fundamental problem of inadequate water control in the main and secondary canal systems. The modernization of main and secondary canal systems will facilitate more intensive use of irrigated areas, since water can be delivered more reliably and be more easily controlled. The modernization effort should give primary attention to reliable and self-controlling regulators which can be easily implemented using present day technology. The modernization of main and secondary canal systems should also be complemented by the improvement of tertiary systems and by on-farm development.

Another significant factor contributing to the inefficient use of water is that most farmers think that water is free and unlimited. Water pricing would definitely reduce wastage. Most farmers are willing to pay water charges if the supply is dependable. However, a water pricing policy will have to be carefully formulated and assessed in terms of dependability and equity of supply. There are two ways of charging for water. One is the area-based charge and the other is the volumetric charge. In terms of equity and efficiency, the latter is preferred. However, the method would require the costly installation of metering systems. The area-based charge thus raises the question of equity, because different crops yield different income. No matter what charging method is finally selected, the RID will have to provide dependable irrigation. A water pricing policy is urgently needed if water shortages are to be avoided. Revenues collected could increase the capacity of the RID for maintaining and expanding irrigation systems. The so-called farm development charge applied to the pilot on-farm development projects is a move in the right direction.

Flood and Drought Protection Measures

Studies are being carried out to find the most effective means of flood protection for the Bangkok Metropolitan Area, but

relatively little attention has been given to flood and drought problems in rural areas. There are four major aspects involved in dealing with the flooding phenomenon; flood prediction, flood protection, flood warning and flood relief. In the rural areas, flood prediction and flood protection are not economically justified. However, a well organized flood warning and flood relief system could greatly alleviate the flood damage in these areas. As time is crucial in the event of a flood, relief work can be carried out faster and more effectively by provincial governments. The government should establish standard guidelines or procedures for provincial governors to help them coordinate flood relief work. In each province prone to flooding, an emergency relief fund should be made available at all times. This would at least ensure that local governments could start relief work immediately, without having to wait for the arrival of external aid.

The measures adopted for drought relief in 1980 are a good example of what can be done. The experience gained from the relief work could serve as a model for basic guidelines in formulating a standard procedure for drought relief in the future. A special release rule for all major dams in times of drought should be planned ahead of time to alleviate the problems that could arise from future droughts. Planning for groundwater utilization, to cater for domestic water supply and augment irrigation during a drought period, is another area which should be carefully considered.

Future Water Supply Options

As previously discussed, the Central Plain is facing a shortage of water for dry season irrigation. Not all suitable dry season cropping land can be irrigated. Certain areas receive dry season irrigation on a rotational basis. On average, only 0.4 million hectares out of 0.5 million hectares of potential dry season cropping land receive adequate irrigation. This water shortage will become more severe with the planned expansion of the Metropolitan Water Works Authority (MWWA). Water availability from the Bhumiphol and Sirikit dams, which control the flow of the Chao Phraya River, is unlikely to increase unless other new water sources can augment their inflows. The maximum volume of water flow the MWWA can extract from the Chao Phraya River, as agreed by MWWA, EGAT and RID, is about 2.6 MCM/day (30 m^3/s). It has been estimated that, by the year 2002, the MWWA will require raw water for its treatment plants on the order of 5.2 MCM/day (60 m^3/s), and perhaps even as high as 6 MCM/day (70 m^3/s), to supply piped water to the BMA, Samut Prakan and Nonthaburi (Srisathit, Nimkulrat, and Anutampai, 1983).

It is of utmost importance that supplementary dry season water sources be found for the Chao Phraya Plain as soon as possible. There are two possible options available. The first is the transbasin project, which can divert excess water from other basins into the Chao Phraya Plain. The other is the development of groundwater as a supplementary water source for the dry season.

Various studies have shown that there may be approximately 50 m^3/s of excess water in the Maeklong Basin which could be diverted to the Chao Phraya Plain (e.g., Acres International, 1979). This amount is approximately equal to the amount that has to be supplied by the Chao Phraya River to the Tha Chin River to control salinity. The diversion of water from the Maeklong Basin will make an additional 40-50 m^3/s available to the Chao Phraya River for the lower Chao Phraya and the MWWA. This water could provide sufficient dry season irrigation for approximately 50,000 hectares in the lower Chao Phraya. However, the government has not yet made a decision on this transbasin project. Indeed, the feasibility study for this project has not yet been carried out.

For the upper Chao Phraya, the Kaeng Sua Ten project on the Yom River is the first stage of the Kok-Ing-Yom-Nan transbasin project (EGAT, 1984b). The first phase of the Kaeng Sua Ten project is the construction of a dam to a height of 72 meters, mainly for agricultural purposes, which can supply dry season irrigation to some 50,000 hectares in the Yom Basin. The second phase will increase the dam height to 96 meters for hydropower generation of 230 MW capacity. Other stages of the Kok-Ing-Yom-Nan project are to divert water by pumping and by gravity from the Kok and Ing basins to the Kaeng Sua Ten reservoir. Some of the storage in the reservoir will then be diverted to the Sirikit reservoir on the Nan River. This means that the Sirikit Dam will receive more inflow and hence will be able to increase its releases for the Central Plain. It has been estimated that the first phase of the Kaeng Sua Ten Dam will cost 4.2 billion baht (unpublished data from Project Planning Division, RID). About 900 families will have to be resettled in the first phase and 5,000 families in the second phase.

As with the Maeklong transbasin option, the government has not made a decision on the Kaeng Sua Ten project. The longer the government delays its decision, the greater the likelihood of additional population moving into the reservoir area. Resettlement of families is a sensitive socio-political issue. The increasing number of families to be resettled may eventually make the option unfeasible. Considering the importance of future water supply for the Central Plain, especially for the agricultural sector, and the fact that Kaeng Sua Ten is one of the last feasible sites for major storage reservoirs remaining in the upper Chao Phraya, an early decision should be made by the government.

In selected parts of the country, the use of groundwater seems to have good potential as a supplementary dry season water supply. Until now, however, the role of groundwater development in agriculture has been relatively small. There are only two experimental projects in operation, at Sukhothai and Phichit. In all cases, groundwater is used only in the dry season. In favorable areas where the aquifer yield is high, the use of groundwater to augment the flow in irrigation canals would be economical. The use of groundwater for supplementary dry season water for irrigation would also be very beneficial to the Northeastern region, where the shortage of water for dry season irrigation is most severe as the available water in some parts of the Northeast can hardly meet domestic requirements. Transbasin projects are impractical in the Northeast. This leaves groundwater as the only available option to supplement the numerous small-scale projects and to provide pumped irrigation in this region.

The government could encourage the utilization of groundwater in appropriate areas by providing credits, subsidies and technical assistance. The Department of Mineral Resources (DMR) should also closely monitor groundwater utilization to prevent overpumping.

Development of a Rural Water Supply

Recently the NESDB has commissioned the Asian Institute of Technology (AIT) to prepare the Master Plan for Rural Water Supply and Sanitation in Thailand (AIT,1985). According to the Master Plan, only 15 percent of the rural population in 1983 had access to a safe water supply, such as piped water, deep wells and sanitized shallow wells. It was also noted that 85 percent of the rural population did not have an adequate water supply year round. Based on a targeted household coverage of 75 percent, the Plan concentrates on unpiped water supply, such as wells and rainwater jars. The construction of approximately 4 million jars of $2m^3$ capacity and 377,000 thousand jars of $1m^3$ capacity during the decade plan was recommended. Other recommendations are the construction of 25,053 sanitary shallow wells, 21,805 deep wells, plus over 1,000 small-scale piped water systems. To implement the Master Plan, it has been estimated that the government will need to invest about 1.5 billion baht annually until the year 1991.

The construction of rainwater jars is perhaps the most effective means of providing potable water to the rural people over a wide geographic area, especially in areas of low population density, where the provision of piped water supply is not economically feasible. The implementation of the jar construction program is within the remit of many government agencies active in rural development programs. However, efforts should be made right from the beginning to alleviate problems faced by the rural water subsector in the past, such as uncoordinated activities, duplication of effort and competition.

For the rural piped water supply, the responsibility has rested on the Provincial Water Works Authority (PWWA), established by the Provincial Water Works Authority Act of 1979. At present there are 674 rural water supply service areas, which only serve about 5.1 percent of the rural population (PWWA/GTZ, 1986). There are also approximately 20,000 small-scale piped rural water supply schemes serving an additional four million people, which increases the total of rural population served to 14.9 percent.

In its Rural Water Supply Decade Plan (1985-1995), the PWWA has set the target of providing 75 percent of the population in the 674 rural water supply service areas with safe water by 1990, and of increasing this percentage to 90 percent by 1995. The consultant's report (PWWA/GTZ, 1986) estimates the cost of the Decade Plan to be 1.5 billion baht, at 1985 prices. The report assumes that part of the cost will be covered by community contributions, at a ratio of 35 percent for rehabilitation and 40 percent for new construction. About 27 percent of the cost will come from government loans and the balance will be financed by a revolving fund and foreign donors. The Plan also calls for an increase of PWWA staff from 161 at present to 3,265 by 1995.

On the legal side, the government has reaffirmed the 1979 PWWA Act by a Cabinet resolution. It has ruled that all piped water supply schemes (urban, except BMA, and rural), not yet operated by PWWA, are to be handed over to PWWA. Considering the cost implications of the Act and the PWWA Decade Plan, the government is obliged to give full financial support to the PWWA. The PWWA Act is the beginning of steps to solve the problems faced by the rural water supply sector in the past and to improve the chance that the government's goal for the International Drinking Water and Sanitation Decade can be achieved.

Water Law and its Implementation

We have seen that existing water laws are inadequate. To achieve better maintenance of irrigation systems and to attain efficient use of water, Thailand needs a water law which clearly defines the right to the use of water, especially the use of irrigation water at the farm level, the forming of irrigation water user groups, and the charging of water prices. On the administrative side, some laws are incoherent and ambiguous. There are many agencies with mandates in the administration of water usage. For example, the Public Irrigation Act applies to irrigation canals; the Ditch and Dike Act applies to ditches and dikes; and the Land Consolidation for Agriculture Act applies to land within the irrigated area. This example clearly demonstrates that there are three different laws exercised by different government agencies within a single irrigation system. This situation often leads to a lack of continuity in policy and planning, lack of coordination, and financial waste.

Another important issue is law enforcement. There are cases where a law exists, but where the mechanism of law enforcement is ambiguous. For example, in the case of natural water resources boundaries, there is no single government agency which has the authority to define the extent of the natural water boundaries. As a consequence, families move in and settle within the preserved natural watersheds.

The increasing competition for water resources may create conflicts among users because of the equity issue. The situation calls for a major review of all laws concerning water resources and irrigation. The review should attempt to solve the problems of the coverage of the laws and their enforcement. Perhaps the National Agency for Water Resources Development, as discussed in the next section, could be the enforcing authority for the revised laws.

National Agency for Water Resources Development

There are many agencies carrying out work on water resources development. This situation, plus the complicated budget allocation system within each agency, has resulted in uncoordinated planning of water resources development. Sometimes

the apparent benefit gained by one agency's project may be canceled out by the negative effect it has on another project of another agency. Water is becoming scarce and the demand for it is increasing. This has given rise to the formation of the National Water Resources Board (NWRB), under the NESDB, in 1983. However, the NWRB has limited authority and resources for planning and implementing water resources development effectively on a national scale. Its mandate emphasizes an advisory role, rather than an administrative one.

As a solution, a national agency for water resources development should be established to plan and coordinate the work of RID, EGAT and other government agencies. An example of such coordination work could be the formulation of release rules for all RID and EGAT reservoirs so that maximum benefit can be gained by all sectors. The agency should have at least a departmental status (Kiravanich, 1983), and preferably ministerial status. The authority of the agency could be strengthened by enacting a law to define its role, function, organization and resources. It can make more efficient use of available resources and budget, and eliminate duplication of work, through programmed budgeting of all water resources development in the country. This agency could carry out the drafting of the master plan for river basin development, as discussed in the next subsection.

A national agency could also assist in coordinating a network of water resources information sources. Hydrological, meteorological and hydrogeological data have been collected for a long time by various agencies, but there has been no standard format for the measurement, recording, archiving, analysis or dissemination of data. Consequently some agencies are doing duplicate work. Although an attempt has been made by the Project Planning Division of EGAT to establish a Water Resources Information System for Thailand, the acquisition of data for use in various projects is difficult and time consuming. Progress so far has been slow due to insufficient staff. However, a national agency with specifically allocated resources could act as a center for coordinating a network of water resources information. This agency could be responsible for setting a standard format for the interchange of data collected by various agencies. It could act as a network information center for all variables related to water resources and disseminate information to the public.

Master Plan for River Basin Development

On a national scale, water resources development lacks a master plan to cover development in all river basins as a whole. Thus, collectively, no priorities are defined with respect to overall national benefits. In the past, the construction of a particular project was usually planned for its own benefit and did not take into account completed and still-to-be constructed projects. Development in one basin often went ahead without any consideration of what impact it might have on other basins. In view of the transbasin project options, as previously discussed, the alleviation of the shortage of water in the Central Plain will affect several river basins at once. Therefore, it is necessary to have a master plan for river basin development to identify priorities in all river basins, to safeguard for the interests of the nation as a whole. A master plan would also enable efficient water resource utilization and management, and could begin to eliminate conflicts among the beneficiaries.

Development should be planned for benefits from all aspects, i.e., hydropower, irrigation and flood protection, in an integrated manner. This includes the service infrastructures, environmental impact and conservation aspects. Other related activities, such as land development and agricultural technology, should be planned in parallel with water resources development from the outset.

Groundwater Development Master Plan

The increasing utilization of groundwater for both domestic consumption and for supplementary irrigation in the dry season raises the prospect of uncontrolled groundwater development. The enactment of the 1977 Groundwater Act represented an attempt to ensure that groundwater abstraction does not exceed the safe yield of the aquifer, which may subsequently lead to problems of land subsidence and saltwater encroachment. However, the enforcement of the Act only applies to the BMA and adjacent provinces at present. There is still no direct government control of groundwater abstraction elsewhere in the country. Recently more and more government agencies have become involved in groundwater development for various reasons. Some of the agencies involved are the Department of Mineral Resources (DMR), the Office of Accelerated Rural Development (ARD), the Department of Public Works (DPW), the Department of Health (DOH), and the National Security Command (NSC).

Development carried out so far seems to be very much localized, with no consideration given to the adverse effects which might result in the long run. In some areas, saltwater encroachment and the pollution of groundwater by pesticides, fertilizers and underground waste dumping have been observed. Such situations cannot be allowed to go unchecked if groundwater is to remain a valuable water resource.

Farmers have shown an increasing interest in groundwater development and are aware of its benefits, especially in the dry season. It can be predicted, in the light of the dry season shortage of water for irrigation, that private irrigation wells will become more popular in the Central Plain. With favorable results from the experimental projects at Sukhothai and Phichit, the use of groundwater for irrigation is expected to increase in the future. The DMR (which has the power to control the exploitation of groundwater under the 1977 Groundwater Act), the NESDB and the NWRB should begin formulating a master plan for groundwater development. The RID, with its experience in developing groundwater for irrigation, could also cooperate in the formulation of the master plan. This master plan could ensure that the adverse effects of groundwater exploitation, such as those experienced by BMA, would not be repeated in the future.

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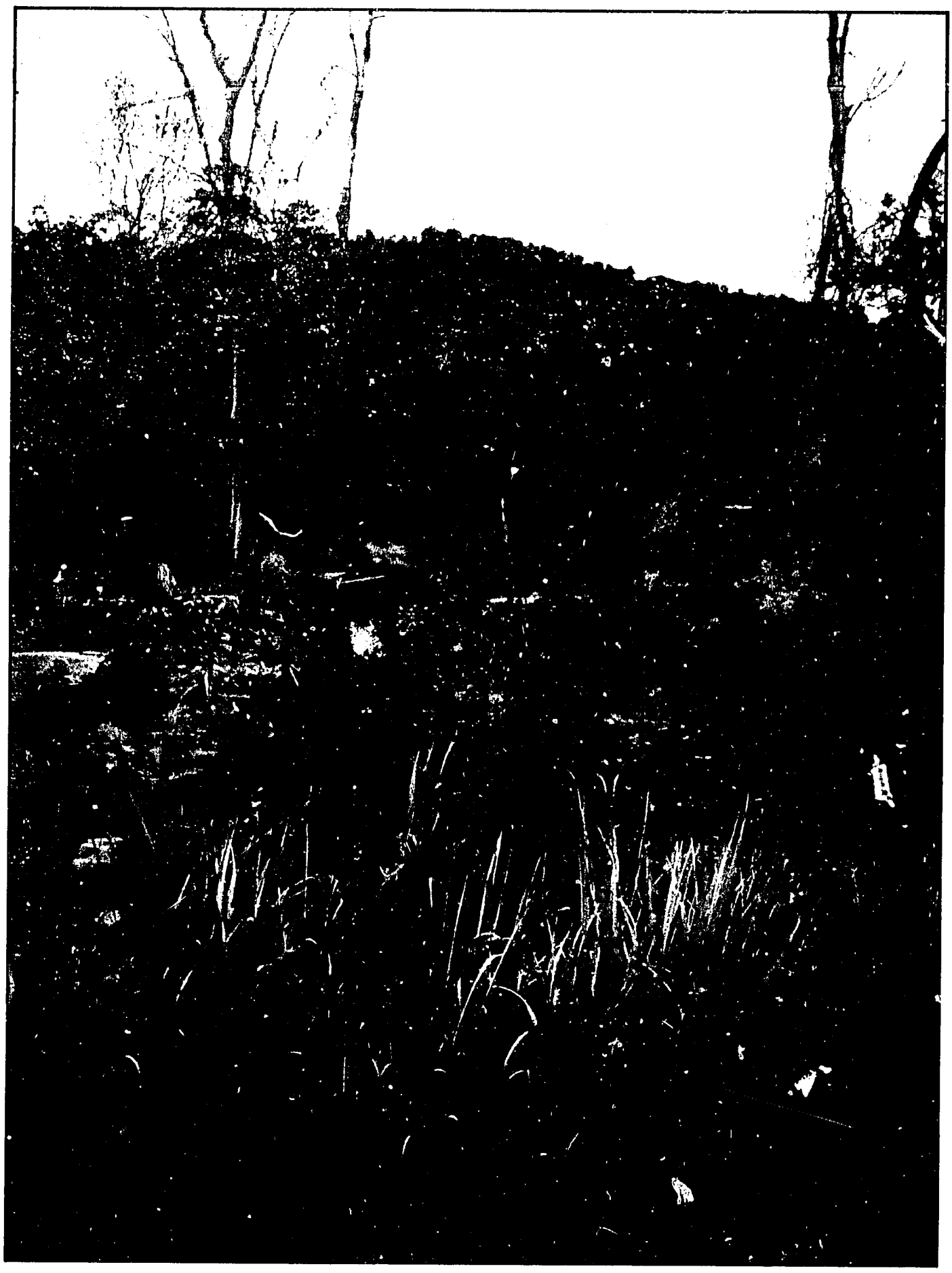


4 Forest Resouces

4.1 OVERVIEW

This chapter provides a general introduction to Thailand's forest resources, but focuses only on the country's inland forests. The mangrove forest is discussed separately in Chapter 7.

Definition and Scope

A "forest" can be defined as a community of living trees and associated organisms; covering a considerable area; utilizing sunshine, air, water, and earthy materials to attain maturity and reproduce itself; and capable of furnishing mankind with indispensable products and services (Allen, 1969). The ecological concept is implied in this definition, and it is increasingly accepted in the scientific community. On the other hand, in the Forest Act of 1941, the "forest" is defined as the land area which no-one has authority to occupy or use.

In practice, both definitions are applicable. The most appropriate definition will depend upon the specific location and the issues of the time. This chapter will mainly concentrate on the former definition, as it relates closely to the objective of the Natural Resources Profile.

In general, tropical forests play a vital role in nutrient storage and cycling on land. Nutrients are distributed not only through the trees, but also in the soils, with nutrient cycling playing a key role in the functioning of tropical forest ecosystems and enriching soils, especially surface soils. Any disturbance of forest cover can cause a significant loss of nutrients from the land.

The forest types of the country are influenced by local climatic conditions (see Chapters 1, 2 and 3). Tropical Rain Forest is the dominant type of Evergreen Forest and is concentrated in the highest rainfall zone — in the Southeast, East, and along the peninsula. Dry Evergreen Forest and Hill Evergreen Forest cover the southeast and the mountainous areas of the north and west. Mixed Deciduous Forest is found widely at low elevation in some provinces of the north and west. Dry Dipterocarp Forest is found mainly on the terrace formation areas and the lower sandstone ridge of the Northeast Plateau. Pine Forest is usually located in small pockets of the North and Northeast, particularly in mountainous areas (Table 4.1).

The preservation of Thailand's forests should be of concern to everyone (see Box 4.1). Population growth and excessive utilization of forest resources are both major causes of the depletion of the country's forests. This over-exploitation increasingly has resulted from the clearing of forest land, whether due to illegal logging operations, land encroachment or to shifting cultivation by the hill tribes. The Royal Thai Government (RTG) has attempted to retrieve the situation by replanting trees in degraded forests and, in areas where shifting agriculture is practiced, by stricter enforcement of the laws, but overall it cannot be said to have been successful. The following sections emphasize the status of forest resources in Thailand, the emerging trends, and provide suggestions on how to best manage the nation's forest resources.

Standing Volume

The question is simple: How much wood is there in Thailand's forests? The answer, however, is rather more difficult to pin down. Because of the considerable variations in stand density found in areas of different forest types, it is insufficient simply to quantify the total forest area. What is needed is information

Table 4.1 Forest Area by Type and Region in 1983

(rai)

Type	North	Northeast	East	Central and West	South	Total
Tropical Evergreen	15,980,000	5,815,625	3,885,000	7,780,625	8,951,875	42,413,125
Mixed Deciduous	15,628,750	1,636,250	695,625	3,245,000	-	21,205,625
Dry Dipterocarp	21,448,750	8,636,875	158,125	337,500	-	30,581,250
Mangrove	-	-	261,250	209,375	1,324,375	1,795,000
Pine	1,261,250	90 000	-	-	-	1,351,250
Scrub	528,750		-	-	-	528,750
Total	**54,847,500**	**16,178,750**	**5,000,000**	**11,572,500**	**10,276,250**	**97,875,000**
Para Rubber Plantation	-	-	**406,250**	-	**9,500,000**	**9,906,250**

Source: RFD, 1985a, p. 25

Box 4.1 Thailand's Vanishing Forests

At a time when there is growing worldwide concern about the destruction of tropical forests, Thailand's forests continue to disappear at a considerable rate. The pace of deforestation has been accelerating since the early years of the century, but it has moved into a higher gear since the 1960s. In 1961, for example, some 53 percent of the country was still covered with forest, a proportion which declined dramatically to the 1986 figure of 29 percent. In other words, Thailand lost about 45 percent of her forests over this 25-year period (Figures 4.1-4.3).

There are many reasons why the country's forests are shrinking, but several key pressures stand out. An estimated 500,000 tribespeople practice shifting cultivation in the hills, removing forest cover for several years (see Box 4.2). On steep slopes, the result is soil erosion and sedimentation of downstream rivers. At the same time, the ability of watershed areas to absorb rainfall and release it slowly is degraded, often leading to flooding in downstream areas.

Meanwhile, lowland agriculture and the demand for new areas for settlement have severely cut into the remaining lowland areas of forest. The Royal Forest Department (RFD), for example, has had to grant STK (right to farm) certificates to the growing numbers of squatters living in or alongside Thailand's forest reserves. And these pressures have been further aggravated by illegal wood cutting and legal industrial wood consumption whether for construction timber, fuel or charcoal.

The environmental, economic and social costs involved are considerable and growing. The extensive denudation of critical watershed areas has led to widespread flooding, as described in Chapter 3, while severe impacts are also being reported in other key sectors, including wildlife management (see Chapter 5) and coastal fisheries (Chapters 7 and 8).

Strikingly, the value of Thailand's forest exports dropped from 354 million baht in 1978 to 104 million baht in 1984, a 70 percent fall. In 1967, Thailand was forced to begin importing timber, with the value of these imports growing by over 90 percent between 1973 and 1984, a 16-fold increase in just 12 years. All the signs suggest that Thailand's timber deficit will continue to worsen for the foreseeable future.

To counter these threats, the Royal Thai Government has stepped up the enforcement of existing laws, and launched reforestation programs in some of the worst affected areas. However, as this chapter shows, the scale and complexity of these problems have so far defied the government's best efforts. A new structure has been proposed for the RFD, but in the meantime its efforts to accelerate reforestation are still hampered by the fact that its funding and manpower have not kept pace with the increasing responsibilities laid upon it.

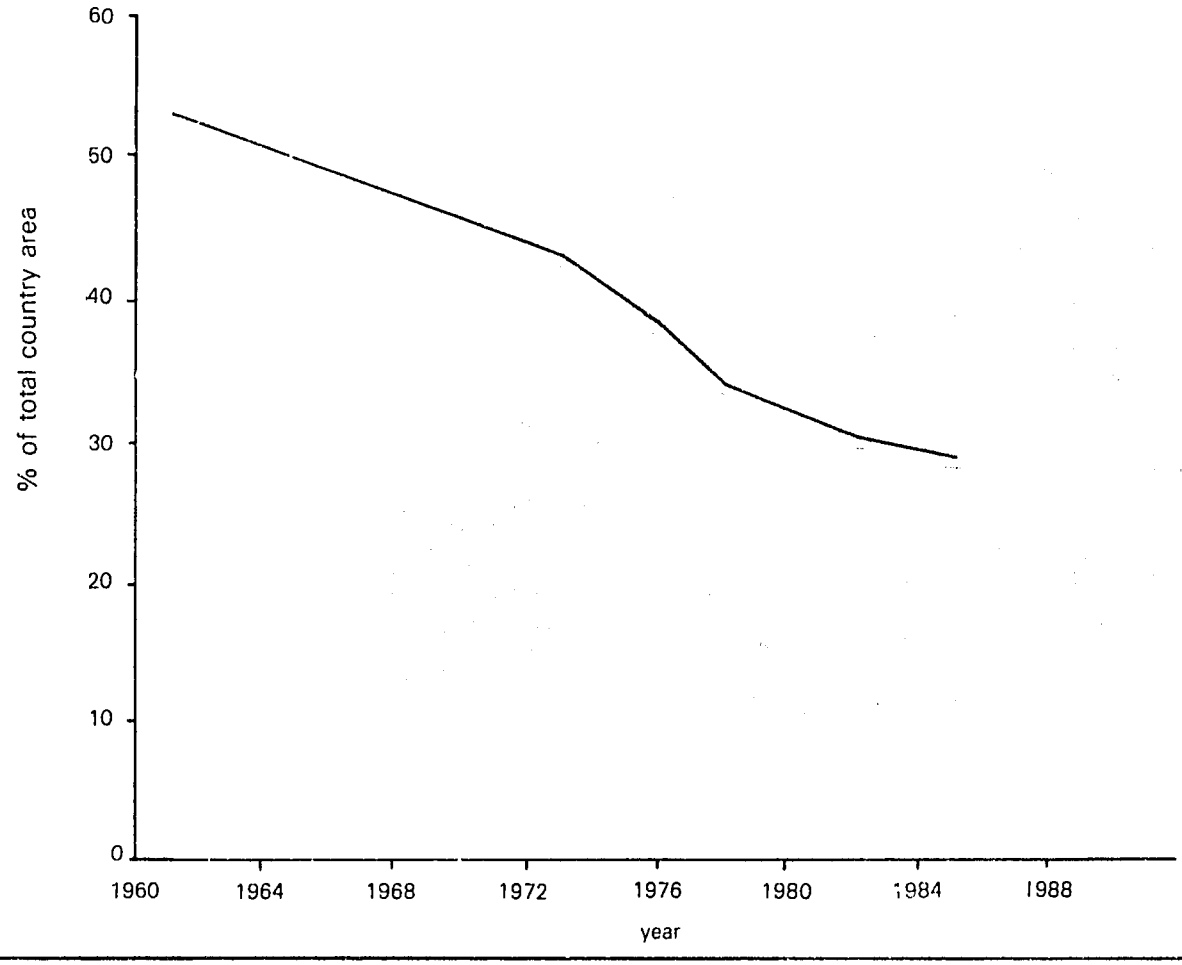
The maintenance of forest cover at around 40 percent of Thailand's total area is the National Forest Policy target, with 15 percent devoted to conservation forests and 25 percent to productive forests. A great deal of work remains to be done, however, in defining which areas of forest should be left intact, which should be converted to other uses, and where the priority areas for enrichment planting and commercial plantations need to be. The production of the National Forest Policy in December 1985, with the support of all agencies involved in forests and forestry, was a positive step in this direction.

Box 4.1 (contd.)

Clearly, the government cannot cope with this problem in isolation. There is growing interest in private sector forestry initiatives and in so-called "social forestry", with plantations of fast-growing trees developed under the control of local communities. Small-scale plantations, mainly of teak, started in the early years of the twentieth century by RFD, with large-scale replanting dating from the early 1960s by state and private sectors. The role of private sector was initiated from the 13 rai replanted with fast-growing trees in 1966. There has been a fair acceleration in the rate of replanting, with a 1985 figure of nearly 31,000 rai.

But even the total area of over three million rai replanted by the RFD, the Forest Industry Organization, and private concessionaires between 1961 and 1985 looks precariously low when compared with the rate of forest encroachment during that 20-year period. Indeed, it effectively compensates for the average forest encroachment of just one year.

Figure 4.1 Remaining Forests in Thailand, 1961-1985



both on the area covered by forest and on the forest type and typical stand densities (Table 4.2). The volume of Thailand's growing stock of forests was last estimated in 1978, with the total tree volume at that time thought to be of the order of 175.47 million cubic meters (Table 4.3).

Wood is used for many purposes, including construction and fuelwood applications. Once, Thailand was self-sufficient in wood products, but this has changed. In 1967, Thailand began to import timber at about 38,410 m^3 and this inflow has gradually increased, to 1,033,110 m^3 in 1979 and 614,299 m^3 in 1983. Economically, import values increased from 91 million baht in 1973 to 1,438 million baht in 1984, an increase of about 16-fold over a period of 12 years. In contrast, total timber exports were valued at 1,076 million baht in 1973, falling to 104 million baht in 1984. This represented a 10-fold decrease over a period of eight years. (Information from Planning Division, Royal Forest Department.) In other

Figure 4.2 Encroached Forest Areas in the Eastern Region of Thailand, 1973-1985

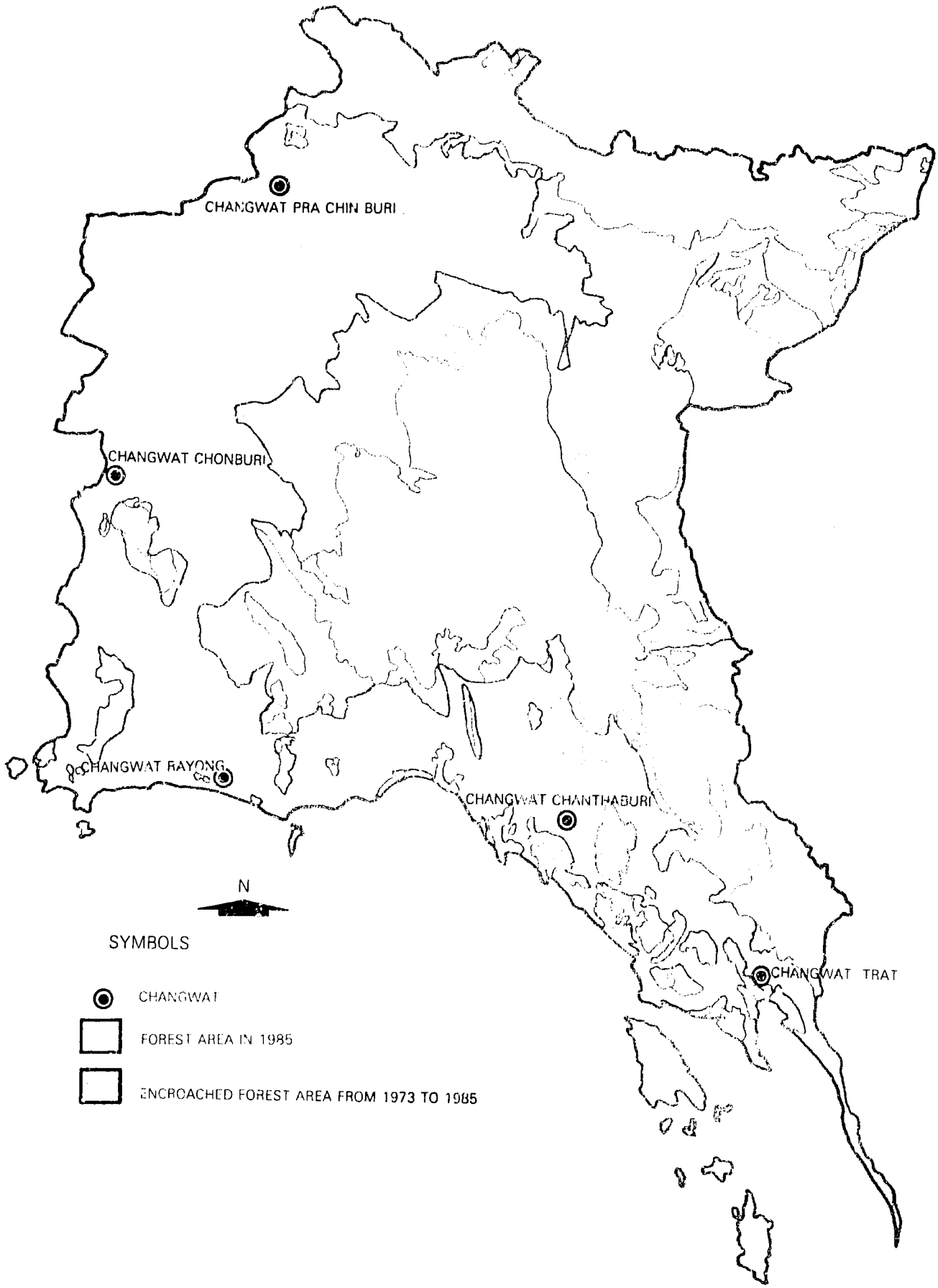


Figure 4.3 Encroached Forest Areas in the Western Region of Thailand, 1973-1985

Table 4.2 Stand Density of Different Forest Types in Different Regions of Thailand

	Stand density, (m^3/ha) (Hoppus) [a,b]			
	Highly commercial species	Commercial species	Other Species	Total
1. Dry Dipterocarp Forest				
North	8.02	10.90	0.99	19.91
Northeast	4.08	6.16	0.19	10.43
East & West	4.29	0.98	0.33	5.60
2. Mixed Deciduous Forest				
North	9.04	8.78	3.02	20.84
Northeast	6.80	13.36	3.01	23.17
East & West	3.94	7.71	5.49	17.14
3. Mixed Deciduous Forest with Teak				
North	17.30	9.01	1.98	28.29
4. Pine Forest				
North	33.35	13.36		46.71
5. Dry Evergreen Forest				
Northeast	12.76	6.67	2.47	21.90
East & West	-	4.62	3.90	8.52
6. Tropical Rain Forest				
South	12.22	9.34	11.78	33.34

Notes: *a. Volume of trees with girth at breast height (GBH) above 100 cm.*
b. Based on data from measurement of permanent plots.
Sources: *1. Royal Forest Department, 1982.*
2. ESCAP, 1986.

words, the forest economy's share of gross domestic product had diminished since 1980.

This trend was reversed in 1985, however, with forestry products earning nearly 270 million baht in the first three quarters, increasing forestry's share of total exports to nearly 0.2 percent. This 61 percent increase in the value of forest product exports was the result of a decision by the Ministry of Commerce to allow the export of wood and wood products from both privately owned and national forest reserves, beginning in September 1983. During this same period (1978-1984), the import of forest products (wood, lumber, cork, pulp and waste paper) recorded a 32 percent increase, although growth was not constant. From 1970 to 1985, the average annual increase in demand for forest products was 5.33 percent. The trend is for imports to continue to rise as Thailand's forests continue to be depleted.

As discussed later in this chapter, the forestry sector is a significant employer. According to the Royal Forest Department (RFD), 130,000 individuals were employed in 1982. Mechanized operations producing forest products, such as saw mills, employed over 50 percent of that total.

National Parks and Wildlife Sanctuaries

Forests clearly produce direct and indirect benefits for people. Among these benefits, forests as National Parks and Wildlife Preservation Areas have been rapidly increasing in popularity. The RFD has conserved forest areas for recreation in the form of National Parks, Wildlife Sanctuaries, and Non-hunting Areas. Millions of people use these recreational areas, which comprise 52 National Parks (16.3 million rai), 28 Wildlife Sanctuaries (12.7 million rai), and 37 Non-hunting Areas (1.8 million rai). A functional classification of forests is shown in Table 4.4. At the same time, the RFD has also established other types of recreational areas, namely arboretums, botanical garden and forest parks. It is estimated that the total area is about one percent of the country. Furthermore, there are still other types of land areas that could be considered as recreational areas, such as beaches, islands, historical areas, city parks, and public areas. Also, headwater areas, such as the Highland Watershed Research and Rehabilitation Stations in the north, could be considered as recreation areas, since many tourists have visited these sites. Overall, many feel that at least 20 percent of Thailand's total area should be devoted, wholly or in part, to recreation.

Headwater Areas and Uses

The characteristics of Thailand's watersheds vary considerably from place to place, due to differences in physiography. The North, where the Ping, Wang, Yom, and Nan rivers originate, is the country's most important watershed region. These rivers converge in the Central region to form the Chao Phraya River. The Northern region is mountainous, with long ridges and steep, narrow valleys on headwaters. The altitude ranges from

Table 4.3 Volume of Growing Stock of the Natural Forests in Different Regions of Thailand, 1978

Regions	Forest area (ha)	Volume of growing stock, (m^3) Highly commercial	Commercial species	Other species	Total
Terrestrial forest					
North	8,711,960	39,835,615	36,549,698	6,514,709	82,900,020
Northeast	4,781,171	18,005,432	18,005,119	3,766,359	41,072,910
Central	2,292,150	4,783,045	8,089,306	7,377,724	20,250,070
South	1,829,226	13,660,990	6,621,253	10,968,392	31,250,630
Total	**17,614,506**	**76,285,082**	**69,265,376**	**28,627,184**	**175,473,630**

[illegible]

100 meters to about 2,685 meters above sea level. Most of the streamlets are perennial streams, with dendritic patterns.

In the Northeast, there are four main rivers, the Chi, Mun, Songkhram, and Loei. These flow eastward through the region and join the Maekhong River. The topography of the basin is characterized as plateau, which gradually changes from rolling hills in the lower portion into mountainous areas in the upper portion. The Northeast is the most critical area as far as drought is concerned. There is insufficient water during the dry season, followed by soil erosion in the wet season. The soil is quite sandy, with a low nutrient content and low water holding capacity. This is due to the fact that it is mainly derived from sandstone. In the South and East, along the Peninsula, watershed basins are characterized by steep narrow valleys plunging to the coasts. The mean slope is higher than that found in other regions of the country.

Many problems affect these headwater regions. Conversion of forest areas to agriculture has spread from the lowlands to the highlands. The depletion rate was estimated at about 3.5 million rai/year. Two population groups have been responsible: local Thai people, who convert forest areas into cultivated land for growing rice, corn, cassava, and other crops, and the hill tribes, who use slash-and-burn farming techniques. There are estimated to be around 500,000 hill tribespeople in Thailand. The RTG has devoted considerable efforts to solving the problems they cause, but without any great success (see Box 4.2).

Forest fires normally occur in the dry period or summertime in all headwater areas, particularly in the north. Fire not only causes damage to plants and trees, but also stimulates further soil erosion during the rainy season. Forest fires extend from small areas to larger areas. It has been estimated that forest fires damage about a million rai a year. Other problems can be attributed to road construction, providing new access for forest encroachment, and minerals exploration in forest reserve areas.

Environmental Protection

From an environmental perspective, forests are seen to play a vital role in the regulation of ecosystems, influencing the balance between inputs and outputs. If their living resources are to be managed on a sustainable basis, their ecological integrity must be protected. Where their integrity is under challenge, various symptoms will soon become obvious. Deforestation, by promoting increased soil erosion, often boosts the sediment load in nearby streams and rivers. Simultaneously, the rate at which rainfall runs off into watercourses will be accelerated, and the combination of greater volumes of water racing into sedimented rivers will often lead to flooding.

Table 4.4 Various Forest Areas by Function in 1985

	Number	Area (rai)
Logging Concessions	621	122,479,056[a]
National Forest Reserves	1,158	136,347,175
Pre-reserved Forests	84	15,506,075
National Parks	52	16,724,600
Forest Parks	57	938,200
Wildlife Conservation Area	28	12,909,050
Non-hunting Area	38	1,871,250
Wildlife Park	2	15,344
Botanical Gardens	5	6,250
Arboretum	42	19,544

Note: a. Only about 15 million rai are actually open for logging
Source: RFD, 1985a, p. 26, 27, 66 and 67

According to figures produced by the Royal Irrigation Department (RID), the sediment yield in one northern river, the Mae Tang, increased from 1,000 kg/ha in the late 1960s to more than 3,000 kg/ha in the late 1970s. The Maekhong Committee forecasts that sedimentation in the Nam Pong reservoir, in the Northeast, will reach a maximum of 2.4 million tons per year by 1987 (MOAC, 1986). As far as sediment inputs into the Gulf of Thailand are concerned, these are thought to be running at about 47.6 million cubic meters a year, as shown in Table 4.5.

These statistics, however, tell us little about the costs imposed by such sediments. In this respect, it is interesting to note that the RID has also estimated that the proportion of

Box 4.2 The Hill Tribes

As far as the tourist visiting Thailand is concerned, the hill tribes of the northern highlands are exotic, exciting. The streets of Bangkok are dotted with hill tribe craft shops, selling their colorful handiwork. But for the Royal Thai Government, the hill tribes pose a series of profound political, social and ecological problems. Much highland deforestation, for example, can be laid directly at their door.

It is only since the end of World War II that the Thai Government has attempted to introduce a coherent administrative structure into the country's highlands, and the process has proved far from easy. Apart from the fact that these are marginal populations living outside the Thai mainstream, there is the additional complication that many of the hill tribes are often on the move. National borders mean little or nothing to them. The borders with Burma and Laos, for example, are hard to police, and there is much movement to and fro. This is not simply a matter of administrative tidiness: much of the opium grown in the infamous "Golden Triangle" is harvested in Burma and the processed derivatives are then smuggled into Thailand, which is much more international, for export.

The sheer number of hill tribespeople, about 500,000 is also exacting a growing toll on the highland environment. A high natural fertility rate among the hill tribes combines with influxes of refugees from politically troubled neighboring countries, and with the movement of landless lowland Thais into the mountains in search of land to farm. The end result is that large areas of forest are cut down, denuding important watershed areas. Forest reserves, which are protected for conservation purposes, are continually encroached. Soil erosion increases, as does sedimentation in rivers which originate in the highland areas, promoting downstream flooding and, by accelerating run-off, aggravating drought problems in the dry season.

A further factor in this worrying equation has been the change in the styles of farming used by some of the hill tribes. Traditionally, many of them practised "swiddening", an old English word meaning a "burned clearing in the forest." The surface soils in the highlands are poor, but by burning trees, whose roots have drawn up nutrients from deeper down, the hill farmer can release some of these nutrients into the soil and "capture" them in his crops. The fire temporarily rids the soil of pests, too, but the nutrients are soon exhausted and the pest populations build back up to troublesome levels. In the old swiddens, trees were left standing in the middle of cleared plots, to ensure natural regeneration when the plot was abandoned. Later, when the forest had recovered, the process was repeated.

This style of farming can support light population densities at best, but as long as it was practised in the traditional way, by reasonable numbers of people, the process was sustainable. Now, as populations increase and farmers become more interested in extracting as much as they possibly can from a plot before moving on, many plots are totally cleared of trees, and the natural regeneration process is much less effective.

The government, therefore, is presented with a series of extremely thorny dilemmas. If it wants to protect the highland watersheds, it will be forced to institute widespread resettlement of hill farmers from such areas, protecting the watersheds thereafter with force, if necessary. In a democratic society, even if vitally necessary, such programs can be hard to push through.

Increasingly, government agencies are looking for ways of combining watershed and other natural resource protection programs with projects designed to promote social and economic development in highland communities. The aim in forest reserves, for example, is to employ local people on the reserve, to give them a vested interest in maintaining it. If the goal of maintaining some 40 percent of Thailand's surface area is to have any chance of success, these programs must succeed first.

Table 4.5 Estimated Annual Sediment Yields as Contributed by the Central, Eastern and Southern Regions to the Gulf of Thailand

Region	Watershed Area (km^2)	Average Sediment ($tons/km^2/yr$)			Annual Sediment (million tons/yr)		
		suspension	bedload	total	suspension	bedload	total
Central[a]	67,189	183.0	36.6	219.6	12.3	2.5	14.8
East	36,394	190.0	38.0	228.0	6.9	1.4	8.3
South	70,188	295.0	59.0	354.0	20.4	4.1	24.5
Total	-	**668.0**	**133.6**	**801.6**	**39.6**	**8.0**	**47.6**

Note: a. including headwaters from the North
Source: Department of Conservation, Faculty of Forest, Kasetsart University, 1984.

paddy in non-irrigated areas which has been adversely affected by such watershed disruption grew from less than 10 percent during the 1960s and early 1970s to about 20 percent (over six million rai) during the late 1970s.

Clearly, Thailand's headwaters have not been well managed to date. Many are now known to be denuded, either by upland agriculture or by fuelwood collection. Watershed management is rarely an easy task, but here the basic management problems are enormously complicated by the remoteness of the affected areas, the ethnic and cultural diversity of the peoples who live there, their poverty, and the political sensitivity of the whole issue.

4.2 HISTORICAL DEVELOPMENT AND EMERGING TRENDS

Forest Destruction

The latest assessment of the status of forest areas in Thailand indicates that only about 29.05 percent of the country's total area remains under forest cover (Table 4.6). This represents a reduction in forest cover of around 45 percent between 1961 and 1985 (Table 4.7), and this trend is expected to continue (Figure 4.1).

This dramatic depletion of Thai forests has occurred as a result of forest clearance after logging operations, crop cultivation in the highlands, and encroachment by hill tribe squatters. So far, at least, attempts to reverse the trend have failed. Some of the areas lost to forest is now permanently lost as far as the forest sector is concerned, because of its suitability for agriculture. But other areas will need to be rehabilitated and reforested for such purposes as watershed protection.

Reforestation and Forest Rehabilitation

When the First National Economic and Social Development Plan was drafted, the RFD reserved 50 percent (161 million rai) of the country as forest land. This proportion fell to 40 percent (128 million rai) in the Second, Third, Fourth and Fifth

Table 4.6 Forested Areas in Various Regions of Thailand, 1961, 1973, 1976, 1978, 1982 and 1985

(rai)

Region	Total Land Area	Forest Area					
		1961	1973	1976	1978	1982	1985
North	106,027,680	72,671,875 (68.54)	70,996,875 (66.96)	63,954,375 (60.32)	59,335,625 (55.96)	54,847,500 (51.73)	52,578,750 (49.59)
East	22,814,063	13,226,875 (57.98)	9,397,500 (41.19)	7,894,375 (34.60)	6,898,125 (30.24)	5,000,000 (21.92)	4,993,750 (21.89)
Northeast	105,533,958	44,315,000 (41.99)	31,669,375 (30.01)	25,933,750 (24.57)	19,513,125 (18.49)	16,178,750 (15.33)	15,140,000 (14.35)
Central Plain	42,124,189	22,287,812 (52.91)	14,981,250 (35.56)	13,641,250 (32.38)	12,766,250 (30.31)	11,572,500 (24.47)	10,767,500 (25.56)
South	44,196,992	18,516,250 (41.89)	11,521,875 (26.07)	12,586,875 (28.48)	11,001,875 (24.89)	10,276,250 (23.25)	9,678,125 (21.90)
Whole Country	**320,696,882**	**171,017,812 (53.33)**	**138,566,875 (43.21)**	**124,010,625 (38.67)**	**109,515,000 (34.15)**	**97,875,000 (30.52)**	**93,158,125 (29.05)**

Notes: All data derived from LANDSAT except 1961 data from aerial survey.
Values in parenthesis are percents of total land area in each region.
Source: RFD, 1985a, p. 20-24.

Table 4.7 Forest Encroachment, 1961-1985

	1961-1973	1973-1976	1976-1978	1978-1982	1982-1984	1961-1985
Total Forest Encroachment During Period (rai)	32,450,625	14,556,250	14,495,625	11,640,000	4,716,726	77,859,538
Average Annual Forest Encroachment During Period(rai/yr.)	2,704,219	4,852,081	7,247,813	2,910,000	1,527,242	3,244,147

Plans. Despite this target, however, only about 29 percent (93 million rai) of the nation's forest cover was left by 1985, of which nine million rai (or some 10 percent) are in headwater areas.

The rate of reforestation has lagged behind the rate of deforestation. To date, as Table 4.8 shows, the total area reforested amounts to something over 3 million rai, while deforestation, as later sections explain, has been running at a similar rate—every year. As far as the reforestation of mountainous watershed areas is concerned, the rehabilitation units report having achieved a total of 697,425 rai of new plantations over a 21-year period, representing about 31,500 rai per year. The RFD planted just over 200,000 rai a year from 1982 to 1984, with a figure of 246,675 rai reported for 1985. For the period covered in the Sixth National Development Plan (1987-1991), the RFD's target will be to plant 300,000 rai per year, in the following proportions: 17 percent for watershed protection, 40 percent for commercial purposes, and 43 percent for fuelwood and charcoal.

Land Pressure and Degazetting

Altogether, there were 1,158 units of forest reserve in 1985 (Table 4.9), an increase of 140 units since 1981. These units covered an area of 136.35 million rai, although only 93.16 million rai were forested. The 43.19 million rai difference is presumed to be occupied by squatters, as shown in Table 4.10.

Unfortunately, these forest reserves have decreased from the initial areas because the RFD had to grant STK (right to farm) certificates to squatters who live inside or near the reserves. The RFD's initial target was to implement the STK program to completion in all forest areas between 1982 and 1986. This target will not be met, as only 4.2 million rai had been degazetted in 574 national forest areas by 1984, as shown in Table 4.10. However, the RFD was expected to degazette about 6.36 million rai of national forest reserves in 1985. The RFD believes that the STK program area may also help in meeting forestry and rural development targets.

Table 4.8 Reforestation by Government Agencies and Concessionaires 1961-1985 (rai)

	up to 1980	1981	1982	1983	1984	1985	Total
Afforestation in Forest Villages	1,002,644	94,713	56,281	56,094	56,450	66,330	1,332,422
Watershed Reforestation	394,625	87,250	48,750	46,925	56,575	63,300	697,425
Reforestation of Degraded Forests	375,706	89,781	30,600	30,100	32,575	48,200	606,962
Concessionaires' Reforestation	361,569	69,400	74,981	96,569	67,244	68,875	738,638
Total	**2,134,544**	**341,144**	**210,612**	**229,688**	**212,844**	**246,675**	**3,375,507**

Source: RFD, 1985a, p. 29.

Table 4.9 Number and Area of National Forest Reserves, 1982-1985

Region	1982		1983		1984		1985	
	Units	Area (rai)	Units	Area (rai)	Units	Area (rai)	Units	Area (rai)
North	211	59,714,643	220	62,115,219	228	61,814,600	239	64,902,044
Northeast	298	30,549,919	301	30,563,181	314	32,653,413	331	33,398,488
Central and East	119	19,643,231	121	19,674,606	133	22,294,100	140	21,958,019
South	406	14,894,544	417	15,070,319	435	15,909,050	448	16,088,625
Total	**1,034**	**124,802,337**	**1,059**	**127,423,325**	**1,110**	**132,671,163**	**1,158**	**136,347,176**

Source: RFD, 1985a, p. 26.

Table 4.10 National Reserve Forest under the STK Program, 1982-1985

Year	No. of Forests	Total forest area (rai)	Area Under STK		Leased Area	
			(HH)	(rai)	(HH)	(rai)
1982	43	13,427,568	78,712	836,211	3,643	252,867
1983	122	24,383,678	169,197	1,736,132	54,863	1,089,315
1984	191	27,564,048	201,844	2,162,760	76,010	1,330,674
1985	218	40,806,694	174,295	1,625,346	41,255	740,112

Notes: a. STK allows 15 rai/family, additional land must be leased.
b. HH = No. of households.
Source. Royal Forest Department, 1986.

4.3 LEGAL AND ADMINISTRATIVE FRAMEWORK

The Legal Background

In the early history of Ratanakosin, there was plenty of forest land. It belonged to the feudal chiefs, particularly in the north, i.e., Chiang Mai, Lampoon, Lampang, Phrae, and Nan. Those forests were recognized, in general, as properties to be maintained by these chiefs and passed on to their heirs. According to the property rights of the day, the chiefs allowed concessionaires to exploit the teak forests. Inevitably, there were problems, since there was more than one concessionaire, there was no silviculture system, and the rate of working of timber was three and one-half times the rate of timber growth. Moreover, the deterioration of forests was evident and disputes among the concessionaires were widespread. As a result of these problems, several laws were initiated during this period: (1) the City Land Supervisor Act of 1874 which concerned the contract between the feudal chiefs and foreign concessionaires; (2) the Royal Proclamation of 1884 concerning the sale of teakwood; (3) the Royal Proclamation of 1887 concerning the transportation of teakwood; and (4) the Royal Proclamation of 1887, concerning teak log possession.

The problems seemed to be solved in 1895, when H. Slade, a British forest expert, was hired by the Royal Thai Government from the Government of India. In that same year, after he had finished his study of the forests in the north, he recommended the establishment of the RFD. In 1896, the RFD was established by King Chulalongkorn. Slade was then appointed as the first Director-General. Three years later, in 1899, ownership and control of all forests were transferred from the feudal chiefs to the government. At the same time, several laws, rules, and regulations on forest protection were promulgated. Among these were: (1) the Forest Protection Act of 1897; (2) the Teak Trees Protection Act of 1897; (3) the Act prohibiting illegal marking of timber in 1898; and (4) the Act prohibiting the extraction of teak timber without paying royalties or duties, enacted in 1899.

As the years passed, however, new problems arose. The government then established laws, such as: (1) the Forest Care Act of 1913, which was revised in 1936; (2) the Protection and Reservation of Forests Act of 1938 revised in 1953 and 1954, and repealed and replaced by the National Forest Reserve Act of 1964; (3) the Forest Act of 1941, revised in 1948, 1951, and 1960; (4) the Wildlife Protection and Reservation Act of 1960; and (5) the National Park Act of 1961.

Forest Protection Programs

Generally, forest protection measures stemmed from the Forest Act of 1960 and the National Forest Reserve Act of 1964. Other major Acts include the Wild Animals Reservation and Protection Act of 1960, and the National Park Act of 1961, both of which aim to protect and maintain the natural features and resources of forests. There are also a number of policies, regulations and rules which help provide the legal and administrative framework for forest management. Commitments to forest protection can be found, for example, in each of the National Development Plans.

The Sixth National Economic and Social Development Plan includes the following forestry objectives: (1) an increase in forest cover, from 29 percent to 40 percent of Thailand's surface area, with an increased emphasis on community involvement in forestry programs: (2) the division of Thailand's forests into two categories: protected forest (goal, 15 percent of the country) and economic or productive forest (goal, 25 percent of the country); (3) a revision of the laws and regulations governing the management of forest lands, especially in relation to private sector initiatives; (4) the development of coherent short, medium and long-term plans for forest and forest industry development; (5) the reform of forest administration, to link it in with these plans; (6) the identification and introduction of technical innovations, designed to boost the productivity of forestry operations; and (7) the development of a public awareness program, to educate and inform people about the important of forest resources.

Implementing these policies is the responsibility of a number of different agencies, some of which are briefly profiled below. As in other policy areas, there are overlapping areas of responsibility and, in some cases, competing objectives. A major step towards reconciling these different approaches to forest management was the production of the National Forest Policy in December 1985, which has the support of all the relevant agencies.

The Royal Forest Department (RFD)

The RFD was established in 1896 to oversee the logging activities of the time. Its subsequent development was based on the expansion of its administrative functions. The technical aspects of forest development were assigned to the RFD in 1935, with the creation of four technical divisions, namely, the Forest Products Research Division, the Forest School Division, the Silviculture Division, and the Forest Control Division. At the present time, the RFD has eight technical divisions and three administrative divisions operating from Bangkok. The three major divisions are under the Central Office Administration.

RFD field operations are managed through the Territorial Officiais Administration which is comprised of 72 provincial offices, 585 district offices and 87 sub-district offices. Each provincial office oversees the use and protection of local forests, issues permits, collects revenues, and establishes policies for the transportation and processing of forest products. The responsibilities of the regional offices (of which there are 21, 6 of which are in the Northern Provinces) tend to overlap with those of the technical divisions; for example, some nurseries are run by the regional offices under advice from the Silviculture Division, while others are controlled directly by the Silviculture Division. The regional offices act in an advisory capacity to the provincial offices.

Forest Industry Organization (FIO)

The FIO is an autonomous government corporation, set up to harvest the teak forests. In line with the Thai Government's policy of encouraging concessionaires to reforest, the FIO has been widely involved in reforestation. The FIO forest village system is now operating in a total of 53 forest areas (24 in the north, 16 in the east and northeast, and 13 in western and southern Thailand). By 1983, the FIO had established 42 forest villages involving a total population of 9,518, or 1,847 households, with one-half of the households located in northern Thailand. The FIO also operates a network of forest tree nurseries, which supply plant materials for reforestation activities.

Thai Plywood Co.

This state enterprise was established in 1951, with an initial investment of 80 million baht, to operate within the Ministry of Agriculture and Cooperatives. The company's purpose is to make more efficient use of forest resources by producing wood products of a standard quality and at a price which will attract consumers of higher quality wood products. In addition to the production of two types of plywood, the firm also produces prefabricated wooden doors and pre-cut lumber. Raw materials for these products are derived primarily from four forest locations managed by the company, covering an area of about 32,000 rai (5,120 ha). A variety of trees are grown in five plantations and one seed centre, including, teak, eucalyptus, leucaena, and acacia etc. This company was sold to the private sector in 1985.

Constraints to Forestry Development

The RFD recognizes three principal obstacles in the way of an accelerated forestry development program: (1) the lack of consistent land use policies, which should be coordinated to provide efficient use of natural resources, including land, forests, water, and minerals. Lacking such policies, the results have been competition and inefficiency in the use of land for agricultural purposes; (2) the RFD's manpower and funding have not kept pace with its increased responsibilities and demands for increased efficiency—the forest industries and their estimated employees are listed in Table 4.11 and (3) the laws and regulations governing forest resource administration are also seen as constraints on innovations and new approaches to forestry department.

4.4 KEY ISSUES

The Royal Thai Government (RTG) is well aware of the damage that has been done — and is being done — to Thailand's forests. Badly managed official logging and illegal logging, and encroachment by landless farmers, hill tribesmen and other shifting cultivators are just some of the threats to the country's remaining forest cover. The RTG has devised and adopted a number of strategies designed to halt, or at least slow, the process of deforestation. These have included the 40 percent forest target; watershed classification; privatization programs; the fast-growing tree and social forestry programs; the STK program; management programs designed to tackle the side-effects of shifting cultivation; and investment in improved forest management techniques.

But, all too often, these strategies have been stalled because: (1) there is inadequate cooperation between government agencies, or between the public and private sectors; (2) the legal framework is inadequate, either because it is too old or too weak; (3) there is a lack of adequate land use planning; (4) research results are too rarely incorporated into practical forest management procedures; and (5) and by no means finally, but fairly fundamentally, there has been a lack of an effective enforcement program to deal with encroachment and illegal logging.

Preserving Forest Cover at 40 Percent

The National Forest Policy has set the minimum requirement for forest coverage at 40 percent of the whole country's land surface area. The area can be divided into two parts: (1) the conservation forest of about 15 percent, which is composed of headwater source areas (first class watersheds), national parks, wildlife sanctuaries, non-hunting areas, reserved parks, arboretums, botanical gardens, and reserved areas for specific

Table 4.11 Employment in Commercial Forestry Activities, 1982

No.	Activity	No. of Business Units	Estimated Employees
1.	Logging	336 Concessions	6,700
2.	Mangrove Clearing and Charcoal Production	309 Concessions 1,280 Ovens	9,270
3.	Mechanized Sawmills	464 Mills	23,200
4.	Mechanized Production of Forest Products	2,833 Factories	70,825
5.	Unmechanized Sawmills	230 Mills	1,380
6.	Unmechanized Production of Forest Products	1,103 Factories	3,380
7.	Lumber Stores	1,741 mills	10,446
8.	Forest Product Sales	1,789 Individuals	5,367
	Total		**130,568**

Source: Forestry Development Under the Fifth Economic and Social Development Plan, NESDB 1983.

studies ; and (2) the commercial forest or productive forest of about 25%, which is composed of forest reserves, plantation areas, community forests, private tree farms (forests), and timber concession areas.

As the forest coverage at the present time is about 29 percent, there will need to be an increase in forest coverage of about 11 percent or, about 35.3 million rai, to reach the target. If the government achieves about 300,000 rai per annum, as suggested by the current planting rate, it would still take about 118 years to reach the target. However, if the government increases its efforts and budget, replanting about a million rai per year, then it will take about 35 years to reach the target, if, and only if, the preserves on the existing forest have been effectively controlled.

To accomplish the target and select suitable forest locations, the following strategies would be helpful. The government should: (1) clearly specify the location and size of the conservation forests throughout the whole country; (2) stake out the boundaries of productive forests, such as forest reserves, concession areas, and areas of watershed class; (3) prepare an effective plan for reforestation in the shifting cultivation areas and denuded lands, and determine the areas of responsibility for the government, private sector, and community; and (4) assign responsibilities and set guidelines for other government agencies and for the local community on how to implement the forestry work. Furthermore, (5) future forest protection should be undertaken not only by the RFD, but also by other agencies, such as local communities, schools and universities; (6) laws and regulatory improvement and development are urgently needed to help implement the National Forest Policy; and (7) wood utilization and conservation should be emphasized in relation to extension programs.

Watershed Classification and Management

Watershed management is defined as "the management of the land for desirable quality, and regulation of water flow along with soil erosion control, flood reduction and other resource utilization." The watershed area is synonymous with basin, drainage area, catchment area, hydrological unit or resource system.

Since the land in the watershed area varies from one place to another, watershed classification is needed. The term "watershed classification" is used here as synonymous with "land use planning for watershed areas". Land use planning or watershed classification is an effort to make man's uses of land as compatible as possible with the features of the environment and to mitigate any adverse effects. Watershed classification will help to achieve this goal by identifying which areas should be maintained as protected forests and by prescribing guidelines for associated areas which may be used for the culture of trees or crops. However, the watershed classification, as approved by the Cabinet, requires a system for establishing potential uses of land based on the physical characteristics of landscape units, namely elevation, slope, landform, geology, and soils.

(a) Watershed class 1: Protected forest (Conservation forest)

Class 1A includes areas of protected forest and headwater source areas, usually at higher elevations with very steep slopes. These areas still remain under permanent forest cover. Class 1B are areas having similar physical features and environments as Watershed Class 1A, but where portions of the area have already been cleared for agricultural use or occupied by villages. These areas require special soil conservation protection measures and, where possible, should be reforested.

(b) Watershed class 2: Commercial forest

Class 2 comprises areas of protected and/or commercial forest (usually commercial forests). For the most part, these areas are located at higher elevations, with steep to very steep slopes. Landforms are less erosive than in Watershed Classes 1A or 1B. Areas may be used for grazing or for certain crops. Soil protection measures are required.

(c) Watershed class 3: Fruit tree plantations

Class 3 covers upland areas with steep slopes and less erosive landforms. These areas are usually used for fruit tree

Table 4.12 Plantation of Fast Growing Trees by Private Sector in Various Regions, 1966-1985

Tree Species	Central & East		North		Northeast		South		Total	
	(rai)	%	(rai)	%	(rai)	%	(rai)	%	(rai)	%
Eucalyptus camaldulensis	47,738.70	55.88	11,579.86	13.55	26,001.26	30.43	118.25	0.14	85,438.07	100.00
Casuarina junghuhniana	30,425.39	78.26	710.75	1.83	7,373.25	18.97	366.50	0.94	38,875.89	100.00
Rhizophora indica	8,534.25	99.59	-				35.00	0.41	8,569.25	100.00
Anardiam occidentale	2,798.50	68.73	36.00	0.88	204.25	5.02	1,033.00	25.37	4,071.75	100.00
Acacia auriculaefomis	-		896.00	96.27	34.75	3.73	-	-	930.75	100.00
Leucaena glauca	491.00	31.68	891.75	57.54	167.00	10.78	-	-	1,549.75	100.00
Casuarina equisetifolia	1,414.50	84.35	93.00	5.58	45.00	2.70	114.50	6.87	1,667.00	100.00
Acrocarpus fraxinifolius	-	-	220.25	67.74	-	-	104.75	32.23	325.00	100.00
Others	5,714.00	62.18	3,075.00	33.46	367.25	4.10	33.00	0.36	9,189.25	100.00
Total	**97,116.34**	**64.48**	**17,502.61**	**11.62**	**34,192.76**	**22.70**	**1,805.00**	**1.20**	**150,616.71**	**100.00**

Source: Planning Division, Royal Forest Department

plantations or certain agricultural crops, and may be used for commercial forests, grazing or other uses. They require soil conservation measures.

(d) Watershed class 4: Upland farming

Class 4 describes areas of gently sloping lands, suitable for row crops, fruit trees, and grazing with a moderate need for soil conservation measures.

(e) Watershed class 5: Lowland farming

Class 5 groups gently sloping to flat areas, used for paddy fields or other agricultural uses, with few restrictions.

In 1985, the Government of Thailand extended the watershed classification program to the Ping and Wang river basins. The government is considering the Yom-Nan River Basin next and plans to use this classification system for the whole country by the end of 1992.

Privatization of Forestry Works

The Sixth Plan calls for the RFD to continue its operations in highland watershed development by preparing annual plans with objectively verifiable and reachable targets. For example, a feasible target figure would be 100,000 rai (16,000 ha) per year for watershed improvement and reforestation. In addition, a target of 300,000 rai (48,000 ha) per year is proposed for reforestation in highland areas. The RFD also proposes to establish mechanisms for the increased participation of the private sector in forest development. In addition, the Sixth Plan proposes to conduct forestry works in national parks. Another proposal is that conservation forests be run by the private sector, including hotel and tourism businesses.

Some obstruction of project plans would be expected due to the present forest laws and regulations. Delays for preparation of working documents for beginning the project and obtaining licenses for leasing the government forests have to be expected. Tax-exempt loans for investment would also be needed at the beginning.

It is believed that privatization of forestry works would help the National Forest Policy to reach the target of 40 percent forest coverage area and also to increase the protection measures of the forests in the whole country in the future. The situation in the past has shown that the government — or the RFD — cannot achieve Thailand's forestry objectives in isolation. Besides the private sector, the community and other government agencies will need to participate in the forestry works proposed in the Sixth Plan. If all the agencies mentioned above can participate in reforestation, and in the preservation of the forest lands they occupy, the 40 percent forest coverage target could be achieved in less than 35 years.

Multipurpose Tree Programs and Social Forestry

Small-scale plantation work, mainly based on teak, started at the beginning of the century, but large-scale replanting only began in 1961. Due to developing wood shortages over the last decade, fast-growing tree plantations have been promoted. There are about 26 tree species, such as pine, persian lilac, eucalypt, leucaena, casuarina, acacia, duabanga, acrocarpus and mahogany. The planting area for all these fast-growing tree species can be quantified as shown in Tables 4.12 and 4.13. Most plantings are in the western, eastern central and northern regions of Thailand. Although the increasing rate of planting has not quite approached the target, significant social development gains from this activity are already evident.

The Sixth Plan emphasizes reforestation with fast-growing trees under community control. This could be expected to both increase the forest area and promote community development.

The STK Program

One of the RFD's most important programs is the granting of STK or "right to farm" certificates (usufruct licenses) to squat-

Table 4.13 Plantation of Fast Growing Trees in Thailand, 1966-1985

Year	Area (rai)
1966	13.00
1967	793.25
1968	164.00
1969	185.75
1970	849.50
1971	99.00
1972	297.00
1973	590.25
1974	489.75
1975	396.50
1976	598.75
1977	3,480.50
1978	5,423.00
1979	9,188.25
1980	11,067.64
1981	18,863.25
1982	9,803.50
1983	21,097.25
1984	36,265.82
1985	30,951.00
Total	**150,616.90**

ters in national reserve forest areas. In principle, the STK program is aimed at halting further encroachment of forest reserves located near squatter settlements. The granting of STK certificates gives affected farmers a sense of ownership they might not otherwise have had, and an incentive to settle on and invest in the land they occupy. The STK program also engages these individuals to work for RFD to replant forests and maintain standing forests in the STK designated areas that are for agriculture. The program serves to establish closer relations between squatters and the RFD, while providing a base upon which other RTG agencies can operate complementary development programs. Through the STK program, the RFD can apply the full strength of legal sanctions against individuals who continue to destroy unencroached forests.

The RFD's initial target was to implement the STK program to completion in all forest areas between 1982 and 1986. This target will not be met, as only 6.3 million rai had been allocated in 574 national reserve forest areas by 1985 (Table 4.10).

The operation of the STK program will also serve the purpose of meeting forestry and rural development targets. Within ten years of the initiation of the STK program, RFD anticipates that visual improvements will take place in the STK forest areas which can be verified using aerial photographs. Both the beneficiaries and the RFD will be involved in an organized, methodical reforestation program, with each RFD forest replanting unit planting at least 500 rai of trees per year. With the STK program serving as a base, the government's rural development effort can be expected to have a more significant impact, leading to a higher standard of living, linked to a decrease in forest destruction. The STK program is expected to affect the lives of one million families during the program's implementation. The government's Rural Work Generation Program will provide the infrastructure required in STK areas.

Shifting Cultivation

Forests are easily encroached once access roads are opened up to the forest concession areas. As Box 4.2 explains, hill tribespeople and other shifting cultivators have had a considerable impact on the highland forests, particularly where they have attempted to farm steeply sloping land.

The prevention of deforestation by shifting cultivators has been discussed for years. At the beginning, reforestation programs were seen as part of conventional rural development programs. However, as the pressures mounted, the objective was extended to include the reforestation of damaged forest reserves. But the replanting units ran into severe difficulties in areas where land had been encroached and the encroaching communities were still in residence. As a result, reforestation goals have rarely been met.

Increasingly, it is recognized that programs designed to achieve the reforestation of watershed areas should incorporate subprograms designed to promote the social and economic development of encroaching communities. This often requires that several agencies collaborate on the program, underscoring the need for a broad-based approach to this whole issue, with strong government backing for those involved.

Forest Management Practices

Forests are renewable natural resources. When wood timber is harvested from forest land, the resource should renew itself. In principle, if the harvest is undertaken in an amount equal to the annual increments, a year later the same amount of harvested wood timber could again be harvested. If overexploitation has taken place, however, the forest cannot recover this quantity of cut timber. Thereafter, the status of the forest deteriorates, and finally the yield cannot be sustained.

From the standpoint of sustainable yield, Thailand has applied the selective cutting system for harvesting the wood timber even before the establishment of the RFD in 1896. This method of forest management seems unlikely to meet the goal, because it can only be applied by disciplined forest users with technical know-how. In the past, the selective cutting system was highly efficient and productive. Since the population of the country increased from about 18 million in 1953 to 52 million in 1986, the selective cutting system seems out of date and needs improvement or replacement. The RFD recognizes the problems and the need to change from the selective cutting system to a clearcutting system. The economic return on the clear-cutting system was found to produce better benefits. Clear-cutting is also easier requiring immediate tree planting in the cutting site to carry out, requires less investment, and is the best way to prevent encroachment.

Unfortunately, the forest laws are obsolete and do not provide any way to alter the cutting method. Past experience in forestry has demonstrated that the change of cutting systems from selective cutting to clear-cutting should be implemented very soon, or else forest protection measures will fail.

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5 Nature Conservation

5.1 OVERVIEW

Definition and Scope

Currently, the best and most authoritative definition of conservation is: *"the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining the potential to meet the needs and aspirations of future generations"* (IUCN, 1980). In developing countries such as Thailand, conservation is not a luxury, but a vital activity to maintain long-term economic stability and the quality of life. In fact, conservation is what this whole volume is about: maintaining environmental quality and sustaining the productivity of natural resources. Nature conservation in this broad sense is therefore not a narrow sectoral activity, but affects all sectors of human activity.

This chapter, however, does not cover the broad sphere of conservation as defined above, but focuses on the management of natural areas commonly used for recreation, species preservation, and other related uses, the most important of which (though not all) are included in national parks and wildlife sanctuaries managed by the Royal Forest Department (RFD). These "nature conservation" areas affect the economy and quality of life of Thai people in many ways now, and have the potential for contributing much more to economic welfare in ways which are not at present realized. Thus, nature conservation areas contain real "resources", even though they are not harvested. These resources must produce benefits for as many people as possible consistent with their protected status; otherwise their conservation will not be seen by planners as fully justified. This chapter will define what these resources are, discuss how they are now being used, and suggest how they may be more effectively conserved while providing increased benefits.

Although these resources may be referred to as "natural heritage resources", they have more to do with our future than with our past. The heritage from our past is our hope for the future.

Wild Populations

Natural heritage resources include wild populations of both animals and plants and their natural environments. These environments are kept in a substantially natural condition, but may be modified to a limited degree to allow access and management activities, or to enhance their value for wildlife. Included are marine environments containing fishes, sea turtles and corals.

These wild resources are self-sustaining, as they have been throughout their evolution, and are not dependent on man except for habitat protection. This aspect has great ecological and economic significance. It means that their birth and death rates balance themselves through natural feedback mechanisms. For forests, it means that material cycling mechanisms are relatively closed, with natural losses balanced by natural gains in a steady state. It also means that the populations are dependent on the functioning of their ecological community at large for food energy and many other requirements for survival such as shelter, dispersal, pollination or waste recycling.

Because commercially harvested wild populations (trees, fishes, etc.) are discussed in other chapters, we arbitrarily restrict this chapter to those which are not harvested, or which are harvested, legally or illegally, as relatively minor products. Included, however, are protected populations of many species which are harvested in unprotected areas elsewhere, and thousands of species which have potential for development into managed commercial resources.

Aesthetic and Recreational Areas

Natural heritage resources include natural areas or physical features valued for scenic beauty, recreation, tourism, education, research and other non-consumptive uses. Protected natural areas may also contain man-made structures of cultural, historical or religious value; it is recognized that one possible function of conservation areas may be to preserve such cultural objects where they exist in natural surroundings (IUCN:ICNPPA, 1984). There may also be overlap between the cultural and the natural heritage around religious shrines, where nature is to some degree protected.

City parks also have a natural aesthetic and recreational value, with their trees, flowers and ponds. Although they must be intensively managed as artificial ecosystems, they provide a setting of living things that offers some of the peace and inspiration that is found in nature.

Value of the Natural Heritage

That natural heritage resources have "value", is implied in their being called "resources". Their value is ultimately economic, but for a variety of reasons this value cannot always be traded in readily as market value, with which most economists are concerned. In some cases the value is a potential value or opportunity value which may be unpredictable. In other cases, the value is clearly present but difficult to price without considerably more data and research, such as the watershed value of a forest. Pricing our natural heritage is one of the most difficult challenges facing decision makers in determining how much effort should be spent in maintaining it. This is particularly true of environments prized for their great biotic diversity, such as tropical forests, which are great storehouses of potential economic resources. Below is a classification of different types of value attached to conservation resources.

Species of potential use

Species of potential value as resources, but not presently identified as such, fall into this category. That a tremendous variety of tropical plants and animals produce useful products is undeniable. They include pharmaceuticals, insecticides, fuels, lacquers, dyes and many other industrial compounds (Myers, 1983, 1984). But while new products have undeniable benefit, they may not have immediate economic value upon discovery, and considerable technology is often required to realize these benefits.

Non-human primates, our closest living relatives are of great importance to biological and medical research. Because their populations are declining all over the world, however, their continued use depends on the development of captive breeding programs. Most tropical countries, including Thailand, have halted the export of wild-caught primates to foreign laboratories and pet markets. The study of comparative ecology and social behavior of monkeys and apes in their natural environment has been of particular importance during the past 30 years.

Native animal species have great economic value as pets or for ornament —including hundreds of species of birds, fishes, turtles, snakes, mammals and even invertebrates. Among plants, orchids support a large and increasing commerce, but considerable effort is still needed to breed them artificially in order to satisfy demand and halt their tragic and destructive collection from the wild (Sagarik, 1985).

Genetic variation

All of our domestic species, whether used for food or special products, were originally derived from wild populations, and in most cases the wild relatives are still present in our natural environments. Most domestic forms are considerably altered in their characteristics through selection of different genotypes, either consciously and scientifically, or without any particular design. The traits selected may be higher productivity, increased or reduced size, gentle temperament, or the ability to flower at a different time of year. Artificial selection inevitably reduces the overall genetic variability in the population, however, and eliminates many traits which the animals or plants required to survive in the wild; for example, hardiness under drought or chemical resistance to insect attack in crop plants. Plant breeders are increasingly looking for wild populations to recover genetic variability and search for genes for new desired characteristics.

Some of the most important genetic reservoirs with economic potential are the populations of wild cattle in Southeast Asia: the gaur, banteng, wild buffalo and the nearly extinct kouprey (Lekagul, 1984). Recent experiments on crosses between wild gaur and domestic cattle in Malaysia have revealed that hybrids are about 75 percent more productive than domestic cattle and resistant to some parasites (Dhillon, 1985). Local wild populations can be expected to be better adapted to native plant foods and to the climate, and to be more resistant to disease.

Recreation

The most appreciated benefit of conservation areas is recreation for the Thai people. Visitors to national parks and wildlife sanctuaries now number about four million per year (statistics from Royal Forest Department). The value of recreation can be expressed in monetary terms to some extent; however, the money spent by visitors would underestimate the economic value of the recreation because it is largely subsidized by the

government (as is education, for example). Furthermore, the benefit has fallen on middle and lower income persons more than on wealthy persons, who tend to visit more highly developed tourist resorts in the private sector.

Tourism

Conservation areas have great potential to attract tourists from abroad, increasing government revenue and benefiting the private tourism sectors such as airlines, hotels, restaurants, guiding agencies, and so on. Tourism, if carefully planned, can also provide wages and jobs for local residents as trekking guides, carriers, cooks and other service personnel, as indicated below.

Education

Extension services have been developed in some protected areas for educational purposes, and school children are increasingly taken to parks to learn about the natural environments. The potential for using protected areas for school educational purposes has hardly been tapped; protected areas are now scattered in virtually all provinces and could have a tremendous impact if suitable arrangements were made between schools and conservation area personnel.

Local employment and development

Unfortunately, many protected areas have been perceived by locals as having negative value to them, preventing them from growing crops or hunting wild animals. But, conservation areas have considerable potential to offer benefits to local residents (who are usually poor farmers) near their borders. These benefits could come from increased employment opportunities, especially those arising from recreation and tourism. Such tourism, however, must be planned and executed to benefit locals, or else it will benefit primarily tourism promoters. Little effort has been made to develop foreign tourism for local rural benefit, but a considerable potential exists, especially for activities such as hiking, trekking and nature study, which can employ locals as guides and for other services at generous wages.

Ecological services

Ecological services are indirect benefits that are derived from the functioning of ecosystem processes such as those associated with the water and mineral cycles, the carbon cycle or effects of forests on weather and climate. They include watershed benefits (see Chapter 3). Some important ecological services are:

a) Protection against soil erosion

Tree cover tends to protect soil against the force of rain and tree roots hold the soil. This results in reduced sediment load in streams and reduces siltation downstream (see Chapter 3).

b) Control of water flow and quality

The effect of forests on the water cycle is still somewhat controversial and in need of further research, especially in tropical environments (e.g., Hamilton and King, 1983), but most ecologists agree that forest cover alleviates flooding in the rainy season by holding back some water and returning some to the atmosphere through evaporation and transpiration. Precipitation is also increased in mountain forests through condensation on leaf and twig surfaces. Forest cover holds rainwater and may facilitate recharge of underground aquifers which supply water after the rainy season. Forested watersheds provide water of higher quality for household use and aquatic life than do deforested watersheds. In these ways, the benefits of nature conservation reach virtually everyone in the kingdom.

c) Effect on rainfall

By maintaining the humidity in the atmosphere, forests probably increase the amount of rainfall, though to degrees which vary from place to place and which are not yet predictable. For example, it has been estimated that about 50 percent of the rainfall in the Amazon Basin is derived from evaporated and transpired moisture from trees there and another 50 percent from oceanic evaporation (Salati and Rose, 1984).

d) Effects on temperature

Effects on the water cycle lead to temperature changes; evaporation and transpiration have cooling effects, for example. Forests have a tendency to reduce solar-caused temperature fluctuations.

e) Carbon storage

Forest vegetation and accumulated soil and litter store carbon drawn from the atmosphere during photosynthesis. The level of carbon dioxide in the atmosphere has been steadily increasing over the last several decades, mainly due to combustion of coal and oil, but some proportion of the increase is believed to be due to tropical deforestation and the accompanying oxidation of carbon in wood and litter (Woodwell, et al., 1983). The rise in atmospheric carbon dioxide is expected to produce a "greenhouse effect," which is an alteration of the heat balance of the earth, increasing average temperatures. While atmospheric carbon dioxide does not affect the light energy entering the atmosphere, it slows the passage of heat energy from the earth back into space. An increase in global temperature could alter the climate and weather over much of the earth and cause a rise in sea level due to the melting of some of the polar ice caps (Hansen, et al., 1981). The probable economic consequences of the greenhouse effect, and responsibility for them, however, are still much debated.

Table 5.1 List of National Parks in Thailand, Including Total Area and Year of Gazettment by Royal Decree
(For marine parks, the land area is given in parentheses under the total area.)

No.	Name	Province	Area (ha)	Year
1.	Khao Yai	Nakhon Nayok, Saraburi Nakhon Ratchasima, Prachinburi	216,863	1962
2.	Phu Kradung	Loei	34,816	1962
3.	Khao Sam Roi Yod	Prachuab Khiri Khan	9,808	1966
4.	Nam Nao	Petchabun	96,600	1972
5.	Tarutao	Satun	149,000 (26,000)	1974
6.	Khao Luang	Nakhon Si Thammarat	57,000	1975
7.	Doi Khuntan	Lamphun, Lampang	25,529	1975
8.	Nam Tok Phriu (Khao Srabap)	Chanthaburi	13,450	1975
9.	Thung Salang Luang	Phitsanulok, Petchabun	126,240	1975
10.	Phu Phan	Sakhon Nakhon, Kalasin	66,470	1975
11.	Erawan	Kanchanaburi	55,000	1975
12.	Khao Chamao - Khao Wong	Rayong, Chanthaburi	8,368	1975
13.	Khao Kitchakut	Chanthaburi	5,870	1977
14.	Doi Inthanon	Chiang Mai	48,240	1978
15.	Lansang	Tak	10,400	1979
16.	Phu Rua	Loei	12,084	1979
17.	Chaloem Rattanakosin (Tham Tam Bot)	Kanchanaburi	5,900	1980
18.	Ramkhamhaeng	Sukhothai	34,100	1980
19.	Sai Yok	Kanchanaburi	50,000	1980
20.	Thale Ban	Satun	10,160	1980
21.	Mu Ko Ang Thong	Surat Thani	10,200 (1,800)	1980
22.	Khao Sok	Surat Thani	64,552	1980
23.	Tad Tone	Chaiyaphum	21,718	1980
24.	Doi Suthep-Pui	Chiang Mai	26,106	1981
25.	Aow Phangnga	Phangnga	40,000	1981
26.	Si Satchanalai	Sukhothai	21,320	1981
27.	Khao Sam Lan	Saraburi	4,457	1981
28.	Kaeng Krachan	Prachuab Khiri Khan	291,500	1981
29.	Mu Ko Surin	Phangnga	13,500 (3,300)	1981
30.	Khao Phanom Benja	Krabi	5,012	1981
31.	Hat Nai Yang	Phuket	9,073 (2,200)	1981
32.	Mae Ping	Chiang Mai, Lamphun, Tak	100,300	1981
33.	Kaeng Tana	Ubon Ratchathani	8,000	1981
34.	Khao Laem Ya - Mu Ko Samet	Rayong	13,100 (800)	1981
35.	Wiang Kosai	Phrae, Lampang	41,000	1981
36.	Hat Chao Mai	Trang	23,088	1981
37.	Nam Tok Surin	Mae Hong Son	39,660	1981
38.	Srinakarind	Kanchanaburi	153,200	1981
39.	Thap Lan	Nakhon Ratchasima, Prachinburi	224,000	1981
40.	Ton Krabak Yai	Tak	14,900	1981
41.	Pang Sida	Prachinburi	84,400	1982
42.	Khao Pu - Khao Ya	Phatthalung, Trang	69,400	1982
43.	Mu Ko Similan	Phangnga	12,800 (1,400)	1982
44.	Khlong Lan	Kamphaeng Phet	30,000	1982
45.	Mu Ko Chang	Trang	65,000 (19,200)	1982
46.	Lam Son	Ranong, Phangnga	31,500 (4,800)	1983
47.	Hat Nopparatara - Mu Ko Pi Pi	Krabi	38,996 (6,400)	1983
48.	Phu Hin Rong Gla	Phitsanulok, Loei	30,700	1984

Table 5.1 (contd.)

No.	Name	Province	Area (ha)	Year
49.	Mu Ko Phetra	Satun	49,438 (2,600)	1984
50.	Phu Kaeo - Phu Phan Kham	Udon Thani, Khon Kaen	32,200	1985
51.	Mae Yom	Phrae, Lampang	45,475	1986
52.	Phu Jong Nai Yoy	Ubon Ratchathani	25,443	1986

The Protected Area System

The only land categories under the RFD that are completely protected by law from encroachment, logging, collecting and hunting are national parks and wildlife sanctuaries. The areas cannot be entered without permission of the relevant authorities. "Non-hunting" areas are wildlife areas protected from hunting and trapping only.

National parks

The first national park, Khao Yai, was gazetted in 1962. National parks presently number 52, and 6 are to be gazetted soon. The total land area is presently 26,760 square kilometers, covering 5.2 percent of the area of the kingdom (Table 5.1 and Figure 5.1). Parks in upland areas are still covered with dense forest, but there are also 13 parks covering marine areas. The first, Ko Tarutao, was added in 1974. Marine parks protect coral reefs, turtle laying beaches, mangroves, beach vegetation, and beach recreation areas.

The forest in parks is generally in excellent condition because most park areas were not encroached on previously and the National Park Division (NPD) maintains permanent staff, including armed guards, to protect them. The most difficult maintenance problem, however, appears to be poaching by local villagers which is still widespread in most parks, and cannot be completely guarded against. Many parks, in fact, have become "islands" of forest surrounded by local villages which have run out of new land to clear for crops. In at least four national parks, hill tribes are present who continue to practice shifting cultivation, hunting and gathering. The total numbers are unknown and fluctuate. Considerable areas of some parks, for example Doi Inthanon, have been deforested by hill tribes. Hill tribes are widely scattered in the mountains of north and northwest Thailand (Kunstadter, 1983) and are found in many protected areas of these regions.

According to the National Parks Act of 1961, the function of the national parks is to preserve land in a natural state in the interests of education and public pleasure (recreation) (IUCN, 1979). This definition of the function of national parks is now outdated, as it is recognized that the national park system also serves many other important functions. For example, national parks (along with wildlife sanctuaries) provide the most effective protection of watersheds.

Wildlife sanctuaries

Provision for the establishment of wild animal protection areas was made under the Wild Animals Reservation and Protection Act (WARPA) of 1960, and the first wildlife sanctuary was gazetted in 1965. Since then the number and areas of sanctuaries have increased rapidly to the present 28 areas, including 20,654 square kilometers or 4.0 percent of the kingdom (Table 5.2 and Figure 5.2). They are managed by the Wildlife Conservation Division (WCD) of the RFD.

Wildlife sanctuaries are generally in excellent or pristine condition, except for some in the north and northwest that house hill tribes. Much attention has recently focused on the tribes present in Huai Kha Khaeng and Thung Yai Naresuan Wildlife Sanctuaries — which contain a total of approximately 4,000 Hmong and Karen. At least 11 wildlife sanctuaries have had resident hill tribes which have created difficult management problems. Poaching in wildlife sanctuaries by Thai villagers, and occasionally even by more affluent and informed citizens, is also a serious problem.

In addition to protecting and managing wildlife, education is an important function of the WCD and seven nature education centers have been established in sanctuaries, located in all major regions of the kingdom. These education centers have displays of pictures and posters illustrating animals, plants and conservation principles, exhibits of captive native animals in enclosures and nature trails through nearby habitat. These are well visited by local Thais who are mostly weekend tourists or school children.

Non-hunting areas

Non-hunting areas, protected only against hunting and capture of animals, are specified in the WARPA and since 1975, 38 areas have been established totaling 2,994 square kilometers in area. These areas are generally smaller than wildlife sanctuaries and cover a great variety of smaller habitats and populations or colonies of particular species. Many of the areas have potential for the promotion of education and limited tourism (Table 5.3).

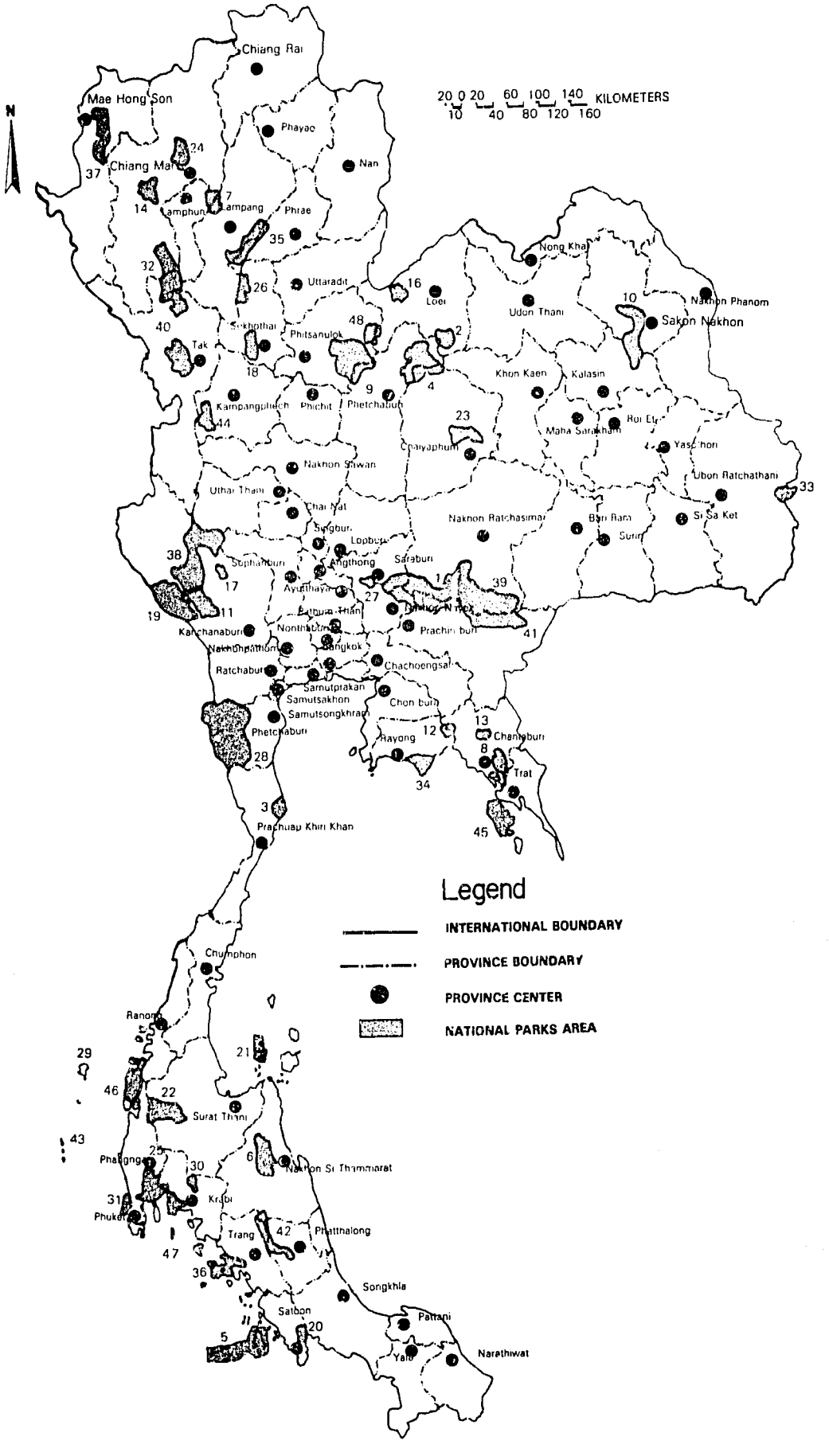

N
20 0 20 60 100 140 KILOMETERS
10 40 80 120 160
Chiang Rai
Mae Hong Son
Phayao
Nan
Chiang Mai
Lamphun
Lampang
Phrae
Uttaradit
Nong Khai
Loei
Udon Thani
Nakhon Phanom
Sakon Nakhon
Sukhothai
Phitsanulok
Tak
Khon Kaen
Kalasin
Kampangphet
Phichit
Phetchabun
Maha Sarakham
Roi Et
Yasothon
Chaiyaphum
Nakhon Sawan
Ubon Ratchathani
Uthai Thani
Chai Nat
Nakhon Ratchasima
Buri Ram
Si Sa Ket
Surin
Singburi
Lopburi
Sophanburi
Angthong
Saraburi
Ayutthaya
Pathum Thani
Nonthaburi
Prachin Buri
Kanchanaburi
Nakhonpathom
Bangkok
Ratchaburi
Chachoengsao
Samutprakan
Samutsakhon
Samutsongkhram
Chon Buri
Phetchaburi
Rayong
Chanthaburi
Trat
Prachuap Khiri Khan
Legend
INTERNATIONAL BOUNDARY
PROVINCE BOUNDARY
PROVINCE CENTER
NATIONAL PARKS AREA
Chumphon
Ranong
Surat Thani
Phangnga
Nakhon Si Thammarat
Krabi
Phuket
Trang
Phatthalong
Songkhla
Satoon
Pattani
Yala
Narathiwat

Table 5.2 List of Wildlife Sanctuaries in Thailand with Area and Year of Gazettment

No.	Name	Province	Area (ha)	Year
1.	Salak Phra	Kanchanaburi	85,855	1965
2.	Khlong Nakha	Ranong	48,000	1972
3.	Phu Khieo	Chaiyaphum	156,000	1972
4.	Khao Soi Dao	Chanthaburi	74,502	1972
5.	Huai Kha Khaeng	Uthai Thani, Tak	163,100	1972
6.	Lum Nam Pai	Mae Hong Son	119,400	1972
7.	Thung Yai Naresuan	Kanchanaburi, Tak	320,000	1974
8.	Khao Khieo - Khao Chomphu	Chonburi	14,470	1974
9.	Khlong Saeng	Surat Thani	115,620	1974
10.	Phu Luang	Loei	84,800	1974
11.	Phu Wua	Nong Khai	18,650	1975
12.	Khao Banthat	Phattalung, Trang, Satun, Songkhla	126,720	1977
13.	Yod Dome	Ubon Ratchathani	20,255	1977
14.	Phu Miang - Phu Thong	Phitsanulok, Uttaradit	54,500	1977
15.	Khao Ang Ru Nai	Chachoengsao	10,810	1977
16.	Ton Nga Chang	Satun, Songkhla	18,200	1978
17.	Maenam Phachi	Ratchaburi	48,931	1978
18.	Mae Tuen	Tak	117,300	1978
19.	Doi Chiang Dao	Chiang Mai	52,100	1978
20.	Salawin	Mae Hong Son	87,500	1978
21.	Khao Phanom Dong Rak	Si Sa Ket	31,600	1978
22.	Doi Pha Muang	Lampang, Lamphun	58,560	1980
23.	Doi Pha Chang	Phayao, Nan	57,675	1980
24.	Khlong Phraya	Krabi	9,500	1980
25.	Om Koi	Chiang Mai, Tak	122,400	1983
26.	Doi Luang	Phrae	9,700	1984
27.	Khao Sanam Priang	Kampaeng Phet	10,100	1985
28.	Mae Yuam	Mae Hong Son	29,200	1986

Miscellaneous nature areas

Temples and shrines provide areas which protect some nature, including some rather important colonies of mammals and birds. These include monkeys, most often long-tailed macaques *(Macaca fascicularis)*, but sometimes stump-tailed and rhesus monkeys *(M. arctoides* and *M. mulatta)* are present. The monkeys are usually in remnants of natural habitat surrounded by cleared and hunted-out areas, and are fed by visitors and protected by religious sanction or by the resident priests or custodians.

Colonies of monkeys exist at religious shrines near Bang Saen, Chonburi Province, at the Khmer ruins in Lopburi, at Wat Phra Chai Temple near Saraburi, at King Mongkut's palace in Petchaburi, on a hill shrine near the sea in Pracnuab Khiri Khan, and many other places. These small populations may be the last of their species to remain over large areas, and have considerable local value for tourism and entertainment. They are not always properly managed for the joint benefit of humans and monkeys. The WCD has declared the territory of some colonies near temples to be non-hunting areas, such as the open-billed stork colony at Wat Pai Lom, Ayutthaya Province.

Buddhist monasteries often occur in or near forest areas, or small patches of forest surrounded by deforested areas. These forest patches are refuges for insects, reptiles, smaller birds and mammals, but not for larger species.

Captive Propagation of Wildlife

The WCD has established nine wildlife propagation centers and is carrying out research on the captive breeding and management of approximately 50 species of birds, mammals and reptiles, with particular emphasis on pheasants and deer. The main purposes of such propagation are to provide captive stocks for commercial exploitation, thus alleviating hunting and trapping in the wild and promoting rural benefits, and to permit eventual restocking of wild habitats. The major propagation centers of the WCD are now located at Khao Khieo and Bang Lamung, Chonburi Province, Khao Soi Dao in Chanthaburi, Phu Khieo in Chaiyaphum, Pang Tong in Mae Hong Sorn and Chong Klambon in Prachinburi.

The Department of Fisheries has been engaged in sea turtle research and management. Collection of eggs from nests for sale and export is a traditional local industry on southern beaches. The Department collects 10 percent of those collected and attempts to rear the young at the Phuket Marine Biological Center for release at about six months of age. In addition, a project under Her Majesty's patronage has been initiated for captive breeding of adults and rearing of young on Ko Man Nai, an island off Rayong Province (Phasuk, 1985).

Figure 5.2 Wildlife Sanctuaries in Thailand

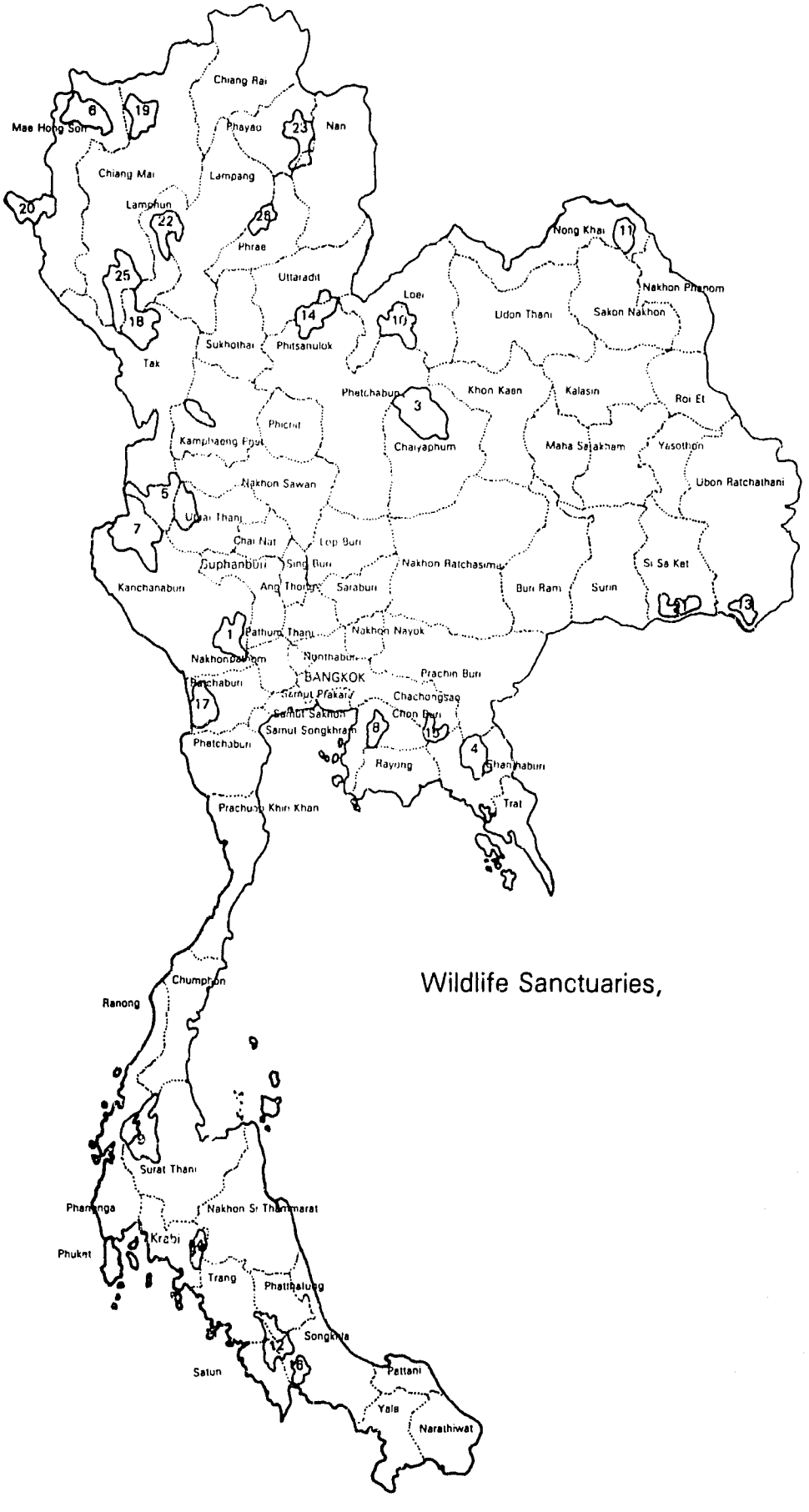


Table 5.3 List of Non-hunting Areas and Their Main Features

No.	Name	Province	Area (ha)	Features
1.	Thale Noi	Nakhon Si Thammarat Phattalung, Songkhla	45,000	Headwaters of Songkhla Lake; waterfowl
2.	Bung Borphet	Nakhon Sawan	21,280	Natural reservoir; waterfowl, only location for White-eyed River Marten
3.	Pa Phru	Narathiwat	16,000	Peat land forest, swamp; ducks
4.	Nong Thung Thong	Surat Thani	2,956	Marsh; waterfowl
5.	Wat Tan En	Ayutthaya	16	Herons, egrets, Indian shags, fruit bat, roost
6.	Bang Phra	Chonburi	1,856	Reservoir; waterfowl
7.	Lawa Cave - Daowadung Cave	Kanchanaburi	4,150	Bats (now in Sai Yok National Park)
8.	Doi Suthep	Chiang Mai	1,750	Forest (now in Doi Suthep National Park)
9.	Thale Sap	Songkhla, Phathalung	36,466	Brackish lake; waterfowl
10.	Khao Tha Phet	Surat Thani	463	Patch of forest near town; birds
11.	Wat Ratsattha Krayaram	Samut Sakhon	7.5	Roost for herons and shags
12.	Wat Phai Lom - Wat Amphu Wararam	Pathum Thani	11.8	Breeding colony Open-billed Stork
13.	Bung Kroeng Kawia - Nong Nam Sap	Kanchanaburi	51,200	Reservoir; waterfowl
14.	Li Bong Islands	Trang	44,750	Mangrove, mud flats for waders
15.	Khao Nam Phrai	Trang	2,080	Limestone mountain; serow, langurs
16.	Khao Phra Thaeo	Phuket	2,228	Rain forest, waterfall, wildlife park
17.	Nong Prak Phraya - Khao Raya Bangsa	Satun	2,043	Swamp; limestone mountain; serow waterfowl
18.	Huai Chorakay Mak Reservoir	Buri Ram	620	Waterfowl
19.	Sanam Bin Reservoir	Buri Ram	570	Reservoir; rare ducks
20.	Huai Talad Reservoir	Buri Ram	709	Ducks
21.	Nong Waeng	Chaiyaphum	17.5	Pond; waterfowl
22.	Khao Kra Dong	Buri Ram	232	Forest park
23.	Tam Rakang and Khao Phranon	Ratchaburi	17	Limestone cave; bats
24.	Khao Chong Prarn	Ratchaburi	12.3	Limestone cave; bats
25.	Pa Grard	Songkhla	412	Forest area in lowland
26.	Bung Khong	Nong Khai	1,382	Marsh along Maekhong River; waterfowl
27.	Bung Chawak	Suphanburi	320	Pond and marsh; waterfowl
28.	Pha Ta Pon Cave	Phitsanulok	284	Limestone cave and forest; bats
29.	Khao Yai - Khao Pha Natang	Uttaradit	2,400	Limestone cave; bats
30.	Khlong Lamcharn	Trang	5,400	Small ponds; waterfowl
31.	Pa Rangkai	Pattani	25	Roost for zebra dove etc., recreation-education area

Table 5.3 (contd.)

No.	Name	Province	Area (ha)	Features
32.	Laem Taloompook	Nakhon Si Thammarat	5,673	Mangroves, sandy beach; wading birds
33.	Mae Lao - Mae Sa	Chiang Mai	24,500	Mountain forest; goral, serow
34.	Nong Hua Khu	Udon Thani	11.2	Natural pond; waterfowl
35.	Khao Chi On	Chonburi	368	Forest limestone mountain near temple
36.	Khao Pa Chang	Songkhla	23,500	Melaleuca forest, mountain, near shore
37.	Thale Sap Nong Bon Kai	Chiang Rai	434	marsh; waterfowl
38.	Khao Prathap Chang	Ratchaburi	206	Hill forest on limestone; cave; monkeys

Source: Wildlife Conservation Division, RFD.

Zoos have a potential role to play in captive propagation for conservation purposes, but mostly they simply display animals for the public to see. Zoos by and large depend on natural populations for new acquisitions. Both the Bangkok Dusit Zoo and Chiang Mai Zoo would like to establish more propagation programs but have limited budgets for doing so. Most private zoos are managed by wildlife dealers whose income comes from the animal trade; they may contribute significantly to declines in some natural populations. This is particularly true for species with relatively delayed maturity or low reproductive rates that are desired by pet dealers or by zoos, such as monkeys, gibbons, hornbills, some parrots, pittas, Asian bony tongue (or "dragon fish"), and others.

The private sector could play a greater role in breeding and managing wildlife species in captivity but present laws and the policies of the RFD do not encourage much private sector participation. One example of successful commercial breeding is the crocodile farm in Samut Prakan, which breeds two native species which are nearly extinct in the wild in Thailand in large numbers.

It must be emphasized, however, that captive propagation is not an effective substitute for protection of populations in their natural habitats. Only a few species in the world can be bred in sufficient numbers for release, and there is no guarantee that released animals with no previous experience in the wild will be able to survive.

Overall Flora and Fauna

Our knowledge of the flora and fauna of Thailand is still very incomplete but is progressing slowly. Plants are the basic source of food, energy and provide the habitats and shelter for other living things. They also supply us with most of our useful resources. Perhaps the most basic and urgent cataloging priority is the *Flora of Thailand* (Smitinand and Larson, 1970, etc.), which now lists and describes about 20 percent of the vascular plants of Thailand. Work is continuing steadily on the *Flora*, by many Thai and foreign collaborating botanists. The total number of vascular plants native to the country is estimated by RFD botanists in the Forest Herbarium at 20,000 to 25,000, and flowering plants are believed to number 10,000 to 15,000 species in 260 families. This includes more than 500 species of trees and over 1,000 species of orchids. Khao Yai Park alone is estimated to contain perhaps 2,500 species of flowering plants. It is estimated that only about 60 to 70 percent of the vascular plants of Thailand have been described by botanists.

The value of our flora cannot be costed; it is the key to our survival in very many respects, and an important key to economic diversity. Hundreds of species have been found to be useful to man. Approximately 100 species of native forest trees are listed by Kanchananaga (1973) as being of commercial importance, and about 40 minor forest products are described. Pongpangan and Poobrasert (1972) list 157 Thai forest plants that are either edible or poisonous; plants with poisonous compounds often yield useful pesticides or pharmacological agents. These numbers are certainly minimum figures, but they give some idea of the potential of Thai forests to yield useful products. None of these species will remain if forests are not properly protected, or if they are converted to tree plantations which are usually monocultures of exotic species.

Thailand also has a very diverse fauna, but its smaller animals, including most invertebrates are poorly known. Approximately 900 species of birds occur in Thailand, of which 578 are resident forest species (Round, 1985). No fewer than 87 forest species are thought to be endangered, threatened, vulnerable or indeterminate in status. The most seriously threatened species are large water birds of swamps and marshes and forest species preferring level lowland rain forest, of which practically none has been preserved.

Thai mammals number about 265 species (Lekagul and

McNeely, 1977), of which about 92 species are bats (important insect predators and pollinators of some species of trees), 70 are rodents, 36 are carnivores, 18 ungulates and 13 primates. Somewhat less well known are the fishes (about 600 fresh-water species and 850 marine species), reptiles (at least 300 species), and amphibians (at least 100 species) (Nutaphand, 1979; Taylor, 1962, 1963, 1965).

The fauna of Thailand includes many large and spectacular species of worldwide renown, including the Asian wild elephant, tiger, clouded leopard, gaur, banteng, Malayan tapir, Asian wild dog, sambar deer, painted stork, open-billed stork, helmeted hornbill, great hornbill, argus pheasant and green peafowl. Primates include three species of gibbons, including the pileated gibbon found only in Southeast Thailand and Western Kampuchea, four species of leaf monkeys and five species of macaques.

Many of these species have become endangered and others are so rare that no recent records exist from the wild, or are now confined to small local populations. A few have already become extinct; as is described in the next section.

Much research remains to be carried out on the native flora and fauna. Needed research falls under the following categories:

a) **Systematics:** Taxonomy and the cataloguing of species of animals and plants.

b) **Ecology and Distribution:** Surveys are badly needed to determine the present ranges of species and their habitat requirements. Population sizes of important species must be estimated more accurately.

c) **Beneficial Uses:** The value of plants and animals to man needs to be explored to derive the most benefit from native species.

d) **Conservation and Management:** The conservation, protection and management of species needs research, including the propagation in captivity of beneficial species.

5.2 HISTORICAL DEVELOPMENT AND FUTURE TRENDS

There seemed to be little need for special measures to protect wildlife before World War II, when forest cover exceeded 60 percent of the kingdom and large herds of big game animals such as elephants, gaur, banteng and rhinoceros roamed the forests, and large flocks of storks, ibises and other large waders fed on the plains (Gairdner, 1915; Lekagul and McNeely, 1977; Jintanugool, et al., 1982). After the war the increased avajlability of firearms, the demand for timber for export and a rapidly expanding human population caused a steady reduction of wildlife and habitat in every region of the country.

To check these trends, the government enacted the Wild Animal Reservation and Protection Act (WARPA) in 1960, establishing hunting limitations, and capture and trade restrictions, and making provision for the wildlife areas described above. Lists of protected species have been updated from time to time in response to increasing threats to their populations. For example, the export of monkeys was curtailed in 1976, in response to a growing demand for them (especially the stump-tailed macaque) for laboratory research. At present, the Royal Forest Department lists 228 types of vertebrates on reserved and protected lists which prohibit or restrict hunting and trade (Jintanugool, et al., 1982).

Nothing is done to prevent hunting of protected animals outside of the protected area system and most large species no longer survive in significant numbers outside of protected areas, except in a few remote regions. A considerable amount of subsistence hunting and trapping takes place in rural areas, both inside and outside of protected areas.

The local trade in wildlife species is extensive and it is uncertain if laws have much effect on it, especially in the case of small species which are easy to transport and conceal. It is virtually impossible to prevent animals from being bought and sold, even in the large markets, as almost any animal can be concealed, or be claimed by an owner not to be for sale. Trade in wild animals is carried out by hundreds of small vendors, pet stores, private zoos, large international dealers, game meat restaurants, and jewelry stores which sell endangered cat skins, teeth and claws, all conspiring to find loopholes in the laws or simply ignoring them. Additionally, the present regulation allowing persons to own one pair of any protected species has been counterproductive in that it has created a convenient loophole for dealers and does nothing to aid captive propagation.

Some international wildlife dealers are influential and wealthy, using existing loopholes to trade in spite of the regulations. There are many ways of getting animals past wildlife checkpoints which are difficult to stop: shipment in boxes labeled as poisonous snakes; carriage of young gibbons by airline passengers in the cabins (where there is no wildlife inspection) or hidden in boxes of orchids; the use of smuggling routes to Vientiane, whence the animals are exported as Laotian wildlife; shipment in domestic airline cargo with connecting flights abroad; or smuggling by road or rail into Malaysia and Singapore.

Wildlife authorities lack the manpower and support from higher levels of the government to do their job effectively. Most officials do not regard hunting and smuggling of protected wildlife as a serious crime or as a significant national problem. Given the difficulty of suppressing the wildlife trade, great emphasis must be placed on improving direct protection of wildlife and habitats in sanctuaries and parks.

Trends in Wildlife Populations

The difficulty of censusing populations of most wildlife species makes it impossible to present statistics showing population trends. Some general conclusions are possible, however.

Table 5.4 Endangered Vertebrate Species in Thailand

Species	IUCN Classification	Thailand status
FISHES:		
Scleropages formosus (Asian bonytongue fish)	vulnerable	prized in pet trade
Catlocarpio siamensis (Giant carp)	-	
Balantiocheilos melanopterus (Burnt-tail carp)	-	probably extirpated
Xenocheilichthys gudgeri (Backwater fish)	-	endangered
Hemisilurus heterorhynchus (catfish)	-	endangered
REPTILES:		
Batagur baska (River terrapin)	endangered	endangered
Lepidochelys olivacea (Pacific Ridley's turtle)	endangered	nests on few beaches in South
Caretta caretta (Loggerhead turtle)	vulnerable	no longer nests
Dermochelys coriacea (Leatherback turtle)	endangered	nests on few beaches in South
Crocodylus porosus (Saltwater crocodile)	vulnerable	possibly extirpated
Crocodylus siamensis (Freshwater crocodile)	endangered	nearly extinct
Tomistoma schlegelii (false gavial)	endangered	probably extirpated
BIRDS: (Only species breeding in Thailand included)		
Pelecanus philippensis (Spot-billed Pelican)	-	no longer breeds
Sula leucogaster (Brown Booby)	-	no longer breeds
Anhinga melanogaster (Oriental Darter)	-	very rare
Mycteria leucocephalus (Painted Stork)	-	very rare
Ciconia episcopus (Woolly-necked Stork)	-	extirpated
Ephippiorhynchus asiaticus (Black-necked Stork)	-	extirpated
Leptoptilos dubius (Greater Adjutant)	-	no longer breeds
L. javanicus (Lesser Adjutant)	-	no longer breeds
Threskiornis melanocephalus (Black-headed Ibis)	-	no longer breeds
Pseudibus davisoni (White-shouldered Ibis)	indeterminate	extirpated
P. gigantea (Giant Ibis)	rare	extirpated
Sarkidiornis melanotos (Comb Duck)	-	no longer breeds
Cairina scutulata (White-winged Duck)	vulnerable	very rare
Ichthyophaga ichthyaetus (Grey-headed Fish Eagle)	-	possibly extirpated
Gyps bengalensis (White-rumped Vulture)	-	no longer breeds
G. indicus (Long-billed Vulture)	-	no longer breeds
Aegypius calvus (Red-headed Vulture)	-	very rare
Arborophila charltonii (Chestnut-necklaced Partridge)	-	rare, lowland forest
Rollulus rouloul (Crested Wood Partridge)	-	rare, lowland forest

Table 5.4 (contd.)

Species	IUCN Classification	Thailand status
Lophura ignita (Crested Fireback)	-	rare, lowland forest
Syrmaticus humiae (Hume's Pheasant)	rare	no recent sightings, montane
Polyplectron malacense (Malaysian Peacock-Pheasant)	-	rare, lowland forest
Grus antigone (Sarus crane)	-	extirpated
Treron fulvicollis (Cinnamon-headed Pigeon)	-	rare, lowland forest
T. olax (Little Green Pigeon)	-	rare, lowland forest
T. capellei (Large Green Pigeon)	-	rare, lowland forest
Otus sagittatus (White-fronted Scops-Owl)	-	rare, lowland forest
O. rufescens (Reddish Scops-Owl)	-	rare, lowland forest
Batrachostomus auritus (Large Frogmouth)	-	rare, lowland forest
B. stellatus (Gould's Frogmouth)	-	rare, lowland forest
Harpactes orthophaeus (Cinnamon-rumped Trogon)	-	rare, lowland forest
Megaceryle lugubris (Crested Kingfisher)	-	rare, lowland forest
Rhyticeros corrugatus (Wrinkled Hornbill)	-	rare, lowland forest
Anthroceros malayanus (Black Hornbill)	-	rare, lowland forest
Megalaima rafflesii (Red-crowned Barbet)	-	rare, lowland forest
Gecinulus grantia (Pale-headed Woodpecker)	-	probably extirpated
Pitta gurneyi (Gurney's Pitta)	indeterminate	rare, lowland forest
Pseudochelidon sirintarae (White-eyed River Marten)	indeterminate	rare, breeding status uncertain
Pycnonotus zeylanicus (Straw-headed Bulbul)	-	rare, lowland forest
Malacopteron affine (Sooty-headed Babbler)	-	rare, lowland forest
M. magnum (Rufous-crowned Babbler)	-	rare, lowland forest
Napothera macrodactyla (Large Wren-Babbler)	-	rare, lowland forest
Stachyris maculata (Chestnut-rumped Babbler)	-	rare, lowland forest
S. nigricollis (Black-throated Babbler)	-	rare, lowland forest
Macronous ptilosus (Fluffy-backed Tit-Babbler)	-	rare, lowland forest
Saxicola jerdoni (Jerdon's Bushchat)	-	rare, grassy flood-plains of North
MAMMALS:		
Dugong dugon (Dugong)	vulnerable	very rare
Rhinoceros sondiacus (Javan rhino)	endangered	probably extirpated
Dicerorhinus sumatrensis (Sumatran rhino)	endangered	very rare
Cervus porcinus (Hog deer)	-	very rare
Cervus schomburgki (Schomburgk's deer)	-	extinct; lowland plains species

Table 5.4 (contd.)

Species	IUCN Classification	Thailand status
Cervus eldi (Eld's deer)	endangered	possibly extirpated
Bubalus bubalis (Wild water buffalo)	vulnerable	one small herd in Huai Kha Khaeng Wildlife Sanctuary
Bos sauveli (Kouprey)	endangered	possibly extirpated from Thailand

Sources: Bain and Humphrey, 1982; Phasuk, 1985, Round, 1985 and personal communication.

Natural forests are shrinking in area very rapidly (see Chapter 4), and most species which depend on forests for survival will soon survive only within the protected area system. This system is nearly all forested and now contains nearly half of the natural forests remaining in the kingdom. There is an urgent need to search all remaining forests outside the protected area system for wildlife populations and habitat worthy of saving.

Even within protected areas, populations of some species are declining or have been extirpated. Large hornbill species have been eliminated from Doi Suthep—Doi Pui National Park (Round, 1984), and gibbons have been hunted out of many areas of national parks that are easily accessible to villagers. A recent survey of stump-tailed macaques in southern Thailand has failed to reveal more than a few scattered groups within protected areas, whereas they were once exported from Thailand in large numbers (Eudey, 1978). Recent surveys of elephants in Khao Yai National Park have revealed that elephants less commonly utilize parts of the park that are near boundaries close to villages or areas that have been disturbed by poachers (Dobias, 1985).

Table 5.4 lists species of vertebrates that may not survive in Thailand due to their extreme rarity, caused by severe hunting pressure or disappearance of habitat. One species, Schomburgk's deer, is definitely extinct and many others have not been seen in recent years and may also be extinct. All the listed species could become extinct within the next decade or two, and many within the next five years.

Special habitats in particular need of conservation are lowland forest on level areas, freshwater swamp habitats, and high altitude mountain or hill evergreen forest which harbors species of birds not found elsewhere (Round, 1985). Only small remnants of such habitats now remain.

The National Park System

Number and area

The national park system increased at an accelerated rate after 1973, when new parks began to be created more rapidly. This growth has continued, and new parks will soon be approved to bring the total to 57 areas comprising 5.2 percent of the land area of the kingdom. Each park has a headquarters with living quarters for resident officials, workers and a permanent guard force. Most parks have a number of guard outposts to aid with law enforcement, in addition to headquarters and main checkpoints on roads. Khao Yai, for example, has 13 such outstations.

In addition to national parks, the NPD manages 35 "forest parks" whose primary function is recreation. These areas are generally smaller and often more disturbed than national parks, and although they are protected from deforestation, mining, and other activities, the law is less stringent in this regard. Forest parks usually protect sites of outstanding recreational value such as waterfalls. The total area in forest parks is now 68,628 hectares. Several forest parks have been upgraded to national parks.

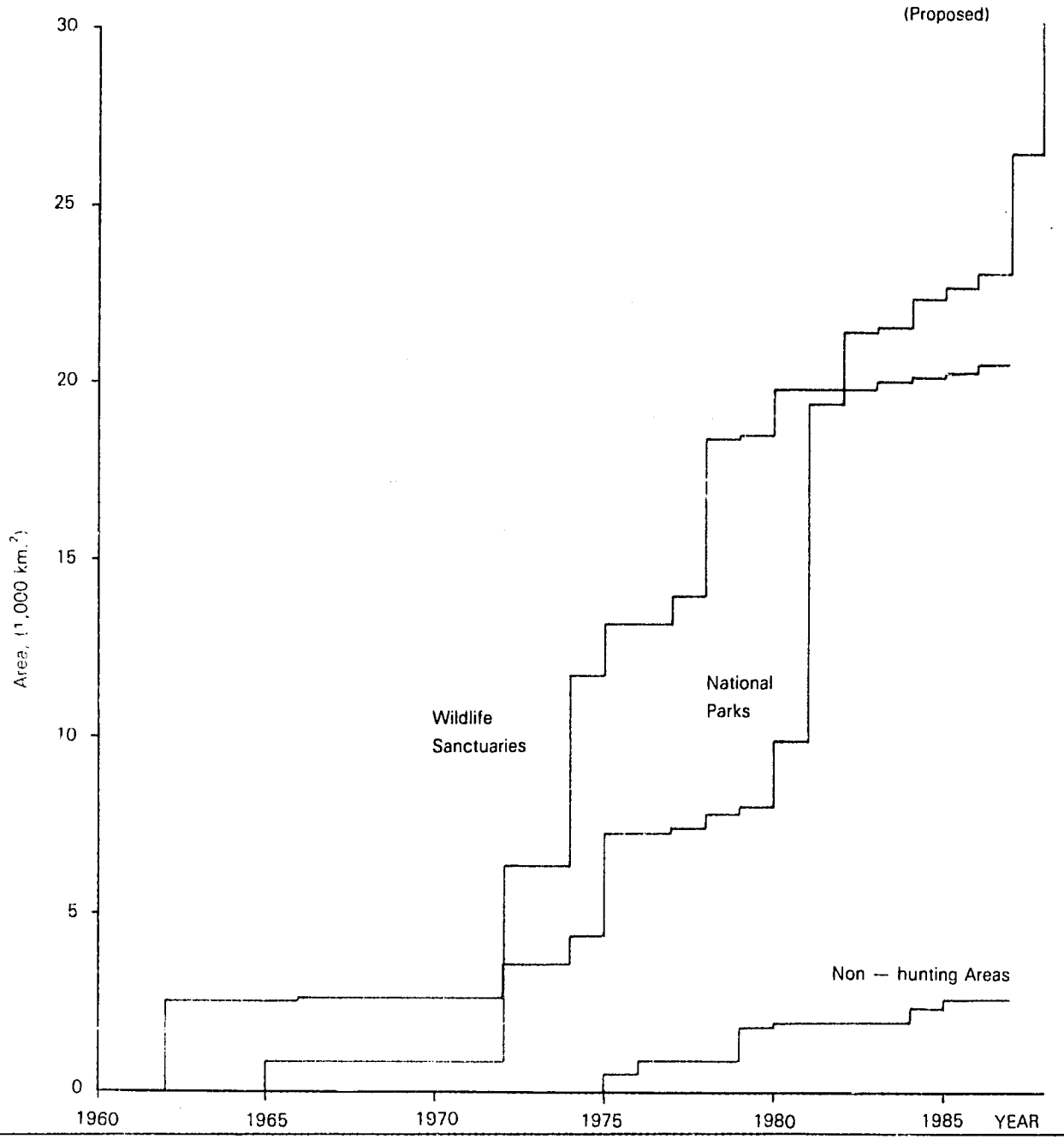
Each park is headed by a chief, aided by extra officials in larger and better established parks. Patrolling of parks is carried out by armed workers or guards, and a force of permanent guards. The NPD presently employs 406 permanent guards and hopes to increase this number. Without sufficient guards to man headquarters, checkpoints and outstations, patrolling cannot be carried out effectively, and poaching cannot be stopped.

After a relatively slow start, the number and total area of Thailand's national parks increased quite rapidly after 1980 (Figure 5.3). Proportional budget increases for the NPD followed during the next two years (Figure 5.4). The present budget received is in fact the amount required to manage only 20 national parks effectively, according to some park officials. This has required that resources be spread thin, with many parks not yet receiving adequate attention.

Tourism

The number of visitors to parks has increased tremendously during the last ten years (Figure 5.5). Most visitors (about 66 percent) go to the best developed or most accessible ten parks (Table 5.5), but the number of visitors to all parks is increasing. Most visitors are day visitors who come on weekends. Waterfalls are the most popular attractions for these visitors.

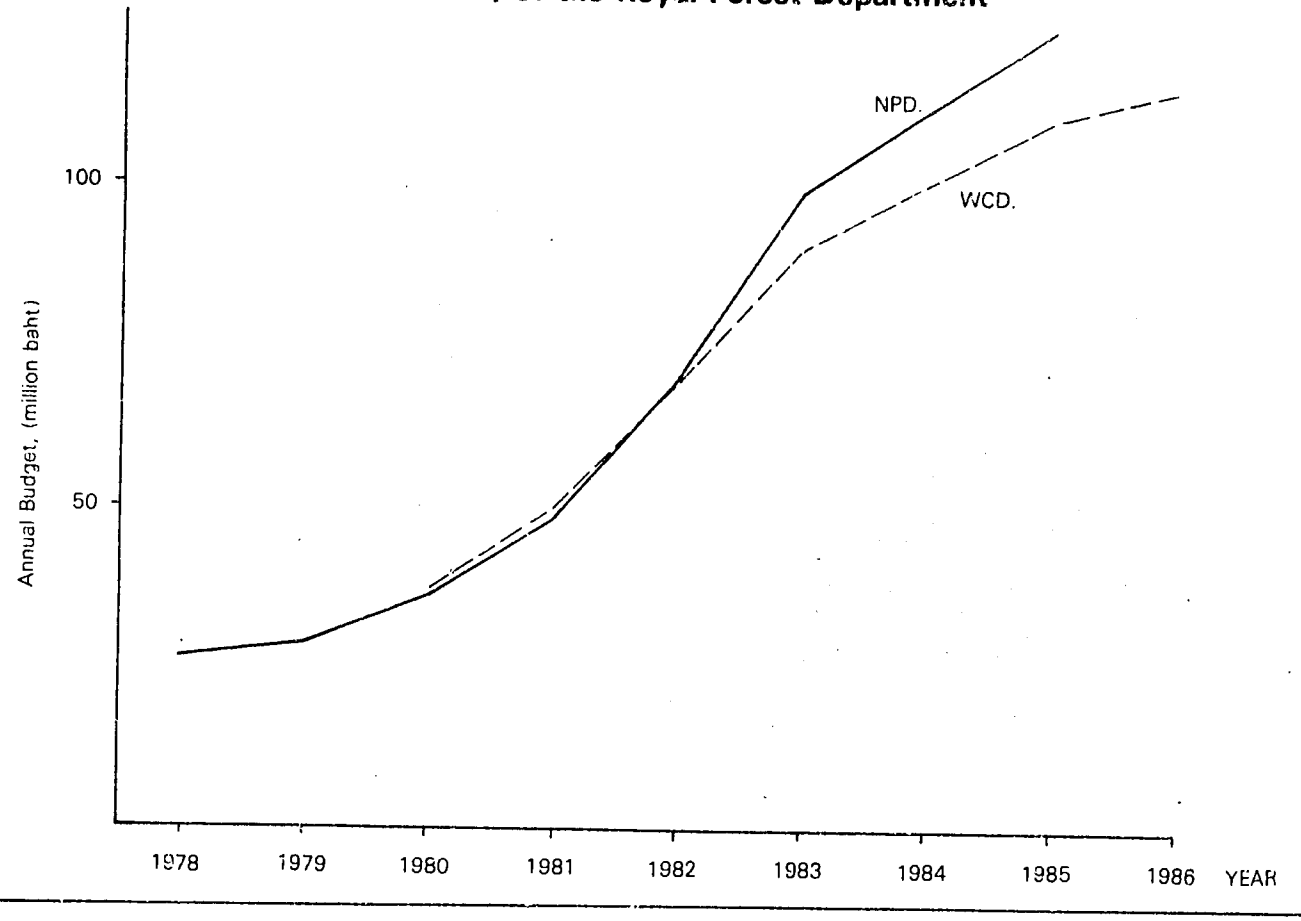
Figure 5.3 The Growth of the Protected Area System in Thailand



Overnight accommodation in most parks is booked to capacity on weekends. These figures illustrate the great demand for recreation facilities throughout the kingdom. Approximately 90 percent or more of all visitors are Thais, but exact data have not been kept on types of visitors. The demand for recreation in all parts of the kingdom is high. Income from visitors (mostly admission fees and bungalow rental fees) was about 13.7 million baht in the 1984 fiscal year.

The relatively low number of international tourists visiting national parks is due more to lack of promotion than to any lack of desire of foreigners to visit the parks. One guide to national parks in Thailand has been written (Dobias, 1982) and has sold out; most tourist guides make only brief mention of parks, and then only of the most prominent ones, such as Khao Yai, Doi Suthep, and Ko Tarutao. Lack of suitable transportation and reception facilities for English speaking tourists are the major limiting factors. Among resident foreigners there is active interest in parks and conservation areas, and organizations with educated Thais and resident foreigners such as The Siam Society, Wildlife Fund Thailand or the Bangkok Bird Club, which sponsor special tours to parks and conservation areas find that demand exceeds their ability to satisfy it.

Figure 5.4 Growth of the Budgets of the National Park Division (Since 1978) and the Wildlife Conservation Division (Since 1980) of the Royal Forest Department



The Tourism Authority of Thailand (TAT) manages extensive accommodations in Khao Yai Park, but tends to gear its promotion to the needs of "ordinary" tourists rather than those interested in nature or hiking. Consequently, the very large and growing numbers of young affluent Western tourists interested in nature and outdoor experiences throughout the world (e.g., Sobek's International Explorers Society, 1983) have not been attracted to these facilities.

Thus, there is a considerable gap in tourism promotion in national parks. By careful planning and development this gap could be filled to the benefit of the kingdom, regions where parks are located and the parks themselves.

Wildlife Sanctuaries

Number and area

The area included in wildlife sanctuaries has also greatly increased, especially since 1972 when five new sanctuaries were added, including three units exceeding 1,000 square kilometers. Although no large units have been added since 1983, several new sanctuaries are proposed.

Since the major purpose of wildlife sanctuaries is to protect wildlife, the sizes of areas are critical. Studies in the relatively new ecological field of "island biogeography" have revealed that large areas of forest are more effective in conserving species over the long term than small areas (MacArthur and Wilson, 1967; Terborgh, 1975; Diamond, 1974). Historically, large islands have retained a greater diversity of bird species than small islands; an increase in area by ten fold is associated with an approximately 50 percent increase in the number of species. There is no "threshold" area beyond which the relation does not hold — even the largest islands of many thousands of square kilometers show the same species-area relationship. To maintain the diversity of vertebrate species in forest areas or islands less than continental size will require easy colonization of locally extinct species from other areas or careful human management, including, for some, captive breeding and reintroduction. This is especially true of areas less than 1,000 square kilometers (Sullivan and Shaffer, 1975).

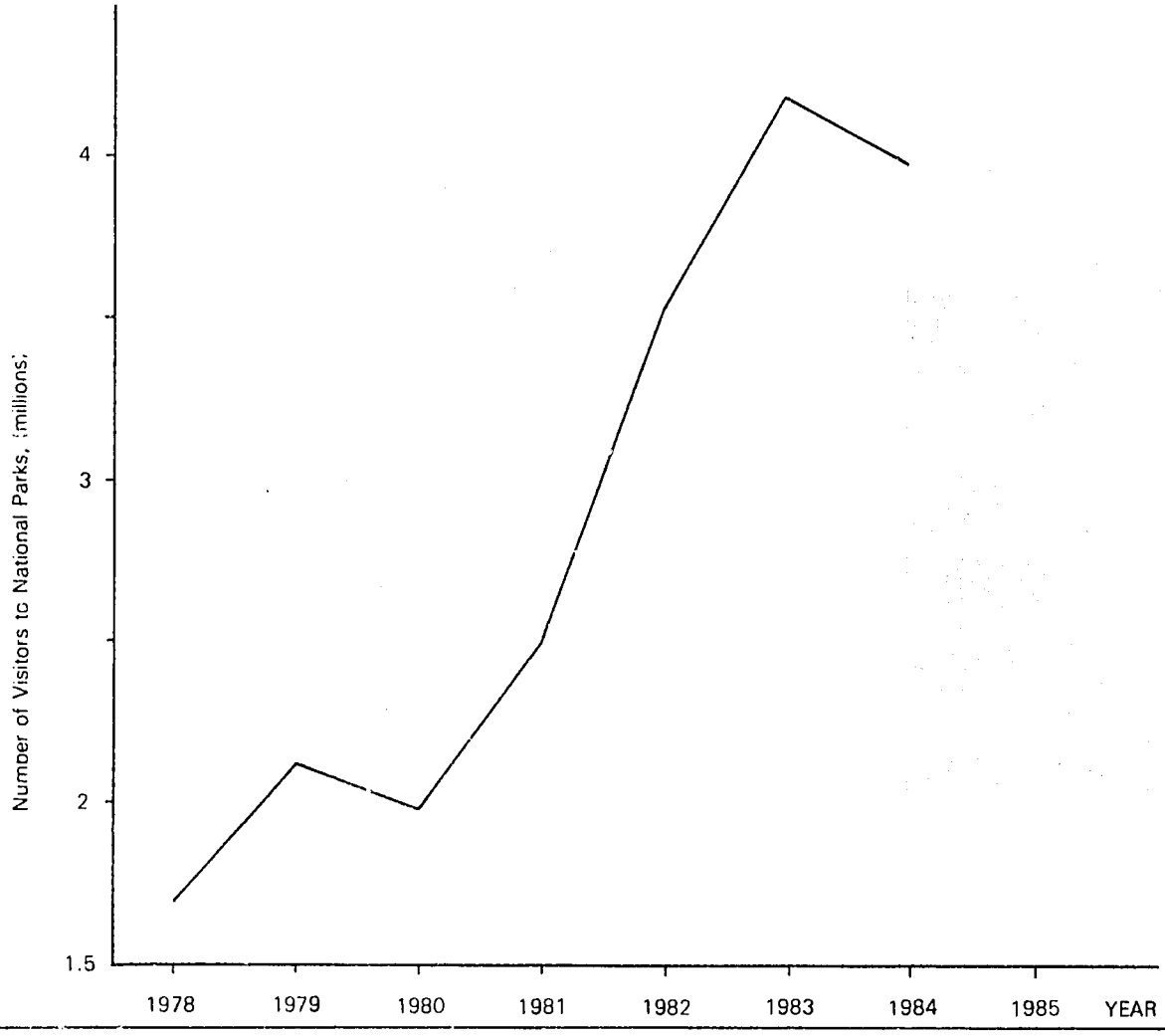
Consideration of species population dynamics and genetics also supports the argument that large wildlife sanctuaries are necessary for conservation purposes, because large game species may have to migrate large distances seasonally to find food and water. Also, small populations of

Table 5.5 Ten Most Visited National Parks in October 1983-September 1984 Season

Name	Province	No. visitors
1. Erawan	Kanchanaburi	482,536
2. Doi Inthanon	Chiang Mai	330,553
3. Pliew Falls	Chanthaburi	318,769
4. Doi Suthep - Doi Pui	Chiang Mai	297,505
5. Ao Phangnga	Phangnga	278,820
6. Khao Yai	Nakhon Nayok, Saraburi, Khorat, Prachinburi	258,803
7. Khao Lam Ya - Mu Ko Samet	Rayong	225,915
8. Sai Yok	Kanchanaburi	165,506
9. Hat Nonparatthara - Mu Ko Pi Pi	Krabi	154,235
10. Khlong Lan	Kamphaeng Phet	122,160
Total, top 10		**2,634,802**
All other parks		**1,344,692**
Grand total		**3,979,494**

Source: National Park Division, Royal Forest Department.

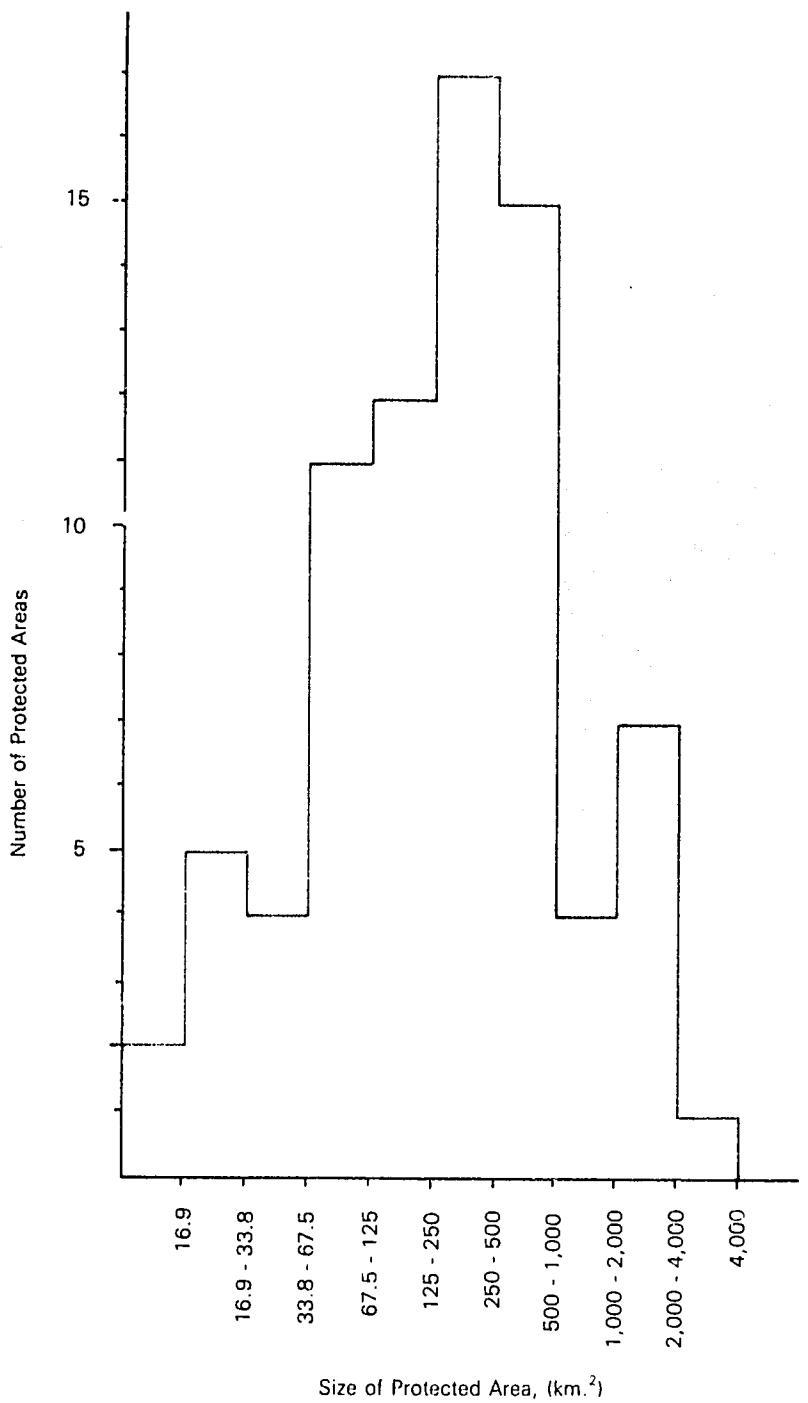
Figure 5.5 Growth in Annual Numbers of Visitors to National Parks Since 1978



100 individuals or less have an unacceptably high probability of going extinct by chance, and contain too little genetic variation for long-term survival. Populations smaller than this may require careful management to prevent their extinction. Most populations of sea turtles, crocodiles, tigers, elephants, gaur, large hornbills, cranes, storks and eagles, in Thailand are probably less than 100 breeding adults.

The size distribution of wildlife sanctuaries is thus of major concern to species conservation. The size distribution of protected areas is shown in Figure 5.6. Units known to be contiguous and to allow wildlife passage between them have been lumped together. It can be seen that 12 units exceed 1,000 square kilometers and 8 exceed 2,000 square kilometers. The largest unit is the combined Thung Yai Naresuan—Huai Kha Khaeng Wildlife Sanctuaries, with a respectable 4,831 square kilometers. There is still forest contiguous with these sanctuaries that could be included. This area is the best hope in Thailand for preserving large mammal species, providing that poaching can be controlled.

Figure 5.6 Frequency Distribution of Sizes of Protected Areas (Excluding Non-hunting Areas, most of which are Wetlands)



Wildlife species of particular concern are wild cattle which may have to migrate in seasonal habitats in search of forage and water, elephants which migrate over large areas (Olivier, 1987; Storer, 1981), and large predators such as tigers which require large hunting territories of many square kilometers.

A number of relatively small parks and sanctuaries have large animal species such as elephant, gaur, banteng and tigers which will almost certainly disappear in time without reintroductions. These include Khao Chamao (84 square kilometers) and Khao Ang Ru Nai (108 square kilometers) in the Southeast; Phu Rue (121 square kilometers), Phu Kradeung (348 square kilometers) and Phu Wua (186 square kilometers) in the Northeast; Ton Nga Chang (182 square kilometers) and Thale Ban (102 square kilometers) in the South; and Tham Tarn Rod (59 square kilometers) and Lan Sang (104 square kilometers) in the West. Only the relatively large (1,000 square kilometers) protected areas offer much hope of saving large animals in the long term (hundreds of years), and then only with careful protection and management.

Manpower and budget

The 28 wildlife sanctuaries and 38 non-hunting areas are protected by a total of 404 permanent guards, and a larger but indefinite number of workers. This represents approximately one guard per 58 square kilometers of area. The budget of the WCD was relatively low prior to 1980, but has increased fairly rapidly since. The WCD has fewer visitor facilities to construct and maintain, so its budget requirement is less than that of NPD. Nevertheless, the personnel and guard force are still inadequate to protect the large area within the sanctuaries.

Law enforcement in protected areas

Patrolling of protected areas, arrest of poachers and prosecution are labor intensive and time-consuming missions, and tax the capabilities of both divisions. In sanctuaries and non-hunting areas, 319 infractions involving 368 violators were prosecuted in the first five months of 1986.

In spite of these enforcement attempts there is ample evidence that the amount of poaching in protected areas is far higher than these figures suggest, and the proportion of poachers actually caught or seen by guards is very low — perhaps no higher than 5 to 10 percent. Information on poaching in some parks and sanctuaries comes occasionally from naturalists, biologists or hikers who hike deep into these areas (Brockelman, 1986; Brockelman and Sophasan, 1981; Brockelman and Srikosamatara, 1978; Dobias, 1985 Hill, et al., 1986; Srikosamatara, 1980; Storer, 1981).

In Khao Yai Park, for example, poachers' camps are found along every stream in remote areas and poachers, mostly teams of persons collecting fragrant wood ("mai hom") from the tree *Aquilaria crassna*, as well as animal hunters, are frequently encountered. Increased attempts to reduce poaching in Khao Yai alone have resulted in 258 violators being caught in the first four months of 1986. Poaching must be halted by active enforcement activities. There are several reasons why the problem is so serious and is probably increasing.

Insufficient patrolling

In most parks and sanctuaries guards and armed workers rarely go deep into the forest on patrol. There are usually no regular patrol schedules and in many areas there are said to be not enough guards to patrol. The existence of border guard posts alone has no effect on poachers, who can cross the boundaries anywhere on foot. There are no regular budgets for equipment and supplies for patrolling.

Poor relations with local residents

Patrolling in some areas has resulted in armed clashes with local villagers and an estimated 40 guards and officials having been killed on duty by local residents during the last 20 years in parks and sanctuaries. Relations between protected area personnel and local residents are usually very poor as residents often believe that they have been unjustly deprived of land for farming or natural hunting rights in forested areas, without receiving any benefits in compensation. There is the very real belief that parks and sanctuaries are being preserved for the pleasures of outsiders or officials themselves while depriving local residents of their economic and subsistence needs.

How much patrolling is actually carried out, and the quality of relations with locals, depend very much on the attitude and leadership of the chief official of the protected area, and varies greatly from one area to another.

In a few places local residents have received some material benefits from protected areas. In some sanctuaries (i.e., Huai Kha Khaeng) some of the employees are recruited from local villages. In the Thale Noi non-hunting area, local fishermen are hired to carry visitors about the lake in their boats to observe birds. At Phu Kradeung National Park, several hundred local people earn wages carrying visitors' packs up the mountain. These persons even report park violations to officials, a sure sign that they see the park as an asset.

Resistances of local people will have to be overcome to reverse what is probably a worsening enforcement problem as rural populations increase around protected areas and farmland becomes less available. Forestry authorities tend to consider the problem only in terms of public relations, education and greater enforcement effort, but alternative solutions will have to be found. The most serious wildlife management problem is the management of people. For too long local people have been left out of management planning, even though they are very much a part of the systems being managed.

Hill tribes

The existence of hill tribes in protected areas of the north and northwest has created special problems to which satisfactory solutions have not always been found. At least four national parks (and one proposed one) and 11 wildlife sanctuaries in

the region have had resident hill tribes (mostly Hmong and Karen), numbering several thousands in all. The policy of the RFD is that these persons are illegal squatters who must be removed to other settlement areas. Only the regional armies have the power and authority to move the tribes, however, and their collaboration to do so must be sought. Hill tribes have been moved from some areas, including Mae Ping and Khlong Lan National Parks and Huai Kha Khaeng Wildlife Sanctuaries, but remain a serious problem in other areas such as Thung Yai Naresuan, Lum Nam Pai, Doi Pha Chang Wildlife Sanctuaries and Doi Inthanon National Park, where their shifting cultivation methods cause destruction of primary forest. However, no analyses have been made of the rate of destruction of primary forest by hill tribes in any protected area. In contrast to the position in some countries, the RFD has no policies or budget for incorporating tribal people into the management of parks and wildlife sanctuaries, nor for creating reserves (such as "biosphere reserves") where tribes may continue their traditional life styles. Such policies are being tested, however, in some special watershed management project areas.

Value and Functions of Protected Areas

Both national parks and wildlife sanctuaries have recognized value in protecting wildlife, habitats, and watersheds, but parks are used for promotion of recreation, whereas wildlife conservation activities emphasize management of wild animals and also public education. There is, therefore, some overlap in function. Many parks are in fact very important wildlife refuges and many sanctuaries have considerable potential to attract tourists.

The value and functions of sanctuaries and parks vary from one to the other, and ideally the functions of each should be stated in a management plan (Thorsell, 1984). In 1984 the World Wildlife Fund funded a project (WWF/IUCN 3001—Thailand) for Khao Yai National Park which included preparation of a detailed management plan by a team of NPD officials and outside local experts. This is the first detailed management plan for a conservation area in Thailand.

The Khao Yai management plan was innovative in being specifically concerned with the well-being of local communities. A pilot project to initiate appropriate tourism with the aim of benefiting local villagers was funded in the WWF project (see Box 5.1). Both the NPD and WCD have recently established planning sections with the intention of preparing management plans for other protected areas. It is hoped that such plans will result in increased support from the government and outside agencies to more fully realize the potential benefit of parks and sanctuaries.

The area included within national parks, wildlife sanctuaries and non-hunting areas constitutes 9.1 percent of the area of the kingdom and the rate of increase has exceeded the ability of the NDP and WCD to bring the areas under complete protection and manage them effectively.

The system of parks and sanctuaries now serve functions not originally prescribed in law, mainly protection of valuable watersheds and other ecological services described earlier, and conservation of both fauna and flora from continued destruction. These important functions are served somewhat by default because of the failure of the forest reserve system (set up by the National Forest Reserve Act, 1964) to effectively preserve forest cover and enforce sustained yield of forest resources. Present policy (Royal Forest Department, 1985) will result in conversion of most reserve forest areas to tree plantations of fast growing species for wood, fuelwood, rubber, etc., which will result in nearly complete loss of native flora from reserve forests.

Conflict between Conservation and Development

Apparent conflicts between development interests and conservation have occurred in Thailand as in every other country with active conservation programs. Such conflicts will undoubtedly increase in the future as land areas are more intensively used and the number of competing demands for any given area increases. Most conflicts are not merely political debates but involve real issues which must be discussed publicly to ensure that the costs are minimised and the benefits maximised. The purpose of this brief discussion is to review some of the basic issues which require closer attention by policy makers and more research by concerned experts.

Logging vs. protection

At the time of the creation of the system of reserve forests, parks and wildlife sanctuaries, there was relatively little conflict between "preservation" and exploitation interests, as there was sufficient forest to satisfy loggers (both legal and illegal), slash-and-burn farmers and conservationists. Encroachment in reserve forests was sometimes referred to by agricultural experts as an important "safety valve" for the poor landless, ensuring that they would not all migrate to urban areas or create civil disturbance. While the public and the government became increasingly disturbed by the irrefutable evidence from Landsat images of massive encroachment and conversion of natural forests in the 1970s, enforcement measures were not strong enough to halt the trend. With undisturbed forest cover now below 30 percent of the land area, the disposition of the remaining tracts will become the subject of increasing contention. The forest area targets of the RFD approved in 1985 probably signal the beginning of a serious policy debate. Will conversion of the remaining reserved forests to plantations of reduced stature and biomass provide adequate watershed and soil protection? Is 15 percent of the country's area in protected forests adequate to cover all important watersheds? Should this include watershed protection areas containing largely degraded forest, or should totally protected forest area in parks and sanctuaries be allowed to increase further? What economic or non-monetary values do parks and sanctuaries have for the kingdom? How can the RFD or other decision makers evaluate these?

Development projects in protected areas

Hydroelectric projects produce many of the most intense conflicts between technological development and nature conservation, and Thailand has had its fair share of them. Six large dams constructed between 1964 and 1985 have inundated approximately 2,052 square kilometers, and waters rising behind the Chiu Larn Dam in the South are flooding lowland areas of Khlong Sang Wildlife Sanctuary and Khao Sok National Park. The Ubonratana Dam in the Northeast, completed in 1966, illustrates how devastating a poorly planned hydroelectric project can be to forests and wildlife, as poor farmers immigrating into the reservoir region have destroyed most forests in the watershed.

Some projects have been shelved because of opposition from the RFD and nongovernmental organizations, for example, three projects that would have flooded parts of Khao Yai Park: on the Klong Tha Dan, Sai Yai, and Lam Phayathan Rivers. The Sai Yai project would have involved construction of two shallow reservoirs in the center of the park that would have eliminated many square kilometers of optimal elephant, gaur and endangered pileated gibbon habitat.

Developments to enhance access to and human activity in national parks have also recently come under some discussion and debate. Appropriate development in parks is desirable to enhance their ability to fulfill their objectives, but should be confined to areas zoned for that purpose. Debate in the public press has questioned the desirability of the highway recently completed through the southern portion of Khao Yai Park, and more recently the appropriateness of building a cable car in Doi Suthep—Doi Pui National Park in Chiang Mai. (see Box 5.2)

Box 5.1 Conservation for Rural Development in Ban Sap Tai —A Case Study

Protected areas can offer material benefits to poor rural residents, and this can change their attitudes and behavior toward conservation. It does, however, require concerted efforts to bring this about. Experience in a small village of farm families near the border of Khao Yai Park, where several development oriented projects have been carried out by conservationists, illustrates the problems and opportunities.

The village, Ban Sap Tai, is located in a valley surrounded by ridges, inside the park boundary, which rise sharply to high mountain bluffs that dominate the scenery. It is probably the most beautiful area of the park, but was rarely visited by park guards and never by outside visitors. In 1981, however, some naturalists decided to hire local villagers as guides and trek up into the unknown northwest part of the park. Their excitement over discovering a new beautiful area was dampened only by signs of poachers or encroachment nearly everywhere they visited. In spite of that, northwest Khao Yai was found to be the best stronghold of gaur *(Bos gaurus)* in the park.

More hikes followed. It was realized that trekking in this part of Khao Yai might provide significant financial benefit to the villagers, and with a view toward developing a pilot "jungle trekking" tourist industry, guides and porters were always paid a minimum of 100 baht per man per day, which is more than twice the normal rural wage for labor. Bonuses were offered if large wildlife species were seen by hikers. Individual treks by local organizations such as the Siam Society and Swedish tour groups have put as much as 10,000 baht into the hands of the villages for a single hike. The groups of visitors recruited tended to be well educated people desiring to see and experience rural life and culture in Thailand, in addition to nature.

The use of trekking through the forest over elephant trails as a method of promoting benefits from the park was promoted by a World Wildlife Fund Project, "Elephant Conservation and Protected Area Management," during 1984-1985. Far more significant benefits materialized, however, when another organization, the Population and Community Development Association of Thailand (PDA) and the conservation group Wildlife Fund Thailand (WFT), were asked to become involved. PDA, with a grant from the German foundation Agro-Action, has set up an agricultural cooperative fund and provided help in selecting, planting and marketing new crops.

To withdraw low-interest loans from the fund, villagers must join the "Nature Protection Society" and pledge not to hunt in the park. This is a considerable incentive for joining because loans from the local middleman and merchants cost 5 percent per month. Encroachment has been halted and gunshots are rarely heard in the nearby forest. Khao Yai Park officials and guards no longer fear to enter the village to discuss problems with the villagers.

In spite of the success of these projects in changing the villagers' perceptions and habits, there are still problems to be overcome. The major ones are: (1) how to insure an effective and strong village organization to maintain the Nature Protection Society and insure continuing cooperation when PDA finally pulls up anchor; (2) how to set up a permanent trekking agency to continue to bring in hikers; (3) how to initiate similar Protection Society Cooperatives in other villages with smaller initial inputs of capital and expertise; and (4) how to develop a greater role for the Thai Government, especially the Royal Forest Department, in promoting and carrying out such projects.

Presently controversy surrounds the plans to construct the large Nam Choan Dam on the Upper Quae Yai River, which would create a reservoir 223 square kilometers in area lying mostly in Thung Yai Naresuan Wildlife Sanctuary (see Box 5.3).

Development vs. conservation conflicts raise a number of important basic policy issues which concern policy makers. Attention to these issues will not eliminate conflicts but may permit more rational resolution of conflicts. There are signs that concern with these issues has been increasing in Thailand.

Thailand is noted for its relatively free and healthy press, and the press has played an important role in defending conservation and bringing important environmental issues before the public. This role is indispensable in any democratic society. Government line agencies, however, as in most countries, often restrict information regarding their projects and activities on the grounds that the public is not sufficiently well informed to make judgment. This policy sometimes leads to increased controversy and less informed public debate when information about the projects finally and inevitably leaks out.

Box 5.2 Cable Car on Doi Suthep: Lessons in Public Participation

The city of Chiang Mai lies at the foot of a mountain called Doi Suthep. Part way up the mountain, partly hidden by the green forest which blankets the mountain, is a temple, Wat Phra That, whose beautiful northern style central chedi houses a relic of the Buddha. Since 1981 the mountain has been included in Doi Suthep—Doi Pui National Park. Its flora of orchids and other plants, and its bird community, are known to be extremely diverse.

In 1980, the Tourism Authority of Thailand hired a consulting firm to help prepare a master plan for tourism in Chiang Mai. The company conducted feasibility studies to construct an electric cable car from Chiang Mai city up to the foot of the temple on the mountain. The cable car, it was argued, would relieve the severe traffic congestion on the highway up the mountain on holidays, promote tourism in the city and on the mountain, and make it easier for visitors to reach the temple. The architect-manager of the company had done his homework and prepared economic justifications for the project, and carried out a preliminary environmental assessment.

The project made its way successfully through the maze of Government bureaucracy: the Tourism Authority, Chiang Mai Provincial Administration, Phra That Doi Suthep Authorities, Royal Forest Department (RFD), Zoological Organization, National Environment Board, National Park Committee, and the Office of the Royal Household (there is a Royal Summer Palace on the mountain). It passed many committees set up to study it. The project manager was persuasive and passed all the major hurdles. Except one—the general public.

In 1986, articles and letters opposing the project began appearing in the *Bangkok Post*, *Matichon*, and local newspapers in Chiang Mai. The objections raised were numerous: the cable car would destroy forest and wildlife species, disfigure the mountain, scare the animals in the Chiang Mai Zoo, intrude on the tranquility and sanctity of the mountain, promote forest fires, contribute to litter and refuse, promote inappropriate development near a holy shrine and in a national park, reduce the merit of pilgrimages to the temple, be plagued by power shortages, and stand virtually idle most of the time except for holidays and some weekends.

The project manager waged a courageous public relations campaign against these claims, but to little avail. An ad hoc organization was formed in Chiang Mai, based on the university campus, to fight the project. While the majority of Chiang Mai residents appeared to support the project or had no serious objection to it, a rather large percentage (40 percent according to one opinion poll) opposed it. The Center for Promotion of Arts and Culture at Chiang Mai University opposed the location of the cable car on Doi Suthep. All senior priests in Chiang Mai (except the abbot at Wat Phra That) opposed it.

In April of 1986, 750 people of Chiang Mai, including many monks, signed a letter to the prime minister opposing the project. The governor of Chiang Mai, who had earlier expressed surprise over the speed with which the RFD's National Park Division had approved the project, decided to recommend against the project. Interestingly, RFD and National Environment Board officials have not been drawn into the dispute. On June 28 nearly 1,000 people staged a protest against the project at a holy place in Chiang Mai. The provincial authorities finally decided to hold the projection in abeyance for the time being.

This episode is interesting for several reasons. First, it illustrates the importance of "intangible" environmental factors, which are difficult if not impossible for technical experts to quantify or evaluate. In this case, the environmental values in question are mostly cultural and aesthetic, and the protest involved educated cultural leaders more than ecologists or traditional conservationists. Environmental impact assessments and benefit/cost analyses must somehow come to grips with these values. They exist in the minds of people and not in technical reference manuals or architects' plans.

Box 5.3 The Nam Choan Dam Controversy

The planned Nam Choan hydroelectric dam on the Upper Quae Yai River, in Kanchanaburi Province, has stirred fierce opposition by conservationists. This dam would back up a 75 kilometer long reservoir, which could completely divide Thung Yai Naresuan Wildlife Sanctuary, the largest in Thailand and probably the most important wildlife refuge in Southeast Asia, into three pieces. This has caused delays in final approval of the project, and several re-evaluations of its environmental effects. Yet this further work has not really brought pro- and anti-dam people any closer together, nor has it improved the agreed basis on which a decision might be reached, one way or another. It has demonstrated, however, that the evaluation of benefits and costs still rests on people's personal values and preconceptions.

This is not the way environmental assessment should be in a perfect rational world, but in some senses there are different forms of rationality at work here.

The Nam Choan Dam, when completed, would produce 576 MW in dependable peak capacity, and 1,100 GWh per year in average energy output. The dam would help sustain growth in energy consumption of about 9 percent per year, but the value of its contribution would depend heavily on economic factors such as the price of imported oil, the availability of natural gas, and the general rate of industrial and economic growth which is not necessarily limited by energy availability or cost.

The Japan International Cooperation Agency performed a reconnaissance study of the Upper Quae Yai hydroeletric project for the Thai Government, completing a feasibility study in 1980. The National Environment Board requested the Electricity Generating Authority of Thailand (EGAT), which has responsibility for the project, to carry out an environmental impact assessment, which was completed by a consulting firm in 1980. It focused on geology, minerals, fisheries, forestry, wildlife, archaeology, public health, and socioeconomic effects.

Opposition to the dam became very vocal around 1982, when many conservation groups and individuals, both in Thailand and abroad, wrote letters to government officials and to the press decrying the dam's irreversible effects. Emotional statements, however, lend little credibility to the conservation movement.

Since the major non-monetary cost of the Nam Choan Dam will be damage to the wildlife sanctuary, one would assume that the probable damage to wildlife would have received the most thorough survey and evaluation. Not so. This lack of adequate assessment of the likely forests and wildlife impacts was due mainly to lack of appropriate funding, shortages of manpower, a lack of time in which to survey, and in the case of this project, to the insecurity of the area, preventing survey teams from penetrating very far into the sanctuary. Despite the fact that it is now safe to travel through the sanctuary, the surveys have never been finished.

The damage done by the reservoir to the sanctuary will be far greater than implied by the amount of land inundated. First of all, the reservoir will eliminate virtually all habitats at elevations of less than 380 meters above sea level. Forests at low elevations are now rare in Thailand and poorly represented in the protected area system. Riverine habitats are becoming especially rare, and are particularly rich in wildlife and recreational value. With an annual drawdown of 39 meters of elevation, the long shore of the Nam Choan reservoir will become a broad treeless expanse of rocks and mud, useless for both recreation and wildlife during most of the year.

The most serious effect of the reservoir, which has been pointed out by some biologists but ignored in environmental assessments, is the division of the large contiguous Thung Yai — Huai Kha Khaeng Sanctuaries into three smaller areas. Zoogeographers in recent years have accumulated much evidence showing that the number of species that survive over the long term (hundreds and thousands of years) is related to the size of the area, because smaller areas contain smaller populations which more frequently become extinct by chance. Thus, as the regions outside the boundaries become less habitable for wildlife, sanctuaries becomes a certainty. *Large* wildlife refuges are the only guarantee of the survival of species such as elephants, wild cattle, tigers, peafowl, primates and other large species. The new reservoir would make survival of these species more uncertain.

Hydropower is known to be one of the cheapest sources of energy supplying reliable base load to the ever increasing demand for electricity. But no one is claiming that new energy development is not important; that is not what is really at stake. The question is whether energy produced (which is quite replaceable) minus the direct costs, will be worth all the nonmonetary costs, which include forests and wildlife (which are not replaceable). There is no simple way to evaluating and comparing these assets which satifies everyone.

If all protected areas had detailed management plans, which included a statement of each area's objectives, its values and benefits to the public and a zoning plan, analysis of environmental effects would be made easier. Development agencies and even consulting experts are often ignorant of the values of conservation areas. The wildlife and park agencies of the RFD are, in fact, now establishing planning units for the purpose of preparing management plans for all protected areas. This will automatically enhance their role in the overall decision-making process.

5.3 LEGAL AND INSTITUTIONAL FRAMEWORK

Legal Issues

The previous sections have outlined in some detail the values of the conservation area system, and briefly reviewed the development of policies regarding the management of such areas. Conservation legislation has been comprehensively reviewed in *Conservation for Thailand—Policy Guidelines* (IUCN, 1979). The legal base and policy commitment of the Thai Government to nature conservation is strong, and outstanding progress has been made in many aspects, particularly in the establishment of national parks and wildlife sanctuaries. The laws governing use of the areas and penalties for violations are stringent and appear to be adequate; the major problems appear to lie in enforcement.

Functions of the Protected Area System

As stated before, the acts setting up national parks and wildlife areas specified mainly recreation or pleasure and wildlife protection, and did not anticipate the range of important functions that these areas increasingly perform. The lack of recognition of important functions in law or formal policy regulations will increasingly exacerbate the following problems: (1) the lack of sufficient budget or mandate to fully realize the benefits of the protected area system; (2) the lack of a sufficient budget to protect the areas adequately; and (3) in particular, the lack of a sufficient budget or responsibility for contributing to regional and local development or for providing benefits for local villagers who are the major violators of protected area regulations.

Expansion of the function of parks and sanctuaries will, in general, permit nature conservation to be more fully integrated into the social and economic development of the kingdom (Snidvongs, 1984).

Total Area in Protected Area System

At present, there is no unanimous agreement among forestry officials and other conservationists concerning the desirability of increasing further the protected area system. The policy adopted by the government in 1985 (RFD, 1985) set a general overall target of 15 percent of the area of the kingdom for protected forest and 25 percent for productive forest, for a total of 40 percent of forest area (see Chapter 4). These figures were arrived at through estimation of the amount of upland watershed area requiring permanent protective forest cover, and crude calculation of the fuel and construction wood needs (based on per capita consumption) of the Thai population. The policy stresses that the private sector will be encouraged to help meet the need for wood through plantation forestry.

Protective forest is to be safeguarded in national parks, wildlife sanctuaries and special upland watershed management areas. The upland watershed areas are now being mapped, and will overlap with both parks and wildlife sanctuaries. A number of important issues are not settled by the policy guidelines, such as: (1) how many such watershed areas will lie outside parks and sanctuaries; (2) how these watersheds are to be protected, as such areas do not have a resident guard force to prevent encroachment; and (3) how much additional area should be brought under the protection of parks and sanctuaries.

Since it is likely that all other natural forests will be degraded or destroyed, many people presently feel that the target of 15 percent is too low, and that it should also include more lowland forest for conservation of plants and animals of lowland habitats.

Wildlife Management

At the time of writing, legislation is pending in parliament that will enable private and public institutions to manage and breed animal species with the permission of the WCD. This law has been much debated and is long awaited, and could make a positive contribution to saving some endangered species through management in captivity.

Administrative Issues

Neither the NPD nor WCD have adequate budgets to comprehensively manage the areas under their jurisdiction, and probably cannot do so with their present manpower and organizational structure.

The NPD is divided into the following sections: (1) administration; (2) research (mostly compiling information on fauna, flora, and other resources); (3) promotion and public relations; (4) forest park management; (5) national park management; (6) construction and maintenance; and (7) planning.

The following potentially important functions are missing or are inadequately covered in existing sections: interpretation and education, wildlife survey and management, promotion of international tourism, extension services to local residents and promotion of rural development. Some of these functions, of course, lie outside the present mandate of the division.

The WCD is divided into the following sections: (1) administration; (2) research; (3) extension; (4) wildlife sanctuaries; (5) law enforcement; and (6) wildlife propagation.

Omitted or inadequately covered are the following potential functions: recreation, international tourism, extension services to local residents and rural development promotion. These also lie outside the division's mandate as presently conceived. Many of the division's best qualified wildlife researchers appear to occupy administrative posts of various sorts, leading to a shortage of high quality personnel available to carry out needed surveys and wildlife

management work. In addition, there appears to be insufficient high-level positions and career opportunities for technical personnel as opposed to administrators. To help counter this problem, the division has encouraged collaboration with local university researchers.

To achieve full benefits from conservation areas will require both policy and administrative changes. While conservation leaders frequently urge that conservation in general, and wildlife sanctuaries in particular, play a positive role in social and economic development, there is as yet no blueprint for administrative organization offered which would allow achievement of such an ambitious goal. This requirement must be filled by each nation in the context of its particular limiting constraints and existing bureaucracy. The current policy discussion and proposals for reorganization and streamlining of the conservation agencies in Thailand (the NPD and WCD of the Royal Forest Department) provide the vital opportunity to insure that conservation serves national economic and social development goals.

A number of arguments can be stated in favor of combining the NPD and WCD into a single agency (see also FAO, 1981). It would reduce the present overlap in function between the NPD and WCD, for example, in law enforcement, protected area management and research. Second, there is no marked distinction in practice between parks and sanctuaries. Reorganization would permit them all to be zoned and reclassified according to their particular assets. Third, it would permit negotiation with foreign and international bodies as a single, more streamlined entity.

For the full development of conservation benefits to the kingdom over the long term, the following important functions would need to be reflected in the organization and staffing of a unified agency: administration, planning, training, upcountry protected areas, law enforcement, interpretation and education, tourism management and promotion, community help and development; research and survey, wildlife propagation, and herbaria.

In park management the word "extension" is often used to cover interpretation and community relations, but these missions should be seen as completely separate in the context of a rural developing country and the word "extension" here is regarded as too vague. Rural development concerns promotion of economic and other material benefits, not merely education (although education programs for local children may be included).

The present RFD proposal to combine the NPD and WCD into a single division within the RFD, if approved and implemented, must be seen as only a temporary measure prior to upgrading of the combined agency. Under the proposal, the two divisions could hardly maintain their present functions let alone take on an expanded role in increasing conservation benefits to the kingdom.

The question inevitably will arise where an upgraded conservation department or other agency should be placed and in what ministry. This is a practical administrative concern that cannot be resolved here.

5.4 KEY ISSUES

From the viewpoint of decision makers in the government, the most important general issue concerns the role that conservation resources, particularly those in conservation areas, should play in the overall development of the kingdom. The topics discussed below deal with this important policy issue. The protected area system will soon reach 10 percent of the area of the country, and the government has mandated that 15 percent of the country remain covered with "protection" forest; at least this area is to have its vegetation preserved in a more-or-less natural state. This is a large area to manage. Many conservationists feel that government officials, as well as the public, do not fully appreciate the value of the area and its potential benefits to the kingdom. Many also feel that the area cannot yet be properly protected and managed to produce these benefits.

The main problems concern defining and recognizing these values, protecting the conservation resources, and realizing their benefits more fully.

Value and Functions of Conservation Resources

The various values of conservation areas and resources were defined earlier: conservation of species and genetic diversity, recreation, tourism for national benefit, education, local employment and ecological services such as watershed protection and climate control. More values could abe added in particular areas. The laws creating the national parks and wildlife sanctuaries do not recognize all these values. The policies of the two managing divisions do somewhat better in promoting the benefits of the system, but there are still inefficiencies and gaps in administration, as well as limitations of mandate imposed by their administrative histories, as well as by law.

The first step in correcting the limitations of mandate and functions of the agencies concerned should be the redefinition of the function of protected areas (see also FAO, 1982), based on a thorough reanalysis of their actual and potential values. If this definition is written into the law or regulations, improvements in administrative organization and policy will follow logically.

A step in this direction has been made by the National Environment Board, in adopting the Policy Guidelines recommended by IUCN (1979), which sent a team of experts to Thailand to evaluate government programs and policies in conservation. These guidelines, however, have had little direct impact on the policies and budgets of the main implementing agency, the RFD. The guidelines' main effect has been to guide the development of some conservation projects for outside funding.

An analysis of values of protected areas and conservation resources must include tentative economic analyses and projections where possible. Sweeping generalizations about the value of conservation resources, or ethical arguments, may have recognized merit but are rarely sufficient to bring about

needed budget or manpower allocations. The government should therefore encourage resource economists to carry out analyses of the value of conservation resources in the context of social and economic development.

This is not to say that resources that do not have clear monetary value should be discounted. It is only a recognition of the fact that "hard decisions" are aided by such analyses and they should be made for conservation resources whenever possible. Without full recognition of the values of conservation it is doubtful if sufficient budgets and manpower will be committed to their protection, management and beneficial development.

Problems of Protection

It has been argued occasionally that protection and consolidation of parks and sanctuaries must precede development and management of the areas for full public benefit. This does not now seem to be a viable approach, as the solution to protection problems may not be feasible without concurrent promotion of increased public benefits from the areas. With increased realization of benefits from conservation areas, better support for protection and cooperation will be obtainable from the government, regional officials and rural residents near the areas, who are the major management problem.

There are several important issues here which are worth highlighting.

Information and monitoring

Protected area officials, especially those in Bangkok, sometimes have inadequate information concerning poaching and encroachment problems. Such officials need to develop regular channels for obtaining information. A regular reporting and monitoring program should be required by higher officials. Such monitoring could be achieved by requiring officials to go on more patrols, requesting regular wildlife surveys or monitoring, or by increased development for hiking or tourism which results in more frequent visits to remote areas.

The development of increased benefits from protected areas will automatically yield more information about enforcement problems. This is illustrated by the rural development project in Ban Sap Tai, a small village bordering a remote region of Khao Yai Park that has been plagued with poaching and encroachment and which was seldom patrolled in the past (Dobias, 1985) (see Box 5.1).

Relations with local villagers

Poor relations with local villagers often prevent management personnel from visiting or patrolling areas far from headquarters. Sanctuary officials who enforce regulations against poaching too diligently have been shot at by local residents in several protected areas. To treat this as only an enforcement problem does not ordinarily result in its being solved. Often enforcement is simply relaxed — the safest solution.

Relations with local residents cannot be improved simply by education or public relations efforts. Villagers must be given incentives to obey protected area regulations. To some forestry officials, this would appear to represent a policy of rewarding potential criminals to entice them not to commit crimes. On the contrary, it must be seen as an effort to allow poor rural residents to share the benefits of conservation resources, as all Thai citizens should. After all, the local residents are the ones who have been required to make the most sacrifices.

Substantial improvements in relations with rural residents probably cannot be achieved without high-level changes in policy and some reorganization of wildlife and park agencies.

The problem of protecting conservation areas against poor people in developing countries is recognized by responsible world conservation leaders. A shift in emphasis will be necessary if we are to implement the strategy relying on conservation to help sustain development.

Enforcement and prosecution

Penalties for protected area violations are sufficiently high to deter would-be violators if apprehension and prosecution are carried out. Lack of cooperation by police and courts in imposing full penalties is certainly not the only problem in preventing violations.

If the chance of being caught is only a few percent, as it probably is in some protected areas, the deterrent value of any penalty is reduced to insignificance. If villagers had, however, at least an even chance of being caught, the mere seizing of their guns, axes and booty, and loss of a couple of days' work would be sufficient deterence to prevent poaching. It then would not be necessary to take such small violators to court — the time would be better spent learning about their problems and educating them. The imposition of high fines and jail terms on the few villagers who are caught seems unfair to them and causes loss of respect for the law. It also invites retaliation.

Hill tribes

RFD policy on settlement by hill tribes in protected areas is clear: it is a violation of protected area regulations. In practice the situation is far from satisfactory, as hill tribe villages still remain in some protected areas, as described above. Inability to resettle hill tribes is due to several problems: (1) lack of sufficient manpower, force or budget to move thousands of people; and (2) lack of desirable places to move them to.

The RFD has sought collaboration from the regional armies in moving tribes from protected areas, and recently has moved a village from Huai Kha Khaeng Wildlife Sanctuary. Plans are being made to resettle several thousand Hmong and Karen out of Thung Yai Naresuan. Many of these tribesmen had settled in the sanctuary before it was created.

Any resettlement schemes must involve agencies concerned with the welfare and agricultural development of the hill tribes, and not only the RFD and Thai Army. Hill tribe resettlement areas have often been selected in lower elevation regions that have already been deforested. Although sustained agriculture may be possible in such areas, the older and more traditional tribesmen may lack the experience to maintain their families without help and capital inputs, and will find it impossible to meet all their traditional needs.

Forced relocation schemes, if they prove necessary, should take into consideration the unique cultures of the highland people and be carried out in such a way that family ties, villages, and cultures are not disrupted. The disruption of anyone's culture is a painful and wrenching experience and will lead to failure to adjust successfully to new circumstances. It destroys morale, the will to work, and the relationships that are necessary for successful performance of work. For this reason, experts on hill tribe cultures, both resident (for example, at the Tribal Research Center in Chiang Mai) and international, should be involved during planning, implementation and post evaluation.

Clearly, hill tribe practices need to be changed in some places in order to improve and preserve watersheds, but the hill tribe leaders should be involved in the planning and implementation of such changes (Eudey, 1986). The changes may be more successful if carried out on a village basis with traditional leaders playing important roles, for example, in getting villagers to implement watershed maintenance and village benefit programs. This way they will better appreciate the reasons that changes are needed. Such an approach is being attempted in some watershed projects in Chiang Rai. The resettlement of hill tribesmen in preselected new plots, house by house, destroying the integrity of the village, should be avoided.

The hill tribe problem is exacerbated by their nomadism (in particular, that of the Hmong) and free movements across the Burmese border and between provinces. There is no easy solution to these problems.

An alternative that has not been seriously considered by the RFD is to allow a certain number of tribesmen to remain in protected areas and participate in their management. They could be allowed to maintain a certain area in subsistence crops, but be prohibited from hunting, clearing new fields, or growing cash crops. Cash income could be derived from several possible sources: including hosting and guiding hikers and other visitors, or being employed as workers and guards. The expertise of the tribes in path finding, forest and wildlife lore and their intrinsic interest to visitors could be great assets in promoting northern and western conservation areas. Obviously, however, relatively few tribesmen could be employed in this way, so it would not go far toward solving the whole problem of hill tribe encroachment. It might, however, benefit the management of some protected areas.

The recent creation of a task force on hill tribe problems in protected areas, under the Office of the Prime Minister, is a welcome policy initiative. The participation of representatives from the RFD, Army, Public Welfare Department (Ministry of the Interior), Department of Agriculture and the National Environment Board on this committee is a welcome indication that the government realizes that a total, not merely a partial, solution to the problem is necessary and that it must be initiated at a high level in the government.

Benefits from Conservation Areas

Basic need

Conservation areas have made great progress in satisfying the demand for recreation and education for Thai people. Equal effort should be made to provide benefits to rural residents near their borders. Most visitors now appear to come from urban areas where workers may have more leisure time, although no statistics are kept on this. The provision of local economic benefits and community help are vital to ease public relations and enforcement problems.

The need for providing tangible benefits from conservation areas to locals is being articulated more and more by international conservation leaders and is beginning to be implemented in many other tropical countries. Although Thailand is relatively well advanced in establishing and managing conservation areas for forests, wildlife and aquatic environments, Thai policies have lagged behind in recognizing this need.

It may be argued that conservation agencies must be concerned with protection, wildlife management, visitor reception and education, and should not have primary responsibility for development projects in areas outside of their jurisdiction. There are, however, some good reasons why they should be given responsibility for providing benefits and help to residents near protected areas: (1) conservation areas have some direct benefits to offer local residents, and only the responsible agency, the RFD can provide these; (2) such residents are usually from remote areas, are poor, and are difficult for other development agencies to reach, so are usually accorded low priority; (3) only if the protected area management personnel aid in providing benefits will the attitudes of local persons toward protected areas be changed — residents must see the benefits as due to the establishment of a protected area and the presence of its personnel; and (4) local persons often have skills and knowledge which can be used to advantage in managing protected areas.

Captive breeding

The WCD has been making progress in captive breeding of several species of birds and mammals which may ultimately provide benefits to local people. One project now starting involves breeding deer for meat and for their antlers which are used for medicinal purposes. Deer ranching has proved successful in the Peoples' Republic of China. Development of captive propagation involves the following four phases: (1) exploratory phase — finding the most suitable species; (2) research — solving all the technical and biological problems;

(3) demonstration project — showing that captive propagation can be successful and economical and (4) extension — promotion of captive propagation farms among rural residents. The WCD should attempt to bring propagation of one or two species into the third and fourth phases as soon as feasible to prove the benefits of this kind of activity.

Appropriate tourism

Tourism does not usually provide significant benefits to rural villagers, as stated previously. This is because it is not normally designed to do so. Certain kinds of specialty tourism, however, can provide significant benefits to target areas in or near parks and sanctuaries. "Adventure tourism" and trekking in foreign lands is now a growing, multi-million dollar business in the United States and other Western countries, and Thailand has a great potential to absorb thousands of such visitors each year. So far, it has had very little impact in Thailand because of a lack of promotion, leadership and infrastructure, not because of a lack of potential demand. But such tourism must be carefully planned to produce the desired beneficial effects, and to avoid the undesirable effects.

Trekking tours in hill tribe areas in Chiang Mai are reasonably popular and profitable, but these are not a satisfactory model to emulate for many reasons: (1) they are not designed to benefit hill tribes maximally to begin with; (2) they are too low-budget, inexpertly planned and led, and not highly educational; (3) they draw on young ordinary tourists in the country and are not targeted to the most appropriate groups; (4) such tourism has a number of negative effects on hill tribe culture (Cohen, 1983), though the total impact has not been great so far.

The development of an "appropriate tourism" for rural benefits, although feasible, will require changes in the philosophy and policy of tourism promoters in Thailand, who tend to promote "affluent" types of tourism that maximize total revenue and profits of city based agents and businesses. Government tourism authorities should play a role in mapping out a program for "appropriate tourism" and actively promote agencies to establish it properly. Such authorities already recognize that conservation of nature and environmental protection are vital to the future of tourism (Hiranyakit, 1985).

Resolution of Conflicts over Beneficial Use

Nature conservation should support and contribute to sustained social and economic development and not conflict with it. This is the entire message of IUCN's *World Conservation Strategy* (1980) with which this chapter began. Nevertheless, there are inevitable conflicts between alternative ways of benefiting development. Moreover, all the facts needed for a rational decision are seldom, if ever, available. Unfortunately, conservationists are usually the ones who most lack the facts to support their cause, and are most often on the defensive. The functioning and values of ecosystems are far more difficult to understand and verify than those of buildings, dams or roads.

Here are some considerations that may help reduce apparent conflicts between nature conservation and technological development projects.

Role of the public

The public is often said to be uninformed about environmental issues or conflicts, but often government agencies have themselves to blame for this. The public may not be informed because the agencies do not freely supply people with information, or do not discuss issues in public. In a country such as Thailand, it is probably counterproductive to avoid informing the public. Public outcry and conflict may result when project implementation begins without the prior knowledge or participation by the public.

The National Environment Board could itself take on the task of promoting early public discussion of issues to prevent or head off possible misunderstandings. For example, its *NEB Newsletter* could provide space for a "public forum" for discussion of both sides of controversial issues and call for commentary by recognized experts. There is a great need in Thailand for a magazine on environment and conservation for informed citizens, to cover news and policy issues and to educate the public about the need for conservation and environmental protection.

Management planning

As pointed out earlier, preparation of management or "master" plans for protected areas can lead to more complete and effective evaluation of the impacts of development projects in protected areas. Preparation of detailed management plans can be seen as an extension of policy statements regarding the objectives and functional role of the entire conservation estate. Management planning is nevertheless proceeding in the absence of such a policy statement by the government.

Effective planning requires extensive survey and mapping of the physical, biological and cultural assets of each protected area. Our knowledge of what the protected area system contains, and its potentials for benefiting the kingdom, is developing too slowly.

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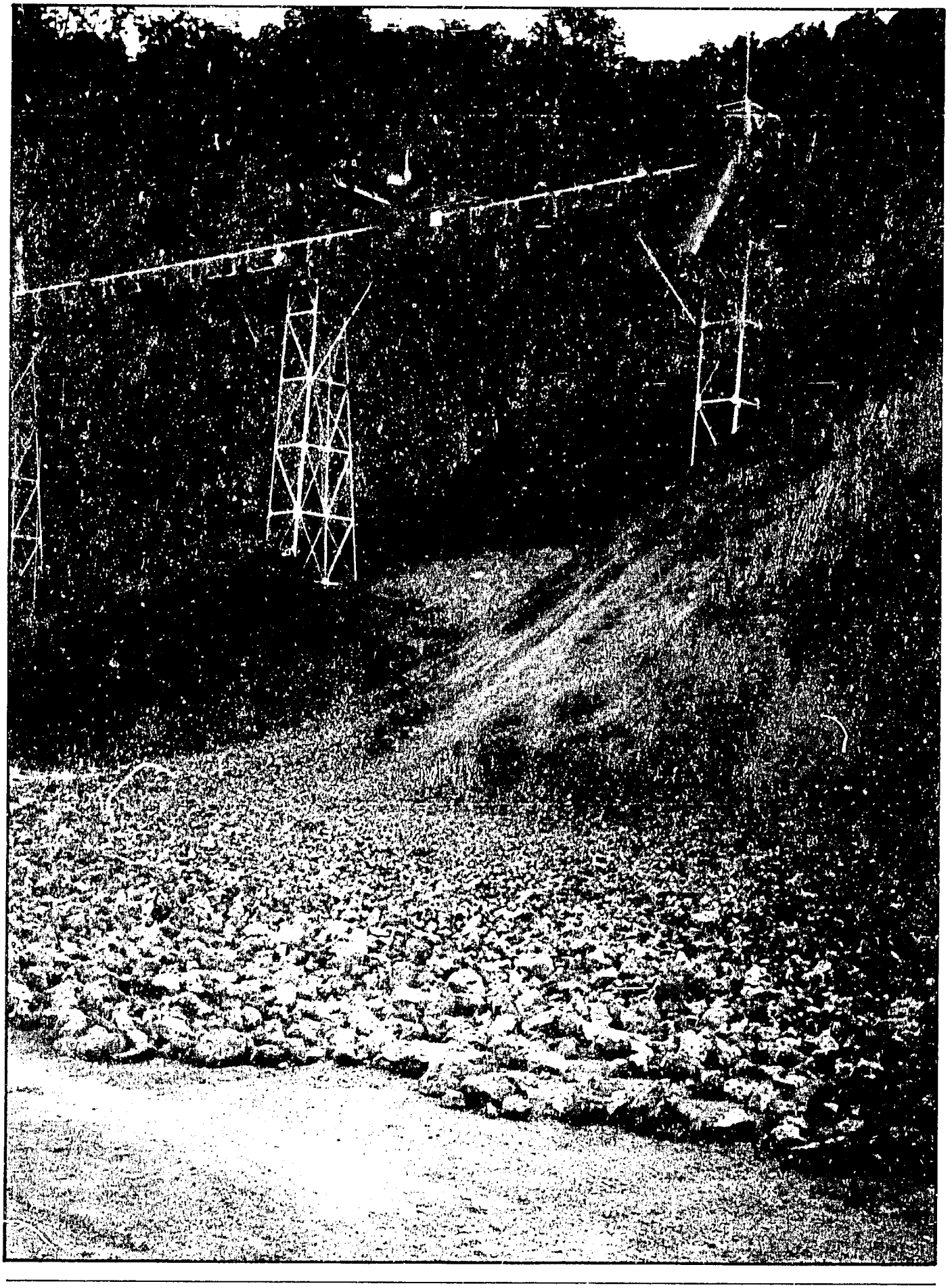


6 Mineral Resources

6.1 OVERVIEW

Despite the depressed state of the world commodity market, the value of Thailand's mineral output grew significantly between 1983 and 1985, from nearly 9.7 billion baht to nearly 11.2 billion baht. Tin accounted for 66 percent of the 1983 value and for 47 percent of the 1985 value. Those are still high proportions, but are dramatically down from the 1980 situation, when tin accounted for some 82 percent of the value of the country's mineral output. Although the international tin market featured high prices and brisk demand in 1980, with unrestricted exports until April 1982, oversupply subsequently led to the imposition of export controls on producing members of the International Tin Council (ITC) and, ultimately, to the collapse of the London Tin Market in October 1985.

The economic impact of the tin industry on Thailand's economy will be referred to constantly through this chapter, because of the metal's dominant economic role, but it is worth noting that more than 30 minerals are currently being produced commercially in Thailand (Table 6.1). Aside from tin, other key minerals include, in decreasing order of 1985 value, zinc, fluorite, gypsum, lead, barite, tungsten, columbite-tantalite, and antimony. Fuel minerals, including lignite, oil and gas, also make a significant contribution to the country's energy budget and GDP (Tables 6.2 and 6.3). The production of lignite, in particular, is likely to grow considerably. The distribution of mineral resources in Thailand is indicated in Figure 6.1.

Contribution to the National Economy

Thailand's mineral industries make a very considerable contribution to the country's economy. Record foreign exchange earning of 15 billion baht was achieved in 1980, with the 33,455 tons of tin exported that year bringing in about three-quarters of the total figure. At that time, minerals were second only to rice in terms of foreign exchange earnings. By 1985, however, the value of (not including exports of condensate) mineral exports had dropped to just under 7.8 billion baht, (not including exports of condensate), roughly half the 1980 figure, with 17,359 tons of tin contributing 70 percent of the 1985 figure (Table 6.4). This drop placed minerals in sixth place in the table of foreign exchange earnings, after textiles, rice, tapioca products, rubber and integrated circuits.

This decrease in the value of mineral exports was attributable both to reduced international demand and falling prices for key minerals such as tin, tantalum and tungsten. Zinc metal was exported for the first time in 1985, following the opening of a zinc smelting plant late in 1984. A total of 21,407 tons of zinc were exported, worth some 470 million baht in foreign exchange.

Exports of condensate, the natural gasoline obtained when natural gas is depressurized at wellheads and separation

Table 6.1 Mineral Production and Value 1980, 1984 and 1985

(production: tons, value: million baht)

Mineral	1980		1984		1985	
	Production	Value	Production	Value	Production	Value
Tin concentrates	45,986	11,545.6	29,979	6,396.9	23,022	5,290.0
Tungsten:						
- Wolfram	2,561	519.4	1,144	162.7	856	112.4
- Scheelite	473	91.9	295	42.3	281	37.4
Fluorite						
- metallurgical	172,784	200.3	230,228	326.6	263,059	449.3
- acid	60,108	105.1	57,151	114.0	35,840	73.3
Zinc ore	-	-	147,993	377.4	276,909	706.1
Lead concentrate	24,847	228.6	39,204	180.8	46,245	220.1
Columbite-Tantalite	356	303.4	477	230.0	268	143.2
Lignite	1,426,166	171.3	2,337,226	661.4	5,146,150	2,552.0
Gypsum	411,977	113.5	1,110,660	401.0	1,273,459	432.9
Barite	305,057	208.1	174,918	153.8	230,970	207.4
Antimony	6,862	134.8	4,636	97.8	2,917	64.7
Limestone (for cement)	3,957,929	98.9	9,223,406	203.6	9,844,610	428.1
Feldspar						
- Sodium	-	-	-	-	92,620	114.1
- Potassium	24,158	12.1	74,404	107.9	11,966	19.3
Kaolin	19,931	14.0	58,616	41.0	106,704	74.7
Manganese						
- battery grade	2,716	7.2	6,110	16.1	3,930	15.9
- metallurgical	51,538	46.4	2,577	2.6	455	0.5
Silica sand	171,000	20.5	166,787	20.0	152,133	52.4
Rock salt	16,744	4.5	9,850	2.6	12,786	3.4
Marble	5,649	2.5	37,927	16.9	21,478	41.9
Others		109.7		120.9		137.0
Total value		**13,937.8**		**9,676.3**		**11,176.1**

plants, have brought in additional earnings since 1984. Condensate exports in 1985 amounted to 63 percent of total production, worth over 5 billion baht in foreign exchange.

Thailand's mineral exports will continue to make substantial contributions to the country's balance of payments, not least because of its close proximity to key consuming nations, including Japan, South Korea, Taiwan and the ASEAN countries.

Minerals also make a significant contribution to the government's revenues, by way of royalties and, to a lesser extent, business and municipal taxes. Indeed, mineral royalties represent a vital source of government income, as Table 6.5 confirms. In 1980, a total of 4 billion baht was obtained from mineral royalties, with tin contributing 85 percent, or 3.4 billion baht, of that figure. The amount collected dropped to 1.5 billion baht in 1985, of which nearly 79 percent came from tin. The business and municipal tax income collected dropped from 482.6 million baht in 1980 to 240.6 million baht in 1985.

To alleviate the financial burden imposed upon tin miners, the government decided in November 1985 to reduce the business and municipal tax rate imposed on tin exports by half, from 4.4 percent to 2.2 percent, with a further reduction to 1.1 percent in June 1986. A special fee, collected at a rate of 5 percent of the tin royalty, had already been dropped to help the mining industry. The money thereby derived had been used to suppress tin smuggling and to mitigate the adverse impact from the mining industry in the areas where it operates. Continuing sources of income from the industry include income tax and the fees payable for various licenses and permits.

The mineral industry is also a significant employer, although its workforce dropped from 90,813 in 1980 to 61,306 in 1984, with a further drop to 40,196 in 1985 — less than half the 1980 figure (Table 6.6). The industry also produces wider benefits, particularly where it operates in remote areas, often bringing in roads, electricity and water. Communities like Phuket, around which tin-mining has long taken place, and Mae Moh which is in the lignite-mining area, can be transformed into major settlements. The number of active mineral mines is indicated in Table 6.7.

The positive multiplier effects of such activity are also significant, although Thailand still has some way to go in developing the necessary "downstream" industries. In this respect, however, it is encouraging to note that growing quantities of such mineral commodities as limestone, shale, gypsum, kaolin, feldspar, silica sand and marble are being used by local manufacturing industries, including the cement, ceramics, rubber, paint and building industries. Thailand's consumption of such minerals is shown in Table 6.8.

Table 6.2 Natural Gas Production, Sales, Value and Royalties, 1983-85

(production and sales : MMscf, value and royalty : million baht)

Gas Field	1983	1984	1985
Offshore Production			
Erawan	54,097.30	68,179.50	67,574.70
Ban-Pot	1,033.00	11,139.90	8,080.80
Satun	-	-	24,969.60
Pla-tong	-	-	21,995.60
Onshore Production			
Sirikit	1,890.16	6,186.45	10,044.62
Total Production	**57,020.46**	**85,505.85**	**132,665.32**
- Sales	55,169.12	82,468.23	125,859.71
- Value	3,344.38	4,940.76	8,021.63
- Royalties	422.40	617.72	1,002.69

Note: MMscf = Million standard cubic feet.
Source: Department of Mineral Resources' Petroleum Statistics, 1983-1985.

A number of tin-smelting and processing plants are already producing tin metal or alloys, prior to shipment abroad. A rebate of 50 percent on royalties is given to domestic users of tin, while domestic consumers of other minerals can claim a 25 percent refund on royalties. Zinc ore is being converted to metal at the Tak plant, both for export and domestic consumption.

As far as fuel minerals are concerned, lignite production has been a star performer, with better than three-fold growth between 1980 and 1985. In 1985, almost 90 percent of total production was consumed by EGAT's thermal power plants at Mae Moh and Krabi. As EGAT installs additional generating units at Mae Moh, further increases in lignite production are likely, with one forecast suggesting that by 1990 the total requirement may have reached some 9.5 million tons. Other lignite users include local cement plants and tobacco-curing factories.

Oil and gas production, meanwhile, has declined somewhat, so that by mid-1986 Thailand was producing daily some 329 million cubic feet of natural gas, 16,000 barrels of condensate and 20,000 barrels of crude oil. Domestic oil and gas production now account for almost 40 percent of domestic petroleum consumption and, a number of downstream activities are planned.

Technology Trends

Given that more than 80 percent of the value of Thailand's mineral output comes from small and medium-scale mines, it is perhaps not surprising that there is an emphasis on "appropriate" technology in the minerals industry. Hand-sorting of ores by local people is often used when producing concentrates of fluorite, barite, feldspar and manganese ore, and is one of the reasons why Thai minerals are competitive in international markets.

Table 6.3 Condensate and Crude Oil Production, Sales, Value and Royalty, 1983-85

(production and sales : million barrels, value and royalty : million baht)

Field	1983	1984	1985
Offshore Condensate			
Erawan	2.20	2.40	2.60
Ban-Pot	0.07	0.61	0.35
Satun	-	-	1.05
Pla-tong	-	-	1.21
Crude Oil			
Sirikit	2.22	5.10	7.59
Total Production	**4.49**	**8.11**	**12.80**
- Sales	4.31	8.26	12.68
- Value	2,722.11	5,283.33	8,988.92
- Royalties	340.26	660.44	1,123.60

Source: Department of Mineral Resources' Petroleum Statistics, 1983-1985.

Instead of making major investments in new plants or equipment, these mines tend to progressively upgrade technology, like gravel-pumping technology, which has been around for many decades. The latest refinement of this technology involves the use of multi-lane sluice boxes (known as "palongs") and jigs for the primary concentration of tin ore. A high degree of personal skill and experience is brought to bear on the mining and dressing of minerals at such plants.

Because advanced technology has to be brought in from abroad, there is some economic disadvantage to its use for small and medium operations, although many of the larger mining operations invest heavily in such technology. A tin dredge can be regarded as advanced tecnology because the whole system must be designed and constructed in a highly technical fashion before it can be commissioned. Other examples of technology would include the new zinc smelter at Tak, and the ill-fated tantalum processing plant at Phuket. Perhaps most strikingly, the petroleum industry requires advanced technology throughout the entire spectrum of its operations.

Mineral Reserves and Potential

According to the International Monetary Fund, world commodity prices hit a seven-year low in 1986. Nevertheless, in longer term, the prospect is that the market will recover. So it is worth considering how long Thailand's reserves of particular minerals are likely to last in such circumstances.

Determining how large a country's reserves of a mineral ore, and how long they are likely to last, is rarely an easy task. Generally, the estimate must be made on the basis of past production records and present knowledge (DMR, 1981). A total of 1.4 million tons of tin concentrates were produced in Thailand between 1907 and 1985, and if the price rises

Figure 6.1 Distribution of Mineral Resources in Thailand

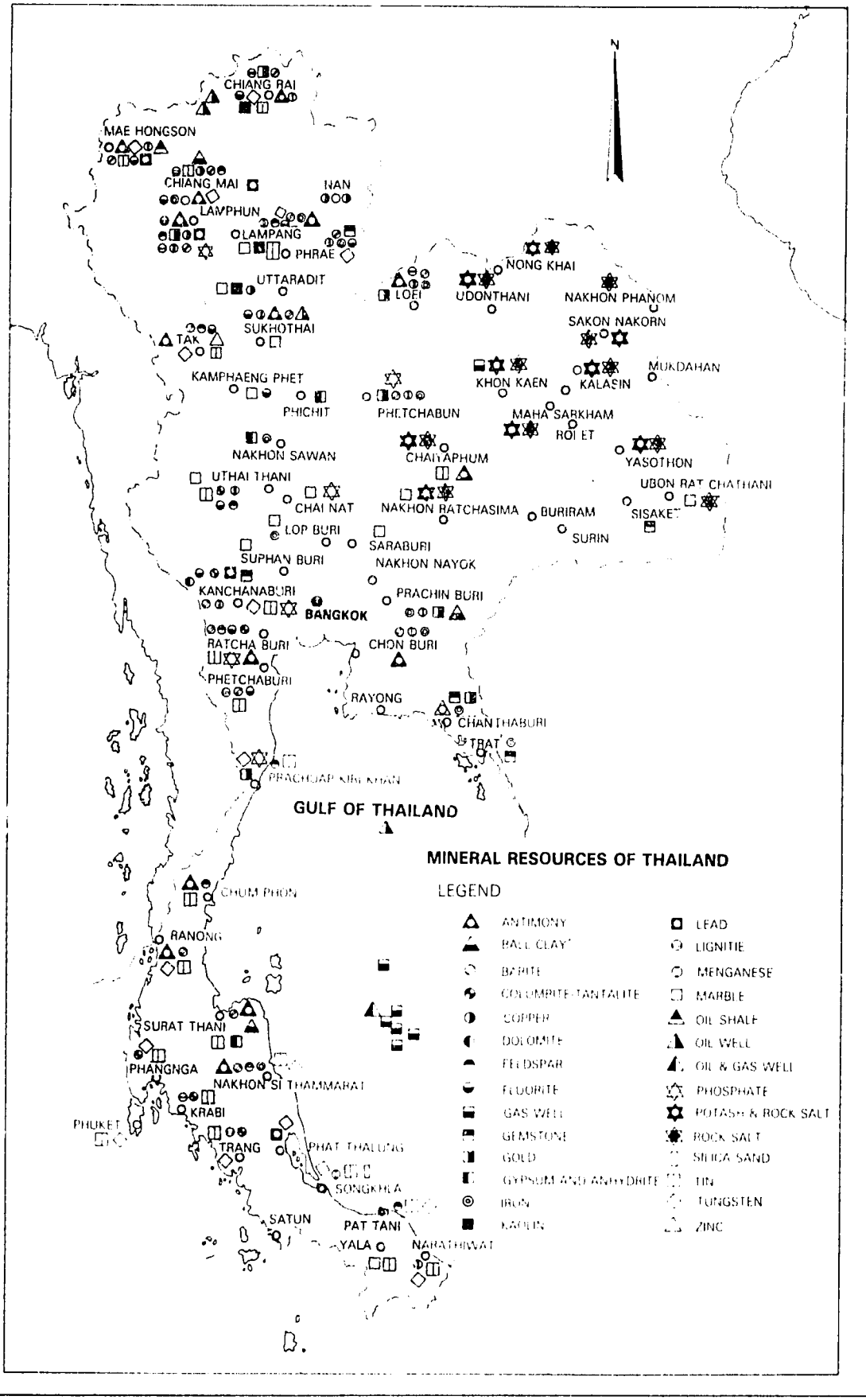


Table 6.4 Mineral Exports 1980, 1984 and 1985

(export : tons, value : million baht)

Mineral	1980		1984		1985	
	Exports	Value	Exports	Value	Exports	Value
Tin:						
- tin metal	33,445	11,168.7	18,332	5,267.5	17,359	5,462.1
- tin-lead alloys	45	12.1	1,140	164.0	1,758	325.4
- present slag	3,306	1,520.6	1,516	178.1	330	27.5
Old tin slag	9,423	558.4			20	0.5
Zinc metal	-	-			21,407	470.7
Tungsten						
- wolfram	3,272	576.5	1,378	158.5	766	85.1
- scheelite	322	61.8	354	46.2	379	48.1
Fluorite:						
metallurgical grade	154,432	185.6	170,133	245.5	168,835	276.2
acid grade	59,824	114.2	54,530	109.6	35,375	85.5
Gypsum	144,536	47.5	737,954	229.7	869,887	265.1
Barite						
- lump	327,000	222.7	163,449	138.5	202,942	185.2
ground	34,732	54.8	18,549	37.5	12,730	28.1
Lead concentrate	34,732	54.8	42,004	175.6	46,375	189.9
Antimony						
ore	4,952	93.1	5,601	105.8	5,284	117.3
metal	68	3.7	-	-		
Columbite-Tantalite	197	69.3	106	41.6		
Xenotime	17	0.4	130	16.7	163	30.2
Monazite	-	-	1,852	19.3	1,277	13.7
Feldspar - sodium	924	1.4	12,400	11.1	33,902	27.1
Others		189.0		85.1		141.5
Total value		**14,934.6**		**7,030.3**		**7,779.2**

Source: Department of Mineral Resources' Mineral Statistics, 1980-1985

significantly, a production of 25,000 tons a year of tin-in-concentrate could be achieved for an extended period.

The proportion of Thai tin produced from offshore fields has fallen in recent years, partly because of falling prices, but also because of the depletion of high-grade offshore tin grounds. Longer term, however, there is considerable potential for exploiting lower-grade tin deposits, both offshore and onshore, in the south of the country and along the Thai-Burmese border.

As far as tantalum is concerned, this valuable mineral is found in close association with tin ore, so that increased tin output will automatically mean more tantalum. Tungsten, meanwhile, should also be available for some time to come, particularly given the geology of the western part of Thailand, which looks especially favorable in this respect. The total output of tungsten in Thailand totaled some 123,000 tons between 1934 and 1985. There are also favorable indications on the future availability of antimony ores, with Thailand having produced a total of over 106,000 tons by 1985 from the past. Current significant production takes place in Kanchanaburi and Chonburi.

Although no reliable figures are available on the likely reserves of fluorite, over 5.4 million tons of metallurgical and acid grade fluorite concentrates were produced between 1964 and 1985, and the existing reserves should be able to support present production levels into the foreseeable future. Declining demand and prices for this mineral have led to a slump in production, from a peak of some 427,000 tons in 1971 to around 200,000 tons of exports a year since 1980.

Estimated reserves of a number of other industrial minerals are shown in Table 6.9 (Sampattavanija, 1984), illustrating the economic potential of some of these materials. The reserves of other minerals used to support domestic production in such industries as cement, ceramic and glass manufacture are considered sufficient for an extended time-frame.

The fuel mineral reserves, are better understood largely because of the more systematic approach which has been used in prospecting. Subject to later revision, these are now thought to be as follows: total proven natural gas, 7.5 trillion cubic feet; total possible natural gas, 12.9 trillion cubic feet; total oil and condensate, 99 million barrels; total possible oil and condensate, 180 million barrels; total proven lignite, 670 million tons; and total possible lignite, 2 billion tons (Suvarnapradip, 1983; Changkasiri, 1986; DMR, 1986).

A comprehensive mineral resource inventory assessment program has been in progress since June 1984. It includes an airborne geophysical survey project, largely funded by Asian Development Bank loans, together with some financial assistance from the Canadian International Development Agency (CIDA). The project is scheduled to be completed by the end of 1987. The entire country is being covered by aerial survey to help in the preparation of aeromagnetic, radiometric and

Table 6.5 Mineral Royalties, 1980, 1984 and 1985

(million baht)

Mineral	1980	1984	1985
Tin concentrate	3,437.5	1,017.2	1,200.3
Tin slag	388.7	63.7	23.5
Tungsten concentrate	125.2	40.1	32.3
Lead concentrate	15.3	10.0	11.2
Fluorite	11.3	20.5	21.6
Lignite	5.3	25.6	104.0
Gypsum	3.0	16.4	17.3
Limestone	2.1	8.9	15.7
Barite	n.d	10.4	13.7
Antimony	8.8	n.d	n.d
Zinc metal	-	-	29.3
Others	29.6	44.9	52.8
Total	**4,026.8**	**1,257.7**	**1,521.7**

Note: n.d. = not determined.
Source: Department of Mineral Resources' Mineral Statistics, 1980-1985

electromagnetic maps. Based on the resulting information, further exploration will be undertaken for petroleum resources, and for metallic minerals such as iron, copper, lead, zinc, antimony and radioactive materials. An integrated database will then be available for both the private and public sectors.

Regional Development

Mineral resources are found in all regions of the country, but the distribution of specific minerals varies greatly between the different regions. The southern provinces along the west coast, for example, are particularly rich in tin ore, almost exclusively occurring in the form of alluvial deposits, which can be won with simpler extraction methods, such as gravel-pumping. These areas are also rich in associated minerals, including tantalum and monazite.

More complex types of tin ore are found in areas of the south-eastern coast. Tin ore also occurs in lode, or hard-rock deposits, necessitating the use of modified or improved mining practices. Deposits of several other minerals are found along with tin in this region.

A number of minerals, including tin and tungsten, are found in the west-central and northern regions, occurring in a variety of different forms. The northeast region is rich in salt and potash, which have not yet been commercially exploited on a large scale.

In order to develop such mineral resources efficiently, the Department of Mineral Resources has set up regional centers to provide technical support to the minerals industry. While the economic benefits associated with the necessary development activities hardly need stressing, the government is concerned that local people be fully informed of the benefits and costs likely to be associated with specific exploration or development projects.

Table 6.6 Number of Mineral Industry Employees 1980, 1984 and 1985[a]

	1980	1984	1985
Mining	90,813	61,306	40,196
Mineral beneficiation	1,605	2,364	2,391
Metallurgical operations (DMR licensing)			3,268

Note: a. Marked decrease was noted for tin mining; other decreases were reported for tungsten and lead operations.
Source: Department of Mineral Resources' Statistics, 1980-1985

Table 6.7 Number of Active Mines, by Mineral 1980, 1984 and 1985

Mineral	No. of mines		
	1980	1984	1985
Tin[a]	737	725	614
Tungsten[b]	27	20	NA
Fluorite	58	61	55
Lignite	9	14	15
Gypsum	9	20	15
Barite	38	56	44
Antimony	36	40	41
Limestone	8	23	24
Kaolin	15	38	37
Feldspar	15	25	25
Silica sand	11	20	18
Marble	4	36	39
Others	77	129	141
Total	**1,044**	**1,207**	**1,068**

Notes: a. including tin-tungsten mines.
b. including wolfram and scheelite mines.

Source: Department of Mineral Resources' Mineral Statistics, 1980-1985

6.2 HISTORICAL DEVELOPMENT AND EMERGING TRENDS

Minerals and precious metals were known (and have been exploited) since time immemorial in Thailand. Tin, lead and copper were extracted, as was gold, with a major find of the metal being reported at Ban Sapan, Prachuap Kiri Khan. Widespread discovery of tin in the South, particularly in Phuket during the Ayutthaya Period, caused the influx of European influences into the kingdom (Sethaput, 1963). Due to the great potential and economic implications of tin, Thailand was requested to conclude the first trade agreement with France in 1685, giving the French a monopoly in the trade of tin. Tin thus became a valuable commodity of international prominence.

Table 6.8 Thailand's Mineral Consumption 1980, 1984 and 1985

(consumption : tons, value : million baht)

Mineral	1980		1984		1985	
	Consumption	Value	Consumption	Value	Consumption	Value
Tin metal	734	243.5	870	250.2	640	199.9
Dolomite	7,980	0.9	4,017	3.2	16,928	14.2
Feldspar-sodium + Potash	14,032	7.0	41,628	60.4		
-sodium					144,329	52.5
-potash					12,075	19.6
Glass sand	140,511	16.0	150,565	18.1	157,571	54.2
Gypsum	256,431	69.9	305,886	110.4	340,488	116.5
Kaolin	17,681	12.4	56,456	39.5	103,127	72.2
Lignite	1,513,390	178.2	2,276,416	644.2	5,180,004	2,568.1
Limestone (for cement)	3,230,159	30.8	9,163,527	229.2	8,700,382	372.6
Manganese -battery grade	6,028	15.9	9,734	25.7	4,204	17.1
Marble	5,651	2.5	16,250	7.2	7,739	15.1
Pyrophyllite	10,110	2.0	9,055	5.8	16,029	7.7
Rock salt	11,000	2.9	9,075	2.4	4,850	1.3
Zinc metal	-	-	-	-	25,482	626.0
Others		100.6		40.3		50.2
Total value		**723.6**		**1,436.6**		**4,187.2**

Source: Department of Mineral Resources' Mineral Statistics, 1980-1985

The Chinese were probably the first tin miners in Thailand. Being traders and travellers by heritage, these people were believed to have discovered, worked and smelted the tin ore found in abundance across the southern peninsula of Thailand. The methods then employed for tin ore mining consisted of ground sluicing, open-cast and shaft-sinking in the then much richer tin grounds. It was not until after 1878 that a more efficient gravel-pump method was introduced for alluvial tin ore from Malaysia.

Tin mining expanded further in various areas of both the west and east coasts of the South, with Phuket becoming the leading center of tin activities. To obtain fuller benefits from the mining industry, the first Mining Law was promulgated in 1901, during the reign of King Rama the Fifth. This early legislation was superseded by the Mining Law of 1918, with later improvements keeping pace with changing needs and conditions. Basically, however, the provisions of this legislation were designed primarily to suit the practice of tin mining, because of the mineral's almost complete dominance in the mining industry of Thailand, especially during that time.

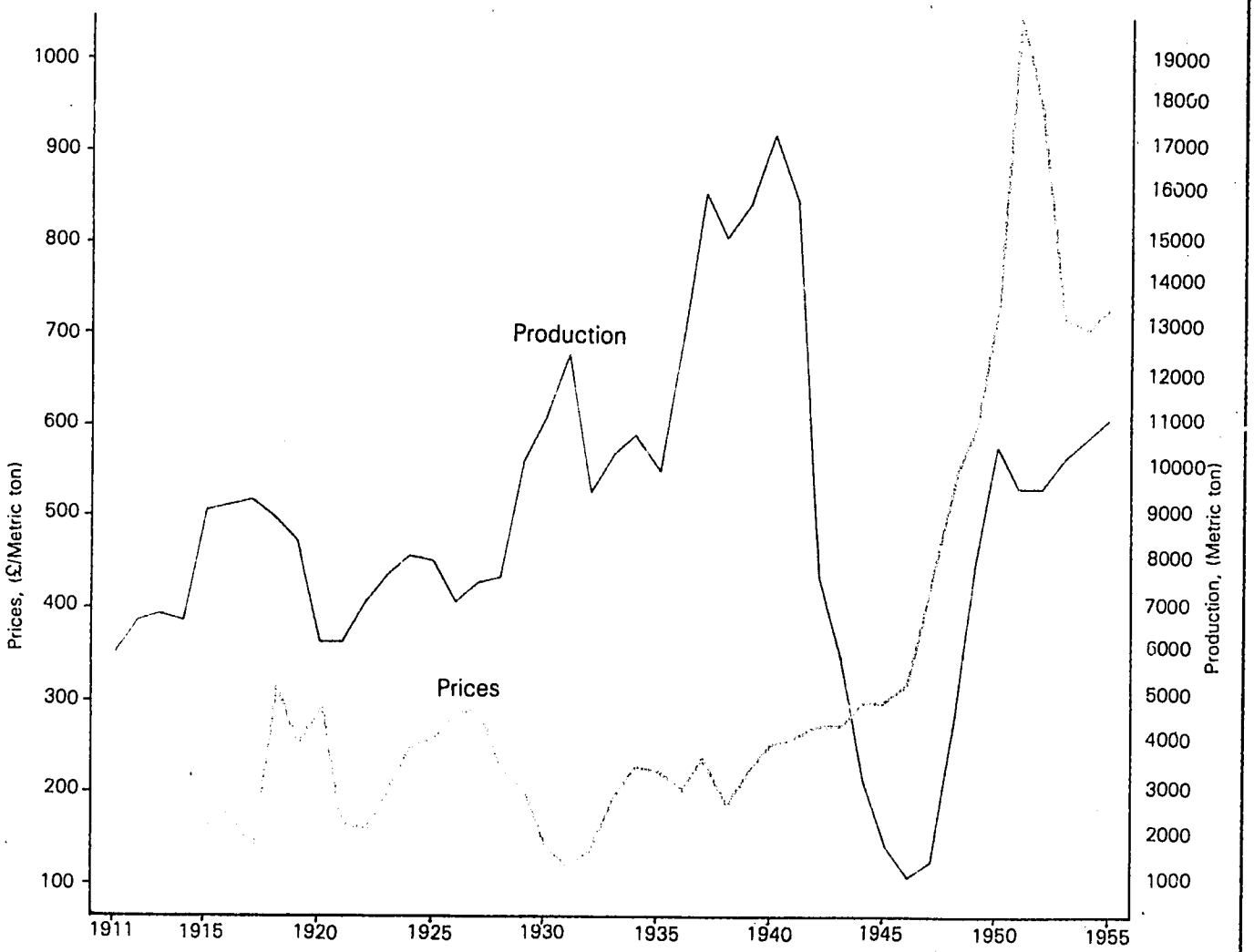
The tin mining industry experienced a major innovative development in 1906, when the first tin dredge was brought into Phuket and worked successfully in offshore areas around the island. Based on this revolutionary new method, production of tin in Thailand was steadily rising, augmented by the output from the gravel-pump mining already established. By

Table 6.9 Estimated Reserves of some Industrial Minerals

Mineral	Tons	Average Grade	Remarks
Barite	18×10^6	Sp. Gr. 4.2	
Diatomite	50×10^6	70% SiO_2	
Dolomite	100×10^6	18% MgO	
Gypsum	40×10^6	90% $CaSO_4 \cdot 2H_2O$	
Kaolin	45×10^6	Mixed grade	
Limestone	very large	Cement and Lime grade	
Marble and building stone	$25 \times 10^6 m^3$	Mixed	
Potash	270×10^9	5% K_2O	Mainly Carnallite
Rock salt	18×10^{12}	90% NaCl	
Silica sand	10×10^6	99% SiO_2	
	100×10^6	95% SiO_2	

Source: Sampattavanija, 1984

Figure 6.2 Production of Tin-in-Concentrates and Tin Metal Prices, 1911-1955 (Before ITA)



early 1911, there were already five dredges operating offshore in Phuket. By 1941, there were altogether 39 tin dredges and 61 gravel-pump mines operating in the country. As can be observed from the illustration in Figure 6.2, the years between 1911-1941 may be considered a period of steady progress for tin as production attained a level commensurate with market demands and prices.

Encouraged by a relatively high price in earlier years, production increased substantially during the period 1929-1941, which led to an oversupply of tin in the market as other countries, especially Malaysia, also stepped up production. An international body comprising only producers was then set up to control production and exports of tin. The effectiveness of this grouping was never exactly evident and it automatically dissolved when World War II broke out. The first Tin Control Act was made in 1931, as a result of the country's participation in the organization. Because of the war, tin production was greatly curtailed, causing shortages of the material which drove prices upwards. Production recovered again after 1946, keeping up with higher demands from consumers. The early development of the industry is reviewed elsewhere (Sethaput, 1963).

Expansion Period

As briefly touched upon, minerals other than tin had already been found and exploited for some time. Prior to 1960, wolframite (tungsten ore), antimony, lead ore, iron ore and gold had been mined. Increasing economic activity in industrialized countries after the war led to increased requirements for raw materials, including minerals. Recognizing the economic importance of mineral resources, the First National Development Plan (NESDB, 1961-1966) set targets for the increased production of tin, wolfram, lead and gypsum, and for a very high

output of lignite as fuel for thermal power plants and as feed stock for a chemical fertilizer plant at Mae Moh.

It was reported towards the end of the First Plan that tin accounted for some 8 to 9 percent of the total export value and Thailand ranked third among tin producing countries in the world, having a 14 percent share of the world supply. As far as other minerals were concerned, the development of rocksalt for industrial purposes was stressed, because of Thailand's huge reserves. The First Plan also mentioned the government's intention to establish an iron smelting facility in the country.

The srecond (NESDB, 1967-1971) and Third (NESDB, 1972-1976) National Plans placed greater emphasis on more production and exports of minerals, especially tin, to earn foreign exchange. Local consumption of indigenous minerals was encouraged, with certain incentives provided. In order to help spread income distribution among the population, the private sector from either local or foreign sources would be stimulated to invest in the mining industry, while the government confined itself to a limited role in the industry through state enterprises, such as the Mines Organization (MO) and the newly-formed Offshore Mining Organization (OMO). A number of exploration and development projects were initiated in the Third Plan to complement the activities undertaken by the private sector in terms of basic information on geology of mineral deposits, and mining and processing technology. Such projects as a financial institution for the mining industry and a center for mining promotion did not receive due attention because of the financial implications, although these two projects were considered essential to future progress.

The Fourth (NESDB, 1977-1981) and Fifth (NESDB, 1982-1986) Plans stressed the new problems confronting the mining industry since implementation of the Third Plan. Of particular concern was the encroachment by villagers onto mining properties held by legitimate owners. Apart from depriving the owners of their mining rights, the minerals had been subjected to extractive processes in a wasteful way and sometimes smuggled out of the country. Although the government acted on the matter, its actions were inadequate and the problem lingered on until those deposits had been more or less exhausted. Tin, tungsten and antimony ores at certain large deposits had been the targets of such illegal activities with great losses to the country.

The competing objectives of different government agencies in terms of natural resource management (i.e., forestry, agricultural land and environment) were considered to represent an important issue affecting mineral development. Towards the close of the Fifth Plan, there has still been no indication of a consensus emerging on national guidelines.

The problems of mineral marketing and utilization were elaborated, and the conclusion was that a national marketing strategy was still needed. Local infrastructure and expertise must be further improved to reduce the cost of production and transportation. Multiple handling and inefficient transportation of bulk minerals were seen as increasingly important problems but, again, such crucial problems remained unresolved towards the end of the Fourth and Fifth Plans.

Through this entire period, the mineral industry experienced expansion and prosperity as prices soared with seemingly unrestricted demand for most minerals produced. Figure 6.3, show that the values of mineral production and exports obtained at the end of National Development Plans were steadily increasing, while the increase was fairly dramatic for the Fourth Plan. Influenced by the worldwide economic boom, the year 1980 could be regarded as the best time yet for the country's mineral industry, with tin prices attaining the highest level in history. The prices of other mineral commodities, such as tungsten at US$ 144.56 per MTU and tantalite at US$ 112 per pound Ta_2O_5 in July 1980, were also high.

Meanwhile, much related development had taken place. The country's first and largest tin smelter was set up in 1965 in Phuket, so that Thai miners could sell tin ore directly to the local smelter, instead of shipping it to smelters abroad. Notable beneficiation plants were established around 1973-1974 at several localities to upgrade fluorite ores, including a heavy mediaseparation plant in Lampoon, and one flotation plant each in Phetchaburi and Krabi. A relatively large and modern underground mine was commenced by a Thai-German joint venture in 1979, to mine and beneficiate lead ore by flotation in Kanchanaburi. The latest notable development involved the setting up in 1984 of the zinc refinery at Tak, utilizing lowgrade silicate/carbonate ores as feed material.

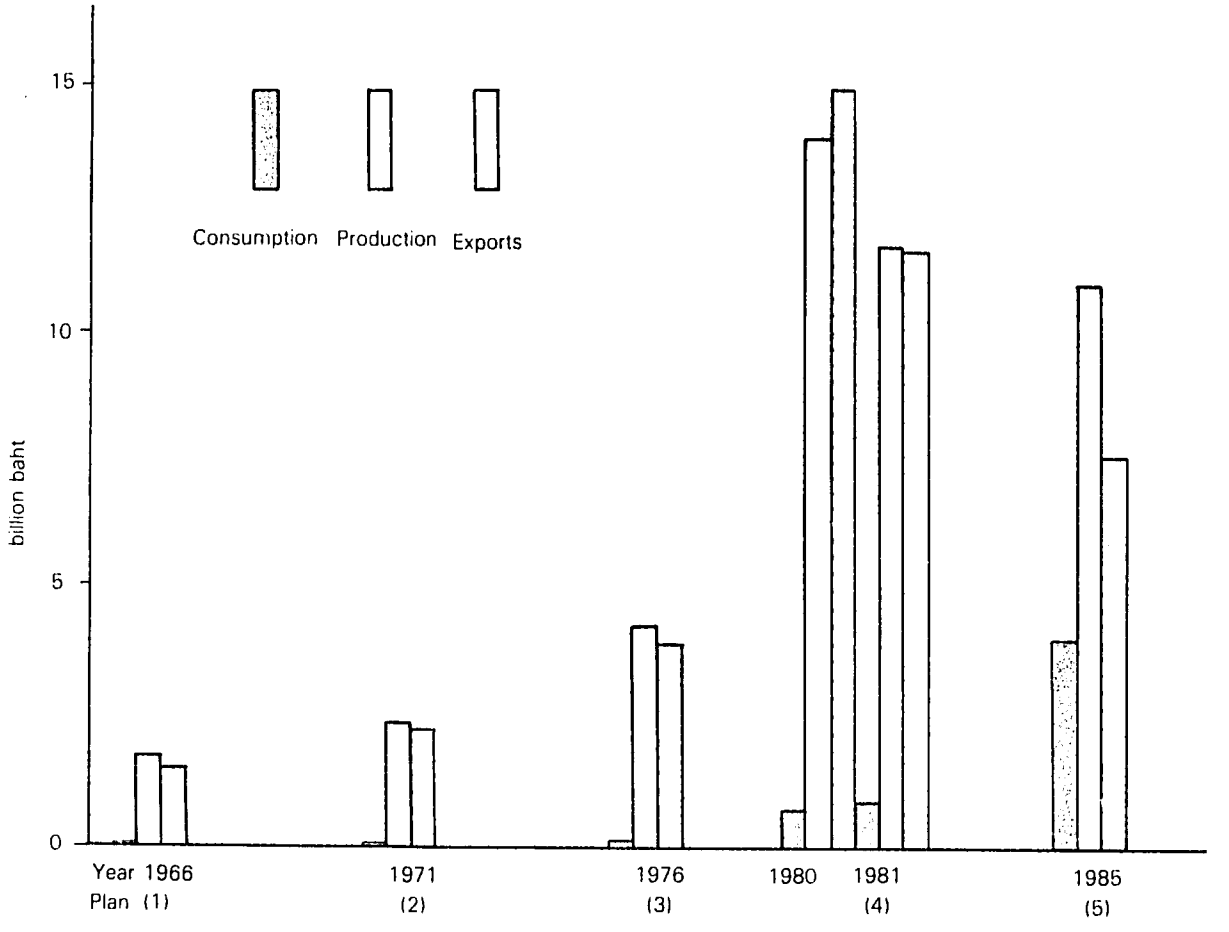
The Declining Period and the Tin Crisis

As illustrated in Figure 6.3, the Fifth Plan has not attained its projected target of 13.1 percent growth per annum. Instead of increasing, tin production has declined since early 1982. In an effort to maintain the supported price, the International Tin Council imposed export controls on its producing members in April 1982. Following this measure, Thailand was obligated to export only 19,000 tons per year (ITC, 1984), against some 41,000 tons projected, in the Fifth Plan. Like Thailand, other producing-exporting member countries had to reduce their tin exports in compliance with the ITC measures.

Tungsten ore and barite production also fell short of anticipated targets, because of world oversupply and the depressed price of tungsten (Figure 6.4) and reduced demand for barite as petroleum exploration and development activities slowed down in the face of cheaper oil prices. Tantalum prices, meanwhile, decreased substantially and demand is still weak. Reduced production of tin, in turn, resulted in reduced output of tantalum, obtained mainly from tin slags. The market share for fluorite abroad, particularly in Japan, was decreasing due to strong competition from China and Mexico. Because of continual oversupply, lead has also experienced a gradual price decline. In summary, market demand for the country's mineral exports has been unhealthy since the beginning of the Fifth Plan.

One encouraging trend, however, has been the growing domestic consumption of some minerals (shown in Table 6.8). The major proportion has consisted of nonmetallic or industrial minerals for cement, ceramic, glass, paint and rubber industries. Some 1,000 tons of tin have been used annually by the

Figure 6.3 Values of Production, Exports and Consumption obtained at the end of National Development Plans (1 to 5)



tin-plate industry. A large tonnage (over five million tons) of lignite was also produced in 1985 for local consumption, mainly in thermal power plants.

Because of its dominant role in the mineral industry (see Box 6.1), the well-being of the tin industry naturally affects the overall economic health of the country. It is therefore worth examining the background to the recent tin crisis. Tin is used in the applications shown in Table 6.10.

Aluminium, plastics and certain steels have for some time replaced tin in some of the applications indicated above, because of the comparatively high price of tin. However, no other material substitutes can take the place of tin in some areas, including solder and some alloys. It should be noted that tin consumption in 1974 reached 200,000 tons when the price was M$ 17-18 per kg, compared with the amounts used of 186,000 tons, at M$ 32 per kg, in 1979 and 161,000 tons, at M$ 30 per kg, in 1983. The decrease in consumption was believed to be caused by three main factors: substitution, optimization of tin use by consuming industries, and the worldwide recession.

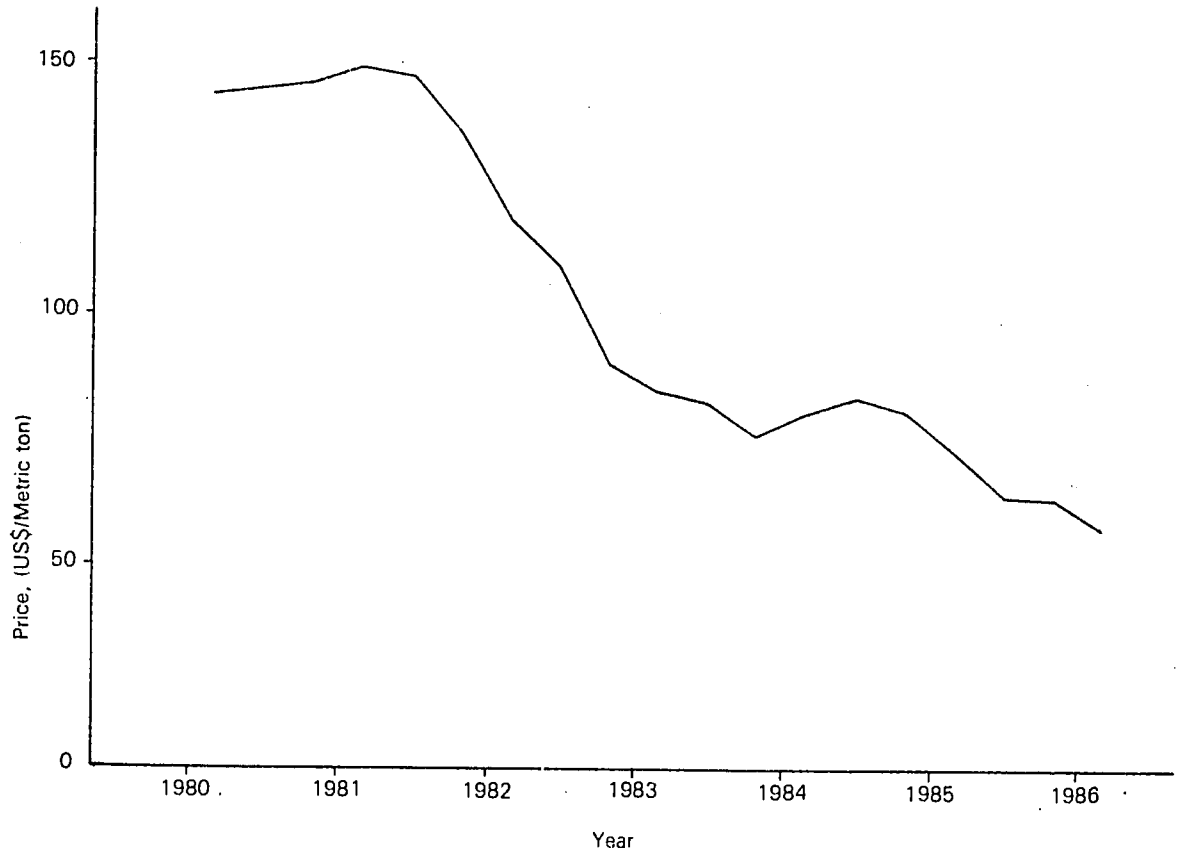
With the tin price at a relatively low level at the present time (M$ 17/kg), the general consensus has been that consumption of tin should recover appreciably in the future, the threat from substitutes is likely to weaken.

The Tin Agreement

Recognizing the economic implications of tin for both producers and consumers, the two sides agreed to set up the International Tin Agreement (ITA), under the auspices of the United Nations. Each ITA lasts five years, with provision for extension by no more than two years. The first ITA was implemented on 1 July 1956 and the latest ITA took effect, provisionally, on 1 July 1982 after a one-year extension of the fifth ITA. Briefly, the ITA aims to stabilize the tin market through providing sufficient supply to consumers at fair prices which are also remunerative to producers.

In order to maintain market stabilization of tin, several economic provisions (measures) are incorporated in the ITA, including the creation of buffer stock and poweres to impose export controls.

Figure 6.4 London Tungsten Prices (65% WO_3), 1980-1986



A fundamental ITA provision requires participating producing and consuming members of the ITA to contribute in cash or in kind towards the buffer stock, so that the manager of the buffer stock can use cash or tin to buy or sell tin where necessary to support the tin price. Under the provisions of the sixth ITA, the total buffer stock size was equivalent to 50,000 tons of tin metal, of which 30,000 tons of normal stock would come from contributions from member countries and the remaining 20,000 tons would be obtained through borrowings. In actual fact, the amount of 30,000 tons expected from normal contributions was not attained, because certain significant consumers did not join the sixth ITA, making the entry into force of the agreement provisional, instead of definitive. For Thailand, contributions towards the buffer stock had always been paid in cash and after liquidation of the stocks of each ITA, substantial profits were obtained until the fourth ITA.

Export controls are another complimentary measure backing up the buffer stock operation. In the later phase of the fifth ITA, it became apparent that the buffer stock operation alone could not stop the oversupply of tin in the market, which caused a steady price decline. As a result, export restrictions were imposed on producing members. The export controls were in effect for most of the sixth, or last, ITA — until early 1986.

In retrospect, it can be said that, through various measures including economic ones, the ITAs had succeeded in safe-guarding the interests of all parties involved. As Figure 6.5 shows, one can observe a generally steady and healthy progress of tin prices since the inception of the first ITA right up to the time of the sixth ITA in late 1985. The tin industry had gained ample economic benefits by having and joining the ITAs. On the other hand, the consuming members also obtained their due and fair share, in the form of a long-term guarantee of adequate supply and projected prices of tin. The artificial price of tin was still acceptable to tin-plate producers, since the cost of the tin typically used accounts for only 13-15 percent of the total cost of tin-plate production.

In spite of the unremitting effort expended by the International Tin Council (ITC) to cope with these problems, the result had been disappointing and the tin situation continued to deteriorate. Because the supply and demand situation had been upset and the surplus tin kept growing, the market was

Box 6.1 The Tin Economy

Although a total of around 90 minerals are known to occur in various parts of Thailand, with perhaps 40 currently in commercial production, tin has long dominated the country's mineral industry. Chinese traders are thought to have been the first to exploit this metal in Thailand, but it also soon attracted European interest, with the first trade agreement in 1685 giving the French a tin trading monopoly. More recently, Thailand briefly became the second largest free-world producer of tin, after Malaysia in 1980.

Tin mining technology has evolved steadily, with a major breakthrough coming in 1906, with the introduction of tin dredging to the Phuket area, permitting offshore tin resources to be exploited at an increasingly large scale. Thailand's first - and largest - tin smelter was established in 1965. Inevitably, the scale of tin-related development has led to concern about the environmental implications. Around Phuket, for example, there have been allegations that local beaches and coral reefs were being damaged. Elsewhere, there has been growing interest in the need to rehabilitate exhausted tin mines.

But the industry has faced a much more serious threat to its viability in recent years — the lack of stability in the international tin market. Although the amount of tin consumed by Thai industry is growing, the metal is predominantly exported, and earns Thailand considerable foreign exchange. It also contributes to the government's revenues through royalty payments and business taxes. These contributions have been heavily undermined in recent years, however.

The worldwide recession has cut demand for tin and, despite the best efforts of the International Tin Council to ensure that supply was kept in line with demand, the instabilities were such that the London Tin Market collapsed late in 1985 and the tin price was cut in half (see Box Figure 6.1A). There were many reasons for this: the high price of tin had encouraged some consumers to use the metal more efficiently, or to look for substitutes, but the main causes related to tin supply itself. Tin smuggling from International Tin Council (ITC) member countries and exports from non-member countries resulted in an international surplus of around 26,000 tons by the end of 1985.

The impact of the collapse on the Thai economy has been substantial. Foreign exchange earnings from mineral exports, with tin accounting for the overwhelming share, were cut in half between 1980 and 1985; the tin royalties collectable by the government were cut by two-thirds; and the number of workers directly employed in the industry was also cut by more than half.

It is estimated that it will take well over 2 years to clear the accumulated international stocks of tin, but the Association of Tin Producing Countries has forecasted that shrinking tin production will lead to higher prices, possibly as early as 1987, and certainly by 1988. Much will depend, however, on the health of the international economy over the next few years.

Tin is a non-renewable resource, which is one reason why the government charges a significant royalty on its production. But even if tin demand grows substantially, Thailand still has considerable reserves of the metal, which should support production into the foreseeable future. As the grade of ore falls, however, the volume of spoil and effluent likely to be produced in metal mining and processing must inevitably rise. As a result, there is concern that the industry should be managed in such a way that it does not unnecessarily degrade Thailand's renewable natural resources. Tin miners now have to submit environmental impact assessments to the National Environment Board before commencing new operations, which is a welcome step forward. But if rapid economic growth were to resume, the industry's environmental performance would need careful monitoring.

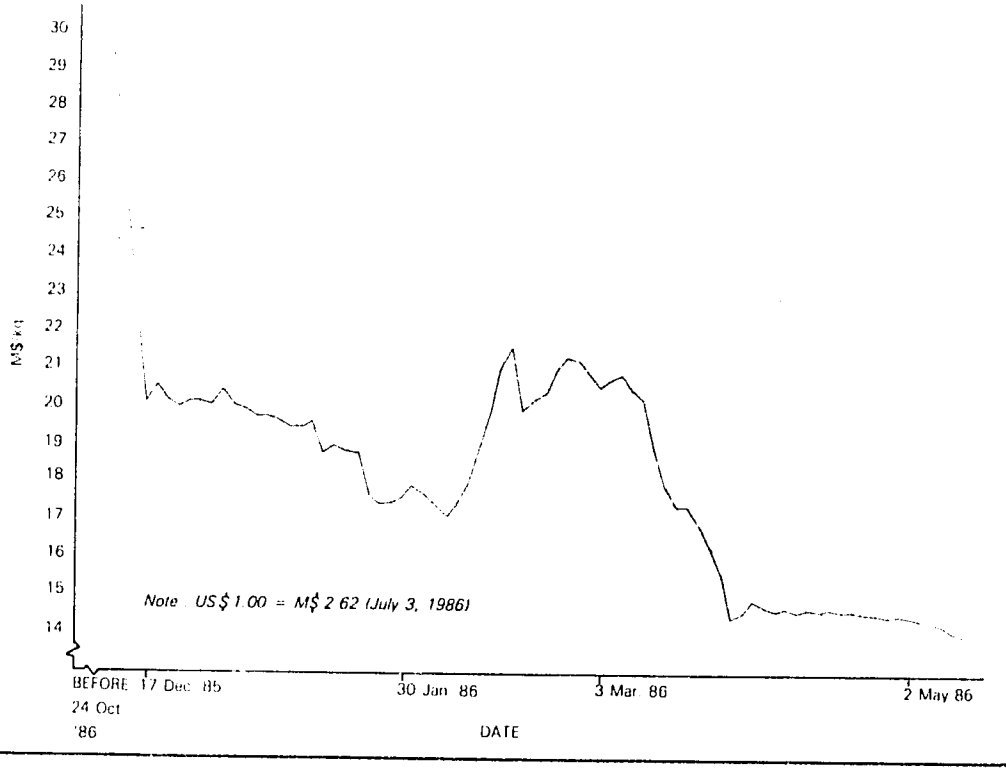
progressively destabilized, making it difficult for the buffer stock manager to support the price. As a result of buying at a higher price and selling at a lower level, more and more money was lost along the way. Other adverse effects stemmed from the weakening of the value of sterling against the US dollar and Malaysian ringgit (M$). During the difficult period from 1983 to 1985, because of sterling's lower value, more pounds were required for market intervention, thus helping deplete the buffer stock fund more quickly.

Unable to resolve the above-mentioned problems, and having run out of money to support the tin price, the ITC had to withdraw from the market. Immediately, the longstanding London Metal Exchange (LME) collapsed, on 24 October 1986, signalling the beginning of the end for the ITC under its present form and also of the tin trade on the LME.

The conclusions that may be drawn from the tin failure can be summarized as follows. (1) The absence of major producers (Brazil, Bolivia) and consumers (USA, USSR) from the ITC makes the operation of the ITA difficult, as tin from nonmember sources eventually upset the supply-demand balance actuated by the ITC, with nonmember consumers free to take up the tin. (2) The artificially high tin price has encouraged substitution by other cheaper materials and optimized tin use in consuming industries, with the result that the overall consumption has been declining. (3) Because of the unusually high price, smuggling of substantial amounts

Box 6.1 (contd.)

Box figure 6.1a Thailand and Kuala Lumpur Tin Prices after Collapse of Market on October 1985



of tin was also encouraged, rendering the effective control of tin supply ineffectual. And (4) with regard to the performance of the ITC, political will appeared to be lacking among members and countries concerned, a factor crucial to the success of the ITA operation.

In general, the well-being of the global economy will have a direct bearing on the well-being of the mineral industry. When world economic conditions improve again, more raw and/or semifinished materials will be required and prices should rise. The lessons and experience gained in the past should be utilized to maximize benefits in the future.

Energy Resources

Lignite

Fuel minerals were discovered and produced a long time ago. The first lignite deposit was investigated in 1898 and mined two years later for five years. In 1917, the Royal State Railways conducted an exploration for alternative fuels for firewood, finding sufficient amounts of lignite at Mae Moh in Lampang and Ban Pu Dam in Krabi. However, no further development of these deposits was conducted due to financial and technical constraints. Another significant coal deposit was found and then developed at Kiansa in 1921, in Surat Thani in the south. After seven years, mining operation ceased in 1928, on grounds of technical difficulties.

In 1950, the government, through the (then) Department of Mines in cooperation with United States Operation Mission (USOM) conducted a more detailed exploration for lignite in the Mae Moh basin. At about the same time, a similar campaign was launched to assess the lignite reserves at Krabi. As a result of these two efforts, it was established that the proven reserves of lignite in these two areas were sufficient to support large-capacity thermal power plants, especially at Mae Moh. Up to 1984, a total of 58 lignite deposits had been located, with the majority (42 deposits) found in the north.

Table 6.10 Industrial Applications of Tin, 1979-1983

	1979	1983
1. Tin-plate industry, %	38	34
2. Solder material, %	29	31
3. Chemical industry, %	9	14
4. Other alloy industry, %	24	21
Total, %	**100**	**100**
Total metal, (tons)	**186,000**	**161,000**

Detailed exploration and development were carried out on several promising fields, with estimates of combined possible reserves of 2 billion tons, including proven reserves of 670 millions tons. Table 6.11 shows the location of active mines and the quality of lignite in the country, including the reserves at various localities. It can be observed that the lignites with a heating value lower than 4,200 calories per gram (cal/g) amount to 1,400 million tons and those having a heat value higher than 4,200 cal/g total at 500 million tons.

Most of the lignite mined has been used by the Electricity Generating Authority of Thailand (EGAT) at the Mae Moh and Krabi deposits. In 1985, the Mae Moh thermal power plants consumed 91.4 percent of EGAT's total production of 4,612,337 tons, while the power plant at Krabi consumed some 395,000 tons or 8.6 percent. The lignites used at these power facilities have heating values between 2,500-3,000 cal/g and high ash contents (10-30 percent).

The lignite mined at other deposits has been extracted by private concerns and the National Energy Administration (NEA). All the northern production of lignite was supplied for use in tobacco-curing and cement plants. The heating values of the lignite for the above purposes are higher (between 4,200-6,000 cal/g). The use of lignite has steadily gained acceptance, because of its attractive price (Table 6.12).

Figure 6.6 shows the consumption of lignite by different uses, with a considerable increase between 1981 and 1985.

Petroleum resources

Petroleum has a long history of development, similar to that of lignite. Because of an indication of asphalt in the Fang basin, north of Chiang Mai, the Railways Department decided in 1923 to drill a well some 216 metres deep to investigate the possibility of oil in the area. The Fang oil deposit was later investigated by several government organizations with a view to develop the field commercially. The Department of Mineral Resources (then the Department of Mines) conducted a detailed study and drilled production wells to obtain crude oil at 1,500 liters per day. The Fang oil facility was then turned over to the Defense Energy Department in 1956. The total oil reserves were later estimated at 21.2 million barrels (Changkasiri, 1986 and Suvarnapradip, 1983).

With continued interest, the Department of Mineral Resources launched a petroleum exploration campaign in 1954 in the Chao Phraya Basin. The results were disappointing, with no oil discovered.

In 1961, the government announced a policy to invite both Thai nationals and foreigners to undertake exploration for and development of indigenous petroleum resources. Subsequently, in 1962, Union Oil of California submitted an application for a license to explore for petroleum in a northeastern area of Kalasin province. In order to facilitate the work of the private sector, manuals or guidelines for license applications were drawn up in 1965. In 1971, the Petroleum Act and the Petroleum Revenue Act finally came into force, serving as the

Table 6.11 Active Lignite Mines and Quality in Thailand

Locality	Operator	Reserves (million tons)		Quality (Proximate analysis, % by wt.)				
		Proven	Possible	Moisture	Ash	Fixed carbon	Sulphur	Heat value (cal/g)
Lampang								
- Mae Moh	EGAT	650	1,134	30-35	10-20	13-26	0.8-1.5	2,500-3,000
Krabi								
- Ban Pu Dam	EGAT	7.40	20.0	30	21	-	1.5-2.4	2,850-3,000
Lamphun, Li								
- Pa Kha	NEA	7.0	11.0	4.32	23.03	50.46	1.32	5,700
- Ban Pu	World Fuel Co., Ltd.	2.2	5.5	26.10	7.47	31.71	1.55	4,270
Tak, Mae Ramat	Thai Lignite Co., Ltd.	1.23	-	19.10	6.2	40.50	0.71	5,000-8,200
Phetchaburi, Non Ya Plong	Asia Lignite	1.38	-	9.1	12.6	46.3	0.5	6,000

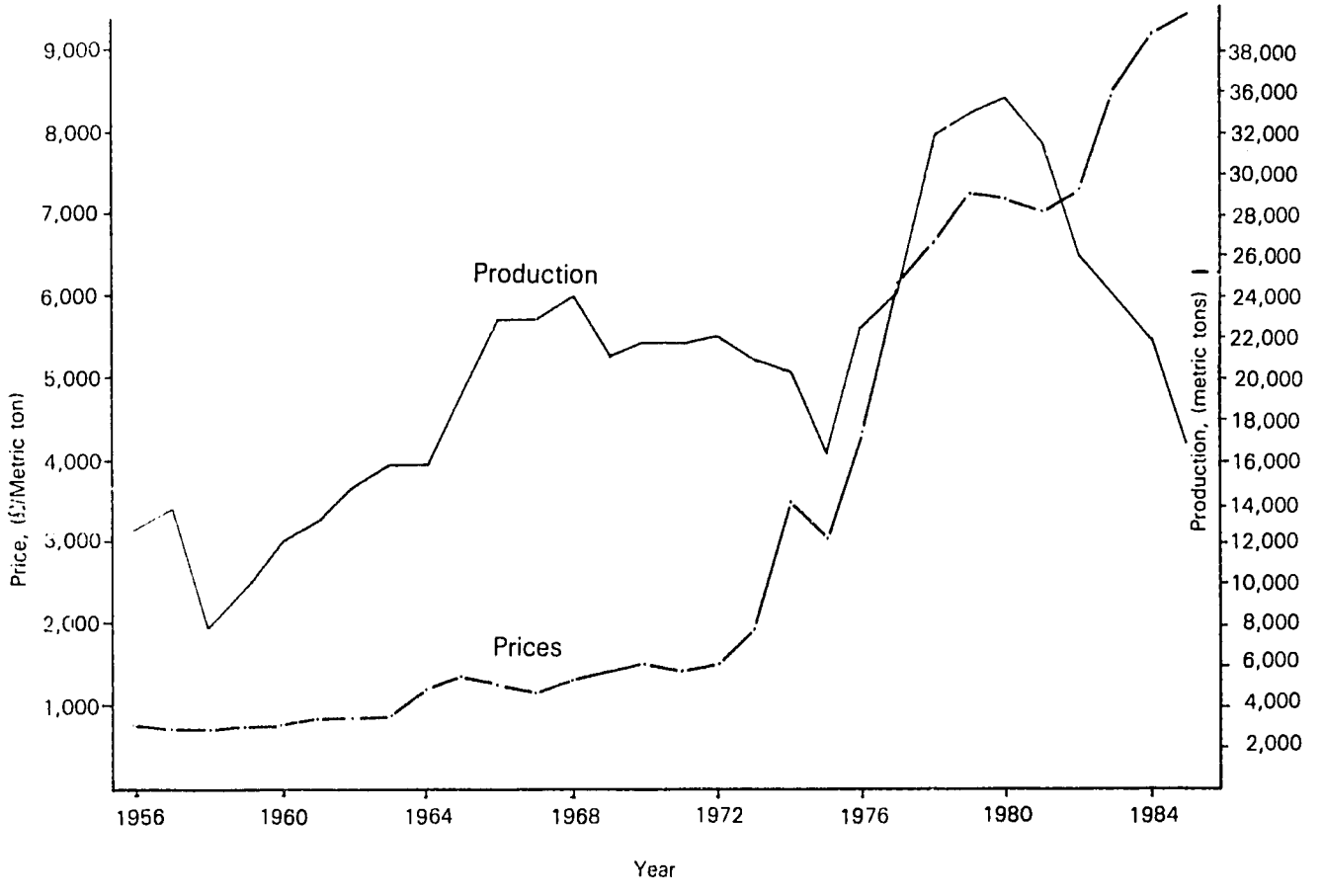
Sources: Department of Mineral Resources, EGAT, and NEA

Table 6.12 Heat Values and Costs of Different Fuels

	Heat Value	Price[a]	Cost (baht/10^6 Kcal)
Lignite	2,500 Kcal/kg	500 baht per ton	200.0
Natural gas	275.71 Kcal per 1000 Cu.ft.	83 baht per 1000 Cu.ft.	301.0
Bunker oil	9,800 Kcal/litre	2.80 baht per litre	285.7

Note: a Official price quoted as of July 1986, (US$ 1.00 = 27.00 baht)

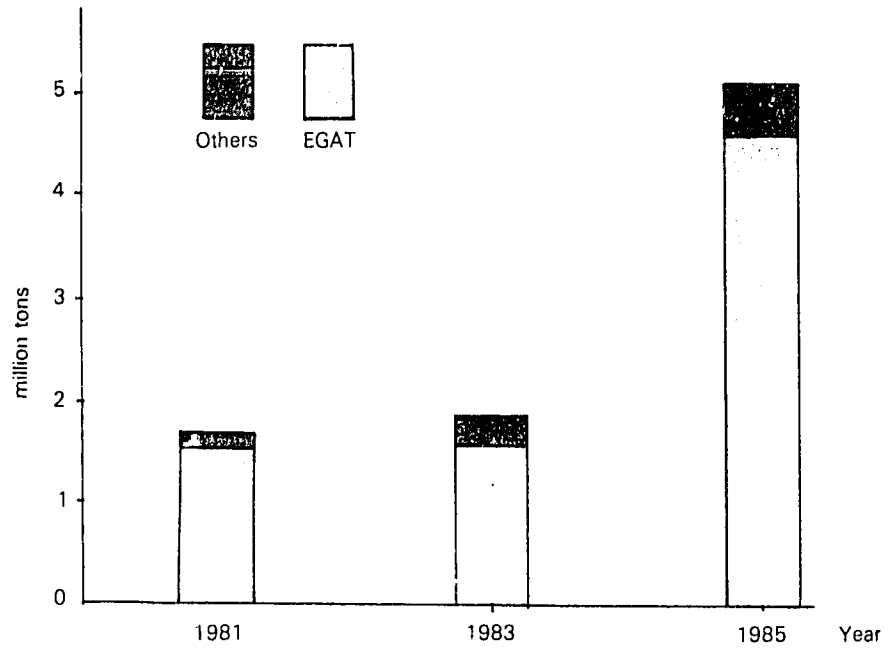
Figure 6.5 Production of Tin-in-concentrates and Tin Metal Prices 1956-1958 (During ITA)



basis of subsequent petroleum industry development in Thailand.

Between 1968 and 1972, a number of companies were awarded concessions in the Gulf of Thailand (Figure 6.7). The results of their exploration can be summarized as follows : (1) Union Oil Company of Thailand was awarded exploration rights in five areas of 10,966 square kilometers. Natural gas, natural gas mixed with condensate, and crude oil were found in commercial quantities. (2) Texas Pacific Thailand, Inc., was awarded four areas and commercial quantities of natural gas combined with condensate and crude oil were established. (3) Triton Oil of Thailand was awarded two areas of 2,819 square kilometers. No petroleum was found. (4) Amoco Thailand was awarded two areas of 10,155 square kilometers. Crude oil was found, but not in commercial quantities. (5) Thailand Sun Oil Co., was awarded three areas of 10,420 square kilometers. No petroleum was found. And (6) Pecten

Figure 6.6 Consumption of Lignite by Different Uses



Thailand Co. was awarded three areas of 26,700 square kilometers. No petroleum was found.

Onshore exploration activities have been conducted by, among others, the following companies: (1) Esso Exploration and Production Khorat, Inc., was awarded five areas of 50,000 square kilometers in the northeast. Natural gas was found at Nampong, Khon Kaen. (2) Esso Udon, Inc., was awarded two areas of 20,000 square kilometers, also in the northeast. No result has been reported. (3) Thai Shell Exploration and Production Co., Ltd., was awarded one area of 10,000 square kilometers in the northcentral region. Crude oil with natural gas of commercial value was found. (4) BP Petroleum Development Co. Ltd. was awarded 10,000 km² in the Central region. Crude oil was struck in June 1986 in Suphanburi. (5) Phillips Petroleum International, Corp. and Terramarine International, Inc., were awarded three and one areas respectively in the northeast. No results of exploration have been reported by either company.

Given the favorable nature of Thailand's geology, more oil and gas could be found in the country which would, in turn, increase the share of domestic oil in total daily consumption. Already, the country's dependence on imported petroleum has been reduced substantially. Since October 1984, Thailand produced between 36.33 and 40.0 percent of its total petroleum needs.

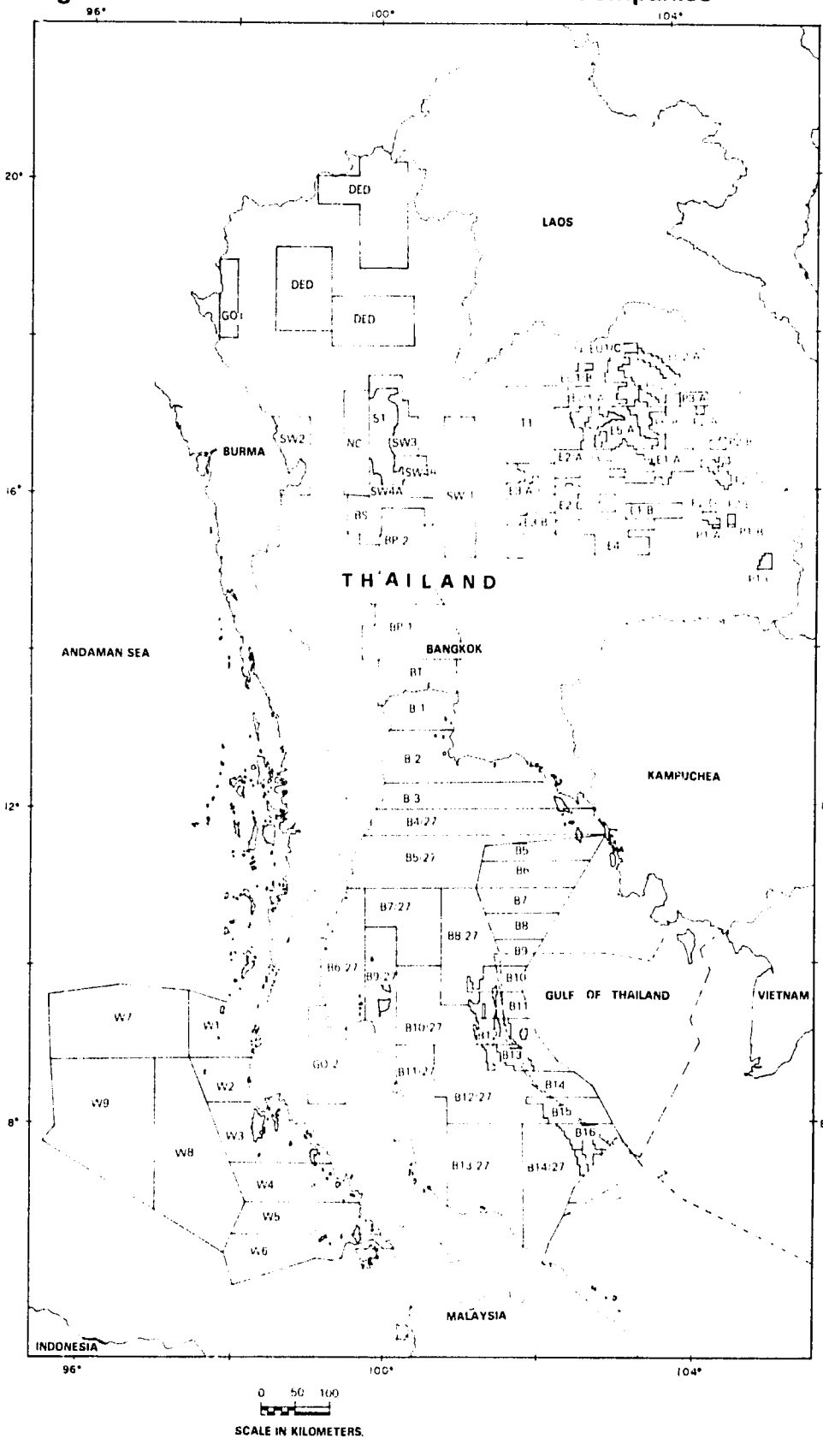
Oil shale

Several oil shale prospects have been located and evaluated since 1973. The Mae Sot basin has been found to contain substantial reserves. An extensive exploration program had been conducted from 1974 to 1979 in two sub-basins covering some 53 square kilometers which indicated probable reserves of 18 billion tons of oil shale. At an average oil yield of 5 percent (by weight), about 6 billion barrels of shale oil could be obtained from the oil shale under investigation (Suvarnapradip, 1983). As a potential source of energy, several utilization approaches have been suggested and given preliminary study in 1982 by the Industry Ministry. It was then found that the cost-benefit analysis did not warrant commercial exploitation of oil shale under the prevailing economic conditions in relation to oil prices. However, this fuel resource was regarded as a significant future source of energy for the country.

Geothermal resources

Geothermal resources were discovered a long time ago in Thailand. More than 90 hot springs have been located around the country. Since 1977, an accelerated exploration program has been under way (Thienprasert, 1986), undertaken by the Department of Mineral Resources (DMR) with the cooperation of EGAT and Chiang Mai University. Foreign assistance was received from Japan, UNDP and France. Up to 50 geothermal areas in the north have been evaluated for further utilization with particular attention to the areas in San Kamphaeng and Fang of Chiang Mai. It was established that San Kamphaeng's geothermal potential, with temperatures over 180 degrees Celsius, could yield around five MW of electricity, whilst the Fang source may generate up to 200 kilowatts through application of a binary system, because of the lower water temperature ($<120°C$). A separate development pro-

Figure 6.7 Concession Areas of Various Companies



Oil and Gas Concessionaires in Thailand

ESSO EXPLORATION AND PRODUCTION KHORAT INC.
Block: E1, E2, E3, E4, E5

ESSO SAKON, S.A.
Block: EU1, EU2

TERRA MARINE INTERNATIONAL INC.
Block: 11

THAI SHELL EXPLORATION AND PRODUCTION CO., LTD.
Block: S1, B6/27

NORTH CENTRAL INTERNATIONAL INC.
Block: NCII

PROMET BERHAD
Block: SW1, SW2

BP PETROLEUM DEVELOPMENT LTD.
Block: BP

BRITOIL PLC.
Block: B12/27

BRITOIL PUBLIC CO., LTD
Block: BT

AMOCO THAILAND PETROLEUM CO.
Block: B5, B6

THAILAND SUN OIL CO.
Block: B7, B8, B9

UNOCAL Thailand INC.
Block: B10, B11, B12, B13

TEXAS PACIFIC THAILAND INC.
Block: B14, B15, B16, B17

TRITON OIL COMPANY OF THAILAND
Block: B18

PLACID OIL COMPANY
Block: W8

PREMIER CONSOLIDATED OILFIELDS PLC.
Block: B11/27

GOPHER OIL LIMITED.
Block: GO1, GO2

BASS STRAIT OIL AND GAS (HOLDINGS) N.L.
Block: B5/27

Others are:
GOVERNMENT RESERVED AREAS

Box 6.2 The High Technology Metals

Tin may dominate the Thai minerals industry, but a number of other metals are also produced and exported, including antimony, lead, tantalum, tungsten and zinc. The uses for some of these metals, including lead and zinc, are well-established, while others like tantalum and tungsten, belong rather to the high technology sector, and their longer-term prospects, particularly in the case of tantalum, are consequently brighter.

Lead has suffered a slow price slide since reaching its peak in 1979. The metal is predominantly (60 percent) used in lead acid batteries, a market which is considered fairly strong, but the outlook for higher lead prices is considered bleak. Thailand only accounts for 0.26 percent of the world's lead production, Turning to zinc. The country's refining capacity is 60,000 tons. About half of the zinc produced is used in automobile coatings and in the construction industry, and the indications are that the metal's price could continue to strengthen.

Despite the fact that world consumption of tungsten has exceeded world production since 1983, the metal's price has been on a downward trend since early 1982. One reason for this paradox is that the non-mine supply of tungsten has been strong, in the form of recycled metal and the release of strategic stock piles. China's policy of allowing her provinces to export tungsten freely has also helped depress the market. But at the same time, there are other economic and technological factors at work. In particular, technical advances and substitution have eaten into tungsten's market share, while the slowing pace of petroleum exploration has badly hit demand for tungsten carbide, used in drilling equipment.

The brightest prospect is probably for tantalum, a metal which is used in the manufacture of super-hard tools, electrolytic rectifiers and microelectronic equipment. Thailand is thought to have around 30 percent of world tantalum reserves (Rossi, 1986), and accounted for nearly half (46 percent) of world production in 1983. Malaysia was the next largest producer, at 13 percent. Around 60 percent of worldwide tantalum consumption is accounted for by the electronics industry, with a further 20 percent being used in metalworking machinery, and 10 percent each in the manufacture of chemical processing equipment and superalloys.

World consumption of tantalum fell from 1,500 tons in 1980 (when a record price of US$100.3 per pound of Ta_2O_5 was reached) to 560 tons in 1984, although rapid growth is predicted for the microelectronic industry in Japan, the United States and Europe. Japan's tantalum requirements alone are forecasted to grow by 50 percent a year.

gram for electricity generation for each of these two energy sources has been initiated by EGAT, with some technical and financial assistance from Japan and France.

Apart from its usefulness for electricity generation, the geothermal energy can be utilized in a variety of industrial and household applications because of its potent heat potential.

Future Trends

The future development of Thailand's mineral industries will be profoundly influenced by the future state of the world economy. Substitution may cut into the markets for some of these materials but, at the same time, Thailand's own industries are beginning to consume increased volumes of raw material, whether they are producing for domestic consumption or for export. The value of domestic consumption of minerals grew by 12 percent between 1983 and 1984, and by an astonishing 104 percent between 1984 and 1985. Most of these materials were used in the ceramic, glass, rubber, paint and paper product industries.

The prospects for tin have been well covered, but it is worth explering the future potential of a number of other minerals. Tungsten, for example, may well be threatened in the long term from substitution by new ceramic materials (PTA, 1984). Tantalum, by contrast, should benefit from the growth of the high technology sector in countries such as Japan, the United States, West Germany and the United Kingdom. The metal is used by the microelectronic industry in capacitors, and rapid growth in demand seems likely.

Reduced demand for lead resulted in growing stocks and falling prices. At least one major Thai lead producer has been forced to cut production by a quarter, from 40,000 tons possibly to 30,000 tons, and to dismiss several hundred workers. Uncertainties about likely demand in acid battery manufacture and in the petrol additives sector inevitably raise a question mark over future demand for lead. Zinc, by contrast, is in steadier demand, both in export markets and, increasingly, in Thailand.

As far as fluorite is concerned, the overwhelming bulk of Thailand's production is exported, mainly to Japan, the Soviet Union, South Korea, Taiwan, India and Australia. Total exports of fluorite from Thailand slipped from 214,256 tons in 1980 to 204,210 tons in 1984, and the prospects for boosting exports in 1986 have not been all that encouraging, with increased exports from China, South Africa and Mexico, and potentially from Kenya, having a significant impact on the international market. Demand for fluorite is likely to be limited by consumption rates in the aluminum and steel industries,

which are unlikely to consume as much per unit of production in the future, due to improved smelting practices and to the recycling of fluorine for environmental reasons. The most likely area for growth is in the chemicals industry, with one particular area of note being the 10 percent annual growth expected in the construction industry's use of fluoropolymers.

Two other significant exports from Thailand are barite and gypsum. Some 85-90 percent of the total output of barite is used as a ballast material in drilling fluids by the petroleum exploration industry. In spite of the downturn in drilling activity, world barite production rose from 5.86 million tons in 1984 to 6.0 million tons in 1985—although this output was still far short of the 8.31 figure achieved in 1981. There seems likely to be significant pressure on barite prices for some time.

The gypsum situation is marginally healthier. Of the total Thai output of nearly 1.3 million tons in 1985, some 68 percent was exported, representing an 18 percent increase in shipments from 1984. But here, too, the price has been falling, from 387.5 baht per ton in 1983 to 266 baht in early 1986. There must come a point where, as competing producers try to maintain market share, it is no longer a viable proposition for the weaker producers to stay in the game. Ultimately, the prospects for gypsum will depend on the health of the construction sector, which is the dominant user.

On the energy front, lignite is likely to be the main growth point, with two more 300MW thermal power plants due on stream in 1987. Other applications of lignite are not expected to change very much. The petroleum prospect is less attractive, with the low price of oil a considerable disincentive for drilling activity and, indeed, for some production activity. But when the energy market recovers, Thailand will be fairly well placed with its reserves of lignite, petroleum, oil shale and geothermal power.

6.3 LEGAL AND INSTITUTIONAL FRAMEWORK

Mining Legislation

The main concept behind mining legislation of Thailand is that minerals are deemed to belong to the State and that no one can explore for minerals or undertake mining, unless a prospecting license or mining lease is first obtained. Since minerals are nonrenewable natural resources, the country as a whole should benefit fully from their exploitation. The government is committed to the development of the mineral industry through the private sector. Accordingly, the management of the mineral industry is placed under the responsibility of the Department of Mineral Resources (DMR), which is part of the Ministry of Industry. The DMR administers and enforces mining laws and regulations relating to exploration for and exploitation of both mineral and fuel resources.

The present mining legislation consists of three Acts, as follows:

The Minerals Act, 1967, as amended by the Minerals Acts, 1973 and 1979, is the main legal instrument affecting all mining and mineral operations. It governs onshore and offshore mineral activities. Under the terms of the Act, the government claims exclusive ownership of all minerals upon, in, or under the surface of public and private land, but may grant licenses to private individuals or entities for prospecting and mining purposes. In essence, the provisions of this Act encompass all activities concerning prospecting, mining, mineral dressing, metallurgical processing, transportation, and the sale and storage of minerals, including the penalties to be imposed upon those found violating the relevant provisions.

The Exclusive Prospecting License (EPL) is granted by the Minister of Industry and is valid for one year (onshore), or up to two years (offshore). An EPL covers a maximum area of 2,500 rai (about 1,000 acres) for onshore and a total area of 500,000 rai (about 200,000 acres) for offshore prospecting. A person or entity may apply for more than two EPLs onshore, provided that the person or entity furnishes, along with the application, detailed information on the project's workplan, capital requirements and staffing. Under this arrangement, only the license holder is entitled to the right to apply for a mining lease, or concession, within the EPL once the mineral has been found in workable quantities.

According to the Ministerial Announcement issued by the Minister of Industry on 10 April 1981, the Minister shall grant each applicant (individual or entity) a total area of not more than 20,000 rai. An applicant who wishes to be granted more than 20,000 rai must submit an application for a Special Prospecting License.

The Special Prospecting License (SPL) may be granted when the proposed project requires large investment and special technical skills. An SPL has a maximum area of 10,000 rai (4,000 acres) and an applicant may apply for several SPLs. Each SPL is valid for three years from the date of issue. The applicant must specify his prospecting obligations by stating the amount of money to be expended each year in prospecting throughout the life of the SPL, and may offer special benefits to the government if a SPL is granted. The SPL is granted by the Minister of Industry, with approval from the Council of Ministers.

The Mining Lease (or Concession) is the last stage in the process. Under the amended Minerals Act, no one shall undertake mining in any place, regardless of any rights over the area, until he has received a mining lease or temporary mining lease. The Minister of Industry has the power to grant both a mining lease or a temporary mining lease. The maximum area for an onshore mining lease is 300 rai (120 acres). For offshore mining, the Minister of Industry is empowered to grant a mining area of up to 50,000 rai (20,000 acres) for each applicant. With the approval of the Council of Ministers, an offshore area of more than 50,000 rai may be granted to an applicant. A mining lease is valid for not more than 25 years. The Act contains provisions covering, among other

aspects, safety and environmental considerations to be taken into account in mining or mineral dressing operations.

The Mineral Royalty Rates Act 1966, as amended in 1977 and 1979, specifies the manner in which mineral royalty rates should be determined.

a) The tin royalty is levied on a sliding, or progressive, scale, but not exceeding 30 percent of the DMR posted price. The present royalty rates are given in Table 6.13.

b) The tungsten ore royalty was revised from the fixed rate of 20 percent of the posted price to the progressive rate in July 1986, in consideration of the financial burdens brought by low ore prices. The present royalty rates for tungsten ore are given in Table 6.14.

Table 6.13 Tin Royalty Rates

Tin Metal Price (baht)	Royalty Rate (%)
0 – 3,000	0
3,001 – 7,000	0.1
7,001 – 9,000	5
9,001 – 11,000	15
11,001 – 14,000	30
14,001 – 17,000	40
17,001 – 20,000	50
20,001 up	60

Table 6.14 Tungsten Ore Royalty Rates

Tungsten Ore Price (baht)	Royalty Rate (%)
0 – 3,000	0.1
3,001 – 4,000	5.0
4,001 – 5,000	10.0
5,001 – 6,000	15.0
6,001 up	20.0

c) The collection of royalties on other minerals is based on the type, nature and content of metal or compound contained in the mineral, at the rate prescribed in the Ministerial Regulations, which shall not exceed 20 percent of the market price. The rates shown in Table 6.15 are a few examples of royalties on minerals produced in Thailand.

The Tin Control Act of 1971, is designed to give the government sufficient legal powers to cooperate fully with the work of the International Tin Council (ITC), under the context of the Tin Agreement. Under the provisions of this Act, the government is empowered to take appropriate actions in compliance with the ITC resolution. The Act covers such activities as the imposition of controls on tin exports and the making of contributions, in cash or metal, to the ITC buffer stocks.

Table 6.15 Some Other Royalty Rates

Antimony	
- ore	10%
- crudum	10%
Barite	
- lump	7%
- ground	2%
Fluorite	
- metallurgical grade	7%
- acid grade	4%
Gypsum	4%
Lead	
- metal	2.5%
- ore	10%
Zinc	
- metal	2.5%
- ore	10%

In addition to the DMR requirements, approval must also be sought from the Ministry of Agriculture and Co-operatives for the right to explore for and mining of minerals in the forest are, under the **National Reserved Forest Act of 1964.** Under a set of conditions and for certain fees, the Ministry of Agriculture and Co-operatives, and the Royal Forest Department, will consider granting the right to individuals or entities to conduct exploration and/or mining operations in the reserved forest areas.

There are some categories of reserved areas which have been declared closed to exploration/mining activities, by the resolution of the Council of Ministers. These include : (1) wildlife reserve areas; (2) National Park areas; (3) first class forest areas of the northern region; and (4) areas reserved for security purposes. The first three categories are administered by the Forest Department, while the fourth comes under the control of the Ministry of Defense.

The Improvement and Conservation of National Environmental Quality Act of 1975, including the amendments of 1978, is administered by the National Environment Board (NEB). Under the provisions of this Act, mining operations of any type and size require prior approval by the NEB, based on the submission of an environmental impact assessment. The report of the assessment study must be prepared by an authorized entity approved by the NEB office.

For offshore mining at certain sites in Phuket, apart from the submission of environmental impact assessment reports, sea-water standards have been set, covering turbidity, suspended solids, temperature dissolved oxygen, and so on, for swimming and coral preservation purposes.

The Petroleum Act, 1971, as amended in 1973 and 1979, contains provisions dealing with the granting of concessions for the purpose of exploration, production, sale and disposal of petroleum (oil and/or gas). The rights and duties of the concessionaire, including royalty payment on petroleum produced, are clearly spelled out by the pertinent provisions of the Act. The Petroleum Act is administered by the Ministry of Industry, through the DMR.

Other Institutions and Organizations

One of the public institutions concerned with mineral development is the Mining Industry Council (MIC), established by law in 1983. All mineral operators, including mineral dealers, are required by law to be members of the Council. The MIC's main duty is to perform functions for the benefit of members and the mining industry in general. It is instrumental in resolving issues and problems impeding the industry's development with government agencies on behalf of the operators. It also serves as a minerals advisor to the government.

The Offshore Mining Organization (OMO) was established in July 1975, to take over the ownership of the offshore concessions held by the former TEMCO company in the areas off Phuket and Phangnga provinces. Presently, OMO operates its own tin dredge, and, at the same time, hires private contractors to mine tin ore on its behalf.

The Electricity Generating Authority of Thailand (EGAT) conducts mining operations for lignite at its deposits at Mae Moh and Krabi. Because large quantities of lignite are required for fuel, especially at Mae Moh, EGAT employs modern equipment. The mine is regarded as one of the largest and most advanced open-cast operations in Asia.

The Phangnga Provincial Organization has played an important role since 1975, upon revocation of the TEMCO offshore tin concessions by the government. It has the authority to take tin ore from suction boats from certain designated areas within Phangnga. It also has a duty to supervise and control offshore tin dredging operations and to see to it that untoward activities do not occur.

6.4 KEY ISSUES

Prospecting in Reserved Areas

As the more easily accessible mineral deposits are exhausted, mineral mining will have to be carried out in increasingly inaccessible areas, and in areas reserved for other purposes. It is probable that, as a result of the airborne geophysical survey conducted since 1984, a number of areas will be discovered with considerable potential for the economic extraction of such minerals as antimony, fluorite, lead, tin, tungsten and zinc. Some of them may well prove to be in such reserved areas as national parks or wildlife reserves.

Wherever they are found, the discovery of mineral deposits can lead to potential conflicts with other important land uses, including agriculture, forestry, water resource development, fisheries, landscape protection or tourism. With different government agencies pursuing separate objectives, some degree of friction is almost guaranteed, and the issue of whether minerals should be exploited in reserved areas — and, if so, how — is likely to become more pressing.

Rather than risk being taken by surprise by such issues, these government agencies should take action now. If there is general agreement that such minerals will never be worked inside reserved areas, no matter how significant the deposits, then there is no problem. If, as seems more likely, some mineral deposits will need to be worked in such areas, for strategic or other reasons, then the legal and institutional framework within which such issues will be resolved should be reviewed and, where necessary, overhauled.

A government review panel, with a proportion of independent members, should be established to carry out the review and, in particular cases, should decide on the respective merits of the cases put forward by those who propose mineral working within a reserved area, and those who oppose the proposition. If a decision is taken to allow the developer to proceed, then the panel would also be in a position to define suitably rigorous conditions to ensure that the environment is properly protected.

The Full Force of the Law

If the imposition of such conditions is to mean anything at all, however, they must be rigorously enforced. Unfortunately, the evidence suggests that the government agencies responsible for enforcement have been less than totally effective.

Consider the illegal mining which has taken place around the country. Whether one thinks of the mining of offshore tin in Phangnga, of wolfram ore at Khao Soon (in Nakhon) Si Thammarat) or Doi Ngom (in Phrae), of scheelite ore at Doi Mok (in Chiang Mai), or of antimony ore at Chonburi, all have been affected by illegal mining. These "mob miners" encroach upon the rights of those who have legitimate rights over the minerals in the area. This illegal activity can lead to a number of highly undesirable results.

First, the legitimate owner or concessionaire is deprived of his rights. Second, valuable minerals are exploited in a wasteful manner, such that the eventual yield of a particular deposit may be significantly reduced. Third, the tin or tungsten ore produced illegally usually finds its way out of the country by illegal means, avoiding the payment of royalties to the government. And, once out of the country, these illegal exports help flood the international market, depressing prices and leading to the imposition of export quotas on legitimate miners.

Clearly, these pressures adversely affect the economic health of important sectors of industry. And it is worth pointing out that, from an environmental point of view, they also make it much harder for legitimate mining ventures to invest money in sensible environmental protection measures. Effective enforcement of the appropriate standards and conditions is clearly going to be essential if the country's nonrenewable and renewable natural resources are to be managed in an economically and environmentally sustainable manner.

Environmental Rehabilitation

There is no denying the fact that Thailand's mineral industries have damaged the environment, nor that such impacts will continue to some extent. Although further action is clearly needed to ensure that industry's environmental performance is up to standard. However, there may a temptation to legislate too fast (Morris, 1983). What is needed, in fact, is steady pressure on an industry, coupled with technical and even financial assistance, where necessary.

The DMR, for example, awarded a seven million baht contract to the Asian Institute of Technology to develop pollution control technology for the offshore tin mining industry around Phuket. The results indicate that a suitable and effective technology can be provided to ensure that slimes discharged from tin dredges are more adequately treated, protecting local beaches and reefs. Funding for this project was derived from special fees collected from tin miners.

The rehabilitation of mined-out land is another DMR responsibility. The law requires operators to restore land to conditions as near as possible to the site's original state. A total of 10 rehabilitation projects have been approved, with combined funding of 47.6 million baht, by the committee set up by the Ministry of Industry to oversee the spending of the special fee fund. Unfortunately, the fees, levied at the rate of 5 percent of the tin ore royalty, were abandoned by the Council of Ministers in November 1985, to help the hard-pressed tin miners.

To ensure further progress in the environmental area, the standards set should be achievable, and should then be progressively tightened as the industry recovers. Precise guidelines should be drafted by the National Environment Board (NEB) to ensure that environmental impact assessments (EIAs) prepared in advance of mining projects cover all the relevant issues and concerns. And the EIAs themselves should increasingly draw on a common environmental database, as is now beginning to happen in such mining areas as Kanchanaburi and Hat Som Pan, in Ranong.

Adding Value Locally

The current economic malaise of the minerals industry reflects the fact that many of its products are, in effect, commodities. With the international economy depressed and commodity markets exerting considerable pressure on primary producers to keep their costs down, the prospect for increasing the mineral industry's investment in more environmentally acceptable technology is not bright. For this reason, environmentalists should support the trend toward value-added businesses in Thailand, with new industries growing up to refine and process a growing share of the country's mineral resources.

Given that mineral exports will need to continue into the foreseeable future, however, there is also an urgent need to consider ways in which Thailand might be able to increase the return on those exports. By increasingly trading such minerals on world markets themselves, Thailand's larger mineral mining companies could win a larger proportion of the value added.

To support such initiatives, the government should ensure that it keeps constantly up to date with market developments, in terms of any changes in global patterns of supply and demand, the consumption trends in consuming countries, and other factors likely to affect the volume and value of Thailand's mineral exports. Private industry organizations, like the Mining Industry Council, should be equipped with sufficient information and personnel to respond quickly and effectively to industry's needs for market intelligence and other forms of marketing support. A government organization should be given overall responsibility for mineral marketing and trade, an approach which would enable the government to handle the sale of certain commodities on its own behalf, as in government-to-government trade. And, to further advance progress in this field, more attention also needs to be given to training Thais in the art of mineral marketing and trading.

Simultaneously, the domestic smelting of ores and their processing into semi-finished or finished products should be encouraged, wherever feasible. The smelting of tin and zinc ores is already helping the economy, and the potential should be investigated in other sectors. It is unfortunate that the proposed tantalum plant ran into such problems, (see Box 12.2), since this is exactly the sort of project, subject to environmental considerations, which Thailand should be trying to encourage. Tungsten ore processing should also be initiated by an appropriate entity, since the price of tungsten ore is very low at present, while semi-finished and finished products continue to command a reasonable price. It would therefore be worth evaluating the possible production of such products in Thailand, possibly on a small scale, mainly for domestic use and perhaps using imported technology.

The primary objective in promoting the increased domestic utilization of ores is to increase the value of Thailand's exports and to achieve import substitution in areas where the country currently imports products made from the minerals that it can produce domestically. The economic multiplier and employment generation effects of such economic activity can be considerable, promoting a virtuous cycle of growth, diversification and further investment.

The government should issue policy guidelines stressing the need for the rapid development of domestic utilization of Thailand's mineral resources. The DMR should be responsible for providing the necessary information on mineral reserves, mineral quality and the current productive capacity of key industries. The private sector should be encouraged to take the lead in the commercial sphere, with technology contributed from the public sector, where appropriate.

The value of tax and other financial incentives should not be underestimated. The DMR already gives a rebate of 50 percent of royalty payments on tin (and 25 percent on other mineral royalties) to local industrial consumers. The royalty system is still probably the most suitable system for Thailand, particularly given the small size of most mining ventures.

The Need for a National Minerals Policy

All in all, a more systematic approach is needed to the development of Thailand's mineral wealth. The minerals industry is too often unsystematic when carrying out exploration and production activities, because its current structure places a considerable premium on producing profits as fast as possible. Given a more systematic approach, it is likely that mining operations would be more efficient, while any environmental impacts could be identified at an early stage and properly managed.

In recognition of the vital role played by minerals development in Thailand, the government should formulate a National Minerals Policy, addressing all of the issues identified above. It should be developed on the basis of an improved understanding of the available mineral reserves, and aim to maximize the ultimate national benefits to be had from the exploitation of the country's valuable, nonrenewable mineral resources.

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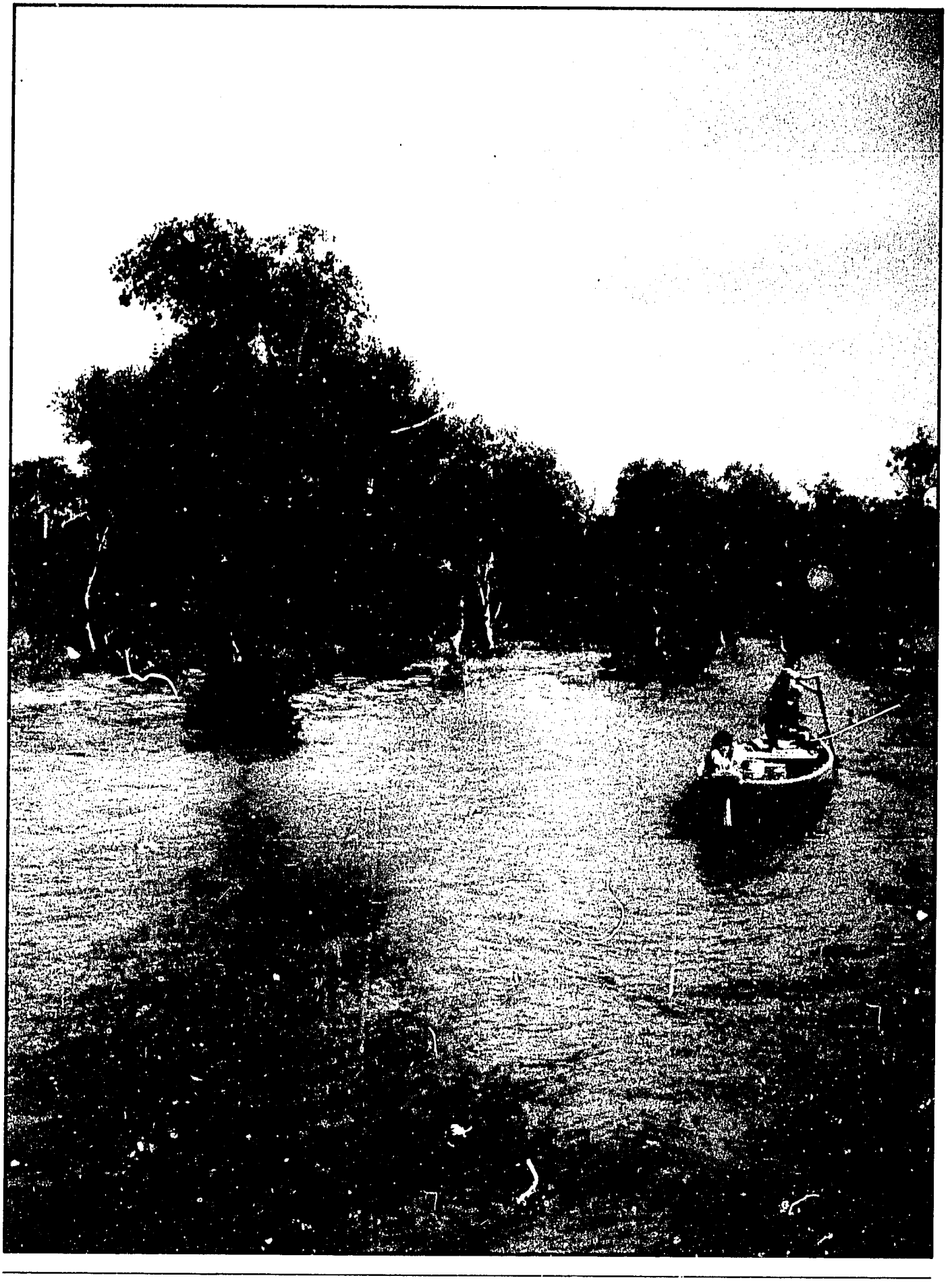


7 Mangrove Resources

7.1 OVERVIEW

The term mangrove forest has been defined by several scientists. Du's (1962) definition involves two different concepts. Firstly, the term refers to an ecological group of evergreen plant species belonging to several families, but possessing marked similarity in their physiological characteristics and structural adaptations to similar habitats. Secondly, it implies a complex of plant communities fringing sheltered tropical shores. Such communities usually have trees, normally species of *Rhizophora*, associated with other trees and shrubs growing in the zone of tidal influence - both on the sheltered coast itself and inland, lining the banks of estuaries. The definition proposed by Saenger et al., (1983) was that mangroves are characteristically littoral plant formations of tropical and subtropical sheltered coastlines. Mangroves are also defined as the salt-tolerant forest ecosystems of the intertidal regions along the coastlines (Hamilton and Snedaker, 1984). Today many workers also use the terms tidal forest and coastal woodland as synonyms of mangrove forest.

Extent and Distribution

In Thailand, mangroves occur on the sheltered muddy shores and low-lying boggy ground of river and stream estuaries along the banks of the Gulf of Thailand and on the west and east coasts of the peninsula (Figure 7.1). The total area of mangrove forests in Thailand, estimated using LANDSAT satellite imagery in 1979 (with deductions made of conversion areas for other purposes such as aquaculture, agriculture, mining, etc., during 1980-1985), is approximately 1.68 million rai (268,694 ha) (Klankamsorn and Charuppat, 1982). About 73 percent of the total mangrove area, or 1.22 million rai, is located along

Figure 7.1 Distribution of Mangroves in Thailand
(Klankamsorn and Charuppat, 1982)

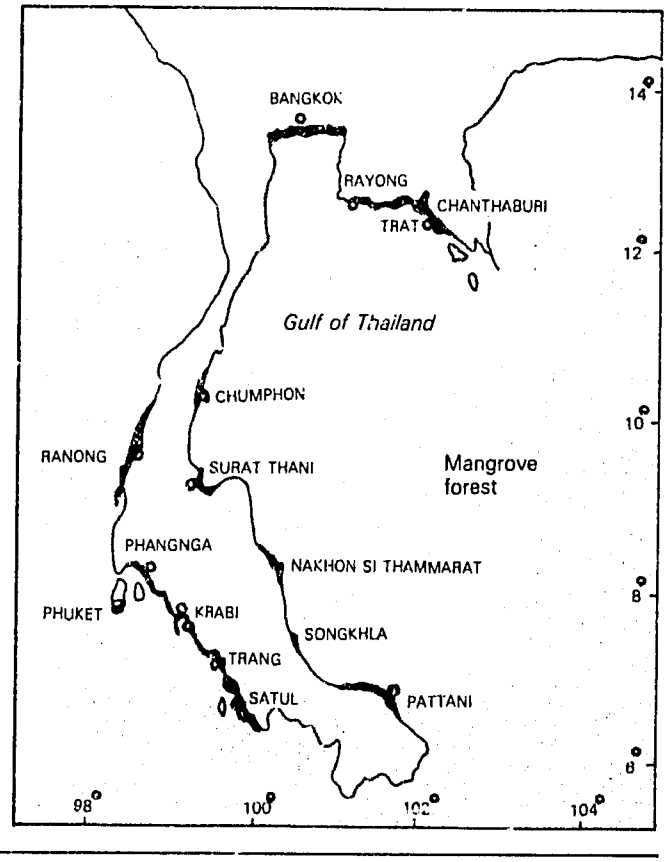


Table 7.1 Estimated Existing Areas of Mangrove Forests in Thailand, 1986

(rai)

Region	Province	Area in 1979[1]	Conversion[2] area 1980-1985	Existing area in 1986	Percent of total area
East	Chonburi	20,700	-	20,700	
	Rayong	28,800	-	28,800	
	Chanthaburi	150,400	7,433	145,967	
	Trat	61,500	3,259	58,241	
	Sub-total	261,400	7,692	253,708	15.1
Upper Gulf	Chachoengsao	14,500	20	14,480	
	Samut Prakan	6,500	-	6,500	
	Samut Sakhon	90,100	-	90,100	
	Samut Songkhram	47,800	-	47,800	
	Phetchaburi	48,700	-	48,700	
	Prachuap Khiri Khan	2,100	1,065	1,035	
	Sub-total	209,700	1,085	208,615	12.4
South	Chumphon	43,300	280	43,020	
	Surat Thani	36,300	27,886	8,414	
	Nakon Si Thammarat	80,200	36,010	44,190	
	Patthalung	10,200	-	10,200	
	Songkhla	32,400	512	31,888	
	Pattani	8,700	472	8,228	
	Ranong	141,200	16,566	124,634	
	Phangnga	304,475	13,996	290,479	
	Phuket	17,800	2,690	15,110	
	Krabi	198,500	2,664	195,836	
	Trang	205,400	1,420	203,980	
	Satun	246,100	5,067	241,033	
	Sub-total	1,324,575	107,563	1,217,012	72.5
	Total	**1,795,675**	**116,340**	**1,679,335**	**100.0**

Sources: 1. Klankamsorn and Charuppat, 1982.
2. National Forest Land Management Division, RFD, 1980 and Chantadisai and Apinan, 1985.

the west and east coasts of the peninsula in the southern part of the country. The remaining mangrove forests occur on the eastern and upper parts of the Gulf of Thailand, with areas of about 253,708 rai and 208,615 rai, respectively. The area of mangrove forests in various provinces is shown, in Table 7.1.

The best developed mangrove forests in Thailand occur on the west coast of the peninsula in Ranong, Phangnga, Trang and Satun, while the mangroves in the inner and western part of the Gulf of Thailand are mainly composed of small-sized trees, since these forests have been cut for many years.

Characteristics of the Mangrove Environment

Physically, the mangrove ecosystem straddles marine and terrestrial environments. The extent and distribution of mangroves depend on environmental factors, the most important of which are climate, soils and water.

Climate

Temperature is a critical factor in the distribution and growth of mangroves (Chapman, 1977a). They require warm, tropical temperatures to develop. Generally, the average temperature of the coldest month is above 20°C and the seasonal temperature range does not exceed 5°C (Dawes, 1981). However, the optimum temperature for mangrove growth is about 25-30°C.

Mangroves occur on tropical shores, from regions of high rainfall and humidity to regions of low rainfall and excessive evaporation, but only in the former regions do they achieve their fullest development (MacNae, 1966). In Thailand, the best developed mangrove forests are in the Ranong area, where the rainfall is between 3,500 and 4,400 millimeters annually (Aksornkoae et al., 1982).

Soils

The development and geographical distribution of mangrove vegetation is also influenced by soil conditions (Aksornkoae,

Table 7.2 Trees and Shrubs of Mangroves in Thailand

No.	Scientific name	Local name	Family
1.	*Acanthus ebracteatus*[a]	Ngukpramo-sikhao	Acanthaceae
2.	*A. ilicifolius*[a]	Ngukpramo-simung	Acanthaceae
3.	*Acrostichum aureu*[a]	Prong-thale	Pteridaceae
4.	*A. speciosum*[a]	Prong-noo	Pteridaceae
5.	*Aegialites rotundifolia*[a]	-	Plumbaginaceae
6.	*Aegiceras corniculatum*[a]	Lebmue-nang	Myrsinaceae
7.	*Allophyllus cobbe*[b]	-	Sapindaceae
8.	*Amoora cucullata*[b]	-	Meliaceae
9.	*Ardisia littoralis*[b]	-	Myrsinaceae
10.	*Avicennia alba*[a]	Samae-khao	Verbenaceae
11.	*A. marina*[a]	Samae-thale	Verbenaceae
12.	*A. officinalis*[a]	Samae-dum	Verbenaceae
13.	*Barringtonia asiatica*[b]	-	Barringtoniaceae
14.	*B. racemosa*[b]	-	Barringtoniaceae
15.	*Brownlowia tersa*[b]	-	Tilliaceae
16.	*Bruguiera cylindrica*[a]	Tua-khao	Rhizophoraceae
17.	*B. gymnorrhiza*[a]	Phunga-huasum	Rhizophoraceae
18.	*B. hainesii*[a]	-	Rhizophoraceae
19.	*B. parviflora*[a]	Tuadum	Rhizophoraceae
20.	*B. sexangula*[a]	Prasak-Khao	Rhizophoraceae
21.	*Cessine viburnifolia*[b]	-	Celastraceae
22.	*Cerbera manghas*[b]	Teenped-num	Apocynaceae
23.	*C. odollam*[b]	-	Apocynaceae
24.	*Ceriops decandra*[a]	Prong-nu	Rhizophoraceae
25.	*C. tagal*[a]	Prong	Rhizophoraceae
26.	*Clerodendrum inerme*[a]	Suma-nga	Verbenaceae
27.	*Cynometra iripa*[b]	-	Leguminosae
28.	*C.ramiflora*[b]	-	Leguminosae
29.	*Cycas rumphii*[b]	-	Cycadaceae
30.	*Dendrolobium umbellatum*[b]	-	Leguminosae
31.	*Derris indica*[a]	Top-tab	Leguminosae
32.	*Diospyros forrea*[b]	-	Ebenaceae
33.	*Dolichandrone spathacea*[b]	-	Bignoniaceae
34.	*Excoecaria agalloch*[a]	Tutum	Ebenaceae
35.	*Ficus microcarpa*[b]	Sai	Moraceae
36.	*Glochidion littorale*[b]	-	Euphorbiaceae
37.	*Guettarda speciosa*[b]	-	Rubiaceae
38.	*Heritiera fomes*[a]	Ngonkai-thale	Sterculiaceae
39.	*H. littoralis*[a]	-	Sterculiaceae
40.	*Hibiscus tiliaceus*[b]	Por-thale	Malvaceae
41.	*Horsfieldia irya*[b]	-	Myristicaceae
42.	*Intsia bijuga*[b]	-	Leguminosae
43	*Kandelia candel*[a]	Rang-keta	Rhizophoraceae
44.	*Lumnitzera littorea*[a]	Fad-dang	Combretaceae
45.	*L. racemosa*[a]	Fad-khao	Combretaceae
46.	*Melaleuca leucadendron*[b]	Samed	Myrtaceae
47.	*Melastoma villosum*[b]	-	Melastomaceae
48.	*Nypa fruticans*	Jag	Palmae
49.	*Oncosperma tigillaria*[b]	-	Palmae
50.	*Pandanus odoratissimus*	Teuy	Pandanaceae
51.	*Paramignya longispina*[b]	-	Rutaceae
52.	*Peltophorum pterocarpum*[b]	-	Leguminosae
53.	*Pemphis acidula*[b]	-	Lythraceae
54.	*Phoenix paludosa*[a]	Peng	Palmae
55.	*Planchonella obovata*[b]	-	Sapotaceae
56.	*Pluchea indica*[b]	-	Compositae
57.	*Premna obtusifolia*[b]	-	Verbenaceae
58.	*Rapanea porteriana*[b]	-	Myrsinaceae
59.	*R. umbellulata*	-	Myrsinaceae
60.	*Rhizophora apiculata*[a]	Kongkang-bilek	Rhizophoraceae
61.	*R. mucronata*[a]	Kongkang-biyai	Rhizophoraceae
62.	*Sapium indicum*[a]	-	Euphorbiaceae
63.	*Scaevola taccada*[b]	-	Goodeniaceae
64.	*Scolopia macrophylla*[a]	-	Flacourtiaceae
65.	*Scyphiphora hydrophyllacea*[a]	Si-ngam	Rubiaceae
66.	*Sonneratia alba*[a]	Lam-panhin	Sonneratiaceae
67.	*S. caseolaris*[a]	Lam-pu	Sonneratiaceae
68.	*S. griffithii*[a]	Lampan-thale	Sonneratiaceae

Table 7.2 (contd.)

No.	Scientific name	Local name	Family
69.	*S. ovata*[a]	Lam-pan	Sonneratiaceae
70.	*Sueda maritima*[a]	-	Chenopodiaceae
71.	*Thespesia populnea*[b]	Po-tale	Meliaceae
72.	*Xylocarpus gangeticus*[b]	-	Meliaceae
73.	*X. granatum*[a]	Taboon-khao	Meliaceae
74.	*X. moluccensis*[a]	Taboon-dum	Meliaceae

Notes: a. Trees and shrubs which are absolutely dependent upon salt or brackish water (true mangrove species).
b. Trees and shrubs belonging to the littoral vegetation which are regularly found in the back mangroves (mangrove association).

1975). Mangrove soils form where a river flows into a relatively calm water body. Coarse materials (sand or gravel) are deposited first, followed by silt and clay.

Mangrove soils are mostly alluvial in nature. They have a high salt and water content, low oxygen and abundant hydrogen sulfide. They are fine-grained soils, often semifluid, poorly consolidated and with abundant humus in parts. The soils are of different types, varying in texture, depending on the ratio between their sand and mud content (Aksornkoae et al., 1978).

Water

Water chemistry is another important factor. Mangroves occur in regions of high, low or variable salinity. In Thailand, mangrove forests are mainly found in areas where water salinities are between 10 to 30 percent (Aksornkoae, 1975).

Periodic seawater inundations are also needed. Most mangrove species, especially *Rhizophora* spp., grow very well in areas where there is sea water flooding (Aksornkoae, 1981). Mangroves grow best where an adequate fresh water supply is available, bringing constant injections of nutrients and silt from the upland catchment areas.

Flora and Vegetation

Santisuk (1983) reported that Thailand's mangrove flora belongs to 35 families, 53 genera and 74 species. (Table 7.2). The 74 species include plants that occur at the limit of salinity influence, that is, at the transition between the mangrove forest and the back vegetation, freshwater swamp or peat-water swamp forest.

There is not much difference in the floristic composition of the mangrove forests in different parts of the country. Only a few species have a somewhat limited distribution, including *Aegialites rotundifolia, Nguankai-thale, Heritiera fomes,* and *Rapanea umbellulata* (Table 7.2). The species, belonging to *Rhizophoraceae,* mainly composed of Kongkang *(Rhizophora* spp.), have the widest distribution.

The algal flora of mangrove forests in various parts of Thailand have been studied by Lewmanomont (1983). She divided them into two groups, based on their habitats. One group is composed of algae that are sedentary on the trunks, roots or pneumatophores of mangrove trees, while the other includes those that grow on the mudflat or sandy mud areas in mangrove forests. Mangrove roots support red algae of the genera *Catenella, Bostrychia* and *Murrayella.* Many other types of red algae found in the mangrove forests of Thailand belong to the genera *Gracilaria, Hypnea, Gelidium, Acanthophora, Herposiphonia* and *Laurencia.* On muddy surfaces, there are a variety of green algae of genera *Cladphora, Chaetomorpha, Enteromonpha,* and *Ulva* and the blue-greens of genera *Lyngbya, Oscillatoria, Phomidium* and *Calothrix.* A few species of brown algae are also found in the mangrove areas, especially species of genera *Ectocarpus, Dictyota* and *Hydorclathrus.* Lewmanomont (1983) recorded about 44 species of algae found in Thailand's mangrove forests.

Fauna

The different types of faunal communities in Thai mangrove forests have been extensively surveyed. Monkolprasit (1983) reported that about 72 species of fish are found in mangrove areas. She noted that the fish communities in mangrove and adjacent areas fluctuate considerably in both species composition and number, not only because of movements related to their reproductive cycles and the tides, but also because of their different responses to changing salinity, temperature and predators. Monkolprasit (1983) divided the fish in mangrove forests into four groups: true residents, partial residents, tidal visitors and seasonal visitors.

Chaitiamvong (1983) reported on the species of shrimp found in the mangroves and adjacent areas. 15 species migrate from marine to coastal areas near mangroves. These mainly belong to the genera *Metapenaeopsis, Metapenaeus* and *Parapenaeopsis.* About 16 species of shrimp migrate from marine to brackish water, the main genera being *Metapenaeus, Penaeus* and *Acetes.* The common species of shrimp found in the mangrove forests are *Macrobrachium equidens, Palaeander* sp. and *Palaemonetes* sp. A few

Box 7.1 The Miraculous Mangrove

If today's plant biotechnologists, operating at the leading edge of high technology, were asked to genetically engineer a tree able to flourish on soils which are regularly inundated with seawater, so that they are both salty and waterlogged, they might despair. But such a tree already exists and flourishes around the coasts of Thailand. The mangrove is at once an extraordinary living system and an increasingly vital economic resource.

The mangrove forest is also a highly symbolic resource, straddling the interface between the terrestrial and marine environments. Thailand is still fairly well endowed with mangroves. LANDSAT data suggest that some 1.7 million rai of assorted mangrove forest can be found around the country, although about three-quarters (73 percent) of this resource is found on the west and east coasts on the southern peninsula. The rest occurs in various places around the eastern and upper coastlines of the Gulf of Thailand.

Traditionally, mangrove forests have been seen as an inexhaustible source of firewood, charcoal, poles and other construction materials, in addition to providing raw materials for fishing gear and some medicines. Now research is beginning to provide incontrovertible evidence that they also play a key role in coastal and marine ecosystems, underpinning the productivity of inshore and offshore fisheries.

But in many areas these vulnerable forests are being exploited faster than they can regenerate. If any one resource best illustrates the growing need to adopt the multiple-use management approach to Thailand's coastal resources generally, it is the mangrove. Now is the time to develop a strategy designed to ensure the conservation and sustainable development of this resource, before the pressures become uncontainable.

One interesting idea involves combining mangrove plantations with aquaculture operations, in what is sometimes called the silvo-fishery system. This approach could help slow the clearance of mangrove land for aquaculture ponds, ensuring that aquafarmers (see Box 8.2) maximize the potential of their land holdings in a way which does not undermine their longer term future.

species of shrimp migrate from fresh water to brackish water mangrove areas, the most common ones being *Marcrobrachium rosenbergii* and *Leptocarpus potamiscus*.

A survey of crabs in mangroves and adjacent areas was carried out by Naiyanetr (1983). He recorded seven families with 54 species. Mangrove crabs were mainly found in families *Grapsidae* and *Ocypodidae*. The common genera of *Grapsidae* are *Sesarma, Parasesarma, Chiromentos, Sarmatium* and *Metaplax*. Family *Ocypodidae* is mostly composed of genera *Macrophthalmus, Ilyoplax* and *Uca*. A few species were in families *Portunidae, Gecarcinidae, Paguridae, Coenobitidae* and *Xiphosuridae*.

Mangrove molluscs both, Gastropods (univalves) and Pelecypods (bivalves), were studied by Isarankura (1976). He observed molluscs both encrusting on (or attached to) stems, roots and leaves of mangroves and living on the forest floor. There are 10 univalve species and three bivalve species living on trees, and eight univalve species and two bivalve species *living on mangrove soils. Two univalve species, Cassidula aurisfelis* and *Onchidium* sp. were found in both habitats, but only one bivalve species, *Isognomon ephippium*, was observed.

The birds, mammals and reptiles of Thai mangrove forests have also been studied. Nabhitabhata (1982) recorded 88 species of birds, both migratory and resident. These include several species of egrets, herons, kites, plovers and hawks. There are 35 species of mammals in mangroves reported by McNeely and Lekagul (1976). Bats, macaques, otters and fishing cats are very common. About 25 species of reptiles have been found in the mangroves, including snakes, amphibians, turtles, lizards and crocodiles (Way, 1977).

There are many different species of insects in the mangroves. Vaivanijkul (1976) recorded 38 species, including many different types of moth, caterpillar, pyralid, beetle, mosquito, biting midge and aphid. Table 7.3 summarizes the distribution of fauna and flora in Thailand's mangroves.

Productivity

Information on the productivity of both plants and animals in Thailand is very limited. Information on forest productivity is mainly derived from plantations, where *Rhizophora apiculata* is grown. Aksornkoae (1975) studied a plantation of *Rhizophora apiculata* in Chanthaburi Province, southeastern Thailand, with a spacing of 1 x 1 meters between trees, and found that the mean annual increment for 14-year old stands was approximately 2.5 cubic meters per rai per year (m^3/rai/yr). The dry weight of stem was estimated to be 1.6 metric tons per rai/year (t/rai/yr). Christensen (1978) reported an above-ground figure of 25.4 t/rai in a 15-year old stand of *Rhizophora apiculata* dominated mangrove, representing an increment of about 1.7 metric t/rai/yr. The productivity of trees in natural mangrove has not received much attention. In the past three years, there have been some studies on productivity of natural mangrove species, but the results have not yet been reported.

Table 7.3 Distribution of Flora and Fauna in Mangrove Forests of Thailand

Community		No. of species	Reference
Flora			
1. Mangroves (Trees, shrubs, fern and palms)		74	Santisuk, 1983
2. Epiphytes		18	Sahavacharin & Boonkerd, 1976
3. Algae		44	Lewmanomont, 1983
Fauna			
1. Fishes		72	Monkolprasit, 1983
2. Shrimps		37	Chaitiamvong, 1983
3. Crabs		54	Naiyanetr, 1983
4. Molluscs		20	Isarankura, 1976
5. Birds		88	Nabhitabhata, 1982
6. Mammals		35	McNeely & Lekagul, 1976
7. Insects		38	Vaivanijkul, 1976
8. Reptiles		25	Way, 1977
1. Snakes	12		
2. Amphibians	6		
3. Turtles	1		
4. Lizards	5		
5. Crocodile	1		

The productivity of litter fall in mangrove ecosystems in Thailand has also been studied. Aksornkoae and Khemnark (1984) reported a mean litter fall in the mangrove forest at Chanthaburi, southeast Thailand, of about 1.5 t/rai/yr. Christensen (1977 obtained a value of 1.1 t/rai/yr for litter fall in a 15-year old *Rhizophora apiculata* forest in Phuket, Thailand.

Publications reporting on the productivity studies of mangrove aquatic fauna in Thailand are limited. But the main studies place emphasis on the biomass, and the biomass of benthic animals may provide a good indication of biological productivity. Paphavasit and Sitti (1982) studied the benthic fauna of three estuaries in Phangnga Province and found an average biomass of about 381 grams wet-weight/m^2, with *Holuthuria atra* forming the largest component. Nateewatana and Tantichodock (1980) compared the biomass of macrofauna on different habitats of mangrove forest in Ko Yao Yai, southern Thailand. Benthic macrofauna in mangroves had a biomass of 3 - 10 grams dry-weight/m^2, mudflats had a biomass of 10 grams dry-weight/m^2,while sand flats had a biomass of 5.3 and grass beds of 3.6 grams dry-weight/m^2.

Volumes and Yields

The density of plants in mangrove forests generally varies with age, ranging from about 160 trees/rai in mature forests to about 1,600 trees/rai in young *Rhizophora apiculata* dominated stands. In Thailand some of the best mangrove forests occur in Ranong province, and are mainly composed of large-sized trees, mainly *Rhizophora apiculata, Bruguiera* spp. and *Sonneratia* spp. A density of about 130 trees/rai and a volume of 36.2 m^3/rai were recorded (Aksornkoae, 1983). Mangrove forests which have been selectively cut for many years, as in Chanthaburi province, have a density of 195 trees/rai and volume of only 8.6 m^3/rai (Aksornkoae, 1975). The stem volumes of mangrove forests throughout the country were estimated to range from 3.0 to 37.0 m^3/rai (Aksornkoae, 1982).

Significance of Mangroves

Mangroves represent a rich and diverse living resource. Their contributions to the Thai economy, in terms of charcoal, wood products, tannin, medicinal compounds and other products are summarized below.

a) Charcoal

Mangrove woods is mainly (90 percent) harvested for charcoal production. Various species of *Rhizophoraceae* can be used for charcoal production, but *Rhizophora apiculata* and *R. mucronata* are preferred. The reason is that the wood of these species is heavy, dense and hard, with a high calorific value. When burned, it creates little smoke. Other species, like *Bruguiera* spp. and *Ceriops* sp., are also used, but the quantity is minimal. The minimum size of stems used for charcoal production is about 5 centimeters of diameter at breast height (dbh), or at 1.30 meters above ground level. The annual production and value of wood and charcoal from Thailand's mangrove forests are presented in Table 7.4

b) Poles and firewood

Poles are used for a number of purposes, but mainly for foundation piling, ore rinsing sluices and fishing stakes. The quan-

Table 7.4 Wood and Charcoal Production in Thailand, from 1970-1984

Year	Wood Production[a] (m^3)[3]			Charcoal production		Value[5] (10^6 baht)
	Managed[1] forest (RFD)	Private[2] plantation	Total	(m^3)[3]	(ton)[4]	
1970	578,237	-	578,237	289,118	196,600	393.2
1971	620,713	-	620,713	310,356	211,042	422.1
1972	683,265	-	683,265	341,632	232,309	464.6
1973	708,229	-	708,229	354,114	240,797	481.6
1974	658,045	-	658,045	329,022	223,734	447.5
1975	685,570	54,000	739,570	369,785	251,453	502.9
1976	714,413	54,000	768,413	384,206	261,260	522.5
1977	759,914	54,000	813,914	406,957	276,730	553.5
1978	770,872	54,000	824,872	412,436	280,456	560.9
1979	810,535	54,000	864,535	432,267	293,941	587.9
1980	813,287	54,000	867,287	433,643	294,877	589.8
1981	752,395	54,000	806,395	403,197	274,173	548.3
1982	772,343	54,000	826,343	413,171	280,956	561.9
1983	782,147	54,000	836,147	418,073	284,289	568.6
1984	776,765	54,000	830,765	415,382	282,459	564.9

Note: a. Wood for charcoal production only.
Sources:
1. Royal Forest Department, 1985.
2. FAO, 1986
3. based on 50% of wood production (Kongsangchai, 1983).
4. based on 680 kg/m^3 of charcoal (Phuritat, 1975).
5. based on present value (2 baht per kg of charcoal) at production areas.

tity of poles used for these purposes is small and no data are available. The common mangrove species used for poles are *Rhizophora apiculata, R. mucronata, Ceriops* sp., *Bruguiera* spp. and *Excoecaria agallocha. Excoecaria agallocha* seems to be more widely used for poles. Firewood from mangrove forests is widely used by mangrove dwellers and by people who live along the coastlines. Statistical data on the amount of firewood consumed each year are not available, with the exception of the data obtained by Aksornkoae et al., (1984) from their socioeconomic studies of two villages of mangrove dwellers in Ranong. They reported that the average household consumption of mangrove firewood was about 2.0 m^3per year, equivalent to 1,500 sticks per year (assuming the size of stick is about 40 centimeters long and 4-6 centimeters in diameter). Most firewood is used for cooking purposes and the rest is used for burning to repel mosquitoes and other insects. The mangrove species commonly used for firewood are *Avicennia, Xylocarpus, Excoecaria, Bruguiera* and *Lumnitzera. Rhizophora* spp. is also used for this purpose, but the quantity is very small because these species are preferred for charcoal production.

c) Construction materials

Mangrove lumber is mainly used for house construction close to the mangrove forests. Wood of various mangrove species can be used for different parts of a house. *Rhizophora, Avicennia, Bruguiera* and *Xylocarpus* are commonly used for columns, bracing members, beams and roof frames. Floors and platforms are made only of *Rhizophora* and *Bruguiera* species. Aksornkoae et al., (1984) estimated the requirement of mangrove wood for the construction of a typical mangrove dweller's house in Ranong province to be about 9-20 m^3.

d) Wood distillation

The only distillation plant, built a few years ago, is situated at Kapur, Ranong province, on the west coast of Thailand. Raw distillate from mangrove wood *(Rhizophora apiculata)* is collected from the vents of a charcoal kiln by condensation. This raw condensate is essentially pyroligneous acid. A more complicated process is required to fractionate it into acetic acid, methanol and wood tar. The percentages of acetic acid, methanol and wood tar that can be extracted from pyroligneous acid are 5.5, 3.4, and 6.5 percent, respectively. This process is not economic, due to product extraction difficulties.

e) Tannin extraction

The utilization of mangrove tree barks for tannin is now very rare. In the past, tannin from *Rhizophora* and *Ceriops* was used by the fishermen for dying their fishing nets. Since nylon nets are mainly used for fishing equipment today, the use of tannin for this purpose has almost ceased.

f) Medicines

Some plants found in mangrove forests can be used as alternatives for medicines, but scientific proof of their effectiveness and research on possible side effects are still needed before they can be widely recommended. Aksornkoae et al., (1984) interviewed mangrove dwellers in Ranong Province and found that three mangrove species are used for medicinal purposes. These are *Acanthus* spp., *Bruqiera parviflora* and *Avicennia alba*. *Acanthus* is used to treat kidney stones, and *Bruguiera* is used to treat thrush in children.

g) Other products

Various types of fishing gear are used by mangrove dwellers, and some of the equipment is constructed of mangrove wood. Most of the mangrove poles from *Rhizophora* spp. are used for crab traps. The most common crab caught in the mangrove area is *Scylla serrata*. The drift gill-nets and the winged set-bag are other types of fishing gear that are made of mangrove posts, and common species used are *Rhizophora apiculata* and *Bruguiera* spp. The total volume of wood used for fishing gear has never been estimated

The mangrove palm, *Nypa fruticans*, is also a valuable species. The main use of the leaves is for thatch materials. Young and unopened nipa leaves are also used as cigarette wrappers. The extraction of alcohol from nipa sap has not been carried out in Thailand.

Mangrove Forests and Fisheries

Thailand's mangrove forests also play an important role in sustaining the productivity of inshore and offshore fisheries. They contribute nutrients to the ecosystem, provide shelter for fish nurseries, and help support extensive mollusc populations.

a) Mangroves as a food source

The primary food source for organisms in mangrove-dominated estuaries is detritus or particulate organic material derived from the decomposition of mangrove forest litter. About 80-90 percent is composed of leaf litter, the remainder being formed from twigs, flowers and fruits. In Thailand, as mentioned earlier, annual mangrove litter fall ranges from 1.1 to 1.5 tons dry weight/rai/yr. This amount of litter, when decomposed, injects a considerable quantity of nutrients into the mangrove ecosystem (Aksornkoae and Khemnark, 1984).

During decomposition, mangrove litter is progressively enriched in protein and serves as a food source for a wide variety of filter, particulate and deposit feeders (e.g. molluscs, crabs and polychaete worms). These primary consumers, which include representatives of most phyla, in turn provide food for secondary consumers. Nakasone et al., (1985) investigated the degradation of leaf litter by grapsid crabs and a snail in the mangrove forests of Ao Khung Kraben and Mae Nam Wen, Thailand. They found that some grapsid crabs and the snail had an ability to change leaf litter to small particles through their digestive tracts. The detrital particles of the feces of grazing animals may also support detritus-based food webs, both in the mangroves and the surrounding waters. The secondary consumer level is usually dominated by small forage fish species and by the juveniles of the larger predatory species that form the third trophic level. In addition, there are commercially important fishery species, such as shrimp, which occupy both primary and secondary consumer levels. They feed directly on particulate organic detritus and also feed, to some extent, upon primary consumers.

Although phytoplankton is not the primary food source for aquatic mangrove organisms, it is an essential link in the grazing food webs. Phytoplankton production may be high where levels of turbidity are low and the flushing time of an estuary is comparatively long. Diatoms, blue-green algae and dinoflagellates are common in the mangrove area especially on mudflats. Some species are not endemic to the mangrove swamp. Boonruang (1985) reported that five oceanic species of diatoms were present, as indicators of oceanic influence along the east coast of Phuket Island, Southern Thailand during the southwest monsoon season. Marumo et al., (1985) reported that diatoms were the most abundant species in Khung Kraben estuary in the Eastern Gulf of Thailand. This was similar to the phytoplankton community in a Hawaiian mangrove swamp, where the diatoms occupied 94 percent of the total 191,856 cells/liter (Walsh, 1967). Marumo et al., (1985) also suggested that diatom cells might be a necessary food source in the food chain at Khung Kraben for molluscan and crustacean larvae, as well as for herbivorous copepods, which in turn were fed upon by carnivorous copepods and chaetognaths.

Zooplankton plays an important role in the secondary food web of the aquatic ecosystem and forms an intermediate link between primary and tertiary production. Suvapepun et al., (1979) reported the species composition and distribution of zooplankton communities in the mangrove forest at Laem Pak Biah, Phetchaburi Province, in Thailand. Crustacean and decapod larvae were the dominant groups. Marumo et al., (1985) also found that copepods were the dominant group in the epipelagic zooplankton community at Khung Kraben, Chanthaburi province, Thailand.

An additional source of nutrition for estuarine organisms is provided by dissolved organic compounds (e.g., amino acids), also largely of mangrove origin. Although relatively few species of invertebrates or vertebrates are known to be capable of utilizing such dissolved material directly, one might expect that algae and unicellular organisms such as bacteria are able to assimilate dissolved organic materials from the water column. These organisms then form part of the food base for primary consumers. Figure 7.2 depicts, in a very simplistic and general way, the mangrove food web.

Figure 7.2 Mangrove Food Web

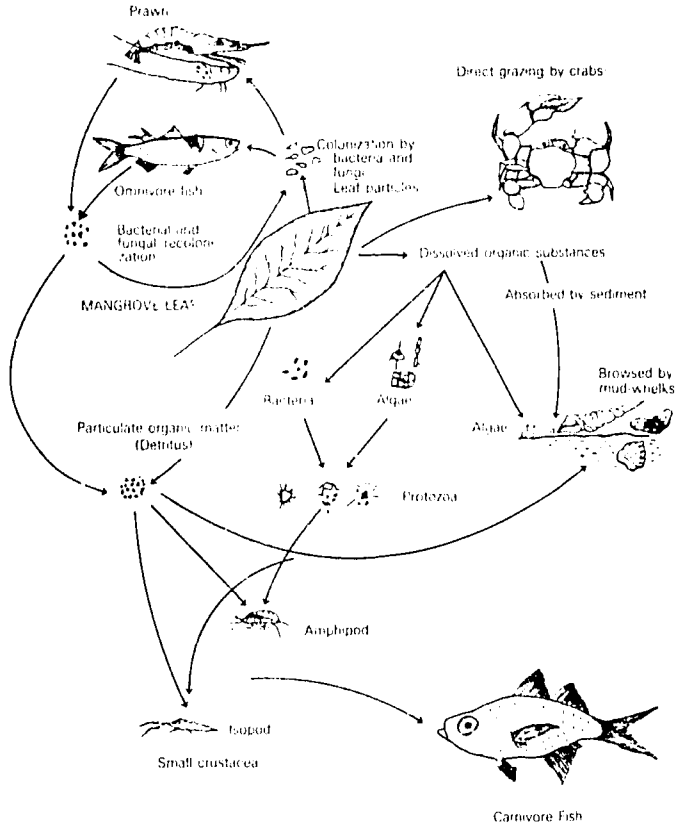
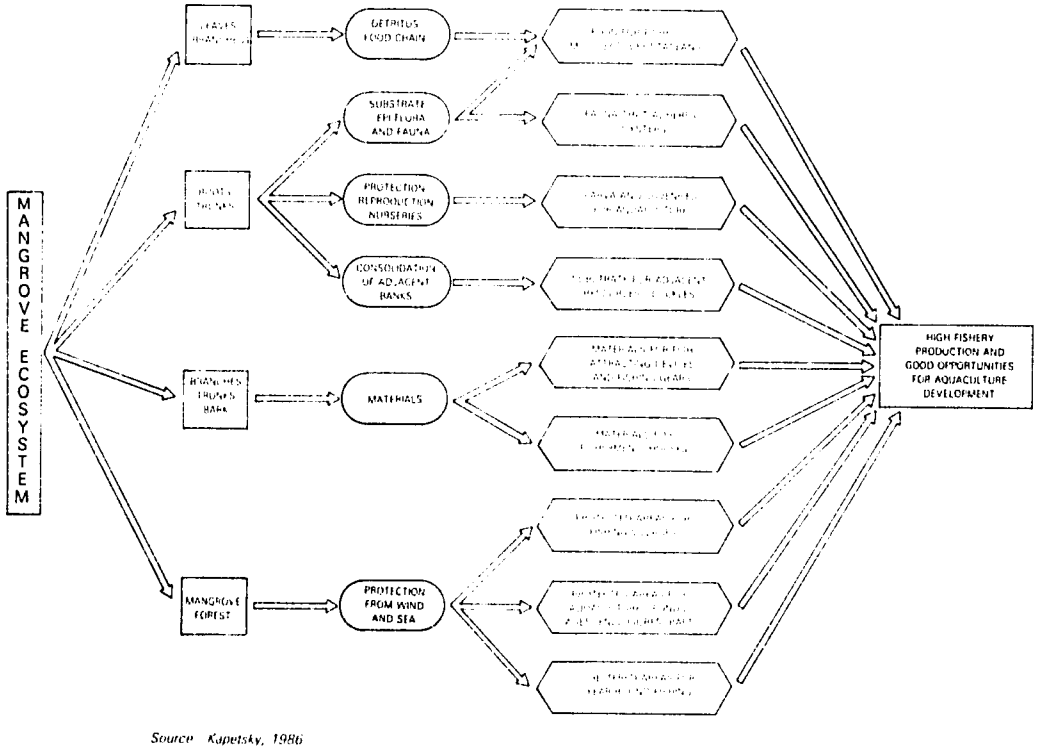


Figure 7.3 Some Functional Relationships of Mangroves with Fishery Resources, Aquaculture and Fishermen



Source Kapetsky, 1986

b) Mangroves as shelters and nurseries

The importance of mangrove forests as shelter and nurseries for commercially important fishery species is increasingly accepted. There is evidence that mangrove forests are used as sheltering nursery grounds, as permanent habitat for some species, and as breeding grounds for some coastal species. Marumo et al., (1985) noted that the zooplankton community in the Khung Kraben Bay where mangroves existed was characterized by a predominance of the larval stages of benthic animals such as polychaetes, bivalves, gastropods, macrurans and brachyurans. Further surveys of these larval stages are very important if we are to understand the life histories, productivities, fisheries and aquaculture potential of adult organisms.

Many species of penaeied shrimp use mangrove forests as shelter and nursery grounds for at least part of their life cycle. McNae (1974) studied the situation around the Indian Ocean and concluded that *Penaeus indicus, P. merguiensis* and *P. monodon* depend on mangrove forests for shelter during their juvenile stages. Most species of *Metapenaeus* depend on mangrove creeks and lagoons but might persist even after the destruction of the mangrove vegetation. Silas (1986) also did some studies on the relationship between mangroves and shrimps in India and he found that tagged juveniles of *P. indicus* move from Cochin where the mangroves have been destroyed to undisturbed mangrove forests in the Gulf of Mannar, south of Tuticorin.

Other aquatic animals in estuarine areas, such as fish and other kinds of shellfish, also use mangroves as a nutrient source, shelter and nursery ground. Wattanachai (1979) reported the species composition and abundances of fish eggs and fish larvae in the mangrove forest at Leam Pak Biah, Phetchaburi Province. He found that the abundance of fish eggs and larvae was dependent on the nutrient or food supply in the area. The highest density of fish eggs and larvae was recorded during November and December. More than 30 families of fish which were of economic importance, such as *Lates calcarifer* and *Chanos chanos*, were recorded from the area. Several marine fishes migrate into the sea to spawn but fish larvae such as those of the milkfish, *Chanos chanos*, migrate back into the estuary and the mangrove area for feeding (Suntharatok et al., 1976) Other marine fishes may spawn inside the mangrove area. Their eggs usually float in a mucous mass, or attach to rocks or the roots of aquatic plants.

Figure 7.3 illustrates some functional relationships of mangroves with fishery resources, aquaculture and fishermen (from Kapetsky, 1986).

c) Mangroves related to fisheries production

Capture fisheries. In Thailand, capture fisheries are spread throughout the marine, estuarine areas and coastal waters. On average, more than 1.8 million tons of marine fish were landed annually between 1978-1982, of which almost 130,000 tons were shrimps (Table 7.5). Many of the shrimps from the capture fisheries in the country are mangrove - dependent species (e.g., *Penaeus merguiensis, P. monodon*, and *Metapenaeus* spp.).

Table 7.5 Marine Fisheries in Thailand, 1978-1982

Year	Total marine fisheries (ton/year)	Marine shrimp (ton/year)
1978	1,957,785	127,404
1979	1,813,158	116,456
1980	1,647,958	118,341
1981	1,824,444	133,435
1982	1,986,571	166,614
Average	**1,845,983**	**132,614**

Source: Statistics Section, Department of Fisheries, 1983.

Mangroves also support the artisanal fisheries. The people who live in or near the mangrove forests catch fish, shrimp, crabs and molluscs daily around the estuarine areas where mangrove exists. Unfortunately, there are no data available on the quantity of the catch so far. The most important species in the fish catch are mullet *(Mugil dussumieri)*, sea bass *(Lates calcarifer)*, tilapia *(tilapia mossambica)*, snake eel *(Ophichthus microcephalus)*, cat fish eel *(Plotosus canius)*, and milk fish *(Chanos chanos)*; the most common species of shrimp are *Penaeus merguiensis, P. monodon* and *Metapenaeus* spp.; crabs are represented by only one species, *Scylla serrata*, while the important species of molluscs are *Nerita* sp., *Anadra* sp. and *Crassostrea commericallis*.

Culture fisheries. Most of the culture fisheries (aquaculture) located in mangrove areas are shrimp farms. The shrimp farms are mainly found in Samut Sakhon, Samut Songkhram, Samut Prakan, Surat Thani and Nakhon Si Thammarat provinces. Most of these farms have been built during the last fifteen years. There was a boom in shrimp farming in 1978 due to the introduction of new economic zones in neighboring countries which has adversely affected capture fisheries.

The 10,090 tons of shrimp produced in 1982 came from 3,943 farms, occupying a total area of about 192,453 rai (Table 7.6). It is estimated that some 144,750 rai of the total of mangrove area in Thailand are suitable for shrimp aquaculture (Brohamanonda, 1985), so there is a large potential for expansion. The present average production is about 52 kg/rai. Some farms operate on a subsistence basis, which are only productive for the first three or four years and are then abandoned. This inefficient and wasteful practice results in the degradation of large areas of mangroves and it may adversely affect the yield of the coastal shrimp capture fisheries. In recent years, however, there has been a significant improvement in the average yield achieved by such aquaculture operations. This is due to better management and widespread introduction of pumping. However, to conserve mangroves, intensive and semi-intensive culture should be emphasized to maximize

Table 7.6 Shrimp Culture Production in Thailand, 1976-1982

Year	Area (rai)	No. of shrimp farms	Production (tons)	Yield (kg/rai)
1976	76,850	1,536	1,533.33	32.96
1977	77,567	1,438	1,589.54	20.49
1978	151,055	3,045	6,394.83	42.33
1979	154,222	3,378	7,064.07	45.80
1980	162,727	3,572	8,063.05	49.55
1981	171,619	3,657	10,727.87	62.51
1982	192,453	3,943	10,090.77	52.43

Source: Statistics Section, Department of Fisheries (1983).

more yield and benefit, rather than extensive culture or extended farm areas, which produce low yields and fewer benefits.

Molluscs have also been cultivated on the mudflats around mangrove areas for many years. Even though molluscs are not raised in the mangrove areas themselves, mangroves are still very important as a source of dissolved and suspended nutrients for the growth and productivity of molluscs. The total area of mollusc culture is quite limited, as in Rayong, Chanthaburi, Chumphon, Phangnga, Krabi and Satun provinces. Table 7.7 shows the area devoted to the culture and production of the major varieties of molluscs from 1978 through 1982. Production is subject to wide annual fluctuations, but in general it declined in this period. The Department of Fisheries now plans to extend production to other suitable mudflat areas near mangrove forests.

The important species of mollusc culture in Thailand include horse mussel *(Modiola senhausenii)*, green mussel *(Perna veridis)*, blood cockle *(Anadara granosa)* and oyster *(Crassostrea commercialis)*.

Maintaining a Natural Ecological Balance

Mangrove forests serve as a link between marine and terrestrial ecosystems. These communities are clearly important to the stability and maintenance of various adjoining ecosystems (e.g., seagrass, coral reef, marine). Mangroves represent a unique ecological niche and habitat for a diverse variety of marine and terrestrial animals. The amount of organic matter produced by mangrove communities will support not only the mangrove ecosystem itself but also other related ecosystems. Moreover, mangroves also play an important role in stabilizing shorelines in coastal streams and estuaries by protecting them against tidal bores, and soil erosion.

It is believed that if the mangrove communities along the banks of estuaries and coastlines are disturbed, or were to be completely cut, there would be no habitats or adequate food to support the organisms in these areas. Consequently, the loss of these mangrove-related ecosystems would disturb the natural ecological systems over a considerable area.

7.2 HISTORICAL DEVELOPMENT AND EMERGING TRENDS

Mangrove Forest Management

Mangrove area

In 1961 the total mangrove forest area in Thailand was approximately 2.3 million rai. Due to the conversion of mangrove areas for other purposes, such as aquaculture, mining, resettlement sites or salt ponds, the mangroves had decreased to about 1.68 million rai by 1986. This indicates an annual conversion of mangrove forest rate of 24,802 rai, or 1-2 percent from 1961-1986 (Table 7.8). Details of the conversion of mangrove forests for other purposes will be discussed later in this Chapter.

Nonetheless, it is believed that the area will increase in the future. There are at least three main important reasons for this prediction. First, the Royal Forest Department (RFD) has established 34 Mangrove Management Units to control forest exploitation and to prevent illegal cutting of mangrove

Table 7.7 Mollusc Culture Production in Thailand, 1978-1982

(area : rai, production : tons)

Year	Horse mussel		Green mussel		Blood cockle		Oyster	
	Area	Production	Area	Production	Area	Production	Area	Production
1978	911	9,563	6,376	30,280	5,053	15,769	4,416	14,385
1979	600	8,351	6,162	25,283	6,846	18,611	4,449	9,301
1980	564	3,429	5,081	6,917	7,842	13,566	5,299	5,339
1981	326	4,388	2,768	18,320	6,172	22,710	5,894	7,728
1982	326	538	2,455	23,009	7,006	5,542	6,331	3,617

Source: Statistics Section, Department of Fisheries (1983).

Table 7.8 Degradation of Mangrove Forests in Thailand, 1961-1986

Year	Mangrove forest (rai)	Degraded area (rai)	Degraded area %	Degradation rate (rai/yr)	Degradation rate %
1961[1]	2,229,375				
1975[1]	1,954,575	344,800	15.0	24,629	1.1
1979	1,795,675	158,900	8.1	39,725	2.0
1986	1,679,335	116,340	6.5	16,620	0.9
1961-1986		620,040	27.0	24,802	1.1

Source: 1. Klankamsorn and Charuppat, 1982.

forests. Second, the legal conversion of mangrove forests to other purposes will be limited and the utilization of mangrove areas for such purposes will be permitted only in the areas allocated by mangrove land use zoning. And third, the RFD is planning to promote the establishment of a large scale mangrove plantation program. The total potential area to be planted will be approximately 300,000 rai. Most of the area to be planted is currently denuded and unproductive (yield below three m^3/rai). Some suitable mudflats will also be planted. The project will run for five years and is scheduled to start in 1988. The annual planting target will be 60,000 rai. This indicates that the denuded area and unproductive forest of existing 327,119 rai could be fully planted during the life of this project.

Up to now, the RFD has replanted about 39,160 rai of mangrove. There are also the private mangrove plantations, comprising about 205,975 rai. Most of the plantations consist of the species *Rhizophora apiculata*, which is used for charcoal production.

By 1992, therefore, it is estimated that the total mangrove area will be back to about 1.68 million rai. Even though the area is the same as in 1986, these should be more productive forests. It will be composed of 1.1 million rai of managed forest area, 0.34 million rai of government plantations, 0.21 million rai of private plantations and only a small area (0.03 million rai) of unproductive forest. Details of projected mangrove areas are presented in Table 7.9.

Silvicultural (cutting) systems

The silvicultural (cutting) system has been revised from time to time in order to suit auction licensing, to promote effective regeneration and to protect against illegal cutting. Before 1961, the sole objective was charcoal production. The management of mangrove forests by that time was operating only in some provinces because only a few concessionaires were interested. The management plan was rather sketchy. The silvicultural system was a shelterwood system, with the cutting rotation varying from 10 to 20 years. The forest area was divided into 10 to 20 annual coupes of approximately equal area. Each year, one annual coupe was granted for wood extraction under a short-term (one-year) permit. Under this cutting system, trees of 30 cm girth at breast height could be cut, but 30-40 big

Table 7.9 Projected Mangrove Forest in Thailand (1986-1992)

(rai)

Year	Mangrove area Managed by RFD: Natural forest: Under[1] Concession	Natural forest: Unproductive[2] area	Plantation: Planted[3] area	Private[4] plantation	Total mangrove area
1986	1,104,081	330,119	39,160	205,975	1,679,335
1987	1,104,081	327,119	42,160	205,975	1,679,335
1988	1,104,081	267,119	102,160	205,975	1,679,335
1989	1,104,081	207,119	162,160	205,975	1,679,335
1990	1,104,081	147,119	222,160	205,975	1,679,335
1991	1,104,081	87,119	282,160	205,975	1,679,335
1992	1,104,081	27,119	322,160	205,975	1,679,335

Sources: 1. Kongsangchai, 1984.
2. Estimated.
3. Kongsangchai, 1985.
4. FAO, 1986.

trees had to be left standing for each rai (0.16 ha), for regeneration purposes.

In 1961, the RFD revised the mangrove operating plans throughout the country. The shelterwood system with minimum girth limit was retained, but a number of additional prescriptions were added, such as number of trees to be left in the cutting areas is determined according to the condition of the mangroves and the sizes of trees in each area. The cutting rotation was revised to 15 years, with 15 annual coupes. The areas were to be auctioned every three years.

During the implementation of the shelterwood system with minimum girth limit (1961-1969), it was found that this cutting system was difficult to supervise and control in the field. In many areas the stock was depleted and the site deteriorated. Some areas were left with only noncommercial species of trees. Another drawback was the impossibility to harvest the sheltered trees without damaging the area's regeneration potential. To solve this problem, in 1969, the Royal Forest Department again revised the mangrove management plans. The silvicultural system applied was clear felling in alternate strips. Rotation was set at 30 years with a felling cycle of 15 years. This is practised by dividing the area into 15 coupes, each of which is further divided into 40 meter wide strips, forming an angle of 45° to the tide. Alternate strips are cut every 15 years, thus giving a rotation of 30 years. This silvicultural system shows promising results and is still used at the present time. The exploitation of mangrove forests is operated under concessions. The period of a concession is fixed by the issue of a long-term permit, lasting 15 years. This cutting system gives a higher yield. The regeneration within a clear-felled area has also improved because once the trees within the allotted strips are cut, the areas have to be promptly replanted. Under this silvicultural system, the mangrove forest can be managed on the basis of sustainable yield. The total managed mangrove forest is about 1,104,081 rai.

The cutting system for the private plantations is clear felling, with a 10 year rotation. The area cut each year is the same and, after cutting, the area should be promptly planted.

Wood and Charcoal Production

Estimates of wood and charcoal production from mangrove forests in Thailand are presented in Table 7.10. From 1965 to 1969, the total wood production from mangrove forest was a small amount, only about 123,574 m^3/yr due mainly to the small size of concessioned areas. The silvicultural system applied, shelterwood with minimum girth, also limited the number of trees to be cut each year. The intensive management of mangrove forests has been carried out since 1970 and the cutting system applied has been clear felling with alternative strips, as already mentioned. This cutting system gave high yields, because all trees within the strips were cut. During 1970-1986, the average wood production from consessioned areas was about 725,782 m^3/yr, with 54,000 m^3/yr from private plantations. Therefore, the total annual wood production in this period was about 779,782 m^3/yr. This amount of wood produces about 389,891 m^3 of charcoal (if 50 percent of wood is lost) (Kongsangchai, 1983) or 265,125.9 tons of charcoal at 680 kg/m^3 (Phuritat, 1975).

Assuming that the past production and cutting areas of concessioned areas (36,803 rai/yr.) and private plantations (20,597 rai/yr.) remain unchanged, with the same cutting systems, future annual wood production can then be estimated as shown in Table 7.10.

In 1987, the Royal Forest Department will begin to harvest the government plantations of 3,400 rai on a 10 year rotation. This area will produce about 10,200 m^3/yr. This indicates that, from 1987, the annual wood production will be approximately 789,982 m^3/yr - or 394,991 m^3/yr of charcoal.

Wood production will increase in 1997 when the government plantations covering another 3,000 rai have to be cut. This will produce about 38,400 m^3 (based on production of 12.8 m^3/rai) (Aksornkoae, 1975). So the total wood production in 1997 will be about 828,382 m^3.

Beginning in 1998, wood production will begin to increase at a considerable rate due to the production derived from the plantation of about 60,000 rai each year under the ADB project. The annual wood production from this area of plantation is estimated to be 768,000 m^3/yr. The total wood production, therefore, from 1998 will be about 1,557,982 m^3/yr. This amount of wood can potentially produce approximately 414,191 m^3 or 281,649.9 tons of charcoal each year (Table 7.10). It is believed that the increasing wood and charcoal production from mangroves will contribute significantly to total wood fuel consumption (about 85 million m^3) in Thailand by 2000 (FAO, 1972).

Fisheries Production Related to Mangrove Forests

Capture fisheries

The importance of mangrove forests for artisanal fisheries is widely recognized. People who live inside or close to mangrove forests have long known the value of mangroves for fishing. So far, no definitive data have been recorded on the total fish catch around the mangrove or estuarine areas. However, as mentioned earlier, mangrove forests serve as nursery and feeding grounds for many marine species of commercially importance.

Even though there are no conclusive data, it has been noticed that the total fish catch in many mangrove and estuarine areas is decreasing. Aksornkoae et al., (1984) reported that mangrove dwellers in Kor Lao and Had Sai Khao villages gave four main reasons for the decreasing marine species. Firstly, the mangrove forests have been severely cut for many years. Secondly, the number of immigrants has increased throughout the years. Thirdly, more efficient fishing gear is used, such as trawls and scissor or push nets. Lastly, the water in this estuary is being heavily polluted by tin mining activities nearby.

Table 7.10 Estimates of Present and Future Wood and Charcoal Production from Mangrove Forest in Thailand, 1965-2002

Year	Wood production, (m^3/yr)					Charcoal production	
	Consessioned[1] mangrove area	RFD[2] plantation	Private[3] plantation	Potential[4] plantation	Total	(m^3 /yr)[5]	(t/yr)[6]
1965-1969	123,574	-	-	-	123,574	61,787	42,015
1970-1986	725,782	-	54,000	-	779,782	389,891	265,125
1987	725,782	10,200	54,000	-	789,982	394,991	268,593
1988	725,782	10,200	54,000	-	789,982	394,991	268,593
1989	725,782	10,200	54,000	-	789,982	394,991	268,593
1990	725,782	10,200	54,000	-	789,982	394,991	268,593
1991	725,782	10,200	54,000	-	789,982	394,991	268,593
1992	725,782	10,200	54,000	-	789,982	394,991	268,593
1993	725,782	10,200	54,000	-	789,982	394,991	268,593
1994	725,782	10,200	54,000	-	789,982	394,991	268,593
1995	725,782	10,200	54,000	-	789,982	394,991	268,593
1996	725,782	10,200	54,000	-	789,982	394,991	268,593
1997	725,782	10,200	54,000	38,400	828,382	414,191	281,649
1998	725,782	10,200	54,000	768,000	1,557,982	778,991	529,713
1999	725,782	10,200	54,000	768,000	1,557,982	778,991	529,713
2000	725,782	10,200	54,000	768,000	1,557,982	778,991	529,713
2001	725,782	10,200	54,000	768,000	1,557,982	778,991	529,713
2002	725,782	10,200	54,000	768,000	1,557,982	778,991	529,713

Sources:
1. *Based on wood production, Royal Forest Department, 1985.*
2. *Based on mangrove plantation working plan, Royal Forest Department, 1986.*
3. *FAO, 1986.*
4. *Based on plantation productivity, Aksornkoae, 1975.*
5. *Based on 50% of wood production, Kongsangchai, 1983.*
6. *Based on 680 kg/m^3 of charcoal, Phuritat, 1975.*

Culture fisheries

At present, due to the loss of access to some 300,000 square miles of high seas fishery areas by the declaration of Exclusive Economic Zones by neighboring countries, and the declining production of offshore fisheries, the Department of Fisheries is attempting to develop coastal aquaculture to offset the loss of marine fisheries. The culture of shrimp, fish and molluscs are being promoted. (see more details in Chapter 8)

Shrimp culture, mainly of *Penaeus merguensis* and *P. monodon*, has been practised in Thailand for many years. Most of the shrimp culture area still uses traditional method, depending on the natural seed stock. But culture methods are evolving from traditional extensive to semi-intensive and intensive systems, utilizing modern facilities, equipment and management techniques. These aim to produce significantly higher yields per unit area. In 1982, there were 192,453 rai of culture area and production was about 10,090 tons (Table 7.6). It is estimated that additional potential areas of about 144,750 rai of coastal area including mangrove forests can be utilized for shrimp culture (Table 7.11).

Although there are quite large potential areas for shrimp culture, the Department of Fisheries aims to intensify existing pond culture rather than to replace mangroves with more ponds. The current traditional (non-intensive) methods will be changed to more semi-intensive and intensive culture. Today the shrimp hatcheries show promising results, but the shrimp seed is not yet enough to supply the increasing demand from shrimp farmers. These two methods will increase the present low average yield of shrimp up to 50 kg/rai/yr (semi-intensive) and 400 kg/rai/yr (intensive) (Varikul, 1985) which is much more than 40 kg/rai/yr produced by the present traditional (non-intensive) methods (Saraya, 1986).

The Department of Fisheries will also promote floating cage culture for fish, which has already proven viable. There are three main species for cage culture: *Lates calcarifer, Lutianus argentimaculatus* and *Epinephelus salmoides*. The suitable area for cage culture must have sufficient water depth to float the cage at low tide. It is estimated that the potential area for fish cage culture is above 100,000 rai in the Southern provinces (Brohmanonda, 1985). The production of *Lates calcarifer* or *Lutianus argentimaculatus* from a cage of 200 cubic meters (10 × 10 × 2) is about 800 kg/yr, while the production of *Epinephelus salmoides* may reach 700 kg/yr.

Molluscs represent another economically important target for culture in Thailand. Four species are currently cultured:

Table 7.11 Potential Areas for Aquaculture in Thailand, by Province
(rai)

Province	Shrimp	Green mussel	Horse mussel	Blood cockle	Oyster
Samut Prakan	1,000	-	-	-	-
Samut Sakhon	-	2,000	500	2,000	-
Samut Songkhram	3,000	4,000	-	3,300	-
Chachoengsao	3,000	5,000	3,000	1,200	-
Chonburi	2,000	2,000	2,000	500	1,000
Rayong	1,100	4,000	1,000	500	1,500
Chanthaburi	3,000	3,600	-	-	3,000
Trat	20,000	-	-	-	-
Phetchaburi	4,000	2,000	-	3,325	1,000
Prachuap Khiri Khan	8,000	4,000	500	1,000	2,000
Chumphon	10,000	3,800	1,000	1,250	940
Surat Thani	20,000	4,000	1,250	18,000	1,562
Nakhon Si Thammarat	30,000	6,250	1,875	14,200	1,875
Songkhla	1,500	1,000	-	-	550
Pattani	16,000	2,000	-	2,000	2,500
Narathiwat	1,150	-	-	-	3,125
Ranong	3,600	3,000	3,125	12,500	3,125
Phangnga	4,500	6,000	12,500	12,500	6,250
Krabi	2,200	3,000	1,000	4,700	1,256
Trang	6,500	2,500	-	6,600	3,125
Stun	4,000	3,000	1,000	6,250	3,125
Phuket	200	1,000	-	600	-
Total	**144,750**	**62,150**	**28,850**	**90,425**	**35,933**

Source: Brackish Water Fisheries Division, Department of Fisheries, 1983.

horse mussel, green mussel, blood cockle and oyster. In 1982, there were about 16,118 rai of culture area and 32,706 tons of production. The farming areas are scattered along the coastlines. In the future, the Department of Fisheries has a plan to extend the cultivated area of molluscs. It is estimated that an additional 217,358 rai of coastal areas could be utilized for mollusc culture (Table 7.11).

Conversion of Mangrove for other Purposes

Approximately 620,040 rai, or 30 percent, of Thailand's mangrove forests have already been destroyed by conversion to other uses during the past 25 years (Table 7.12).

The main conversions of mangrove forest have been to aquaculture, mining, salt pond construction and other activities, including agriculture, urbanization, industrial sites and harbors. Until 1986, the total aquacultural land in mangrove areas was about 237,459 rai, or 38.3 percent of the total conversion area, while mining, salt ponds and other uses covered a total area of about 34,066, 66,000 and 282,515 rai or 3.5 percent, 10.6 percent, and 45.6 percent, respectively (Table 7.12).

It is believed that in the future, the rate of conversion of mangrove areas for other uses, will decrease. One reason is that the government, through the Royal Forest Department and in cooperation with the National Research Council and the National Environment Board, is planning to establish mangrove land-use zones for development. The mangrove forest will be divided into three zones: preservation, conservation and development. Based on this land-use classification, only the development zone could be used for other activities. Details of mangrove land-use zoning will be discussed later in this Chapter.

7.3 LEGAL AND INSTITUTIONAL FRAMEWORK

Laws and regulations concerning mangrove resources management can be categorized into forest laws and regulations, mining regulations under the Department of Mineral Resources, and Cabinet decisions.

Forest Laws and Regulations

Laws and regulations affecting mangrove forests are: (1) Acts, namely, The Forest Acts and the National Forest Reserve Acts; (2) rules and regulations issued for special use of mangrove forests, as well as to facilitate the supervision and control of the use of mangrove forests by field officials; and (3) terms and conditions specified in the concession agreement.

Table 7.12 Conversion of Mangrove Areas for Other Land Uses

Land-use type	Area, (rai) Before 1980[1]	Between 1980-1986[2]	Total	Percent of mangrove area
Aquaculture	162,725	74,734	237,459	38.3
Mining	5,787	28,279	34,066	5.5
Salt ponds	66,000	-	66,000	10.6
Others	269,180	13,327	282,515	45.6
- Agriculture	-	4,386	-	-
- Urbanization	-	4,592	-	-
- Industrial sites	-	1,135	-	-
- Harbors	-	3,214	-	-
Total	**503,692**	**116,340**	**620,040**	**100.0**

Sources: 1. Klankamsorn and Charuppat, 1982.
2. National Forest Land Management Division, RFD, 1980 and Chantadisai and Apinan, 1985.

a) Forest Acts

Forest Act. This Act was established in 1941 and the latest revision was in 1975. It regulates the utilization of timber and forest products in the national forests. It provides guidelines for the Royal Forest Department in supervising the exploitation of the forest, as well as in supervising various activities concerning timber and forest products, from the time of harvesting to the sale of the final products. The main use of mangrove forests has been the harvesting of wood for charcoal production.

Under this Act, the royalty is 5 baht per cubic meter (m^3) of firewood. For charcoal, the rate is twice that for firewood. In practice, the operator who wishes to pay for firewood may not load his kiln before official assessment is made. Similarly, if he wishes to pay for charcoal, he may not unload his kiln before notifying the official for assessment of charcoal quantity.

The main products of mangrove are regarded by law as forest products. Therefore, mangrove products are controlled by this Forest Act. Gathering reserve forest products can be done only by permission and by payment of a royalty. Transportation of firewood or charcoal must be accompanied by transit papers and upon entering check point zones they must be submitted for inspection.

National Forest Reserve Acts. The National Forest Reserve Acts were enacted in 1964. All mangrove forests are declared reserve forests under this Act.

b) Rules and regulations

In mangrove forests there are two types of standards set by the Royal Forest Department: (1) standard procedures for field officials administering concessions; and (2) standard procedures for the use of mangrove forest for other purposes.

In administering mangrove concessions, Mangrove Management Units have been created to supervise the work of the concessionaire. There are 34 Mangrove Management Units all over the coastal provinces of the country.

The main functions of the Mangrove Management Units include: supervising logging in the concession area; measuring firewood for royalty assessment; controlling charcoal production by the concessionaire and measuring charcoal output for the issuance of a transit form; calculating annual yield and marking strips to be cleared and to be retained, proposing logging route and log pond siting; selecting the site for replanting; and estimating the cost of such planting.

There are two major uses of mangroves for other purposes, namely for mining and for shrimp culture farms.

Mining in mangrove forests. Most mangrove forests are in southern Thailand. This part of the country is rich in mineral resources. Tin ore deposits in mangrove areas are not uncommon. Since mining and forestry in mangrove areas are not mutually beneficial, arrangements have to be made so that both can benefit. Proper treatment of the area mined over could lead to successful restoration to mangrove cover. To safeguard both benefits, a series of conferences has been carried out between the RFD and Department of Mineral Resources (DMR), to establish standards of procedure for mining in mangrove areas.

The conference recommendations which have been accepted now as the standard procedure, are as follows: (1) In an area where mining is planned, the DMR must notify the RFD three months prior to the commencement of mining, so that logging can be completed before the area is mined over. (2) All timber logged out by concessionaire will belong to the concessionaire. Any trees left in the area, which the miners has to clear out, belong to the miners, since they have paid compensation to the RFD. (3) The RFD would permit the miner to mine in the concession area, as the operation is clearly beneficial to the state. (4) If DMR approves, prospecting for minerals can be carried out in the concession area if

it is considered that this does not result in damage to the mangroves. (5) Since many areas in the mangroves have been replanted, mining may occur in these areas. To safeguard the investment in replanting, it has been decided that if mining will be done in small areas within the replanted area, and the crop age is less than two years, then the miner has to provide compensation by paying the cost of such replanting. (6) If the crop age is over two years and the mining area is large, mining will have to wait until the logging of such timber has been completed.

Shrimp farms in mangrove forests. Individuals may apply for the use of mangrove forests as shrimp culture farms, which are being promoted by the government. If any individual project has been approved by the Fishery Department, the RFD will provide the requested land. If the land in question is in the National Forest Reserve, then the shrimp farmer has to pay a user's fee at the rate of 100 baht per rai. If the area is not reserved, only the fee for the permit to clear forest land under Forest Act (five baht per permit) and royalty for reserve trees taken out, if any, according to quantity and species as specified in the Royal Decree, are charged.

Mining Regulations under the Department of Mineral Resources

Several regulations on mining have been issued by the Department of Mineral Resources. The regulations that concern mining in mangrove areas are as follows:

(1) An individual may apply for a mineral prospecting license to the local Mineral Resource Office. The license will be valid for one year starting from the date issued.

(2) Each application for a mineral prospecting license must cover an area of not more than 2 500 rai. For marine mineral prospecting licenses, an area of not more than 500,000 rai may be permitted by the Minister or a person empowered by the Minister.

(3) An individual awarded a license for mineral prospecting must start the work within 60 days, and the results should be submitted to the authorities within 180 days from the date of the award.

(4) Mining concessions can be applied for at the local Mineral Resource Office, together with mineral prospecting evidences. Each application for a concession must cover an area of not more than 300 rai, and for marine mining, 50,000 rai.

(5) Mining concessions will expire 25 years after the date of issue.

(6) The applicant must submit his work plan to the local Mineral Resource Office.

(7) In mining operations, every mine must provide a sediment pond to keep the sediments until not more than six grams per liter of suspended solids is left. It can then be discharged into the public water resource.

Cabinet Decisions

There are two relevant Cabinet decisions concerning the utilization of mangroves.

The Cabinet decision of 27 June 1978 specified that: (1) Permission to build fishing ship landing ports or permission for other development activities in the future should consider the minimal area that could be used for such development activities. In addition, the area for road construction in mangrove areas will be limited as much as possible. (2) The regulations should not permit the construction of industrial sites or the development of the community in any mangrove area. (3) Any development project designed to use or modify mangrove resources should include representatives of the National Committee on Mangrove Resources and the Office of National Environment Board on the project team.

The Cabinet decision of 19 August 1980 specified the following: (1) Before project implementation, mangrove areas have to be investigated by aerial photography. (2) The status of mangroves will not be revoked but certain areas can be selected and permitted for implementation of the project. (3) Any land occupation certificates or land titles must not be issued to settlers in mangrove areas. (4) The project owners must make an impact assessment upon the mangrove as instructed by the National Committee on Mangrove Resources and the Office of the National Environment Board.

Institutional and Administrative Framework

Mangrove forests, like other types of forest, belong to the government. The management of mangrove forests is controlled by the Royal Forest Department under the Ministry of Agriculture and Cooperatives. Territorial administration is the responsibility of the Regional Forest Office and the Provincial Forest Office. Mangrove Management Units as referred to earlier are established under the Regional Forest Office.

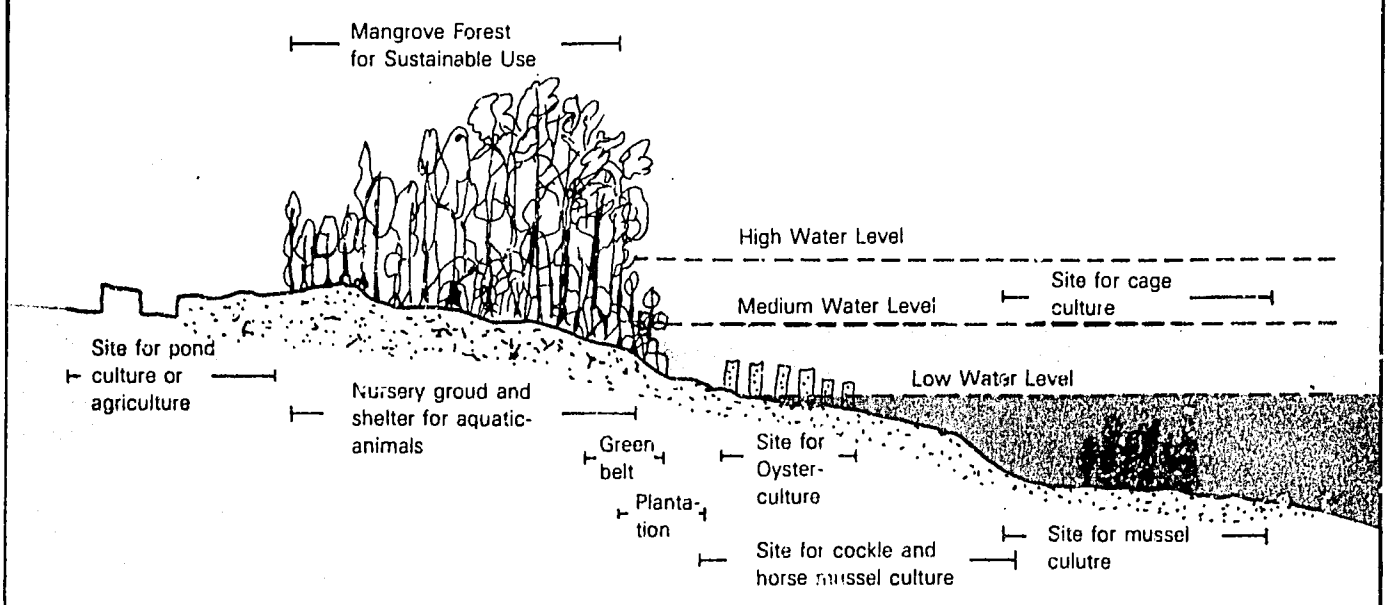
7.4 KEY ISSUES

Solution to Conflicting Mangrove Land Uses

The most effective step towards resolving the conflicts of mangrove land use is the classification of mangrove land use zones.

For management purposes, mangroves may be divided into three zones: the preservation zone, the conservation zone and the development zone. The *preservation zone* mainly covers areas of undisturbed mangrove forest, especially along the banks of rivers, estuaries, coastlines and around islands. This area is important in terms of ecology, supporting and

Figure 7.4 Multiple-use Management of Coastal Area



maintaining the life of both plants and marine animals. The area will be used as a green belt to protect shorelines as well as prevent soil erosion. The preservation zone also includes an area which can be used for scientific research, education, wildlife and national parks. The *conservation zone* covers an area of managed mangrove forest and plantations. This area will be utilized for sustained yields; by means of the careful management of forest production. The development zone mainly covers denuded and unproductive areas. This area would provide for the development of other uses, such as aquaculture, agriculture, salt pans and urbanization.

This zoning approach is now gradually being introduced by the National Environment Board and the Royal Forest Department.

Multiple-use Management System

The use of mangrove areas should emphasize multiple sustainable use, rather than conversion for a single, exclusive use.

Figure 7.4 illustrates the guidelines for multiple-use management of coastal areas for forestry, fisheries and others. In this system the subtidal zone will be used for mollusc culture and pen culture, the lowest intertidal zone for mollusc culture, and the remaining intertidal zone for mangrove.

It is possible, indeed desirable, to combine mangrove plantations with aqua culture (fish or shrimp farms). This system, so-called Tumpang Sari or silvo-fishery system, has been adopted in Indonesia for many years and the system shows promising results. The silvo-fishery system should be applied to avoid the clearing of mangrove forest solely for aquaculture purposes. The system specifies that the fish or shrimp ponds will be constructed surrounding mangrove areas by digging a small canal about 5 meters in width and 1.5 meters in depth. The ditch area for raising fish or shrimp is approximately 20 percent of the total area. The optimal size for such joint operations is about 10 to 20 rai. The coexistence between mangrove and shrimp farm can thus be materialized.

Promotion of Research, Training and Education

Scientific understanding of the mangrove ecosystem and its interaction with the terrestrial and marine environment is essential for the development of national policies for conservation and optimum use of mangrove resources. More relevant research, both basic and applied, is needed. The government should allocate more funds for research projects on mangroves. National and international research collaboration should be stressed.

The government should be alerted to the need for increased numbers of ecological scientists with skills and experiences appropriate to mangrove management. Efforts should be made at the national level to inform policy makers, planners, mangrove managers, mangrove resource users, and the local population living in the mangrove areas or dependent upon mangrove resources, about the widespread economic and ecological functions of mangroves and the negative results of mismanagement. Courses at the university and pre-university levels on the ecological and economic value of mangrove ecosystems should be encouraged.

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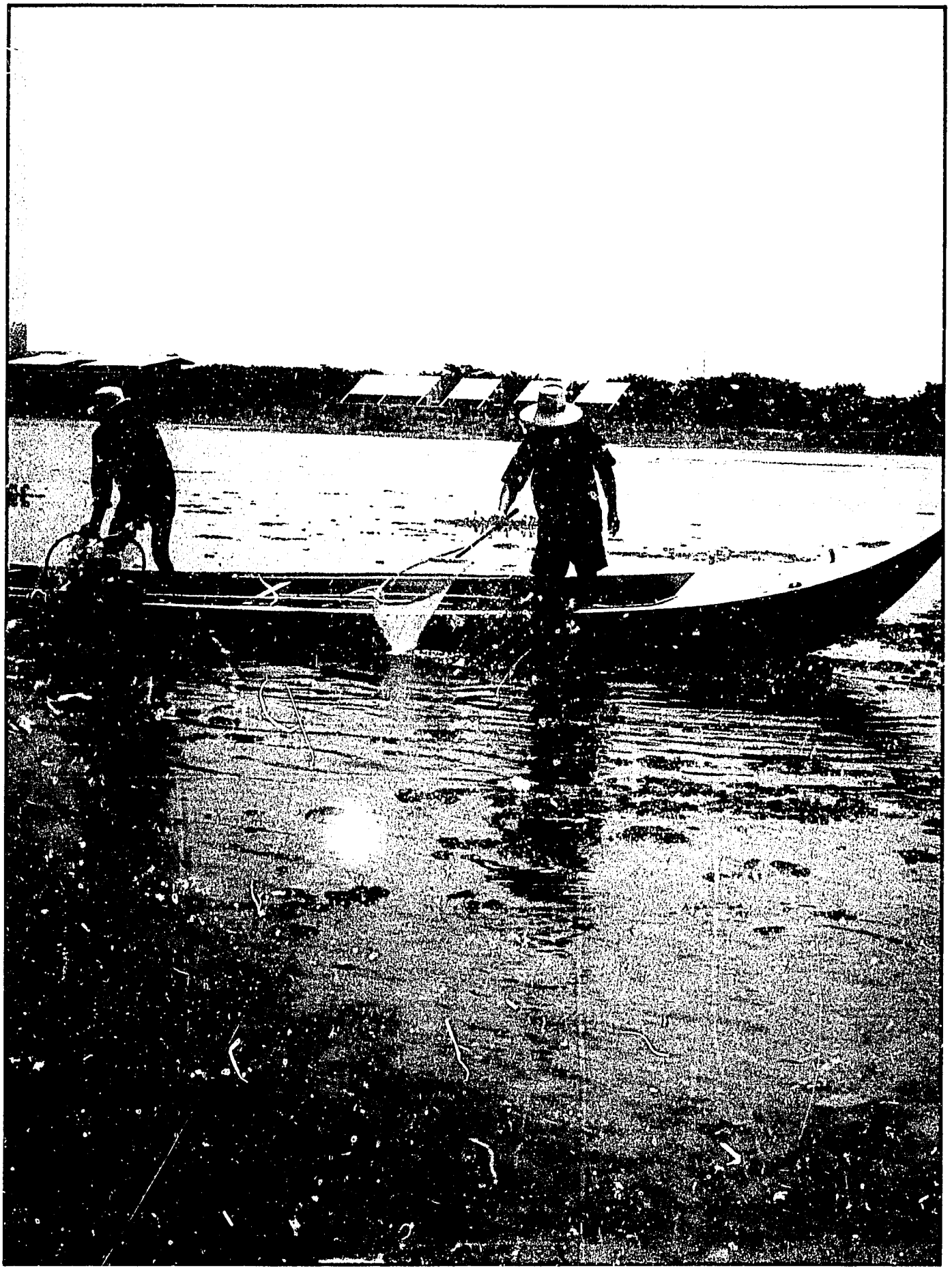


8 Fishery Resources

8.1 OVERVIEW

Thailand has a total land area of 513,115 km^2, with 2,614 kilometers of coastline and 3,750 km^2 of inland water area. In 1983, approximately 280,000 persons were engaged in primary employment in the fishery sector (ADB, 1985), and approximately 90,000 persons were full- time fishermen.

Fisheries represent one of Thailand's important activities, contributing about 2 to 3 percent to the Gross National Product (GNP) annually and accounting for about 11 percent of agricultural GNP. Fishery production is around 2 million tons per annum. In 1983, total production was 2.26 million tons, valued at 19.2 billion baht (US$ 916.1 million) which is the highest figure in the five-year period from 1979 to 1983. Thailand's marine fishery production accounts for approximately 90 percent of the total. Exports to other countries in Asia, Europe, and North America are significant. By exporting fishery commodities, Thailand earned foreign exchange worth 11.6 billion baht (US$ 551.1 million) and there is considerable potential for increasing exports, particularly from the aquacultural sector.

Fishery products constitute an important source of protein in the diet of the Thai people, as reflected by the average annual per capita consumption of approximately 22.5 kg.

General Characteristics of Aquatic Environment

Inland water

The chief river of Thailand is the Chao Phraya. It serves as a main source of water supply and as a large inland waterway. Bangkok is situated on its tidal reach, about 50 kilometers from the river mouth. The river occupies as much as 177,000 km^2 of drainage basin, covering 31 percent of the country, and carries an average annual peak flow of nearly 4,000 m^3/sec, handling about 31,000 million m^3 of runoff yearly. Its tributaries have their sources in the mountainous region in the north. Other important rivers in the central region are the Maeklong, Thachin, and Bang Prakong.

In the northeastern region, the Maekhong is the most important river. This river has a very large catchment area covering four countries in Southeast Asia. A part of this river is used as a border between Thailand and Laos. Mun and Chi are the two important tributaries of Maekhong.

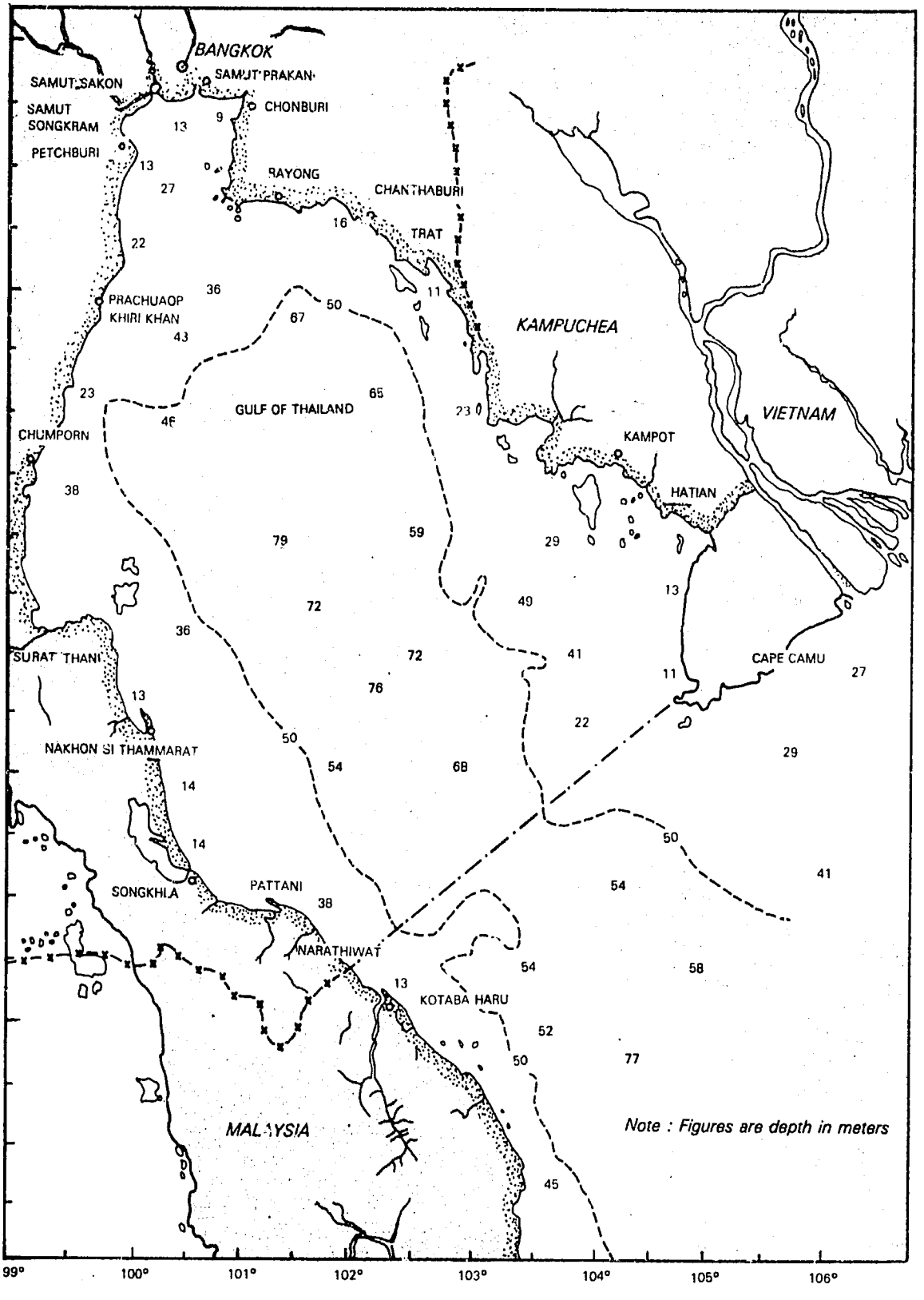
Thailand also possesses a large number of natural and manmade reservoirs. The largest natural reservoir is Songkhla Lake, situated in the south. This reservoir has a surface area of 1,400 km^2. It is relatively shallow, with an average depth of 1.5 meters. The reservoir is connected to the sea and is therefore partly brackish.

Marine environment

Thailand has two coasts. One curves around the scooped out shore of the Gulf of Thailand and has a length of 1,870 kilometers. The other lines the shore of the Andaman Sea of the Indian Ocean and has a length of 800 kilometers extending northwards from the Malaysian border to the Burmese border.

The Gulf of Thailand (Figure 8.1) extends northwest from the southern part of the South China Sea. It is approximately 835 kilometers long on its northwest axis. The maximum

Figure 8.1 The Gulf of Thailand Showing 50 Meter Depth Contour



width is approximately 555 kilometers. The mouth of the Gulf, as indicated by the dotted line, is about 370 kilometers. The Gulf of Thailand covers an area of approximately 350,000 km^2.

Being a part of the Sunda Shelf, the Gulf is relatively shallow, with a mean depth of approximately 45 meters and a maximum depth of approximately 80 meters. The deepest part is located in a central basin between latitude 9°N and longitude 101° and 102°E. This deep basin extends northward to the vicinity of Ko Chuang off Sattahip, Rayong province, and is separated from the South China Sea by two ridges. One of these ridges extends southwest from Cape Camau at various depths of less than 25 meters for more than 110 kilometers and the other extends northeast off the Thai-Malaysian border for a distance of 167 kilometers at various depths of less than 50 meters. Between these two ridges, there exists a deep channel with a sill depth of 67 meters (Robinson, 1974).

Another general characteristic of the Gulf, which is typical of the Sunda Shelf, is the lack of an extensive distribution of coral reefs like those in Philippine waters. The corals that exist are located around some small islands in the Gulf, usually far from the coasts.

The Gulf of Thailand is an integral part of the Asian Continent. The sediments deposited on the bottom of the shelf are largely muddy, with sandy components brought in during the Pleistocene. Studies of the sediments at different parts of the Gulf during a series of exploratory trawling and resources surveys carried out by the Department of Fisheries revealed that the bottom was covered with ooze, or mud mixed with sand or shells (Pasuk, 1969; Ritraksa, Thamaniyom and Sittichaikasem, 1968). The bottom of the inner Gulf, into which four rivers drain a considerable amount of sediment annually, is covered with loose mud. In the central basin, where the sediments are deposited, the bottom is again covered with soft mud.

Robinson (1974), in summarizing the results or the NAGA Expedition, concluded that the Gulf is a two-layered shallow water estuary. This means that low salinity water which has been diluted by rainfall and freshwater runoff flows out of the Gulf at the surface, while high salinity and relatively cooler water from the South China Sea flows into the Gulf over the 67-meter sill at the mouth of the Gulf. Various forces arising from monsoon winds, heavy precipitation and tidal currents create complex circulation in the Gulf. There exists localized areas of divergence of upwelling, downwelling or convergence of waters.

Robinson further observed that the general circulation and physical properties of the water all varied to some extent both during seasonal periods and also during short periods, and that the monsoon winds play a major role influencing the circulation in the Gulf of Thailand. In the inner Gulf area where four major rivers drain, there is a rapid confluence of river and Gulf waters.

The southwest monsoon, starting in March or April, is usually well established in May and ends in September. This wind, after having blown across the Indian Ocean and the Bay of Bengal, brings rainfall to Thailand, Kampuchea and Vietnam between July and October. October is the lull between the southwest and the northeast monsoons. From November to February, the northeast monsoon winds, after having blown across the continent, bring low-moisture, cool air to Thailand and over the Gulf. March and April are the inter-monsoon months.

In general, surface salinities in the Gulf are between 30.5 and 33 parts per thousand (ppt). Salinities at the deepest part of the central basin, where South China Sea water flows in, are higher ranging, i.e., between 33 and 34 ppt or above. Low oxygen concentrations (less than 2.5 mg/1) and high salinity of surface water in certain areas indicate localized areas of divergence or upwelling. Likewise, high oxygen concentrations and low salinity found at lower depths indicate localized areas of convergence or downwelling.

From a study of horizontal charts of temperature, salinity and sigma-t, it was concluded that in October the surface water flowed into the Gulf in a counter-clockwise direction, i.e., inflow along the east coast and outflow along the west coast of the Gulf; while at the central part, there was sluggish circulation. During the peak of the northeast monsoon, water of low temperature and high salinity moved into the Gulf around Cape Camau, but did not penetrate deep into the Gulf; instead, the water flowed out of the Gulf, slightly west of its mouth. During the peak of the southwest monsoon (August), there was a strong flow into the Gulf along the east coast on the surface and at 30 meters, and a strong northward flow along the west coast. The survey carried out during 1970 and 1971 by H.T.M.S. Chanthara of the Hydrographic Office of the Royal Thai Navy indicated that there was an intrusion of water mass from the South China Sea along the western coast of the Gulf and an outflow of less saline, but cooler, water along the eastern coast of the Gulf (Pongsapipatt and Sapsomwong, 1973).

Concerning the inner Gulf of Thailand (Bight of Bangkok), Hongskul, et al., (1979) summarized the results of a series of investigations carried out by the Department of Fisheries as follows. The circulation in the inner Gulf was influenced more or less by tidal currents and the circulation of surface water was clockwise in direction at the beginning and at the end of the year (during the northeast monsoon period) and counter-clockwise in the middle of the year (southwest monsoon period). The average surface salinity was 27.1 to 29.8 ppt. In estuaries, during the peak of freshwater runoff (November to December), the salinity was quite low. Oxygen concentration at the surface was more than 4 mg/1 but at the bottom it was very low, being 2.9 mg/1 or less. The concentration of phosphate varied from 0.1 to 0.9 µg-at P/1 and of nitrite from 0.05 to 0.1 µg-at N/1. The increasing trend of biochemical oxygen demand (BOD) in this area indicated that the water quality was becoming increasingly poor.

The amount of plankton, ranging from 200 to 1,000 ml/1,000 m^3, indicated that the inner Gulf of Thailand is one of the most productive areas of the world. The peak of the abundance of plankton was found to be in December. High plankton concentration areas are located in the inner Gulf of Thailand, at the estuaries of the four rivers and along the upper west coast of the Gulf. Along the west coast of the Gulf,

plankton was most abundant during March to August. Hence, off the west coast several species of fish spawn, and their larvae and young feed in this area until October, when they move to a new feeding ground in the inner Gulf of Thailand.

The upwellings off the west coast, especially in the Gulf waters off Prachuab Khiri Khan and Chumphon provinces, have a very beneficial effect on fishery resources, because of the resulting high levels of nutrients in the area. The Department of Fisheries found that this area is the spawning area and larval rearing area of pla tu, or the Indo Pacific mackerel *(Rastrelliger neglectus)*, a staple item in the Thai diet.

The high productivity of the inner Gulf of Thailand was also revealed by a study on the primary production of the waters there. Luasinsap (1979) reported that the average primary production rate of sampled waters in the inner Gulf was 3.51 g-C/m^2/day in 1978 and 3.45 g-C/m^2/day in 1979.

Fishery Resources

Fishery resources comprise all aquatic species which can be utilized by man. They include fish (the most important group), shrimp, crabs, clams, and aquatic plants such as seaweed. Fishery resources can be divided into three groups; i.e., freshwater fishery resources, brackish water fishery resources, and marine fishery resources.

Freshwater fishery resources

Freshwater fishery resources are found in streams, canals, rivers, marshes, swamps, lakes, and manmade ponds. The level of species diversity and standing crop depends on the location and fertility of the area.

The species of fish found in fast running waters (streams and small rivers) are different from those found in large rivers and lakes. These species usually develop organs enabling them to attach to stream floors or rocks. They are also fast swimming and prefer cool, constant temperatures. These species are for instance pla ekud *(Gyrinocheila aymonieri)*, pla learhin *(Garataeniata)* and pla kodkae *(Glyptothorax spp.)*. Fishes found in mature rivers are not necessarily fast swimming, but they have to be able to adjust themselves to turbid water and fluctuating water temperatures. These fishes include pla tapean *(Puntius* spp.), pla sawai *(Pangasius* spp.) and the giant prawn *(Macrobrachium rosenbergii)*.

The factors which govern species diversity and abundance in the fish populations of running water are: (1) temperature; (2) current velocity; (3) discharge; (4) dissolved oxygen; (5) nutrients and salt concentration; (6) dimension of river floor; (7) turbidity; (8) natural food; and (9) predators.

Within closed water bodies such as marshes, swamps, lakes, manmade ponds, and manmade reservoirs, the common wild fish species include snake-head *(Ophicephalus* spp.), walking perch *(Anabas testudineus)*, snakeskin gouramy *(Trichogaster pectoralis)*, pla slad *(Notopterus notopterus)*, and marble goby *(Oxyleotris marmoratus)*. These species are usually slow moving and can tolerate low oxygen levels in water. The standing crop of fish depends on the availability of nutrients.

Brackish water fishery resources

The brackish water fishery resources include aquatic species existing in estuaries, mangrove areas, and mud flats. These areas are subjected to tidal currents and freshwater runoff from land. Hence water salinity varies from 3 to 28 ppt.

There is a number of economically important species in brackish water areas, such as cockle *(Anadara granosa)*, oysters *(Ostrea* spp., *Crassostrea* spp.), mud crab *(Scylla serata)*, marine shrimps *(Penaeus* spp.), and white sea bass *(Lates calcarifers)*.

Fishermen usually use stationary fishing gear in brackish water areas. Aquaculture is becoming increasingly popular, especially in the coastal areas of the Gulf, including areas of Samut Sakon, Samut Songkhram, Samut Prakan, Chachoengsao, Chanthaburi, Songkhla, Surat Thani, and Phangnga provinces.

Marine fishery resources

Owing to the unique topography and general oceanographic characters of the Gulf of Thailand and the Andaman coastal sea, these marine areas are abundant in living resources, which are typical of the Indo-Pacific fauna and flora.

a) Marine flora

The marine flora referred to in this study are seaweed and marine algae. Marine algae play an important role in the productivity of the Gulf. Some types serve as food for other marine organisms, while others are utilized by man as food or for industrial products.

Generally, seaweed resources in tropical waters are low. In Thailand, the most economically important species is *Gracilaria confervoides*, a red algae which can be used in the production of paste for textiles and agar. This seaweed occurs in shallow bays such as Songkhla Lake. In 1983, Thailand exported 60 tons of seaweed, valued at 20.1 million baht. In the same year, Thailand imported 327 tons of seaweed products, mostly agar from Japan, valued at 104.4 million baht (Department of Fisheries, 1985).

b) Sponges

These are plantlike animals belonging to Phylum Porifera. Only one genus, *Euspongia*, is listed by Suvatti (1950). Samples of sea sponges may be collected from Ko Pangan and Ko Samui on the west coast and off Trat Province on the east coast of the Gulf of Thailand.

c) Corals and jelly fish

These two groups of animals belong to Phylum Coelenterata. Suvatti (1950) reported that there were 8 families, 16 genera

and 21 species of these organisms in Thai waters.

Recent taxonomic studies made by the Phuket Marine Biological Center revealed that there were more than 200 species of corals in Thai waters.

Coral reefs are considered economically important because they provide sanctuary and feeding grounds for animals of higher orders, such as fish which can sustain small-scale fisheries. They play a vital role in supporting the productivity of the waters and in stabilizing the ecological balance. Furthermore, they are attractive to tourists. In the Gulf of Thailand, Ang Tong Archipelago and Ko Tao in Chumphon Province have been declared as Marine National Parks. The Phuket Marine Biological Center (PMBC.) has identified 183 species of corals found along the west coast of Peninsular Thailand (Menasveta, 1980). Besides, extensive studies on the coral reef ecology were carried out by Sichang Marine Science Research and Training Station, Chulalongkorn University.

As regards the jelly fish, we still have a very limited knowledge of its taxonomy, biology, life history and distribution. Among the jelly fish species, *Stomolphus* spp. and *Rhopilema esculenta,* both large size jelly fish, and their kindred species are economically important (Omori, 1978). According to the fishery statistics of the Department of Fisheries, (1977), Thailand harvested 2,353 tons of jelly fish valued at 500,000 baht in 1974. The production of jelly fish increased steadily since that year and reached 180,281 tons in 1983 valued at 65.4 million baht (DOF, 1985).

d) Sea urchins and sea cucumbers

These animals belong to Phylum Echinodermata. They are latent resources, which can be developed in the future.

Among the sea urchins, *Diadema setosum* Leske is the most important in Thailand. The gonads of the sea urchin, considered to be a delicacy, can be exported to Japan for a high price. It is believed that the maturity of the gonads of Thai sea urchins varies by season and locality. Therefore, studies should be carried out to assess the potential of these resources for future fishery development (Shindo, 1977).

Sea cucumbers, or beche-de-mer, are esteemed by Asians or Westerners alike. The most economically important species is *Stichopus* spp., which is 20 to 40 centimeters in length, 5 centimeters in width and has blue-black skin when dried. This species can be exported to Japan.

e) Molluscs

Molluscs belong to a polymorphous phylum called Mollusca. This constitutes the second largest phylum among invertebrates with more than 80,000 species known to exist in the world (Abbott and Zim, 1962). This phylum was traditionally divided into (1) Amphineura (chitons) (2) Scaphopoda (tusk shells); (3) Gastropoda (monovalves); (4) Pelecypoda (bivalves) and (5) Cephalopoda (squids and cuttlefish). In Thai waters, Suvatti (1950) listed 102 families, 205 genera and 578 species of molluscs, which include freshwater and land molluscs.

f) Chitin and tusk shells

As for Amphineura and Scaphopoda, only one species each was recorded by Suvatti as occurring in the Gulf of Thailand. These were Lin Thale *(Chiton* spp.) and Hoi-nga Chang *(Dentalium* spp.).

g) Monovalves and bivalves

Chaithiemwongse (1979) reported on the collection of monovalves and bivalves found in Thai waters which is kept at the Marine Fisheries Division, Department of Fisheries. This collection consists of 44 families and 192 species of monovalves and 24 families and 120 species of bivalves.

The bivalves used as food and harvested in substantial quantities in the Gulf of Thailand are:

(1)	Mussel :	*Mytilus viridis* (Hoi malang pu) *Modiolus senhauseni* (Hoi kapong)
(2)	Cockle or arkshell :	*Anadara granosa* (L). (Hoi krang)
(3)	Baby clam :	*Paphia undulata* (Born) (Hoi lai)
(4)	Hard clam :	*Meretrix mertrix* (L) or *Meretrix lyrata* (Sowerby)
(5)	Oyster :	*Crassostrea commercialis* (Hoi nangrom) *Crassostrea belcheri* (Hoi takrom) *Crassostrea lugubris* (Hoi takrom)

Bivalves that are used for ornamental and decorative purposes include the window pane shell (*Placuna* spp.), mother-of-pearl (*Maxima pinctada*) and giant clam (*Tridancna* spp.).

Bivalve production in Thailand was approximately 115,582 tons in 1983 or 5.5 percent of the total marine production of the country. The production of bivalves can be increased substantially if new technology and techniques are employed in culturing them.

h) Cephalopods

The cephalopods consist of octopus, squid, cuttlefish and chambered nautilus. According to Sithikorakul (1978), 24 species of cephalopods were found in the Gulf of Thailand. Commercially important squid and cuttlefish include: *Loligo fomosana, L. duvaucellii, Sepioteutis lessonniana, L. tagoi, Sipia aculeata, S. pharaonis, S. Lucidas, S. recurvirostra, S. brevimana,* and *Sepiella inermis.*

With the development of Thailand's trawl fishery, the catch of "pla muk" has steadily increased. Production reached 132,044 tons in 1983, valued at 2,687 million baht. Squid and cuttlefish resources also support small-scale and inshore fisheries employing small types of fishing gear such as lift nets or push nets. About two-thirds of the catch is generally composed of squid, the rest being cuttlefish (Menasveta, 1986).

Crustaceans

These animals belong to a very extensive phylum, Arthropoda, which includes a multitude of species of insects, shrimps, crabs, sand bugs and water lice. Crustaceans include crabs, mantis shrimps and horse shoe crabs. The taxonomic study of crustaceans in Thai waters was started around 1899, when a Danish expedition was carried out. Subsequent studies were conducted by T. H. Annandale (1904-1924), H. M. Smith (1923-1935), and Serene and Banner (1940-1960). The Marine Fisheries Laboratory has also undertaken taxonomic studies on commercially important crustaceans. As far as fishery resources are concerned, only shrimps and crabs are of economic importance. Therefore, in this report only mysids, shrimps and crabs will be described.

a) Mysids and acetes

These organisms are small-sized shrimp and shrimp-like animals, sometimes considered as zooplankton. They are collectively referred to in Thai as "kuey". The Fisheries Record of Thailand lists these groups of animals as Acetes. Actually mysids are Malacostracans, shrimp-like organisms, while Acetes are Macrurans, true shrimps. Suvatti (1950) recorded two species of mysids (Family Mysidae) and five species of *Acetes* (Family Sergestidae), known to occur in the Gulf of Thailand.

Mysids and *Acetes* are used for high quality shrimp paste in Thailand, Kampuchea and Vietnam. These organisms live in the inshore waters along the Gulf of Thailand, particularly in bays and estuaries and are caught mainly by small-scale fishermen, employing beach seines, lift nets, baby trawls and push nets.

b) Shrimps or prawns

Among the Macrurans (or true shrimps or prawns), three families are of commercial importance, namely: Penaeidae, Palaemonidae and Palinuridae, of which Penaeidae is the most important family in terms of production and value.

In the reference collection maintained at the Marine Fisheries Laboratory, Marine Fisheries Division, there are 45 species of penaeid prawns (Chithiemwongse, 1975). Ten economically important species of penaeid prawns are listed in Table 8.1.

In 1963, the production of shrimps and prawns amounted to 23,300 tons. They were caught mainly by traditional gear such as push nets, shrimp gill nets, set bag nets, stake traps and lift nets. Since the introduction of trawl-net fishing in Thailand in 1962 and the rapid development of this fishery thereafter, production of shrimps has risen steadily with a total of 139,134 tons produced in 1983.

c) Crabs

There are numerous species of crabs found in Thailand, including freshwater, marine and terrestrial species. Many of them are inedible. Tathbun (1909) recorded 204 species of crabs found in the Gulf of Thailand during the Danish expedition. Suvatti listed 15 families, 99 genera and 227 species of crabs known to occur in Thailand. Tiensongrasmee (1972) subsequently listed 108 genera of crabs with more than 265 species found in Thailand. Among them, the majority of crabs which are edible belong to family Portunidae and are known as swimming crabs.

In Thailand, crab production consists mainly of "pu ma" *(Portunus pelagicua* (L)) and "pu lai" *(Charybdis cruciata)* (Herbst), which account for approximately 80 percent of the total crab landings annually. The rest is composed mainly of "pu thale" *(Scylla serata)* and a few other portunids, such as *P. gracilimanus* (Stimson) and *P. sanunolentus* (Herbst). The volume and value of crab landings from 1980 to 1983, which show a decreasing trend of production, are given below (DOF, 1985):

Year	Quantity (tons)	Value (million baht)
1980	33,929	438.9
1981	33,112	480.4
1982	29,891	539.0
1983	28,563	546.0

Fishes

Among the vertebrates, fishes have the highest number of species, amounting to approximately 20,000 or about 48

Table 8.1 Penaeid Prawns of Commercial Importance

Thai Name	English Name	Scientific Name
Kung chair buay	White shrimp	*Penaeus merguensis* de Man
Kung chair buay	White shrimp	*Penaeus idicus* H. Milne-Edwards
Kung kula dum	Jumbo Tiger shrimp	*Penaeus monodon* Fabricius
Kung kula lai	Tiger shrimp	*P. semisalcatus* de Haan
Kung lueng hang fa	Yellow shrimp	*P. latisulcatus* (Kishinouye)
Kung lueng	Yellow shrimp	*P. longistylus* Kubo
Kung lai sue	Tiger shrimp	*P. japonicus* Bate
Kung takard kree jud	Pink shrimp	*Metapenaeus ensis* (de Haan)
Kung takard	Pink shrimp	*M. mutatus* (Lanchestor)
Kung takard kree dum	Pink shrimp	*M. intermedius* (Kishinouye)

Source: Department of Fisheries, Division of Marine Fisheries, Invertebrate Fisheries Investigation Unit, 1979.

percent of the total number of vertebrates in the world. FAO (1974) listed more than 800 species of bony fishes (Teleosts) in the Western Pacific, which includes the Gulf of Thailand. In the compilation of *Fauna of Thailand*, Suvatti (1950) listed 1,056 species of freshwater and marine fishes. These fishes belong to the Indo-Australian archipelago fauna.

In the Gulf of Thailand, the marine fish fauna is relatively rich. Banasopit and Wongratana (1967) reported that in the reference collection maintained at the Marine Fisheries Laboratory, Marine Fisheries Division, there were 124 families, 289 genera and 574 species. Subsequent studies by taxonomists at the Laboratory (Wongratana and Sukhavisidh, 1979) have added approximately 280 species to the list, thus making a total of more than 850 species known to occur in the Gulf of Thailand.

Taxonomically, the living fishes may be divided into two major groups, namely, the shark-like fishes (Chondrichthyes) which possess a cartilaginous skeleton, among other distinct characteristics, and the higher bony fishes (Osteichthyes) of which teleosts are a major component. However, in considering the economic role of fisheries, they may be divided into groups according to their habitats, namely: marine, freshwater, brackish water, and migratory. The marine fishes may further be divided into two broad categories; i.e., pelagic and demersal fishes.

a) Pelagic fish resources

Among the pelagic fish resources, the following species or groups of species are caught in substantial quantities. "pla tu", "pla lung" *(Rastrelliger* spp.), "pla tu kak" *(Decapterus* spp.), "pla insee" *(Scomberomours* spp.), "pla mali" or "sai ton" *(Stolephorus* spp.), "pla lung keo" or "ok lae" *(Sardinella* spp.) and "pla o" (tunas).

Three species of mackerel *(Rastrelliger* spp.) are caught in the Gulf of Thailand, namely: "pla tu" *(R. brachysoma)*, "pla lung" *(R. kanagurta)*, and "pla tu pak ching chok" *(R. faughni)*. "pla tu" or Indo-Pacific mackerel is a coastal species, while the Indian mackerel, "pla lung" and "pla tu pak ching chok" are offshore species (Menasveta, 1980).

Scad *(Decapterus* spp.) fishery has been developed during the past decade in the offshore waters of the Gulf of Thailand. There are four species caught, namely, *D. Macrosoma, D. russeli, D. maruadsi* and *D. pinnulatus* or *D. maruadsi*. Flatbody scad is dominant in the *Decaoterus* catch from the Gulf of Thailand and round scad *(D. macrosoma)* is dominant in the Andaman Sea catch (Menasveta, 1980).

There are three species of Spanish mackerel: *(Scomberomorus* spp.) caught in the Gulf; i.e. "pla insee-bung" *(S. commersoni)*, "pla insee jud" *(S. guttatus)* and "pla insee kow tok" *(S. lineolatus)* of which *S. commersoni* is the most common, constituting about 80 percent of the Spanish mackered catch. These mackerels inhabit the offshore waters of the Gulf (Menasveta, 1980).

Among the anchovy *(Stolephorus* spp.) caught, ten species are commonly found, and *S. heterolobus* is the most common, accounting for 86 8 percent of the total anchovy catch (Taweesit, 1979). These fish live in the inshore waters of the Gulf of Thailand.

As regards sardine *(Sardinella* spp.) resources, eight species are commonly landed, with *S. gibbosa* being the dominant species, accounting for 93 percent of the total sardine catch (Chulasorn, 1979). These fish inhabit the coastal waters of the Gulf.

Three species of tunas are commonly caught in the Gulf namely: longtail tuna *(Thunnus tonggol)* — in Thai, "pla dum" or "pla mhor" ; little tuna *(Euthynnus affinis)* — in Thai, "pla lai"; and frigate mackerel *(Auxis thazard)* — in Thai, "pla lai" or "pla gluey". These are also coastal species of tunas (Menasveta, 1980).

There has been a trend of increasing catches of pelagic fish in general with the production of 512,603 tons in 1983, valued at 3.9 billion baht (Department of Fisheries, 1985).

b) Demersal fish resources

A large quantity of the so-called demersal fish resources is caught by bottom trawl nets. Several species inhabiting coral reefs are also considered as demersal and are usually caught by trap and bottom long line. Many demersal species, being small in size, are included in the so-called 'trash fish' category and are reduced to fish meal or are used as duck, poultry or freshwater fish feed. In the trawl fishery of the Gulf of Thailand, trash fish, including juveniles of several commercially important species, constitute at present more than 40 percent of the total demersal landing (Menasveta, 1980).

In the Gulf of Thailand and the Andaman coastal sea, approximately 30 families comprising more than 300 species of demersal fish of economic value have been identified (Wongratana, 1968). However, the most common groups of demersal fish of economic value in the Gulf include the following species or groups of species: *Lutianus* spp., *Epinephelus* spp., *Nemipterus* spp., *Scolopsis* spp., *Saurida, Tachysurus* spp., *Priacanthus* spp., *Lactarius* spp., *Sphyraena* spp., *Sciaena* spp., *Chirocentrus* spp., *Polynemus* spp., *Pomadasys* spp., *Caranx* spp., *Leiognathus* spp., sharks and rays, conger eels and *Muraenesox* spp. (Isarankura, 1976).

Since the successful introduction of trawl net fishing by the Department of Fisheries with the technical assistance rendered by the Government of the Federal Republic of Germany, there has been a spectacular increase in the amount of demersal fish caught. In 1983, the landing of demersal fish amounted to 969,245 tons, valued at 2.79 billion baht (DOF, 1985).

Reptiles

The marine animals under this grouping are crocodiles, marine turtles and sea snakes. For crocodiles, Suvatti (1950)

listed only one species which inhabits mangrove swamps and river estuaries, particularly along the southern part of Peninsular Thailand. This is the brackish water crocodile *(Crocodylus porosus* Schneider). This species was found in south Thailand at Ban Don, Surathani and Nakhon Si Thamarat. It is becoming rare, however.

There are five species of marine turtles in the Gulf of Thailand: (1) Leathery turtle or Luth *(Dermochelys coriacea Linnaeus)* which does not have a true hard shell; (2) Green turtle *(Chelonia mydas);* (3) Loggerhead turtle *(Caretta careita* (Linnaeus); (4) Hawksbill turtle *(Eretmochelys imbricate);* (5) Ridley turtle *(Lepidochelus olivacea* (L)).

As regards sea snakes which belong to the family Hydrophiibdae, Suvatti listed 29 species. Sea snakes generally inhabit estuaries and inland seas with muddy bottoms, particularly in shallow areas and mangrove swamps. Only one species, *Pelamis platurus,* lives in the open sea, i.e., the middle of the Gulf of Thailand and the South China Sea. Among the reptiles, marine turtles are commercially important. In 1983, the eggs of these turtles amounting to 94,934 were collected with a value estimated at 688,000 baht. The marine turtles'eggs are collected mainly for local consumption.

Marine Mammals

Marine mammals include whales, dolphins and sirens. Suvatti (ibid.) recorded a small Indian fin whale *(Balgenoptera edenii Anderson)* in the Gulf. Two species of dolphins, namely the Indian porpoise *(Orcaella brevirostris (Owen)*—"pla loma hua bard"), and the long nosed dolphin *(Sotalia sinesis* (Flower) "pla loma hua kuad") are known to occur in the Gulf (Menasveta, 1980).

As regards the sirens, or sea cow in English and "pavoon" or "mu nam" in Thai, only one species, *Halicore dugong* (Erxliben), was recorded by Suvatti. Lekakul (1970) stated that the dugong once inhabited the coast of Sriracha and Rayong. Because of its gentle nature and slow movement they may be accidentally caught by trawl nets and perish. This species is considered very rare. The Fisheries Law of Thailand prohibits the catching of this species (Menasveta, 1980).

8.2 HISTORICAL DEVELOPMENT AND EMERGING TRENDS

Rice and fish are the main components of the Thai diet. Fisheries have played a vital role in the national economy of the country. Fish provides highly nutritious, and relatively cheap, animal protein for the multitude of Thai people, the so-called "poor majority". During the past two decades fishery development has gained momentum with the introduction of efficient fishing gear such as purse seine, gill and trawl nets. The trawl net fishery, commencing around 1962, is now highly developed, with a distant water trawl fleet operating off the coasts of Kampuchea, Vietnam, Malaysia, Indonesia, Burma, Bangladesh and India. The past two decades have seen a spectacular increase in marine fishery production (90 percent or more of the total landing catch), mainly contributed by trawl net fishery.

The phenomenon is illustrated in Table 8.2, which shows that prior to 1960 the total production remained at about 200,000 tons annually, with approximately 50,000 tons of inland production. From 1960 onwards there has been a spectacular increase in production to about 1.7 million tons in 1973. However, total production dropped to around 1.5 million tons in 1974 due to the fuel oil crisis. Nevertheless, it rose again in 1976 to 1.7 million tons and has since fluctuated in the range of 1.8 - 2.2 million tons. For the inland fisheries, the average production over the past few years has been approximately 150,000 tons (including freshwater aquaculture).

The average consumption of fish by Thai people is said to be 22.5 kg/man/year. However, if we include the amount of fish used in the production of feeds for various types of animals, such as poultry and pigs, in addition to highly priced fish cultured in fish farms, the actual total amount consumed would be about 39 kg/man/year.

Table 8.3 shows how the annual marine catch is used. Most is consumed fresh, while the rest is preserved in various forms; frozen; canned; cured (which includes dried and salted, steamed or smoked); made into shrimp paste; or processed into fish meal. From 1966 to 1981, marine fish have been increasingly used in the fishmeal industry and as animal feed. Approximately 40 percent of total marine landings are 'trash' fish, which are used in these lower value markets.

It should be noted that the main changes in the utilization of marine fish have been the increase in frozen seafoods and canned seafoods. Frozen seafoods increased from just over 10,000 tons in 1968 to 152,779 tons in 1983. Canned seafoods also increased from 6,276 tons in 1977 to 110,378 tons in 1983. Frozen products and canned products are mostly exported to the world market.

Fisheries create job opportunities not only in the fishing industry and aquaculture, but also in other related industries, such as post-harvest technology, net-making, cold storage and ship building (Table 8.4).

Fisheries contribute to the country's foreign exchange earnings. The amount of export rose from 88,221 tons valued at 1,549 million baht in 1974 to 344,899 tons valued at 12,677 million baht in 1983. This represents almost a tenfold increase during the ten year period (Table 8.5). The trade balance of fishery products was + 11,584 million baht in 1983. The major export products that contributed to the substantial increase in the export value were canned seafood, frozen shrimps, frozen squid and cuttlefish, and fish meal.

Table 8.2 Fishery Production of Thailand 1952-1983

Year	Quantity (ton)			Value (million baht)		
	Total	Marine	Inland	Total	Marine	Inland
1952	191,500	138,500	53,000	752	428	324
1953	204,500	148,200	56,300	820	507	313
1954	229,800	166,400	63,400	928	581	347
1955	212,970	151,400	61,570	976	604	372
1956	217,960	152,240	65,720	1,146	684	462
1957	234,570	170,900	63,670	1,190	735	455
1958	196,300	145,000	51,300	1,153	725	428
1959	234,570	170,900	63,670	1,233	754	479
1960	219,045	146,471	72,574	1,412	832	580
1961	305,605	233,275	72,330	1,571	1,029	542
1962	339,788	269,709	70,079	1,634	1,106	537
1963	418,685	323,374	95,311	1,935	1,167	768
1964	576,986	493,196	82,790	2,490	1,835	655
1965	619,120	529,483	85,637	2,470	1,798	672
1966	720,282	635,165	85,117	2,578	1,903	675
1967	847,443	762,188	85,256	3,047	2,309	738
1968	1,089,303	1,004,058	85,245	4,037	3,251	786
1969	1,270,034	1,179,595	90,439	4,798	4,011	787
1970	1,448,404	1,335,690	112,714	5,876	5,043	833
1971	1,587,077	1,470,289	116,788	6,375	5,145	1,230
1972	1,679,540	1,548,157	131,383	7,213	5,728	1,485
1973	1,673,901	1,538,016	140,885	8,209	6,562	1,647
1974	1,510,466	1,351,590	158,876	5,984	4,094	1,890
1975	1,555,300	1,394,608	160,692	7,194	5,102	2,092
1976	1,699,086	1,551,792	147,294	7,532	5,379	2,153
1977	2,189,907	2,067,533	122,374	10,660	8,622	2,035
1978	2,099,281	1,957,785	141,496	13,828	11,459	2,369
1979	1,946,334	1,813,158	133,176	14,004	11,318	2,686
1980	1,792,948	1,647,953	144,995	14,067	10,507	3,560
1981	1,939,025	1,824,444	164,581	17,134	13,213	3,921
1982	2,120,133	1,986,571	133,562	18,931	14,246	4,685
1983	2,255,433	2,099,986	155,447	19,238	15,236	4,002

Source: Department of Fisheries

Capture Fisheries

Prior to the Second World War, the fisheries of Thailand were confined to the utilization of freshwater aquatic organisms in inland waters and to marine fish and invertebrates in the inshore waters along the coast. Fishing boats employed in inshore fisheries prior to the Second World War were mainly non-powered sailboats. In the 1930s, purse seines made of cotton twine, introduced from China and therefore still known as Chinese purse seine, were used to catch schools of pelagic fish, such as short bodied mackerel, in inshore waters.

During 1945-1960, besides traditional fishing gear such as hand and troll lines, lift nets, cast nets and push nets which were of minor importance, new types of fishing gear contributed substantially to the approximately 150,000 tons marine catch. These include purse seine, bamboo fish corrals (stake traps) and nylon gill nets.

Two different types of purse seines can be distinguished. The Chinese purse seine mentioned above has a length of 200-300 meters, a depth of 50-60 meters and stretched mesh size of approximately 3.5 centimeters. The gear is operated during dark moonless nights by two row boats. The Aun-Dam purse seine or Aun Cha Lern (so called Thai purse seine) has a length of 250 meters and a depth of 40-50 meters. The gear is operated by a fishing boat, with no row boat.

Bamboo fish corrals (stake traps), locally known as "Poh", used to be very common in the inshore fishery of the country, with a total number of about 1,500 during 1945-1962. However, the number of this type of fishing gear has decreased drastically during the past two decades because it cannot compete with more efficient mobile gear, such as purse seines or trawl nets. Gill nets employed by Thai fishermen are set nets, drift nets and encircling nets. After the Second World War, increased numbers of motorized boats using monofilament nylon and gill nets of various sizes were introduced into Thailand through the technical assistance of the US Government. These nets have gained popularity among Thai fishermen up to the present day. The main fisheries of

Table 8.3 Composition of Annual Utilization of Marine Catch 1963-1983

Year	Percentage					
	Total Catch	Marketed Fresh	Frozen	Cured	Processed into Fishmeal	Others
1963	100.0	47.8	-	24.8	-	27.4
1964	100.0	40.4	-	16.4	-	43.2
1965	100.0	45.3	-	19.7	30.6	4.4
1966	100.0	47.0	-	19.8	28.5	4.7
1967	100.0	55.9	1.2	12.3	17.8	12.8
1968	100.0	48.2	3.5	11.4	16.2	20.7
1969	100.0	42.4	0.4	10.1	24.1	22.0
1970	100.0	38.8	1.6	15.1	24.5	20.0
1971	100.0	39.3	2.4	7.8	21.5	29.0
1972	100.0	34.0	1.8	8.9	23.6	31.7
1973	100.0	36.6	4.3	8.5	37.9	15.7
1974	100.0	33.7	0.8	10.3	41.7	13.5
1975	100.0	35.7	1.7	11.3	41.7	9.6
1976	100.0	42.0	2.0	11.4	35.4	9.2
1977	100.0	33.8	4.7	14.5	29.9	17.1
1978	100.0	28.5	7.7	14.2	47.0	2.6
1979	100.0	31.6	6.1	12.8	45.1	4.4
1980	100.0	26.0	7.5	12.0	49.1	5.4
1981	100.0	27.7	6.7	14.6	42.8	8.2
1982	100.0	23.2	8.6	24.2	38.5	5.5
1983	100.0	22.9	7.4	28.5	38.9	2.3

Source: Department of Fisheries.

Table 8.4 Post Harvest Fish Industries in Thailand 1982-1983

Industry	Number	
	1982	1983
Freezing and cold storage	41	47
Fishmeal plants	94	98
Canning	24	26
Fish paste	2,337	2,603
Salted fish	696	759
Dried shrimps	301	276
Dried squids	826	854
Dried mussels	1,262	1,494
Steamed fish	147	142
Smoked fish	170	184
Fish-shrimp cracker	8	72
Fish-ball	52	72
Fish sauce	35	37

Source: Fishery Statistical Bulletin for South China Sea Area 1982, 1983, SEAFDEC.

the country during 1945-1960 were carried out by about 1,400 motorized vessels and about 1,440 non-motorized vessels (less than 14 meters long), while the number of fishermen during the period was estimated by the DOF to be 32,000. However, if small-scale fishermen had been included, the number would have been higher (Tiews, 1962).

The past two decades have seen a distinct and remarkable change in the structure of the marine fisheries sector. With the successful introduction of trawl net fishing into Thailand in 1962, there has been a spectacular increase in marine catch during 1963-1983. This has resulted in overfishing of demersal fish stocks both in the Gulf of Thailand and in the Andaman Sea.

Table 8.6 shows the breakdown of the country's fishery production during 1973 to 1983 into three major components, i.e., marine (capture only), inland (capture only) and aquaculture. At the beginning of this period (1974-1976), the marine catch declined to about 1.5 million tons because of the fuel oil crisis, but rose again to 1.9 million tons in 1977. Then the catch steadily declined again because of the new sea regime, before starting to recover in 1981. The catch reached a recorded high at 2.25 million tons, in 1983. During the same time span, production from inland waters remained relatively in the range of 100,000 to 130,000 tons.

There are many factors which have influenced the rapid expansion of marine fisheries during the past decades besides the progressive development of trawl fisheries. These factors include: (1) increased efficiency of fishing gear employed and the greater capacity of fishing boats. In recent years not only have trawlers become larger and more efficient in fishing but purse seines have been rapidly modernized; (2) discoveries of new fishing grounds, such as round scad (*Decapterus* spp.) grounds in the middle of the Gulf of Thailand; (3) improved infrastructure of Thailand; and (4) increased demand for fish food, due to Thailand's quickly expanding population.

Structure of Fishing Industry

Prior to 1960, the fishing industry of Thailand consisted virtually of small-scale fishing households. While more than

Table 8.5 Balance of Import and Export of Fish and Fish Products 1957-1983

Year	Import		Exports			Balance of Trade ('000 baht)
	Quantity (ton)	Value ('000 baht)	Quantity (ton)	Value ('000 baht)		
1957	2,938	27,405	19,371	64,041	-	41,636
1958	5,324	52,698	12,359	35,674	-	16,934
1959	8,933	95,151	8,869	29,553	-	65,598
1960	9,287	70,169	8,959	34,259	-	35,930
1961	10,229	63,058	10,640	42,492	-	20,556
1962	7,865	55,738	9,078	41,235	-	14,503
1963	6,578	48,645	9,049	72,723	+	24,078
1964	8,346	55,211	10,911	95,755	+	40,544
1965	11,876	69,099	17,251	149,951	+	80,852
1966	10,132	63,839	18,639	234,971	+	171,082
1967	10,026	65,256	17,390	286,553	+	221,297
1968	9,337	64,134	16,186	309,000	+	244,866
1969	12,196	88,480	21,758	324,105	+	235,625
1970	14,229	85,607	44,956	369,818	+	284,211
1971	15,934	82,325	55,111	497,558	+	415,233
1972	15,139	83,692	82,381	807,165	+	723,473
1973	19,542	92,551	104,133	1,649,930	+	1,557,379
1974	19,965	93,545	88,221	1,548,977	+	1,455,432
1975	19,682	125,192	97,994	2,106,088	+	1,980,896
1976	24,531	149,819	133,454	3,097,741	+	2,947,922
1977	18,634	138,616	180,331	3,590,903	+	3,452,287
1978	28,703	176,307	235,386	5,086,125	+	4,909,818
1979	79,967	432,021	277,896	7,326,244	+	6,894,223
1980	43,569	483,250	262,568	7,250,810	+	6,767,560
1981	47,174	549,959	300,036	8,775,742	+	8,225,783
1982	46,215	725,532	295,500	10,852,617	+	10,127,085
1983	58,942	1,093,081	344,899	12,677,173	+	11,584,092

Source: Department of Fisheries

Table 8.6 Annual Fishery Production of Thailand by Major Types of Fisheries

(ton)

Year	Total Production	Marine	Inland	Aquaculture[a]
1973	1,673,901	1,474,742	110,885	93,274
1974	1,510,466	1,297,174	127,931	85,361
1975	1,555,300	1,284,810	130,717	139,773
1976	1,699,086	1,388,239	113,263	197,584
1977	2,189,907	1,915,999	82,564	191,344
1978	2,099,281	1,837,307	102,129	159,345
1979	1,945,830	1,690,380	108,211	152,239
1980	1,792,948	1,544,434	110,361	138,153
1981	1,989,025	1,756,939	116,468	115,618
1982	2,120,133	1,949,681	87,733	82,719
1983	2,255,433	2,055,225	108,481	91,727

Note: a The sum of freshwater culture, brackishwater culture, and mariculture.
Source: SEAFDEC (1976, 1983 and 1985), "Fishery Statistical Bulletin for the South China Sea Area 1976, 1981 and 1983." Southeast Asian Fisheries Development Center, Bangkok

80 percent of inland fishermen were actually farmers, probably 50 percent of coastal fishing households had more than one main source of income. Typically, they operated within their family unit and rarely hired outside help. They used small, uncomplicated gear which produced relatively low yields.

Since 1962, when otter board trawling methods were introduced, the marine fishery of Thailand experienced rapid growth with a considerable change in the structure of the fishing population. The marine fishery at present is commercial rather than small-scale or artisan-oriented. As

Table 8.7 Marine Fishing Industry Employment

	1976	1985
Fishery Households[a]	31,869	51,678
Marine fisheries	8,329	26,875
Employee		
Total fishery households	**40,198**	**78,553**
Fishermen[b]		
(Extent of employment)		
Solely	51,198	65,569
Mainly	13,754	17,486
Partly	4,975	6,722
Total	**69,927**	**89,777**
No. of Fishing boats		
Non-motorized boats	5,367	8,302
Motorized - out-board	10,333	28,233
- in-board	10,435	16,905
Total	**26,135**	**53,440**

Notes: a. This refers to a household in which one or more members were engaged in marine fishery for the past year. A registered company which engaged in marine fishery is also included herein

b. Use the data of 1983.

Sources: 1. Department of Fisheries (1978), Statistics on the Population of Marine Fishermen.

2. SEAFDEC (1985), Fishery Statistical Bulletin for the South China Sea Area 1983.

3. National Statistical Office (1985), Preliminary Report 1985 Census of Marine Fishery.

indicated in Table 8.7, fishery employees' households increased from 8,329 households in 1976 to 26,875 households in 1985. A change is also reflected in the increase in the number of inboard motorized vessels from 10,435 in 1976 to 16,905 in 1985.

Another trend in the changing fishery employment structure is that brought about by the size of fishing vessels employed by the industry. It should be noted that the proportion of motorized boats in 1985 is much larger than that reported in 1976.

Finally, the rise in the number of high cost gear such as trawl nets, and the decline in the number of traditionally non-mobile gear, for instance, traps and set bag nets, are clear indicators that during the past 20 years the pattern of fisheries has shifted from primarily subsistence to enterprise or commercial fisheries.

At present it can be assumed that large and medium fishery enterprises are the backbone of the marine fishing industry of Thailand. The development of the marine fishing industry of Thailand has reached its peak in employment, boat building and production. Hence, at present this industry must look to expanding its activity in the high seas with a view to reaping benefits and to obtaining investment returns as soon as possible.

As regards the marketing part of the fishing industry, it can be seen that most fish landings are channelled through the private sector. However, there are two semi-government agencies, the Fish Marketing Organization (FMO) and the Cold Storage Organization (CSO), involved in marketing activities.

Major Fisheries

Several types of fisheries are being operated in Thai waters and adjacent areas. Nevertheless, the major ones are trawl fisheries and purse seine fisheries.

Trawl fisheries

With the rapid development of trawl fisheries since 1960, inshore gear such as push nets, set bag nets and bamboo stake traps, account for a negligible proportion of the total catch of demersal species.

Three types of trawls are presently employed in demersal or trawl fisheries. These are otter board trawls, pair trawls and beam trawls. The major portion of the demersal species (over 75 percent) is caught by otter board trawls. Beam trawls fish mainly for shrimps in the inshore waters along the coast. Their catches are quite low as compared to those of the otter board and pair trawls. The majority of the trawlers in operation are otter trawlers of less than 14 meters in length. Only 147 trawlers are 25 meters in length or longer. Hence, it is assumed that intense fishing took place in the waters not far from the coast, i.e., within a depth of 50 meters. The dimensions of the trawl gears depend on the size of the vessels and on whether they are using the 2-sheet German trawl or the 4-sheet Japanese trawl.

Among the multitude of demersal fish caught (over 200 species), less than 15 species are predominant in the demersal catch. These include threadfin bream *(Nemipterus* spp.), goat fish (mullidae), lizard fish (Synodontidae), big-eye (Priacanthidae), sea catfish (Taehysaridae), sharks and rays, travelly (Carangidae), bass (Lutjanidae), baracudas and wolf herring (Chirocentridae).

Trawl gears catch not only demersal fish but some pelagic fish and invertebrates such as molluscs, crustaceans, spanish mackerel and Indo-Pacific mackerel. In recent years, shrimps *(Penaeus* and *Metapenaeus* spp.), squid and cuttlefish, caught by trawl net fishing have contributed substantially to the income of trawlers in general.

The rapid expansion of trawl fisheries has resulted in several developments in Thai marine fisheries, which include: (1) the keen fishing competition in the fishing grounds in the Gulf of Thailand and in the Andaman Sea (off the Thai coast); (2) the development of medium and large-sized trawlers (18 meters or longer) and the formation of a distant water fishing fleet of trawlers operating off the coast of Kampuchea, Vietnam, Malaysia, Indonesia and recently in the Bay of Bengal and India; (3) an increase in the export of some fishery products, notably frozen shrimps and squid, as well as fish fillets; and (4) An increase in the amount of trash fish, which is used for fish meal, and by the duck farming and fish culture industries.

Table 8.8 Level of Exploitation and Maximum Sustainable Yield (MSY) of Marine Fishery Resources in the Gulf of Thailand and the West Coast of Peninsular Thailand

(tons)

Fishing Ground	Resources	Exploitation level		Estimated MSY	
		1982[a]	1983[a]		
The Gulf	Pelagic	466,480	616,800	400,000	Phasuk, (1982)
The Gulf	Demersal	1,170,946	1,136,434	750,080	Boonyubol & Pramokchutima, (1982)
West coast	Pelagic	101,122	93,954	100,000	Menasveta, (1977)
West coast	Demersal	211,133	208,037	200,000	Menasveta, (1980)
Total		**1,949,681**	**2,055,225**	**1,450,000**	

Note: a Data extracted from SEAFDEC (1984 & 1985).

Purse seine fisheries

Prior to the Second World War, pelagic species were mainly caught in the inshore waters of the Gulf using stationary gear such as bamboo stake traps and set bag nets. The Chinese purse seine was introduced to Thailand around 1925, employing a sailboat with two small row boats for setting the net.

Since the end of the Second World War, nylon gill nets have been used wildely and the Chinese purse seine fishing method has been modified. Instead of using two row boats to set the net, the main boat, which is now motorized, sets the net by itself. This method is called Thai purse seining. The Thai purse seine fishing method is now widely practised in Thailand for capturing pelagic fish and can be considered as an enterprise fishery. Since the purse seiners have recently become larger in scale, the gear employed is also larger on the average than that used two decades ago. Large-sized purse seiners are now equipped with labor saving devices such as the purse line winch, thus enabling a boat to reduce its crew nearly by half, from 22 to only 12. In addition, more medium and large-sized purse seiners are now equipped with radar, fish finders, wireless equipment and refrigeration units (Yamazaki, 1978).

However, in contrast to trawl fishery with some large-sized trawlers now fishing in distant waters, pelagic fishery is still practised in the waters of Thailand. Several other types of gear employed by small-scale fishermen, such as gill nets, traps and small seines, also contribute substantially to the pelagic catch.

Since 1973, with the introduction of luring techniques using palm leaves by day and lamps by night, the production of pelagic catches, mainly sardines and scads, has increased sharply, and the number of luring purse seine vessels rose from 100 in 1973 to 410 in 1983. In recent years the catch of scads declined but the catch of small tunas rose significantly. In 1983, there were 691 registered purse seine vessels and the catches by weight of mackerel, sardines, small tunas, and scads were 30 percent, 27 percent, 18 percent and 7 percent of the total pelagic fish catch, respectively (Department of Fisheries, 1985).

Status of Fisheries and Future Development

There are various assessments of the potential yield of the pelagic and demersal resources of the Gulf of Thailand and the west coast of the Thai peninsula. Gulland (1968) concluded that the Gulf of Thailand waters had above-average productivity. It should be noted that the estimated figures on potential yield have risen with better data. The latest estimations on the maximum sustainable yield of the Gulf and the west coast are compiled in Table 8.8.

The table indicates that the exploitation of demersal fishery resources, particularly those in the 0 to 50 meters depth in the Gulf of Thailand and off the west coast of Peninsular Thailand, have been very intense, and overfishing is evident in both areas, e.g., the significant reduction in the catch per unit of effort. For the demersal resource below 50 meters depth in the Gulf (i.e., in the middle part of the Gulf), it is anticipated that there are still some demersal resources available for future development. However, the ground in the middle part of the Gulf is generally very irregular, consisting mainly of soft mud, and is thus not suitable for conventional trawling. Hence, other suitable gears should be developed for these resources, e.g., bottom hand line or the use of better trawling techniques.

As for the pelagic fishery resources, the exploitation level in the Gulf has exceeded the estimated maximum sustainable yield. On the west coast, meanwhile, the exploitation rate is approaching the estimated maximum sustainable yield.

The extreme over-exploitation of both demersal and pelagic resources raises suspicion that a substantial catch might have been taken from elsewhere, outside Thai territorial waters. Suraswadi et al., (in press) estimated that in 1983 about 134,900 metric tons of fish were taken from areas outside Thai

Box 8.1 Keeping Pla Tu on the Plate

"Pla tu", the Thai name for Indo-Pacific mackerel, is a very important staple food in Thailand. In the old days, those who lived in coastal provinces ate pla tu almost every day. Nowadays, because of a limited supply and a greater demand, the price of this fish has risen considerably. Nevertheless, pla tu still makes a significant contribution to the Thai diet. Its dietary importance can be compared to that of the milkfish in the Philippines and Indonesia.

The scientific name of pla tu is *Rastrelliger brachysoma*. Pla tu is widely distributed in the Tropical Western Pacific and has been studied extensively. In the Gulf of Thailand pla tu occurs inshore, where the salinity is less than 28 parts per thousand. The size at first maturity for pla tu in the Gulf has been reported as 17.5 centimeters in length. Fish attaining this length are about one year old. The spawning season of pla tu is long, with pelagic eggs of this fish found throughout the year. However, two peaks of spawning have been observed, the first between February and March, and the second from June to August.

Pla tu spawn in the waters along the west coasts of the Gulf. The highest density of larvae was located in water 20 to 60 kilometers off Prachuap Khiri Khan and Chumphon Provinces. Ready-to-spawn fish stay near the bottom at a 18 to 25 meter depth and the trawl fishery catches a large quantity of mature fish there.

The fecundity of pla tu was estimated to be about 200,000. This number includes immature eggs of less than 0.01 millimeters in diameter. During a spawning season, a female releases eggs in batches of approximately 20,000. The eggs hatch within a period of 23 to 28 hours, depending on the ambient water temperature.

Pla tu feed mainly on phytoplankton. Growth of the fish is very rapid, attaining a length of 15 centimeters five months after hatching. After one year of age, growth becomes slower; it is rare to find fish that are two years old, since most of them are caught during the first year.

The life cycle of pla tu involves a short migration. After hatching during April and May, mackerel larvae are transported by currents into inshore water to feed. During June and July the fish start moving northward along the west coast into the inner Gulf, where they feed extensively and are exposed to the purse seine fishery of the Inner Gulf. The fish stay in the Inner Gulf until October or November. Then they gradually move southward to spawn in the waters off Prachuap Khiri Khan and Chumphon provinces, where they are fished extensively by purse-seiners during November to January.

It is believed that there are at least two stocks of pla tu, one on the Gulf's west coast and the other on the east coast. The east coast stock is subjected to the fisheries of Vietnam, Kampuchea, and Thailand, while the west coast stock is fished entirely by the Thai fishing fleet.

The maximum sustainable yield of pla tu in the Gulf is estimated to be 66,500 tons. During 1971 to 1982, the average catch per year of this fish was 61,472 tons. In 1983, the catch was 79,803 tons, valued at 856 million baht. Hence, it can be said that pla tu is fully utilized and should be maintained at this level; otherwise overfishing may adversely affect the stocks.

territorial waters. Of this amount, about 102,696 tons were taken from the Gulf areas beyond Thailand's EEZ. This estimate, if correct, shows that only a small percentage of the total catch was taken from other waters.

Future Trends

There is no potential for future development of trawl fisheries which exploit mainly demersal fishery resources, since the production at present is higher than the estimated maximum sustainable yield from the Gulf. In the Andaman Sea, increasing the fishing effort may not significantly increase the total demersal catch.

The exploitation of small and medium-sized Gulf pelagic resources such as sardines, scad, and mackerel has exceeded maximum sustainable level and a further increase in the fishing intensity may not result in an increase in the total catch. In the Andaman Sea, pelagic resources utilization should be maintained at the present level.

In Thai waters, particularly in the Andaman Sea, there are small-sized tunas, bonitos and skipjacks, and fishing for bonitos and skipjacks could be expanded in the future. There are several other resources which could be utilized in the future, including seaweed, sea cucumbers and jellyfish. An economically important species of seaweed is *Gracilaria confervoides (L)*. The production of seaweed in Thailand in 1983 was 670 tons and there is a potential for seaweed culture to supplement the production from natural stocks, provided that the waters are free from pollution.

The exploitation of the jellyfish resource began during the early 1970s. In 1983, Thailand harvested approximately 180,281 tons of jellyfish, but the problems of jellyfish production appear to be in processing. With improved processing techniques, it is expected that the quality of the production will be enhanced, thus enabling Thailand to command a better export price. The potential of the jellyfish

Table 8.9 Aquaculture Production in Thailand

(ton)

Year	Aquaculture (Total Production)	Freshwater Culture	Brackishwater Culture	Mariculture
1973	93,274	N.A.	N.A.	N.A.
1974	85,361	N.A.	N.A.	N.A.
1975	139,773	N.A.	N.A.	N.A.
1976	197,584	N.A.	N.A.	N.A.
1977	191,344	32,641	10,334	148,369
1978	159,345	39,367	10,049	109,929
1979	152,239	29,465	10,838	111,936
1980	138,153	34,634	11,901	91,618
1981	115,618	48,113	13,759	53,746
1982	82,719	45,829	12,988	23,902
1983	91,727	46,966	14,920	29,841

Note: N.A. = not available.

Source: Fishery Statistical Bulletin for South China Sea Area, 1977-1983 SEAFDEC.

resource in the Gulf and in the Andaman Sea is unknown since this resource is exploited mainly by small-scale fishermen.

Additional resources include sea urchins and sea cucumbers. Among the sea urchins, *Diadema setosum* Leske is the most important and the gonads can be exported to Japan for a high price. The Department of Fisheries has listed eight species of sea cucumbers known to occur in the Gulf. The economically most important species is *Stichopus* spp., which can be exported. It is believed that 1,000 tons of sea cucumber could be harvested annually, since this animal is distributed widely over the coastal areas of Thailand.

Means of increasing the value of the present catch are required. Improved handling methods at sea and during transportation, together with the development of higher value products, are needed. Beside fisheries in our waters, Thailand should increase its joint-venture efforts with neighboring countries and also investigate the potential of high-sea fisheries.

History and Status of Aquaculture

Aquaculture has developed considerably since the beginning of the century. Freshwater aquaculture was developed a long time ago, but coastal aquaculture is much more recent. Prior to the use of synthetic insecticides, substantial amounts of fish could be produced as a by-product of rice cultivation. Aquaculture production during the past decade is shown in Table 8.9.

Aquaculture contributed about 5 to 10 percent of the total fishery production of the country in recent years. According to Table 8.9, aquaculture production increased sharply from 1973 and reached a peak of 197,584 tons in 1976. Since then, production gradually declined to 91,727 tons in 1983. This was due to the variation of mariculture production. In considering the data in Table 8.9, we could observe that freshwater and brackish water cultures had a tendency to increase constantly while mariculture production fell sharply. Since mariculture accounted for a major portion of total production, the decline in this category would certainly be reflected in the decline of the total production. It is generally believed that the declining production of mariculture is due to water quality degradation of farming areas particularly in the coastal area of the Upper Gulf of Thailand. The area is subjected to runoff from the four main rivers of the Central Plain.

The technical level of aquaculture in Thailand is fairly advanced, particularly in the seed production system, applying the induced spawning technique which has become popular in this country. At present, seed of all cultivated species could be produced from hatcheries (Table 8.10). Nevertheless, the seed production of certain species like tiger prawn *(Penaeus monodon)* is still lower than the demand.

In comparing aquaculture production of the countries in the South China Sea region (Table 8.11), it is found that Thailand ranks at a moderate level. Taiwan takes the lead in aquaculture production, despite her limited land area and shortest length of coastline. This means that there is still room for Thailand to accelerate and intensify the aquaculture development program.

Types of Aquaculture Venture

Aquaculture, although it contributes a relatively small portion, about 5 to 10 percent in tonnage, to total fishery production has long term potential for increasing fishery production for either local consumption or export earning from high value shrimps and fish species. Aquaculture activities in Thailand can be divided into three categories, i.e., freshwater culture, brackish water culture, and mariculture. The numbers of aquaculture farms, and rearing areas, and total production in 1983 are given in Table 8.12. The present cultured species of the three categories are listed in Table 8.13.

Table 8.10 Fish and Shrimp Seed Production in 1983

(number)

No.	Common Name	Scientific Name	Seed Production
1	Common Carp	*Cyprinus carpio*	9,982,961
2	Nile Tilapia	*Tilapia nilotica*	15,745,209
3	Tawes	*Puntius goniondtus*	41,908,296
4	Rohu	*Labeo rohita*	21,928,609
5	River Catfish	*Pangasius sutchi*	2,855,520
6	Chinese Carps		
	Silver Carp	*Hypopthalmichthys molitrix*	
	Grass Carp	*Ctenopharyngodon idellus*	436,250
	Bighead Carp	*Aristichthys nobilis*	
7	Sea Bass	*Lates calcarifer*	4,725,610
8	Giant Prawn	*Macrobrachium rosenbergii*	18,575,555
9	Marine Prawn		
	Banana Prawn	*Penaeus merguiensis*	9,765,441
	Tiger Prawn	*P. monodon*	
10	Others		6,542,795
		Total	**131,466,746**

Source: DOF, 1985.

Table 8.11 Comparison of Aquaculture Production Among Countries in South China Sea Area

Country	Total Land Area	Length of Coastline	Aquaculture production (ton)			
	(km^2)	(km)	Fresh water	Brackish-water	Marine	Total
Thailand	513,115	2,614	46,966	14,920	29,841	91,727
Malaysia	332,435	4,405	13,850	960	38,530	53,340
Philippine	299,404	17,460	99,280	183,770	162,020[a]	445,070
Taiwan	36,000	1,566	140,585	61,020	39,182	240,793

Note: a. Mostly seaweed.
Source: Extracted from Fishery Statistical Bulletin for South China Sea Area 1983. SEAFDEC.

Freshwater Culture

As mentioned elsewhere, freshwater fish culture has long been established and practiced in Thailand, and more than 15 species of fish and invertebrates are presently cultured. Freshwater culture consists of four main practices: pond culture, paddy field culture, ditch culture, and cage culture.

a) Pond culture

There were 69,213 rai (11,074 ha) of freshwater culture ponds in 1983, distributed among 28,942 farms with 39,174 ponds. On average, a farm had 1.5 ponds with a net production area of 1.84 rai (0.3 ha). Total production from pond culture in 1983 was 26,071 tons. The major production species were nile tilapia, gouramys, catfishes, carp-like fishes, and snakeheads.

b) Paddy field culture

Fish production from paddy fields totalled 19,697 tons in 1983. The area under production was recorded at 185,450 rai (29,672 ha). The species being cultured in this type of venture are carp-like fishes, especially tawes, nile tilapia, and gouramys.

c) Ditch culture

A variety of fish species are cultured in ditches throughout the country. Culture practices vary and are generally not a well developed subsector. Total production in 1983 was 872 tons, from a total area of 2,038 rai (326 ha).

d) Cage culture

About 600 cage culture farmers produced 326 tons of fish from

Table 8.12 Number of Aquaculture Farms, Rearing Area, and Production in 1983

Category	Number of Farms	Area (rai)	Production (ton)
Freshwater (Total)	**47,480**	**256,764**	**46,960**
Pond culture	39,174	69,213	26,071
Paddy field culture	6,495	185,450	19,697
Ditch culture	848	2,038	872
Cage culture	963	63	326
Brackishwater (Total)	**5,235**	**228,688**	**14,920**
Gulf of Thailand			
Pond culture	4,307	221,606	13,678
Cage culture	639	6,569	879
West coast			
Pond culture	20	500	7
Cage culture	269	13	356
Mariculture (Total)	**2,999**	**15,374**	**29,841**
Gulf of Thailand			
Oyster culture	1,889	5,681	3,453
Sea mussel culture	559	2,719	19,285
Blood cockle culture	81	4,037	6,545
West coast			
Oyster culture	6	37	8
Blood cockle culture	464	2,900	550
Total	**55,714**	**500,826**	**91,727**

Source: DOF, 1985.

963 cages in 1983. The total production area was about 63 rai (10 ha). This corresponds to average production of 3.2 kg/m^2. The fishes being cultured by this type of venture are marble goby and river catfish.

Brackish Water Culture

Brackish water culture is a type of aquaculture which is operated in the coastal area, especially the exploited mangrove forest area. It is the area where there is an interface between freshwater and seawater. Therefore, salinity in this area usually ranges from 5 to 25 ppt. Brackish water culture concentrates on penaeied prawn culture, but is still generally primitive with low productivity. The cage culture of sea bass in the coastal area is also becoming popular.

a) Shrimp culture

In 1983, the number of shrimp farms was 4,327 (4,307 farms in the Gulf of Thailand and 20 farms on the west coast), with a total area of 222,606 rai (35,537 ha, see also Table 8.12). Total production from the farms in 1983 was 13,678 tons which was broken down into 10,399 tons of penaeid prawns, 1,187 tons of shrimps and the rest is made up of miscellaneous fish and invertebrates. The shrimp farms are mainly concentrated in the provinces of Samut Prakan, Samut Sakhon, and Samut Songkhram. During the past decade, shrimp culture development in terms of production and area cultivated increased significantly (Table 8.14).

The farms are constructed along the main or branch canals. Some are located at about five kilometers or more from the seashore. Farms located further inland cannot introduce enough volume of sea water to the pond by only utilizing the tidal elevation, and must use pumps.

The major shrimp culture farms still use an extensive method, the traditional method. This method, initiated from the use of rice or salt fields, involves raising the dikes around the field and constructing a sluice gate. At the beginning of the culture season, the water is introduced through the sluice gate into the pond by pumping it up from nearby canals or ditches. The pump used was introduced about four years ago and is called a push pump. This is assembled with a secondhand car engine (mostly more than 100 horsepower), a long shaft and a propeller.

The water is pushed into a pond by the strong motive force of the propeller's revolution. In this water shrimp fry, crabs and various species of fish are included. By this pumping

Table 8.13 List of Cultured Species and Production in 1983

Group and Common Name	Scientific Name	Production (ton)
Mariculture		
Oysters	*Crassostrea* spp.	3,461
Mussels	*Mytilus* spp.	19,285
Blood cockles	*Anadara granosa*	7,095
Brackishwater culture		
Sea bass[a]	*Lates culcarifer*	1,084
Mullets	*Mugil* spp.	223
Other finfish including grouper	-	2,027
White banana prawn[b]	*Penaeus merguiensis*	
Banana prawn[b]	*Penaeus indicus*	10,399
Jumbo tiger prawn[b]	*Penaeus monodon*	
Shrimp[a]	*Metapenaeus* spp.	1,187
Freshwater culture		
Tawes	*Puntius gonionotus*	
Rohu	*Labio rohita*	
Grass carp	*Ctenopharyngodo idellus*	7,823
Bighead carp	*Aristichthys nobilis*	
Silver carp	*Hypopthalmichthys molitrix*	
Nile tilapia	*Tilapia nilotica*	12,125
Marble goby[b]	*Oxyeleotris marnoratus*	200
River catfish[a]	*Pangasius sutchi*	
Catfish[a]	*Clarias batrachus*	9,924
Catfish[a]	*Clairas macrocephalus*	
Eel	*Anguilla* spp.	70
Gouramys[a]	*Trichogaster pectoralis*	10,260
Snakehead[a]	*Ophicephalus striatus*	4,787
Milkfish	*Chanos chanos*	2
Other finfishes	-	616
Giant prawn[a]	*Macrobrachium rosenbergii*	1,153
Frogs	-	1
Reptiles	-	5
		91,727

Notes: a. *Some are exported.*
b. *Mainly exported.*
Source: *DOF, 1985.*

Table 8.14 Brackishwater Shrimp Culture Development During 1974-1983

Year	Number of Shrimp Farms	Acreage (rai)	Production (ton)
1974	1,518	75,578	1,775
1975	1,568	80,422	2,537
1976	1,544	76,850	2,523
1977	1,437	77,617	1,590
1978	3,045	135,815	6,395
1979	3,378	154,222	7,064
1980	3,572	162,727	8,063
1981	3,657	171,619	10,728
1982	3,943	192,453	10,091
1983	4,327	222,106	11,566

Source: *Department of Fisheries, 1985a.*

method, shrimp fry as well as others are introduced into a pond without suffering appreciable damage.

During the rearing period there is no feeding, and after the water has been in a pond for 45-60 days, the farmers catch shrimps for sale. The other aquatic organisms are also caught and then the pond is drained for subsequent culture activities. This type of shrimp farming is usually undertaken from May to September and from November to March. Thus, the culturing method is very simple, and the production per hectare averages 300 kg/year, depending on the fundamental productivity of each pond and the number of predators and competitors. Unit production is rather low when compared to that of other countries, with figures as high as 625 kg/ha/year reported in some parts of the Philippines.

Recently some progressive farmers have practiced an improved method. A pond about one meter in depth without any shallow parts is made and water is pumped into the pond through a nylon screen to prevent organisms from entering the pond. Then, the shrimp fries which are transported from a hatchery or collected from the wild are stocked in the pond. Supplementary or intensive feeding is carried out. Trash fish, squid and rice bran are mainly used as feed. In this way the number of predators and competitors for food is reduced

substantially and the unit production is increased to 500 kg/ha/year or more.

The size of traditional shrimp ponds ranges from 1.6 to 16 hectares but most are 3.5 to 15.8 ha. Ponds employing improved methods range from 0.5 to 1.6 ha. The cultured species are mainly *Penaeus merguiensis* and *Metapenaeus* spp.

The size of cultured shripm *(Penaeus merguiensis)* is usually smaller than 10 grams in weight, making it suitable for export to foreign countries.

The pond culture of *Penaeus monodon* by the improved method is very seldom practiced, due to the shortage of the fry resulting from scarcity of the gravid female.

b) Sea bass culture

In Samut Sakhon, and Samut Songkhram, *Lates calcarifers*, commonly called sea bass, is raised in ponds and in small-scale cages in Songkhla Lake. In 1983, 1,710 households engaged in sea bass culture in Thailand. The total production was 1,084 tons. The size of farms used for rearing sea bass ranges from 3.2 to 16 ha, with an average of 7 ha. In Songkhla Lake, there are about 200 cage farms, mainly distributed on the east coast.

The net-cage commonly used is 3 x 5 x 2 meters and the mesh size can be increased gradually as the fish grows. The culture period from fingerlings (approximately 1 centimeter in total length) to marketable size (0.7 kg in body weight) is around six months. The stocking density at harvesting is 300-500 fish/cage.

Mariculture

The molluscs which consist mainly of bivalves are cultivated in inshore and coastal areas of Thailand. In 1983 Thailand produced a total of 29,841 tons from cultivation, which was 26 percent of the total shellfish production in the country and made up as follows: approximately 6,545 tons of bloody cockles, 19,285 tons of green mussels, and 3,453 tons of oyster (Table 8.12).

The Department of Fisheries statistics on bivalve culture indicate that in 1983 there were 3,033 farms with 19,290 rai (3,086 ha) engaged in shell fish farming in Thailand (Department of Fisheries, 1985a).The production for various species expressed as per ha per year was estimated as 20.2 tons for bloody cockles, 48.9 tons for green mussels and 20.6 tons for oysters.

a) Bloody cockle culture

This species requires harder bottoms with a good mixture of sand for its habitat and is raised on the bottom in shallow waters. The culture site can be air-exposed during low tide, but preferably not exceeding four hours exposure. Small cockles used as seeds are generally collected from natural cockle grounds or imported from Malaysia. About 3.5 to 4 million seeds are used in a hectare of cockle farm. Scattered seeds grow to marketable size within 1 to 1.5 years. Manual bottom dredges are used for harvesting, and the full-sized cockles are selected while undersized ones returned to the growing beds. Poaching has been a local problem. Although bloody cockles are presently produced in two provinces, Petchaburi and Satun, potential areas for this species are located in Chanthaburi, Rayong, Phangnga, Samut Songkhram, Chachoengsao, Chumphon and Trang.

Great demand for this species exists in domestic markets. The production, however, cannot satisfy the whole domestic demand and a certain amount of cockles is imported from Malaysia.

b) Mussel culture

Green mussels grow in water of about two to eight meters in depth. The culture method used in Thailand is exclusively the stake method. Palm stakes made from the trunk of the mangrove date palm (locally called "mai ping") and bamboo stakes are commonly used. At present, the use of the palm stakes is more widely practiced among farmers, because they are inexpensive and more durable (three years' operation) than bamboo (1 to 1.5 years). The only difference is that the farmer can get longer bamboo stakes (up to 10 meters) which can be used in deeper waters, while the palm stakes are generally from 3 to 6 meters in length. About 5,000 stakes at 0.25 meter intervals are set in every hectare of farm. The culture period is about eight months and the mussels grow up to 7 to 8 centimeters in shell length.

Recently, the hanging method of green mussel culture has been developed experimentally for the purpose of establishing economical culture methods (Chaithanavisut and Menasveta, 1985). This technique should be extended to the mussel farmers. The major areas where green mussels are widely cultured are in Chachoengsao, Chonburi, Samut Sakhon, Samut Songkhram, Samut Prakan and Phetchaburi. Potential grounds for the culture method are extensive in the Gulf of Thailand, including Nakhon Si Thammarat and Surat Thani.

c) Oyster culture

The oyster culture method practiced in Thailand is unusual. Natural rocks, artificial concrete blocks and wooden materials are used as a substratum for the attachment and growth of the oyster. These substratums are settled in the estuary area with a 500 centimeter interval between substratums which enables people to walk across for routine management. Once built, the farm lasts a long time with minor maintenance.

Spats of oyster occur in two seasons during the year, one in May to July and the other in October to November. Harvest is usually made from October to April, depending on the size of the meat. Small and medium-sized oysters are processed as a shellless meat, and large sized ones, mainly produced in the Surat Thani bay area, are served as oysters on the half shell at restaurants and hotels.

Oyster farms are generally small-scale, about 0.6 ha on average. Although oyster farmers cultivate only small areas or a fraction of a hectare, they can get quite a profit as the price of oysters is comparatively high. Presently oysters are cultured in the province of Trat, Chonburi, Rayong, Surat Thani, Chumphon, Pattani, Prachuap Khiri Khan and Songkhla. Potential areas are still available in the above-mentioned provinces and are newly found in Chanthaburi, Rayong, Phangnga, Narathiwat, Trang, Satun, Nakhon Si Thammarat, Krabi, and Phetchaburi.

Future Trends in Aquaculture

Freshwater aquaculture is planned for fishes which are a staple food for Thai people. These fishes include pla salid (gouramy), pla nil (nile tilapia), pla dook (catfish), and snakehead fish (pla chon). Nile tilapia has a particularly good potential for future development, on the account of the availability of technological know-how and market acceptability. Nile tilapia has long been researched around the world. It is generally recognized as a fast growing and easily-propagated species, if properly managed. Nevertheless, a major setback for freshwater aquaculture has been the fish disease problem of the past four years. Unless this problem is solved, aquaculture production from fresh water will be significantly constrained.

The brackish water culture, especially of shrimp, has a high potential and bright prospects. Aquaculture production of shrimp in Thailand is expected to increase even more as present farms convert from low yield, extensive culture techniques to semi-intensive and/or intensive culture, more ponds are brought into production; seed stock availability increases; and pond management practices improve.

Total mangrove area in Thailand is about 1,679,335 rai (268,694 ha). In 1983, the total areas devoted for various types of brackish water shrimp farming was 222,106 rai, which yielded 13,685 tons valued at 963 million baht. A more detailed survey conducted by the Brackish Water Fishery Division indicated that at least 140,000 rai scattered in 22 provinces along the coastline are suitable for brackish water shrimp farming. Beside this, another 200,000 rai behind mangrove areas can be utilized for this purpose. This will make up to a total of 562,106 rai (both being utilized and potential areas). If half of this area is converted to semi-intensive culture practice, a total yield per year would be approximately 73,150 tons at a value of 80,000 million baht (1936). On the basis of the present pace of technology development and investment opportunity, we can expect shrimp production from brackish water culture to reach this level within the next ten years.

As for mariculture, future activities will be focused on the promotion and expansion of mollusc culture to other productive areas. As mentioned elsewhere, water pollution problems have caused a major setback of mollusc culture in the inner Gulf. The problem will be persistent and will not be solved unless wastewater treatment systems are set up in big cities, towns, and industrial plants situated above the inner Gulf. This is likely to be a large, expensive, and time-consuming project. So mollusc culture should be promoted in other potential areas. It can be anticipated that the production from mariculture could easily achieve the same level recorded in 1977 (148,369 tons) within a short period, because the technology is already available

8.3 LEGAL AND INSTITUTIONAL FRAMEWORK

Responsible Agencies

The Department of Fisheries (DOF) under the Ministry of Agriculture and Cooperatives is responsible for the development of the fishery industry and all matters pertaining to administration, planning, enforcement of fishery laws and regulations, training, research, extension and compilation of fishery statistics.

In 1985, DOF had 53 branch fisheries offices covering 53 provinces and 303 districts for enforcement of fishery laws and regulations, for concession management, taxation, and provision of technical guidance to local fishermen and fish farmers.

Current total manpower consists of 1,477 fishery officers and 4,119 support personnel. The key divisions involved in technical matters and support in the provinces are the Freshwater, Brackish Water, and Marine Fisheries Divisions. There are 43 fisheries stations, and units under the supervision of these three divisions

Besides DOF, there are a number of other agencies which are concerned with education, training and research in fisheries. These agencies are attached to state universities, namly: (1) the Faculty of Fisheries, Kasetsart University, Bangkok, (2) the Department of Marine Science, Chulalongkorn University, Bangkok, (3) Sichang Marine Science Research and Training Station, Chulalongkorn University, Sichang Island, Chonburi, (4) Bangsaen Marine Science Institute, Srinakarinwirot University, Bangsaen, Chonburi, and (5) the Faculty of Natural Resources, Prince of Songkhla University, Songkhla.

Fisheries Policies

In the early days the fisheries of Thailand were confined mainly to the utilization of inland fishery and inshore fishery resources. In the 1930s emphasis was placed on the utilization and conservation of inland fishery resources. This policy was followed until the 1950s and fisheries played a minor role in the overall agriculture development of the country.

In 1962, with the First National Economic and Social Development Plan, of which fisheries development was an integral part, emphasis was changed to marine fisheries

Box 8.2 The Aquaculture Industry

Thais eat enough seafood each year to place them among the top in the world fish-eating stakes. Fish is eaten frozen, canned, salted, dried, steamed, smoked or as fish paste. The country has always made extensive use of its rich inland, brackish water and marine fisheries, exporting a significant proportion of the total catch. A huge diversity of species is harvested, from seaweed to sponges, from cephalopods to corals. Some fishermen use push nets, set bag nets or bamboo stake traps, while others have large, seagoing trawlers which operate off the coasts of Kampuchea, Vietnam, Malaysia, Indonesia and India.

But a number of the open-sea fisheries have been exploited well beyond their maximum sustainable yield, with the result that the harvest per unit of fishing effort is falling. Other fisheries could well follow. At the same time, too, the declaration of national Exclusive Economic Zones has led to Thai fishing vessels being excluded from some of their traditional fishing waters.

Aquaculture, the farming of inland, brackish or marine water, now makes a considerable contribution to the Thai diet, accounting for some 5 to 10 percent of the total tonnage produced by all the country's fisheries. However, Thailand still lags way behind such countries as the Philippines and Taiwan as far as aquacultural production is concerned. Yet the potential for this industry is clearly very considerable, if a number of important constraints can be effectively tackled.

The freshwater and brackish water aquaculture industries have been growing rapidly in many areas. Freshwater aquafarmers use cages, ditches, ponds or paddies to raise such species as carp, catfish, gouramys, marble goby and nile tilapia. In brackish water areas, typically in or around estuaries and mangroves, the focus is on such species as prawns, shrimp or sea bass. In 1983, there were over 4,000 shrimp farming operations in Thailand, whose total output was over 13,600 tons. Traditional methods are giving way in many areas to improved techniques: whereas the shrimp farmer traditionally flooded his pond with brackish water already containing the eggs and larvae of wild shrimp (plus many other species, including shrimp predators), he may now buy his shrimp fry at a hatchery.

Mariculture, which involves farming the saltwater environment, has proved somewhat more problematic. Preferred species here have included bloody cockles, green mussels and oysters. But production has slumped from a peak in 1979 of nearly 112,000 tons to just under 30,000 tons in 1983. The suspicion is that a key factor responsible for this slump is the deteriorating quality of water off the mouths of some of Thailand's major rivers.

Aquafarmers are putting increasing effort into improving their breedstock, using techniques such as selective breeding and hybridization to achieve better growth rates, improved resistance to disease (with ulcerative dermal necrosis which is a particular concern at the moment), or enhanced tolerance to degraded water conditions. But, however successful these efforts may be, the evidence suggests that water pollution (see Chapter 10) and the destruction of the country's mangroves (Chapter 7) could emerge as real constraints on the long-term success of this important agricultural industry.

development. During 1962 to 1966, technical assistance from various sources was the impetus for development which resulted in an almost fourfold increase in the kingdom's total fish production (720,282 tons in 1966). Under the Second National Economic and Social Development Plan (1967-1971), the emphasis on marine fisheries development continued with the target production of 860,000 tons set for 1971 — which was exceeded by 730,000 tons.

For the Third National Economic and Social Development Plan (1972-1976), the fisheries development policy was to put increased effort into aquaculture development, with special emphasis on coastal aquaculture. The target was to increase fisheries production by 7 percent between 1971 and 1976. Although the total production in 1976 of 1.7 million tons satisfied the target, the production from aquaculture both from inland and coastal fisheries did not increase at the rate envisaged. The major production continued to come from marine sources. During this period the DOF made a breakthrough in the artificial spawning of some freshwater fish, e.g., catfish *(Pangasius sp.)* and established hatcheries for marine shrimps at Songkhla, Phuket, and Rayong.

The Fourth Five-year Plan (1977-1981) aimed for an annual growth of 7 percent in GNP in real terms.

The Fifth Five-year Plan (1982-1986) was similar to its predecessor, except for an additional item on the promotion of high-sea fisheries and joint ventures between the neighboring countries. This policy was extended to the Sixth Plan with the inclusion of the production of the export of fishery products.

Important Laws and Regulations

Three sets of laws are implemented in the marine fisheries and resources management and development of Thailand. These are: (1) the Fisheries Act, 1947, including its implementing regulations and notifications; (2) the Thai

Vessels Act of 1938; and (3) the law on Navigation in Thai waters (1913).

Under the Fisheries Act, several Ministerial Regulations and Notifications have been issued with the objective of preserving and/or conserving marine fishery resources, which include, inter alia: (1) prohibition of the use of intoxicants, toxic substances, electricity or explosives for fishing; (2) determination of the sizes and kinds of fishing implements that are permitted in fisheries; (3) prohibition of capture of certain rare species such as marine turtles and dugong; (4) establishment of spawning and nursery seasons of particular commercially important species such as "pla tu" and prohibition of the use of certain types of fishing gear during the said seasons; and (5) prohibition of the use of certain types of fishing gear in certain areas.

Trawl Fishery Regulations

Trawl nets are very effective. With the small cod-end mesh size of approximately 2.6 centimeters or less used generally by commercial trawlers, trawl gears catch a lot of small fish, including juveniles of several commercially important species. Hence, the so-called trash fish generally predominate in the trawl catch. Recognizing that juveniles and fry of several demersal species feed in the inshore waters along the coasts and in order to reduce the conflict between inshore subsistence fishermen and trawlermen, the Ministry of Agriculture and Cooperations issued the Ministerial Notification of 20 July 1972 prohibiting the use of trawl nets of various types, such as push nets and shrimp push nets, which are used with motorized fishing boats, within 3,000 meters from the shore line and within a radius of 400 meters from stationary gear being licensed by the Department of Fisheries in the seas or bays of coastal provinces.

Clam dredges used with motorized vessels are also prohibited within 3,000 meters from the shore lines of all coastal provinces. Trawl net fishing is not allowed in Songkhla Lake nor in the waters of Chonburi Province from 1 September to the end of February each year.

8.4 KEY ISSUES

The Exclusive Economic Zone (EEZ) and the Thai Fisheries

During the 1950s and 1960s, challenges to the principle of the Freedom of the Seas governing the use of the oceans, which had been practised for several hundred years, emerged, not only with respect to the exploitation of living marine resources but to other activities such as the exploitation of oil and minerals. As a result, a Committee on the Peaceful Uses of the Sea Bed and Ocean Floor Beyond the Limits of National Jurisdiction was established by the United Nations in 1967. The membership of the Committee rose rapidly as Member States became concerned about the implications which might arise from the deliberations of this Committee. There were several issues relevant to the uses of the oceans to be considered, and the first Session of the United Nations Conference on the Law of the Sea was held in December 1973.

During the period 1973 to 1980, nine sessions of this Conference were held. The discussions during these sessions had far-reaching effects on fisheries. The principle of an exclusive economic zone (EEZ), one of the major outcomes of the Conference, has become universally accepted. Under the new regime of the sea, 100 coastal states have unilaterally declared Exclusive Economic Zones which extend national jurisdiction over fisheries out to 200 miles seaward of the baselines of territorial seas. Now 99 percent of the world's marine fish catch is taken in these zones of national jurisdiction. Hence, the principle of Freedom of the Seas for fishing has now been abolished, except for those fisheries beyond 200 miles.

Thailand, along with neighboring countries, has proclaimed an EEZ. The proclamation of EEZ made by Thailand looked as if it had increased the sea under her jurisdiction by about 50 percent (Figure 8.2). But Thailand, the leader in marine fishing in the region, has lost about 300,000 square miles of the sea that once were utilized by Thai fishermen.

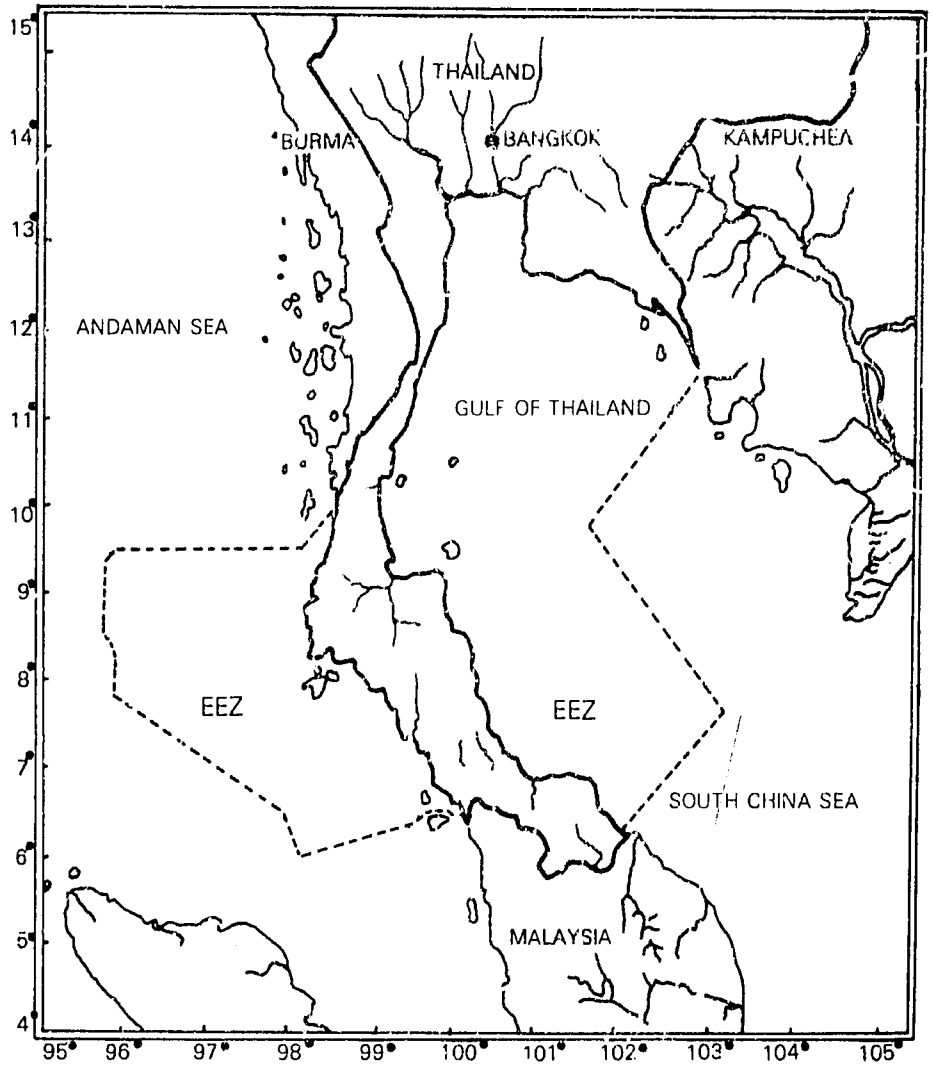
The decreasing fishing grounds resulting from the proclamation of EEZs by neighboring countries has created frequent fishing conflicts. Each year many Thai fishing vessels and fishermen are arrested for alleged violation of neighboring waters. During 1977 to 1985, 469 Thai fishing vessels were seized. Of these, 198 and 107 vessels were seized by Vietnam and Burma, respectively. The rest by Malaysia, Kampuchea, India, Indonesia, and Bangladesh (Suraswadi et al., in press). These records are only those that were reported to the Thai authorities. It is believed that there are more that were not reported.

The damages to the Thai fishing vessels seized so far by the neighboring countries have been estimated to be about 2 billion baht. Moreover, the government has to pay large sums of money for fines, transportation, and miscellaneous expenses to repatriate the fishermen (Suraswadi et al., in press).

As a solution, the government is promoting joint-fishing ventures with other coastal states. So far bilateral negotiations have produced some fruitful results. Countries that have joint-venture fishing arrangements, directly or indirectly, with Thai fishing companies include: Oman, Saudi Arabia, Somalia, Indonesia, India, Bangladesh, and Australia (Suraswadi et al., in press).

Another approach adopted to compensate for the loss of marine fishery production caused by the new sea regime is aquaculture. Increased efforts on aquaculture development are called for in the Sixth National Economic and Social Development Plan (1987-1991). Aquaculture is looked upon as the savior substituting any production loss from marine capture fisheries.

Figure 8.2 The Exclusive Economic Zone of Thailand



The Over-fishing Issue

From available figures, as reported earlier, the Gulf of Thailand is overfished and only the pelagic resources of the Andaman Sea offer room for expansion. Overfishing is a result of various factors including excessive use of fishing vessels and gears. Increasing fishing costs, particularly fuel prices, have put pressure on the fishermen which has resulted in the illegal use of smaller meshes in order to catch more. On top of this, the development of fish meal and animal food industries induces the harvesting of trash fish. In addition, near shore push-netting is another practice that damages the resources because of the high percentage of juvenile shrimp and fish species netted.

Better management of marine capture fisheries in Thailand's EEZ is a prerequisite to any improvement in the existing situation. Emphasis should be given to the use of economic incentives to self-regulate the trawling practices in consonance with the maximum sustainable yields. On this issue, a better understanding of imminent changes due to the introduction of new marine capture fishery technologies and the expansion of the marine product industry is needed. The ultimate objective is to arrest overfishing in Thailand's waters which is now the case.

Constraints of Aquaculture Development

To fulfill its potential, the present obstacles which may impede aquaculture development must be overcome. Major constraints are:

a) Seed production

At present, most aquaculturists still have to rely on nature for the supply of natural seeds. Artificial breeding has been successfully conducted for marine shrimp *(Penaeus* spp.) (Kungvankij, 1982) and giant prawn *(Macrobrachium rosenbergii)* (Menasveta, 1980, 1982). Other species such as the jumbo tiger prawn *(Penaeus monodon)* still require further research and experiment.

Hatchery production of marine shrimp seed requires a reliable source of spawners (gravid females) which will spawn fertile eggs for the hatchery. These eggs will eventually grow and develop into postlarvae. Postlarvae and latter stage juveniles are the primary seed used to stock shrimp culture ponds. In general, gravid females can be obtained from three sources: (1) caught from the wild in a gravid condition; (2) taken from culture ponds in a gravid condition; and (3) obtained either from the wild or ponds in a non-gravid condition, and then induced to maturity in the hatchery.

Most marine shrimp culture today relies on the natural production of gravid females. However, this source is unreliable for many of the most important species. Only the third alternative can serve the increasing demands of the future. However the technique of induced maturity has yet to be perfected and requires more field experiment. The present unreliable and unpredictable nature of seed production continues to be the instability factor in the shrimp culture industry.

b) Aquaculture feed production

Most fish and shrimp farmers presently use conventional diets. These diets include rice bran mixed with water, trash fish, and chicken wastes. Due to this uncontrolled nature of the feed, its nutritional value can not be guaranteed.

Although aquaculture development in Thailand is still in its early stage, its potential is well recognized. Both local and international conglomerates in agribusiness are expanding their investment in this viable sector. It is forecasted that Thailand can become one of the world's leading exporters of aquaculture products. If this is the case, demand for high quality formulation feeds will rise in direct proportion.

Nutrition in aquaculture plays the same dominant role as in any other field of animal husbandry. Sound nutrition ensures growth, maturation and reproduction. At present, there is insufficient knowledge on nutritional requirements of the culture species in Thailand. More research is also needed in the use of feed ingredients of plant origin as substitutes for trash fish and fish meat in aquaculture diets, alternative feed processing methods which consume less energy, and cost-effectiveness of various formulations.

c) Genetic improvements

Seed of various cultivated species are presently produced both by governmental agencies and the private sector. Selling of seed is often very profitable. This is due to the fact that the producers only handle the eggs or hatchelings for a short period of time. Those that may suffer are the farmers who raise the offspring to market size. This is because the offspring produced without genetic manipulation may be genetically inferior. It was reported that farmers in Suphanburi province usually lost approximately 60 to 70 percent of their initial stock in raising catfish. They also noted that the growth rate of fish seemed to be lower than it used to be.

Genetic manipulation can be developed by the methods of selective breeding and hybridization. Hybridization can be both interracial and inter-specific. The objectives of a breedstock improvement program may vary from place to place and with different species. Nevertheless, the general objectives are: (1) better growth rate; (2) disease resistance; and (3) the ability to withstand degraded water quality. A good example of successful genetic improvement is the work that has been carried out at the University of Washington, Seattle. After 36 years of rainbow trout selective breeding, the culture breed stock can produce an offspring that has a growth rate 120 times faster than the wild rainbow trout.

d) Disease problems

During 1982 to 1985, Thailand faced a series of serious fish disease epidemics, causing widespread death of fish in 52 provinces in the country. Loss in 1983 was estimated at 160 million baht. The epidemic occurred both in natural waterways and in fish ponds. Many species of freshwater fish, especially those which are very popular with local consumers, such as snakehead fish *(Ophicephalus striatus)*, eel *(Fluta alba)*, and snakeskin gouramy *(Trichogaster pectoralis)*, were affected. The dead fish were found to have large ulcers on the head, lips, and cheeks, as well as on the body and tail (Menasveta, 1985).

The first serious fish epidemic took place in the south of Thailand, during early 1982. The second outbreak occurred between late 1982 and early 1983. The government took immediate action to combat the disaster and identify the cause. The third and fourth outbreaks occurred between late 1983 and early 1984, and between late 1984 and early 1985, respectively. Thus the outbreaks are usually associated with the cooler months in Thailand (i.e., November to February).

This fish epidemic is not just a problem for Thailand, but can be considered regional in scope. Similar epidemics first occurred in northern Australia about 8 to 9 years ago. When it spread to Java in late 1980, severe losses were experienced by fish farmers. In 1981 it spread to Malaysia and entered the southern part of Thailand in the following year. The central part of Thailand was badly hit in 1982 to 1984 as has been mentioned. Now the epidemic has moved to the northern part of Burma as well as to Laos. The epidemiology of this disease is similar to the ulcerative dermal necrosis (UDN) which was a problem in northern Europe during 1974 to 1976.

During the past three years experts were divided in their opinions on the underlying causes of the epidemic. Some

believe that pesticides and herbicides were the main cause whereas others refuted this hypothesis. Recently, a number of research studies have come up with different explanations.

The causes of the fish epidemic can be divided into two parts, i.e., predisposing causes and the cause of death. The predisposing causes appear to be a combination of abnormally low temperatures, and changes in the acidity of the water brought about by heavy rain. These environmental changes cause stress in the fish as they try to adapt themselves to changing water conditions. Such environmental stress may weaken the fish and make them susceptible to virus and bacterial infections, in particular from *Aeromonas hydrophila*. Other organisms such as fungi, protozoa, and ectoparasites may play a lesser prominent role in causing infection. The present levels of insecticides and herbicides in natural water probably had little to do with this fish disease epidemic (Menasveta, 1985). This has been the most conclusive finding up to date.

e) Water pollution

Aside from fish diseases, aquatic pollution can become a limiting factor to aquaculture development. The damage to the clam culture at the Maeklong estuary due to pollution from sugar mill effluents in the early 1970s can still serve as a good reminder. With the projected growth in both domestic and industrial wastes along the banks of major rivers, namely Chao Phraya, Tha Chin and Maeklong, the generated wastes will eventually find their way to the estuaries and to the Gulf. Hence, the impact to coastal aquaculture in the upper Gulf should be taken seriously.

To rectify the situation, there is a need to coordinate the monitoring program of various governmental agencies so that more meaningful collection and interpretation of data can be achieved. At the same time, long-term projections of waste loads and their impact to water quality should be attempted on a regular basis. The objective is to alert the planners in advance on potential pollution. (More treatment of this subject can be found in Chapter 10.)

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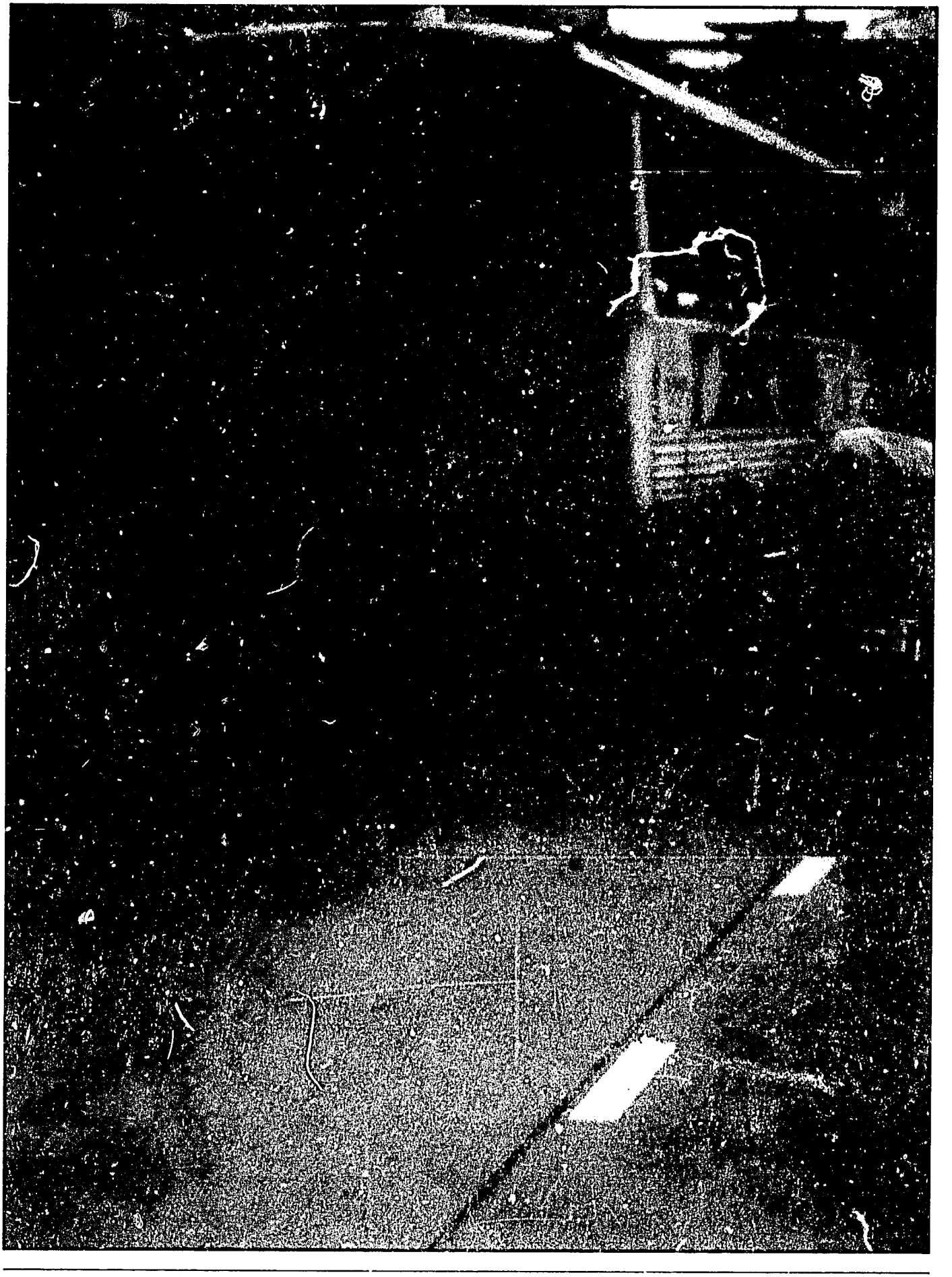


Environmental Quality Management PART III

9 Air and Noise Quality Management

9.1 OVERVIEW AND INVENTORY

Emission Sources

Air pollutant emissions originated mainly from the burning of fuels such as petroleum products, lignite and coal, which are collectively classified as "modern" or "commercial" energy, whereas those from the burning of fuel wood, bagasse, paddy husk and charcoal, are called "traditional" energy.

In 1982, which is taken as the base year for this study, secondary energy[1]/consumption amounted to about 17,400 MMLCOE (Table 9.1). Most energy was used in the transport (29.4 percent) and household sectors (28.2 percent), followed by industry (21.1 percent). Agriculture accounted for about 10.8 percent, the service sector 7 percent and fisheries 3.5 percent.

Modern energy accounted for 62.4 percent of total secondary energy consumption in 1982. The most important type of modern fuel is petroleum products, which accounted for 52.2 percent of total secondary energy use in 1982, followed by electricity (8.1 percent) and lignite/coal (2 percent) (Table 9.2). The balance of 37.6 percent is in the form of traditional energy, which continues to be a very significant energy source, particularly in households. Charcoal is the most important type, estimated at 15.4 percent of total secondary energy, followed by fuel wood (14.3 percent), bagasse and paddy husk (7.9 percent in total).

Source Characteristics

While the volume of emissions is the primary factor in air pollution, impacts are also influenced by air pollutant dispersion and the nature of the affected area.

Transportation sources have the greatest impact on air pollution, due to their dominant role in fuel consumption, large emission factors (Table 9.3) and concentration in populated areas. In 1985, there were more than three million motorized road vehicles, including two-wheel and three-wheel motorcycles. They continue to be the cause of city-wide air pollution problems, including smog.

The household sector, which ranks second in terms of energy demand (28 percent of total secondary energy in 1982), has much less impact on air quality. Urban households, which account for only four percent of total secondary energy use, derive most energy from charcoal (47 percent) and electricity (34 percent). Most air pollutant emissions in this sector come from rural households, which account for 24 percent of total secondary energy, mostly from charcoal (52 percent) and fuel wood (39 percent). Rural household sources, however, are widely dispersed, hence any adverse impact is limited to the local community.

[1]/Secondary energy is defined as the energy delivered to the end-user; e.g. electricity, petroleum products, natural gas as fuel to industry, charcoal to households. (NESDB, 1985).

Table 9.1 Secondary Energy Demand by Sector, 1982

Sector	Amount (MMLCOE)	Share (%)
Agriculture	1,890	10.8
Fisheries	611	3.5
Industry	3,684	21.1
Transport	5,119	29.4
Service	1,224	7.0
Household: Urban	696	4.0
Rural	4,218	24.2
Total	**17,441**	**100.0**

Source: NESDB, 1985

Table 9.2 Energy Demand, 1982

Type of Energy	Amount (MMLCOE)	Share (%)
MODERN		
Petroleum Products	9,130.6	52.2
Gasoline	(1,753.3)	(10.0)
Diesel	(4,008.2)	(23.0)
LPG	(419.8)	(2.4)
Fuel oil	(1,501.1)	(8.6)
Kerosene	(421.0)	(2.4)
Jet Fuel	(1,000.2)	(5.7)
Natural Gas	0.0	0.0
Electricity	1,415.6	8.1
Coal/Lignite	344.3	2.0
Sub-Total	10,863.5	62.4
TRADITIONAL		
Bagasse	1,243.1	7.1
Charcoal	2,691.5	15.4
Fuel Wood	2,500.1	14.3
Paddy Husk	143.0	0.8
Sub-Total	6,577.7	37.6
TOTAL	**17,441.2**	**100.0**

Source: NESDB, 1985

Industrial processes may emit particulates and other pollutants such as hydrogen sulfide, organic solvents, heavy metals and odor.

Power generation supplies about 8.1 percent of the total secondary energy requirements. Although new power plants are usually located in remote areas, there are two existing ones with the total generating capacity of 637.5 MW in Bangkok Metropolis (national power generation capacity totaled 5,853 MW in 1984).

Estimated Emissions from Combustion Sources

Emissions from combustion sources in 1982, which was taken as the base year, were estimated from energy consumption and emission factors. The emission factors were based on *Rapid Assessment of Sources of Air, Water and Land Pollution* (WHO Geneva, 1982), supplemented by the US EPA's *Air Pollutant Emission Factors* (EPA, AP-42, 1976). These factors are given in Table 9.3. No emission control was assumed for the base case.

The amount of energy used in this study is based on *Macroeconomics Situation and Prospects for Energy Demand in Thailand, 1985-2001* (Table 9.4). Its definitions of energy, which include electricity as secondary energy, have been adopted here.

On a country-wide basis, only major air pollutants are included in the estimates. These pollutants are particulates, sulfur dioxide (SO_2), nitrogen oxides (NO_x), hydrocarbons (HC) and carbon monoxide (CO). Almost all of these pollutants except particulates are accounted for by fuel burning sources. For particulates, the cement and iron industries are the major industrial sources, while transportation of agricultural products and open field burning are the major fugitive dust sources. The inventory focused on fuel burning sources, and included industrial processes where appropriate.

The results of the inventory exercise are shown in Table 9.5. It can be seen that transportation sources represent the major emission source of CO (60 percent) and HC (46 percent), as well as NO_x (23 percent). Transportation is solely responsible for high ambient CO concentrations along busy streets in major cities. It is also largely responsible for photochemical smog formation, due to the reaction of HC and NO_x in sunlight. Power generation sources (assuming no emission control) and industrial sources combined account for 82 percent of SO_2 emission, 54 percent of particulates emission and 44 percent of NO_x emission. The siting of power plants and industrial plants away from highly populated areas helps reduce their overall impact. However, the two power plants cited earlier and industrial plants in Bangkok have been identified as the principal air polluters.

Household and agricultural sources emit a significant proportion of the particulates (42 percent, when combined), due to poor combustion of traditional fuels, such as fuel wood and bagasse. However, these sources are widely distributed and in most cases have no impact on the public, apart from the energy consumers themselves.

To put the air pollution problem in Thailand into perspective, the country's emissions are compared with those of the United States, and the Organization for Economic Cooperation and Development (OECD) countries (Table 9.6). In terms of sheer magnitude, Thailand emits about 1.5 percent of the total SO_2 emission in the United States. However, this is already a point of concern, considering that Thailand is only one-eighteenth the size of the USA. In addition, the level of industrialization in Thailand is much lower. The comparative figures also show the high level of particulates in Thailand, which is about 4 percent of the amount in the USA. This is due to the fact that during the past two decades, effective emission control in the USA has significantly reduced the amount of particulates released into the air.

Table 9.3 Emission Factors for Combustion Sources

(kg/ton of fuel)

Sources	Type of Fuel	SPM	SO_2	NO_x	HC	CO
Power plants	Fuel oil residue	1.04	69.6	13.2	0.13	0.66
	Natural gas	0.29	0.056	11.5	0.019	0.32
	Lignite	56	30	7	0.5	0.5
	Coal	1.2	13.3	9	0.15	0.5
Industrial and commercial furnaces	Diesel	2.13	20.1	7.5	0.41	0.59
	LPG	0.38	0.0068	2.6	0.65	0.35
	Fuel oil distillate	2.13	60.3	7.5	0.41	0.59
	Kerosene	3	3.4	2.3	0.4	0.25
	Natural gas	0.34	0.056	3.6	0.058	0.32
	Coal/lignite	56	30	3	0.5	1
Domestic furnaces	LPG	0.42	0.0068	1.8	0.17	0.44
	Fuel oil distillate	1.42	60.3	1.8	0.41	0.71
	Kerosene	3	3.4	2.3	0.4	0.25
	Bagasse	8	-	0.6	-	-
	Fuel wood	13.7	0.5	5	1	1
Vehicles	Gasoline	2.0	0.54	10.3	14.5	377
	Diesel	2.4	19	11	2.6	43.5
	LPG	0.03	-	0.52	0.28	1.7
Boats	Diesel		2.7	27	5.1	11

Sources: WHO, 1982 and USEPA 1976.

Conditions for Air Pollution

Due to the release of air pollutants into the atmosphere, adverse impact might occur both to human health and the quality of the environment. The dispersion of air pollutants will largely determine the route of pollution and its degree of severity. Natural dispersion of air pollutants depends on local geography and on meteorological factors such as wind pattern, air stability and mixing height.

Most parts of Thailand where industrial plants are situated are on flat plains, which allows free air movement to disperse air pollutants. In addition, the coastal areas, including Bangkok, can enjoy the added benefit of a land-sea breeze, which brings in fresh air from the sea and dispels air pollutants out over the sea.

Only the mountainous areas of the North induce an accumulation of pollutants in "air basins" in the valleys surrounded by hilly ranges. Due to natural mountain-valley wind patterns, pollutants can be trapped and accumulated in these "air basins". Chiang Mai, for example, is noted for its smoky air from domestic fuel burning in the early morning and late evening. Smoke from houses at the foot of the hills can be observed close to the ground, hardly dispersing.

The northeast and southwest monsoons are dominant throughout Thailand and determine the direction of pollutant dispersion in a particular season. Due to these counter-flow patterns the impact from air pollution from a stationary source will not last throughout the year. In the case of Bangkok Metropolis, it is geographically located off the northeast-southwest axis from the industrial city of Samut Prakan. Hence air pollutants released from the factories there, can cause less adverse effects to the environmental quality of the capital city. This is also due to the green area of Bangkrajao which is kept as a buffer zone to trap air pollutants blowing towards Bangkok.

Information on atmospheric stability and mixing height is meagre and inadequate. The potential for natural dispersion or accumulation of pollutants depends on these two major factors. For better air quality management, better knowledge and understanding of the relationship between meteorological conditions and air pollution would be necessary.

Physical dispersion of pollutants through tall stacks has been practiced for quite a few decades throughout the world. The tallest stacks in Thailand are 150 meters high, in use at the lignite power plants at Mae Moh, Lampang province.

One of the major global issues of air pollution is "acid rain" which is much debated in both Western Europe and North America. Efforts to disperse pollutants into the atmosphere have backfired when SO_2 and NO_x emissions eventually fall back to earth as acid precipitation. This is due to the high volume of total emissions, more than 21 million tons of SO_2 and 20 million tons of NO_x emitted annually in the USA alone, as shown in Table 9.6. Due to the limited industrial sources of air pollution, acid rain has, so far, not been an issue in Thailand.

Noise Sources

Noise pollution from transportation is an obvious nuisance in Bangkok and to a lesser degree in other major cities. The main source of noise is from motor vehicles, particularly

Table 9.4 Composition of Energy Demand by Type of Energy in 1982, Base Case

(MMLCOE)

Type of Energy	Agri-culture	Fisheries	Industry	Trans-portation	Service	Household		Total
						Urban	Rural	
Petroleum products	324.6	557.6	2,222.3	5,041.6	639.1	86.2	232.2	9,103.6
Gasoline	88.7	1.5	346.2	966.0	350.9	0.0	0.0	1,753.3
Diesel	185.1	535.2	268.6	2,925.6	93.7	0.0	0.0	4,008.2
LPG	1.8	8.1	60.5	147.8	90.9	82.9	27.8	419.8
Fuel oil	5.2	0.0	1,493.9	2.0	0.0	0.0	0.0	1,501.1
Kerosene	43.8	12.8	53.1	0.0	103.6	3.3	204.4	421.0
Jet fuel	0.0	0.0	0.0	1,000.2	0.0	0.0	0.0	1,000.2
Natural gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	38.1	0.2	623.0	38.7	355.7	235.0	124.9	1,415.6
Coal/lignite	0.0	0.0	344.3	0.0	0.0	0.0	0.0	344.3
Modern	**362.7**	**577.8**	**3,189.6**	**5,080.3**	**994.8**	**321.2**	**357.1**	**10,863.5**
Bagasse	1,243.1	0.0	0.0	0.0	0.0	0.0	0.0	1,243.1
Charcoal	0.0	7.6	1.5	0.0	147.7	325.8	2,208.9	2,691.5
Fuel wood	141.1	45.1	493.0	39.0	81.7	48.7	1,651.5	2,500.1
Paddy husk	143.0	0.0	0.0	0.0	0.0	0.0	0.0	143.0
Traditional	**1,527.2**	**52.7**	**494.5**	**39.0**	**229.4**	**374.5**	**3,860.4**	**6,577.7**
Total	**1,889.9**	**610.5**	**3,684.1**	**5,119.3**	**1,224.2**	**695.7**	**4,217.5**	**17,441.2**

Source: NESDB, 1985.

motorcycles. In the last ten years, the number of registered motor vehicles of all kinds in Bangkok has increased from 400,000 in 1976 to more than one million in 1985. In addition, high-speed boats (longtailed boats) are the major cause of noise pollution along the canals and rivers.

Surveys from the curb side have indicated a high level of noise, exceeding 85 dBA, most of the time (ONEB, 1977; Chalermchai, 1977). The existing standard, however, stipulates that the noise level at 7.5 meters from a motor vehicle is not to exceed 85 dBA. Measurements of the noise from motor-tricycles conducted by ONEB show the range of 87.2 ± 4.2 dBA for those using liquid fuel, and 81.2 ± 4.3 dBA for those using LPG, due to more complete combustion. These comparative records confirm the reduction in the noise level when LPG replaces liquid fuel in a motor-tricycle.

Since motorcycles are believed to be the major culprit generating noise, measurements of new motorcycles at their assembly plants were conducted (ONEB, 1985). The results

Table 9.5 Estimated Emission from Combustion Sources

(tons/year and percent)

Year	Sources	SPM	SO_2	NO_x	HC	CO
1982	Transport	7,515	47,339	35,390	17,952	406,570
	%	3	15	23	46	60
	Power generation	96,300	153,087	43,027	1,054	2,143
	%	33	48	28	3	0
	Industry	62,701	106,735	23,970	6,569	110,212
	%	21	34	16	17	16
	Service	4,221	2,145	5,114	1,525	108,937
	%	1	1	3	12	16
	Fisheries	0	1,220	12,204	2,305	4,972
	%	0	0	8	6	1
	Agriculture	54,022	3,607	8,166	1,882	34,666
	%	19	1	5	5	5
	Household	67,109	2,997	24,843	4,942	4,941
	%	23	1	16	13	1
	Total	**291,868**	**317,130**	**152,714**	**39,229**	**672,441**

Table 9.6 Comparative Air Pollutant Emissions between Thailand, USA and OECD Countries
(thousand tons/year)

Source	Area(km^2)	SPM	SO_2	NO_x	HC	CO
Thailand[a]	513,115	291.9	317.1	152.7	39.2	672.4
USA[b]	9,363,123	7,500	21,000	20,000	-	74,000
OECD[c] Countries	32,047,000	16,000	55,000	37,000	-	149,000

Sources:
a. Rough estimates taken from Table 9.5.
b. Council on Environmental Quality, USA (1983).
c. OECD, (1985).

show the low range of 70.8 ± 3.8 dBA. Tampering of exhaust pipes thus has been identified as the major cause of noise pollution.

From March 1984 through March 1985, the Bureau of University Affairs conducted a pollution campaign to spot-check the noise level of 168,565 motor vehicles in the Bangkok area (Table 9.7). The worst offender was the motorcycle with more than 21 percent of the total number inspected violating the noise standard. Truck and motor-tricycles were also identified as other major polluters.

Regarding noise from motorized boats, a study by Chulalongkorn University (1983b) showed that 80 percent of the 120 boats surveyed exceeded the noise level of 90 dBA at 7.5 meters set by the Harbor Department (the noise limit was revised to 85 dBA in 1985). The community noise level averaged over 24 hours [Leg (24)] was recorded at 72.8 ± 5.2 dBA and the public response varied from mildly disturbed to moderately disturbed. Audiometric monitoring of boat operators showed that many had hearing loss due to exposure to extreme noisy conditions (122 dBA at 0.5 meter).

A noise survey at the Bangkok Airport recorded higher noise levels from military aircrafts at 120 dBA while those generated from commercial flights were at 108-118 dBA. (Wismitanunt, 1976).

Table 9.7 Number of Vehicles Exceeding Noise Standard.

Vehicle type	Number surveyed	Exceeded noise standard	
		Number	%
Motorcycle	143,710	30,450	21
Motor tricycle	9,130	1,357	15
Bus	10,865	689	6
Truck	4,103	720	18
Motorboat	757	51	7
Total	**168,565**	**33,267**	**20**

Source: Bureau of University Affairs, 1985.

9.2 PRESENT STATUS AND FUTURE TRENDS

Present Status of Air Quality

National ambient air quality standards were promulgated in 1981 to protect human health. Six pollutants were specified: carbon monoxide, ozone, sulfur dioxide, suspended particulates, nitrogen dioxide and lead (Table 9.8). Their sources and effects are well known, and are used as a basis for standard setting although few studies on local conditions have been carried out locally.

Most of the ambient air quality monitoring works in Thailand have been conducted in Bangkok. However, work has started in other cities and industrial regions such as Chiang Mai, Hat Yai and the Eastern Seaboard.

In Bangkok, there are two separate networks of permanent air monitoring stations. The first network, under the joint operation of the Ministry of Public Health and the Faculty of Engineering, Chulalongkorn University (MPH/CU), was started in 1978. It consists of three monitoring stations, located selectively in residential, commercial and industrial areas of Bangkok. As it is a part of the WHO/UNEP global air monitoring system, the data have been analyzed and published by WHO periodically. The second network, under the Office of the National Environment Board (ONEB), was started in 1983 and consists of eight stations. The air quality situation and trends observed are described in the following subsections:

Suspended particulate matter

Data on suspended particulate matter from all ONEB stations in 1983 and 1984 are shown in Table 9.9. In 1983 seven 24-hour samples exceeded 0.33 mg/m^3, which is the national ambient air quality standard. Comparatively, in 1984, none exceeded the standard.

From the Ministry of Health/Chulalongkorn University network a large number of daily particulate concentrations exceeded the standard (0.33 mg/m^3). Annual geometric mean of particulate concentration also exceeded the long-term standard (0.10 mg/m^3).

From 1979 to 1984, it was observed that annual particulate concentrations, as well as maximum daily concentrations, were increasing (Figure 9.1). At Chulalongkorn University, the annual particulate concentration has increased from around 0.099 mg/m^3 to 0.184 mg/m^3 between the years 1980 and 1984. Air pollution in terms of particulates at the other two sites (Ladprao and Samrong) was even more severe, with annual concentrations of 0.197 mg/m^3 and 0.234 mg/m^3 in 1984.

Particulates are believed to originate mainly from fugitive dust. Higher particulate concentrations are usually observed near roadways. An ONEB survey along major streets in Bangkok in 1984 found that all ten sites exceeded the short-term particulate standard (0.33 mg/m^3) (ONEB, 1985d). The situation is similar in other cities, such as Chiang Mai and Hat Yai, where curb side particulate levels always exceed the national standard (Table 9.10).

Due to its relatively larger size, fugitive dust does not pose a serious health hazard since it can not penetrate deep into the respiratory system. However, particulates do cause irritation and allergy. The sheer unpleasantness breathing in particulates and black smoke is so evident that it warrants rectifying measures.

Lead

Lead analysis by ONEB showed that the daily concentration of lead in Bangkok ranged from 0.01 to 1.96 µg/m^3 in 1983, and from 0.07 to 3.60 µg/m^3 in 1984 (Table 9.11). For MPH/CU stations, daily lead concentrations between 1979 and 1984 ranged from 0 to 1.5 µg/m^3, well below the standard of 10 µg/m^3.

A downward trend in lead concentration was apparent at both MPH/CU Stations, as shown in Figure 9.2. At Samrong, an industrial area, annual lead concentration decreased from 0.914 µg/m^3 to 0.072 µg/m^3 between 1979 and 1984, while the maximum daily lead concentration also decreased, from 1.516 µg/m^3 to 0.375 µg/m^3.

Lower lead emissions have been brought about indirectly by greater consumption of LPG and diesel oil, which are cheaper than leaded gasoline. Direct lead emission control was initiated by the Ministry of Commerce in 1984, with the reduction of the lead limit for gasoline from 0.84 to 0.45 grams

Table 9.8 NEB Air Quality Standards.

Pollutant	NEB Standards	Characteristics	Principal sources	Principal effects
Carbon monoxide (CO)	8 hour: 20 mg/m^3 1 hour: 50 mg/m^3	A colorless, odorless gas with a strong chemical affinity for hemoglobin in blood	Incomplete combustion of fuels and other carbon-containing substances, such as in motor vehicle exhaust; natural events such as forest fires or decomposition of organic matter	Health: Some reduced tolerance for exercise, impairment of mental function, impairment of fetal development, death at high levels.
Photochemical oxidants (O_3)	1 hour: 0.2 mg/m^3	Colorless, gaseous compounds which can generate photochemical smog.	Atmospheric reaction of chemicals under the influence of sunlight	Health: Aggravation of respiratory and cardiovascular illnesses, irritation of eyes and respiratory tract, impairment of cardiopulmonary function. Others: deterioration of rubber, textiles, and paints; impairment of visibility; leaf damage and reduced growth of premature plants.

Table 9.8 (contd.)

Pollutant	NEB Standards	Characteristics	Principal sources	Principal effects
Sulfur dioxide (SO_2)	Annual (geometric mean): 0.1 mg/m^3 24 hour: 0.3 mg/m^3	A colorless gas with a pungent odor; SO_2 can oxidize to form sulfur trioxide, which forms sulfuric acid with water	Combustion of sulfur-containing fossil fuels, smelting of sulfur-bearing metal ores, industrial processes, volcanic eruptions	Health: Aggravation of respiratory diseases, including asthma, chronic bronchitis, emphysema; reduced lung function; irritation of eyes, respiratory tract; increased mortality. Others: corrosion of metals; deterioration of electrical contacts, paper, textiles, leather, finishes and coatings, building stone; formation of acid rain; leaf damage, reduced growth in plants; impairment of visibility
Total suspended particulates (TSP)	Annual (geometric mean): 0.1 mg/m^3 24 hour: 0.33mg/m^3	Any solid or liquid particles (diameter ranging from 0.3 to 100 microns) dispersed in the atmosphere, such as dust, pollen, ash, soot, metals, various chemicals	Stationary combustion, especially of solid fuels; construction activities; industrial processes; atmospheric chemical reactions; smoking tobacco; forest fires, wind erosion, volcanic eruptions	Health: Directly toxic effects or aggravation of the effects of gaseous pollutants; aggravation of asthma or other respiratory or cardiorespiratory symptoms; coughing, chest discomfort; increased mortality Others: soiling deterioration of building materials, other surfaces; impairment of visibility; cloud formation; interference with plant photosynthesis
Nitrogen dioxide (NO_2)	1 hour: 0.32mg/m^3	At high concentrations, a brownish-red gas with a pungent odor, often formed from oxidation of nitric oxide	Motor vehicle exhaust, high-temperature stationary combustion, atmospheric reactions	Health: Aggravation of respiratory illnesses. Others: fading of paints, dyes; impairment of visibility; reduced growth, premature leaf drop in plants; formation of acid rain
Lead	24 hour:0.01mg/m^3	A nonferrous heavy metal occuring in air as vapor, aerosol, or dust	Available in nature; lead mining, smelting, processing; motor vehicle emissions; manufacture of lead products (e.g. batteries)	Health: Accumulation in body organs; anemia; kidney damage; central nervous system damage.

Table 9.9 Bangkok Air Quality Data for Suspended Particulate Matter (SPM), 24-hour concentration

Site	Type of Area	Year	SPM (mg/m³) Min	Mean	Max
ONEB Network					
1. ONEB	residential	1983	0.030	0.107	0.240
		1984	0.050	0.102	0.160
2. Ladprao Chankasem	residential	1983	0.030	0.121	0.410
		1984	0.030	0.117	0.300
3. Bansomdej	mixed	1983	0.040	0.136	0.500
		1984	0.010	0.118	0.270
4. Ratburana	industrial	1983	0.030	0.103	0.420
		1984	0.040	0.126	0.260
5. Saovapa	commercial	1983	0.040	0.094	0.420
		1984	0.050	0.098	0.240
6. Sukhumvit	residential	1983	0.040	0.114	0.280
		1984	0.040	0.096	0.200
7. Bangna	industrial	1983	0.040	0.115	0.390
		1984	0.040	0.143	0.250
8. Ladkrabang	rural	1983	-	-	-
		1984	0.020	0.062	0.130
MPH/CU Network					
1. Samrong	industrial	1979	0.063	0.156	0.364
		1980	0.019	0.158	0.413
		1981	0.068	0.253	0.706
		1982	0.096	0.243	0.897
		1983	0.074	0.215	0.999
		1984	0.057	0.197	0.767
2. Chulalongkorn University	residential	1978	0.072	0.152	0.293
		1979	0.084	0.150	0.350
		1980	0.022	0.099	0.386
		1981	0.043	0.112	0.288
		1982	0.054	0.136	0.403
		1983	0.072	0.155	0.394
		1984	0.076	0.184	0.458
3. Ladprao	residential	1979	0.090	0.184	0.409
		1982	0.039	0.159	0.305
		1983	0.043	0.163	0.405
		1984	0.063	0.234	0.622

per liter. This caused a further drop in ambient lead concentrations in 1984.

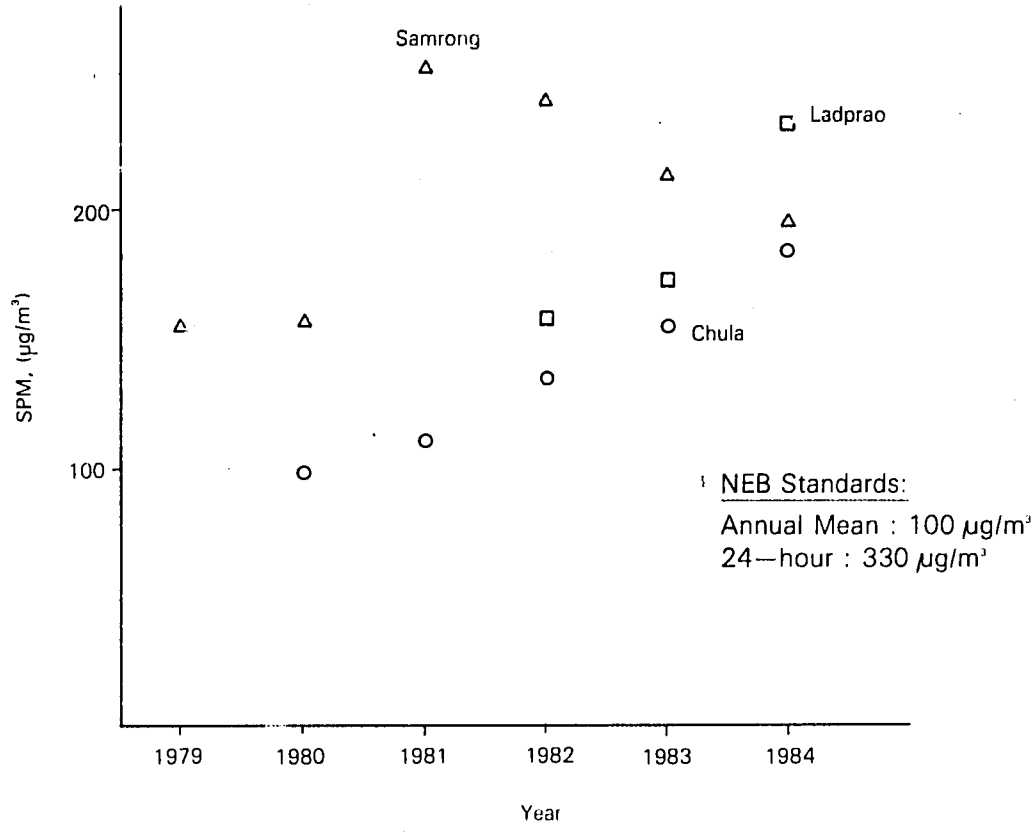
High lead concentrations are found at curb side near traffic. A survey by ONEB in 1984 at ten locations in central Bangkok found 24-hour lead concentrations in the range of 1 to 5 μg/m³. It could be concluded that lead concentrations decrease rapidly with distance from roadways. A recent survey for the Expressway and Rapid Transit Authority (Thorani Tech, 1986) at ten locations, with samples taken at a distance between 5 to 20 meters from curb side, shows lead concentrations (24-hour) between 0.1 and 0.5 μg/m³.

It can be concluded that the level of lead in ambient air is within the safe limit, presenting no immediate danger to general public health.

Carbon monoxide

Motor vehicle emissions are the major source of carbon monoxide. Along narrow congested streets, CO can build up to harmful levels and cause headache, angina attack, and theoretically, at very high concentrations, death. CO, however, disperses very rapidly within ten meters from the traffic and the effects of CO from streets rarely extend much further.

Figure 9.1 Annual Average Particulate Concentrations at MPH/CU Stations



The 8-hour average carbon monoxide concentrations recorded at all ONEB monitoring stations were less than 6 mg/m³ in 1983 and less than 10 mg/m³ in 1984. These stations are all located at fair distance from the traffic. Curb side CO concentration is of greater concern. In 1984, the CO standard (20 mg/m³for an 8-hour average) was exceeded at Pratunam Intersection, Soi Asoke and Nanatai Intersection. ONEB also found other major cities, such as Chiang Mai and Hat Yai, experiencing high CO concentrations along major streets (Table 9.12).

When meteorological conditions allow good dispersion of air pollutants, as on open roads, CO concentration remains low. Factors leading to high CO build up are excessive vehicle emissions and physical obstruction to wind movement, such as tall buildings on narrow streets. The exhaust emission standard for CO was set at 6 percent by volume when measured at idle. However, CO emissions are believed to be falling, due to better engine design of new automobile models, for lower fuel consumption and better emission control.

Table 9.10 Particulate Concentrations near Major Streets in Cities in 1983, 24-Hour Average

Site	Maximum Values (mg/m³)
Bangkok	0.23 – 1.05
Chiang Mai	0.41 – 0.47
Hat Yai	0.42 – 0.45

A vehicle emission survey by ONEB (1985) found that about 28 percent of all cars on the street exceeded the 6 percent emission standard while only 6 percent of new cars exceeded the standard (Table 9.13). In a 1980 survey by ONEB, as many as 54 percent of used cars exceeded the 6 percent CO limit. This encouraging trend, as mentioned earlier, can be attributed to the improvement in the engine design of new car models.

Another contributing factor to the reduction of CO is the changing pattern of energy use in the transportation sector. Under Thailand's energy price differential policy, cheaper fuels, i.e., diesel oil and LPG, are gaining in popularity with consumers. Diesel and LPG-fueled internal combustion engines emit much less CO than gasoline engines. ONEB (1985a) found that about 85 percent of LPG-fueled motor-tricycles emitted less than 1 percent CO.

Table 9.11 Lead Concentration in Bangkok.

Site	Area	Lead ($\mu g/m^3$)			
		Year	Min	Mean	Max
ONEB Network					
1. ONEB	residential	1983	0.13	0.40	1.12
		1984	0.12	0.26	0.64
2. Ladprao Chankasem	residential	1983	0.08	0.36	0.75
		1984	0.08	0.31	0.85
3. Bansomdej	mixed	1983	0.01	0.30	1.96
		1984	0.07	0.29	0.85
4. Ratburana	industrial	1983	0.02	0.32	1.33
		1984	0.08	0.27	0.94
5. Saovapa	commercial	1983	0.21	0.74	1.70
		1984	0.10	0.37	1.90
6. Sukhumvit	residential	1983	0.04	0.42	1.40
		1984	0.12	0.40	1.70
7. Bangna	industrial	1983	0.02	0.33	1.20
		1984	0.07	0.67	3.60
8. Ladkrabang	rural	1983	-	-	-
		1984	0.07	0.24	1.01
MPH/CU Network					
1 Samrong	industrial	1979	0.432	0.914	1.516
		1980	0.009	0.289	1.146
		1981	0.011	0.258	1.233
		1982	0.050	0.201	0.986
		1983	0.000	0.171	0.699
		1984	0.006	0.072	0.375
2 Ladprao	residential	1982	0.018	0.156	0.715
		1983	0.000	0.120	0.363
		1984	0.000	0.092	0.417

Sulfur dioxide

Sulfur dioxide combined with particulates may cause respiratory illness, and in extreme cases, death. While levels of particulates are high in Bangkok, ambient sulfur dioxide is usually very low due to the widespread use of low sulfur fuels in energy consuming sectors. Potential risks are in areas near power plants and industrial boilers.

ONEB stations showed very low sulfur dioxide concentrations, which never exceeded 0.03 mg/m^3 for a 24-hour average. The MPH/CU station at Chulalongkorn University observed a maximum daily concentration of 0.07 mg/m^3 over four years of monitoring, between 1981 and 1984, which is well below the short term-standard of 0.3 mg/m^3. The annual mean SO_2 concentrations are around 0.009 to 0.0015 mg/m^3 as compared to the longterm standard of 0.1 mg/m^3 (Table 9.14). Therefore sulfur dioxide pollution is not a major threat to health.

Table 9.12 Carbon Monoxide Concentration near Major Streets of selected Cities in 1983, 8-Hour Average

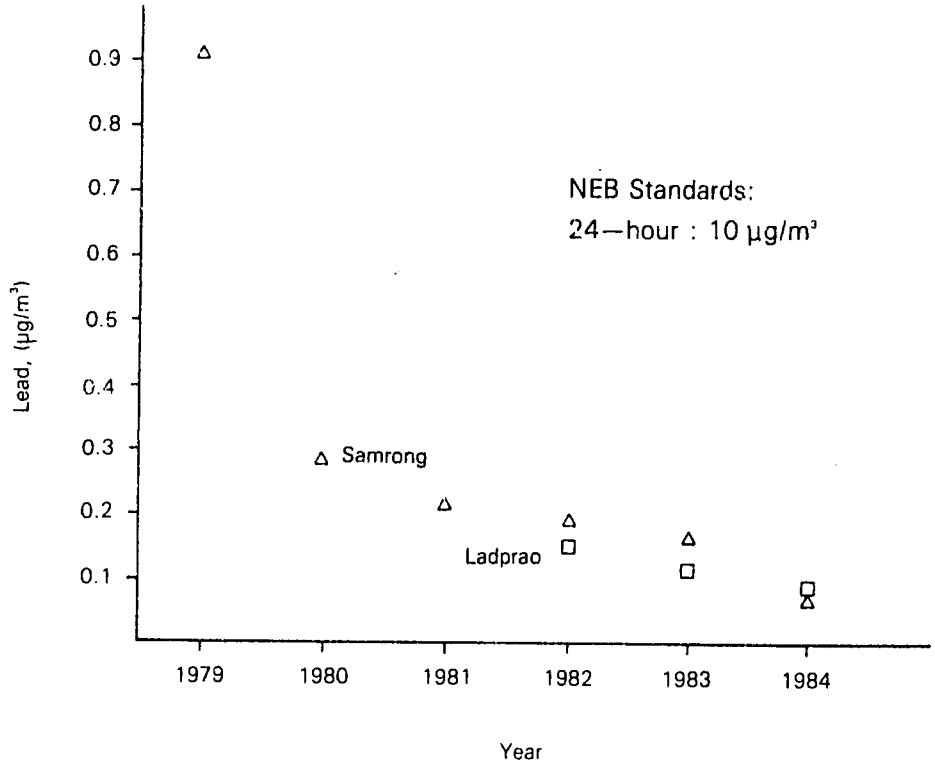
Location	Maximum Values (mg/m^3)
Bangkok	27-37
Chiang Mai	16-18
Hat Yai	6-27

Source: ONEB, 1985e.

Ozone

Ozone is a product of photochemical reactions among hydrocarbons, nitrogen oxides and other gases, under conditions of intense sunlight. The reaction takes about two hours to formulate, during which time the wind may transport

Figure 9.2 Annual Average Lead Concentrations at MPH/CU Stations



the product away from the source. ONEB stations did not detect ozone levels greater than the detectable limit of 0.02 mg/m³ in 1983 and observed a peak concentration of 0.1 mg/m³ at noon in 1984. The levels of ozone detected were always below the one hour standard of 0.2 mg/m³.

Due to its mobility, there is a need for further study on the local ozone formation and its transportation before any conclusion can be made. At present, however, there does not appear to be cause for alarm.

Table 9.13 CO Emission Survey

CO	New Car		Used Car	
%	No.	%	No.	%
< 1	20	21	75	17
1-2	15	15	54	12
2-3	21	22	49	11
3-4	14	14	46	11
4-5	13	14	33	8
5-6	8	8	55	13
> 6	6	6	123	28
Total	**97**	**100**	**435**	**100**

Source: ONEB, Survey of Air Pollution Problem due to Highway Traffic in Bangkok, 1985.

Community Noise Situation and Trends

Noise criteria

Noise can be defined as any sound that is undesirable because it interferes with speech and hearing, is intense enough to

Table 9.14 Sulfur Dioxide 24-Hour Concentration, Bangkok

Site	SO_2 (mg/m³)			
	Year	Min	Mean	Max
Chulalongkorn University	1981	0.002	0.009	0.070
	1982	0.002	0.013	0.048
	1983	0.004	0.015	0.061
	1984	0.004	0.015	0.048

Note: MPH/CU network.

Table 9.15 Sound Pressure and Sound Pressure Level (SPL) Perceived for different Sources of Noise

Sound pressure (μbar)	SPL (dBA)	Example
0.0002	0	Threshold of hearing
0.0063	30	Studio for speech broadcasting
0.02	40	Very quiet room
0.063	50	Residence
0.2	60	Conventional speech
0.63	70	Street traffic at 30 m
1.0	74	Passing automobile at 6 m
2.0	80	Light truck at 6 m
6.3	90	Subway, at 6 m
20	100	Loom in textile mill
63	110	Loud motorcycle at 6 m
200	120	Peak level from rock and roll band
2000	140	Jet plane on the ground at 6 m

Source: Canter, 1977.

damage hearing, or is otherwise annoying. The human ear does not respond linearly to increases in sound pressure; the response is essentially logarithmic. Therefore, noise measurements are expressed by the term "sound pressure level" (SPL), which is the logarithmic ratio of the sound pressure to a reference pressure, and is expressed in terms of decibel (dB). The reference level is 0.0002 microbar, the threshold of human hearing. The logarithmic decibel scale is also useful to describe a very wide range of audible sound in terms of small numbers. Table 9.15 provides a summary of various sound pressures and the corresponding decibel level with examples of noise sources (Canter, 1977).

In most noise research, the A-weighted sound level (dBA) is used. The dBA, in which greater emphasis is given to medium and high frequencies, to which the human ear is most sensitive, correlates well with the subjective impression of loudness. A 10 decibel increase in the sound level doubles its subjective intensity (that is its loudness or noisiness), whereas a doubling of the acoustic energy results in an increased of three decibels only.

Impacts of noise on health are cumulative and the energy-equivalent noise level (Leq) refers to the equivalent steady noise level that, in a stated period of time, would contain the same noise energy as the time-varying noise during the same time period. If the measuring time is 24 hours, the index would be referred as Leq(24). ONEB has not yet established a community noise standard. In this report, noise assessment will be referenced to the community noise standard Leq(24), equal to 70 dBA, adopted by the UESPA.

Community Noise Impacts

Surveys and opinion polls in many countries have found that the disturbance most frequently cited by respondents is noise in the home (OECD, 1985). The prime offending source of noise in terms of the number of people disturbed is road traffic, followed by neighborhood and aircraft noise.

As stated earlier, a large proportion of Thai vehicles violate the noise source standards, and motorcycles are the worst offenders. These sources of noise are increasing at a considerable rate. The total number of vehicles in this country increased from 1.5 million to 2.7 million between years 1978 and 1983. The estimated number of vehicles in 1986 is around 3.2 million, of which nearly 70 percent are motorcycles (Figure 9.3). In Bangkok alone, the estimated number of motorcycles is around 560,000 units, or nearly half the total number of 1.2 million motor vehicles reported in 1986.

While there is a dearth of information on community noise levels, there are several surveys on curb side noise levels in Bangkok. ONEB carried out a curb side noise survey at four locations on busy streets in 1985 and found that noise levels at all four sites exceeded the Leq(24) standard of 70 dBA. Two of these sites, Wang Burapa and Wongwien Yai, also had average noise levels greater than 85 dBA, which is the noise source standard (Table 9.16).

Information on community noise level from the study by Chulalongkorn (1983) and Thorani Tech (1986), as summarized in Table 9.17 and 9.18, showed that most sites along main streets had Leq between 60 to 70 dB, while some houses located close to streets or busy intersections had noise levels exceeding 70 dB.

Away from the sources, noise level decreased with distance from busy streets. ONEB (1981) surveyed 41 sois (lanes) and found that as distance from the street increased from 100 meters to 800 meters, the average noise level went down from 68 dBA to 54 dBA (Figure 9.4).

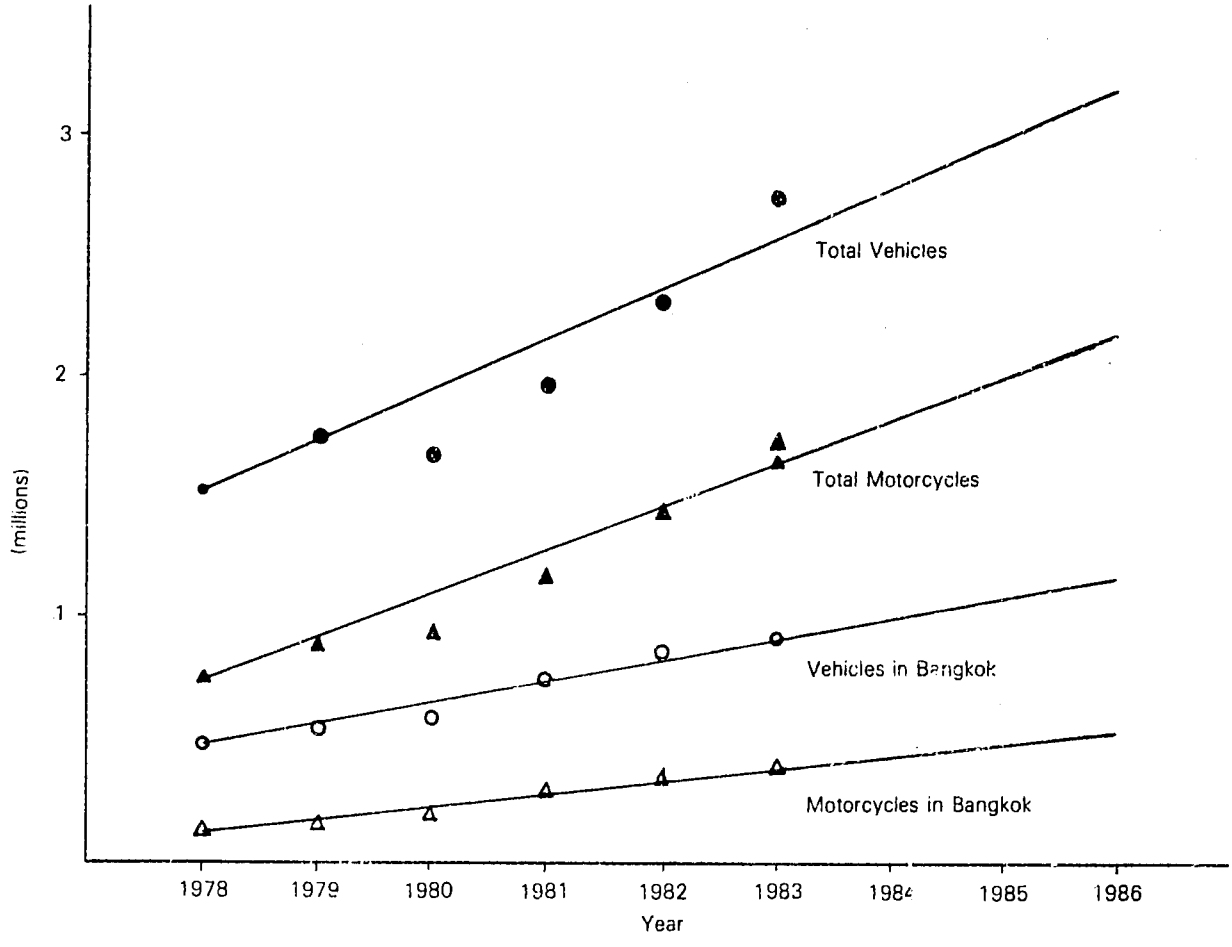
Waterway transportation is an essential part of the Thai life style, and noise nuisance from commuter boats inevitably has an impact on those living along canals and rivers. A survey by Chulalongkorn University (1983) found that the average noise level Leq(24) equaled 72.8 ± 5.2 dBA, with louder noise experienced along small canals rather than on the Chao Phraya River.

Noise Nuisance and Hearing Loss

ONEB has received numerous complaints on noise nuisance from traffic, construction and industry. Affected areas are residential houses, schools, hotels. Examples are: Wat Thepsirin School classroom noise level at the range of 76-95 dBA; and a house in Soi Ruamrudi, close to the expressway, recorded Leq(24) noise levels of 77.9 dBA. These noise levels are unacceptable and cause nuisance to classroom activities, and to working and living conditions alike.

Examination of 85 motorboat operators by Chulalongkorn University (1983) found that 70 persons or 82 percent had hearing loss. The damage was found to correspond with the number of years spent driving the boats. All operators working more than 15 years had hearing loss. However, in the

Figure 9.3 Number of Vehicles in Thailand and Bangkok



Source : Registration Division, Police Department.

beginning the hearing loss occurred outside normal conversation frequency and it was generally too late when these boat operators found that they had problems in hearing.

Noise Trends

As urbanization proceeds and noise sources multiply, more people will be exposed to louder noise for longer periods. If the vehicle growth rate continues at the present rate, the number of vehicles in the whole kingdom will be around 6.5 million, with 2.5 million vehicles in Bangkok alone by the year 2000. While there are no data on number of people exposed to loud noise, the percentage will increase as quiet lanes are turned into busy streets.

Development of housing communities near Bangkok Airport will locate people closer to the noise source. Since the airport will remain there for the foreseeable future, it seems inevitable that more complaints on aircraft noise will come from the growing population in the area.

Table 9.16 Curbside Noise Levels in Bangkok

	Location	Leq(24) dBA
1.	Wang Burapa	87.6
2.	Odeon	77.9
3.	Wongwien Yai	89.3
4.	Krung Thon Bridge	77.1

Source: CNEB (1985)

Box 9.1 How Pollution Control Costs Stack Up for EGAT

Lignite, or brown coal, is increasingly used in electricity generation in Thailand, with significant implications for air quality in lignite-burning areas. Lignite consumption looks set to continue growing, given that it accounts for well over half (57 percent) of the country's proven and possible energy resources. The overwhelming bulk (87 percent) of these reserves are found in the Mae Moh basin, where lignite-fuelled power generation is now concentrated.

With 825MW of installed power generation capacity, accounting for about 5.7 million tons of lignite annually (up from just 433,000 tons in 1975), the Electricity Generating Authority of Thailand (EGAT) is the biggest lignite user. And when a further 900MW of generation capacity comes on stream in 1990, EGAT's annual lignite consumption is expected to increase to about 12.5 million tons.

Work by the Office of the National Environment Board (ONEB) has found significant environmental impacts both in the production and use of lignite. As far as air pollution is concerned, the main problem during lignite production is suspended dust, once the lignite is burned the problems are dust, sulfur dioxide (SO_2) and nitrogen oxides (NO_x). It is estimated that the total flue gas emissions from a 150MW lignite-fired power station total 240.5 kilograms per second.

The pollution control strategy adopted by the electricity generation industry has involved the use of "tall stacks", very tall chimneys which help disperse air pollutants over a much larger area. The first three EGAT lignite-burning units, each rated at 75MW, were fitted with 80-meter stacks, costing 20 million baht each. The other four existing units, of 150MW apiece, are fitted with 100-meter stacks, each costing 35-40 million baht. The next units, each of 300MW capacity, will be fitted with 150-meter stacks, which will cost at least 35 million baht apiece.

The dispersal of pollutants like SO_2, however, is only a stopgap solution. While there are no signs of "acid rain" problems emerging in Thailand, the "tall stack" policy has led to widespread environmental acidification in Europe, Scandinavia and North America. Even dust can cause problems unless further control measures are introduced. EGAT, in fact, already uses electrostatic precipitators, which can remove up to 99.5 percent of the particulates in flue gas emissions, in its seven operational units. For the first three units, the precipitators cost 60 million apiece, while the price went up to 80 million baht each for the precipitators installed in the next four units. A figure of 118 million baht has been given for the precipitation equipment for EGAT's first 300MW plant.

To ensure compliance with air quality standards, EGAT has two mobile laboratories which monitor air quality in the Mae Moh area. The capital cost involved in setting up these laboratories was 11 million baht, and EGAT estimates that it has invested another 10 million baht in environmental monitoring and testing equipment. Increasingly, too, EGAT carries out Environmental Impact Assessments (EIAs) for major new power generation projects. In 1985, for example, it completed an eight million baht EIA covering the entire spectrum of environmental impacts from power generation at Mae Moh.

If there is growing pressure to control SO_2 emissions, EGAT has a number of options. First, it can switch to low-sulfur (two percent sulfur, or lower, rather than three percent) lignite, which is available in the Mae Moh basin. Another, potentially complementary, approach would be to remove some of the sulfur from the lignite before it is burnt, although this would cut SO_2 emissions by only 30 percent. A more effective, and more expensive approach, would be to use flue gas desulfurization. This involves scrubbing the sulfur out of flue gas emissions with wet limestone or lime spray drying.

According to ONEB, the costs of electrostatic precipitation work out at around 0.042 baht per KWh of electricity generation. Flue gas desulfurization, which might remove 90 percent of the SO_2 emissions, would be much more expensive, at 0.22 baht/KWh.

Overall, then, the control of SO_2 would be the most expensive air pollution control challenge for EGAT. If SO_2 controls were to be required, the weighted average cost of electricity would rise to 1.3815 baht/kWh, representing a 0.033 baht/kWh increase. EGAT's prices already include 0.0063 baht/kWh for the cost of dust control. Just for comparison, SO_2 controls would raise electricity prices by around 2.6 percent, which represents a fairly small increase when compared with the 47.75 percent increase in 1981 and 5.64 percent increase in 1982.

The total costs of SO_2 control are potentially high, but it is worth noting that they would represent a relatively small proportion of EGAT's revenues (less than three percent), in the unlikely event that EGAT had to bear all the costs involved. It is also worth noting, however, that they would represent a considerably larger share of EGAT's net profits (21.2 percent of 1985 net profits, for example). There is currently no evidence that EGAT'S SO_2 emissions are exceeding the natural absorptive capacity of the atmosphere, but the growing use of lignite suggests that a close eye should be kept on the emission implications. If action has to be taken, the evidence suggests that it need not cripple the economy.

Table 9.17 Noise Levels along Port-Dindaeng Expressway

No.	Site	dBA 24 hours				
		L_{eq}	L_{dn}	L_{10}	L_{50}	L_{90}
1.	Din-Daeng Fiat	78.4	70.9	81.0	75.3	68.0
2.	Kamolsuksa School (Din-Daeng)	74.0	63.9	77.0	69.0	61.2
3.	Nitiprinya School (Din-Daeng)	59.3	63.4	62.5	56.8	52.5
4.	Opposite to Makkasan railway station	60.8	65.2	63.7	58.1	51.5
5.	Petchaburi Road Interchange (South West side)	67.3	72.0	70.0	64.6	58.0
6.	Petchaburi Road Interchange (South East side)	68.0	73.6	70.6	65.4	60.0
7.	Imperial Hotel	63.0	66.9	66.2	55.7	48.1
8.	International Red Cross (Soi Ruamrudee)	66.3	69.8	68.8	58.5	47.1
9.	Rama IV Road Interchange (North side)	68.9	73.9	71.2	66.8	61.3
10.	Rama IV Road Interchange (South side)	72.5	76.6	74.9	67.5	57.3
11.	Close to Chong Nonsee railway (Port Interchange)	61.0	61.4	64.6	52.6	42.0
12.	Klong Toei Nivet (Port interchange)	57.1	61.0	59.9	54.6	48.4
13.	Pra Harutai Convent	58.2	61.0	59.7	54.5	49.4

Notes: L_{eq} = equivalent noise level
L_{dn} = weighted average daytime (0700 to 2200) and nightime (2200 to 0700) noise level
L_{10} = 10 % of the time the stated level is exceeded
L_{50} = 50 % of the time the stated level is exceeded
L_{90} = 90 % of the time the stated level is exceeded

Source: Chulalongkorn University, 1983.

9.3 LEGAL AND INSTITUTIONAL FRAMEWORK

Laws and Regulations

Air quality standards

Ambient air quality standards are the basic criteria which govern the air pollution control and management program. To achieve the desired air quality standards, the control of emission sources is most important.

Emission standards set the limit on the amount or concentration of pollutants which may be released to the atmosphere. The only emission standards in force are for mobile sources which limit CO emission to 6 percent at idle and limit smoke concentration at 40 percent on the Bosch Scale or 52 percent on the Hartridge Scale. At present, there are no industrial emission standards, although ONEB has already drafted emission standards for oil refinery, cement, and iron smelting and rolling plants. For other industries, the Department of Industrial Works (DIW) has adopted emission guidelines which cover 31 substances and apply to all industries.

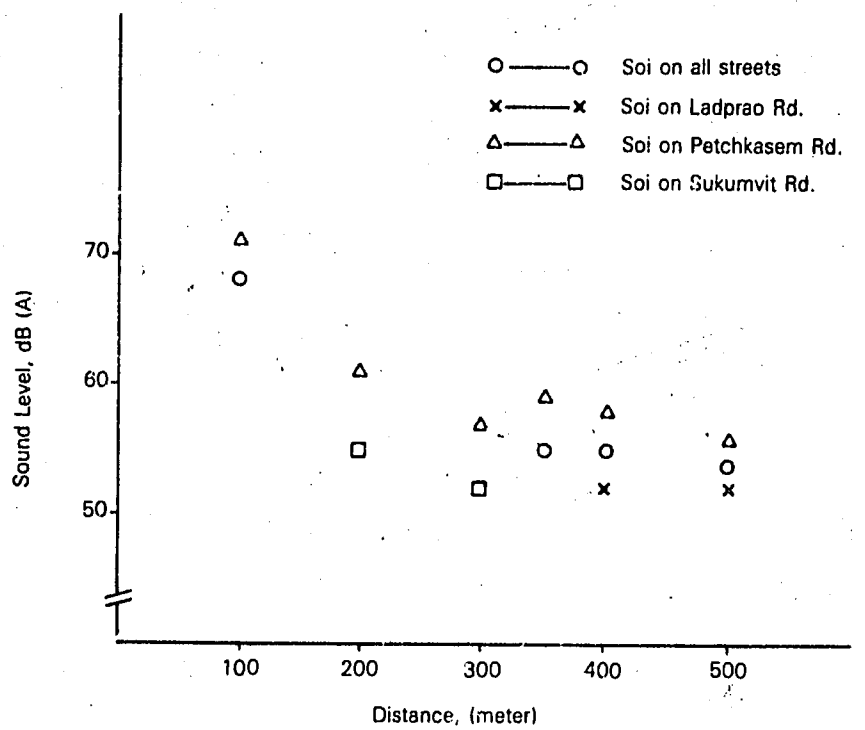
The standard setting process usually requires information on the available control technology. The vehicle exhaust

Table 9.18 Noise Levels along the Present and Proposed Expressway Routes

Location	Distance from the near curb of the expressway or road (m)	Noise Levels (dB) for 24 hours				
		L_{eq}	L_{dn}	L_{10}	L_{50}	L_{90}
Sacred Heart Convent School	33	68.5	74.3	70.5	66.0	59.5
Soi Ruam Rudi	10	66.0	71.3	69.5	62.0	53.0
Sukumvit Soi 66	10	72.5	76.0	76.0	70.0	58.0
Seri Housing Estate	20	51.7	55.1	53.2	46.4	40.3
Siam Cement Housing	2	59.7	64.1	62.2	57.2	50.6
Chanvit School	60	54.4	58.0	55.2	48.8	45.6
Nipat Vittaya School	16	59.0	62.2	62.7	54.9	44.8
Urupong Apartment	40	61.8	66.0	64.4	60.1	53.5
Ngamwongwarn Road	15	67.2	72.2	70.3	64.9	56.0
Changwattana Road	57	61.8	66.1	62.6	56.0	48.0
Mahidol University	10	68.6	75.1	71.4	65.2	53.9

Source: Thorani Tech, 1986.

Figure 9.4 Average Sound Level in Sois at Various Distances from Main Streets



Source: ONEB, Survey of Sound Levels in Sois, 1981.

survey by ONEB in 1980 indicated that as many as 54 percent of all cars monitored at idle exceeded the standard 6 percent by volume of carbon monoxide in the exhaust gas. A subsequent survey by ONEB in 1985, showed a reduction in CO emission with about 28 percent of all cars exceeding the 6 percent standard. However, the improvement was not due to the regulation, since enforcement had been conspicuous only by its absence. Presumably, better engine design in new cars has contributed significantly to CO reduction. This improvement in emission comes about as car manufacturing standards improve worldwide.

There are significant gaps in ambient air quality standards between Thailand and UESPA (Table 9.19). Standards need to be reviewed in accordance with the changing magnitude and sources of air pollution.

Noise standards

After much debate and revision, noise source standards for land and water vehicles were set at 85 dBA when measured at 7.5 meters from the vehicles (January 1985). While new vehicles straight from the assembly lines were found to pass the standards, the survey found that as many as 20 percent of all vehicles in actual use exceeded the standards.

There is presently no community noise standard, although the subject has been much deliberated by the NEB. While the proposed noise standard is based on land use zoning, there is no classification of land-use in Bangkok or in other cities.

The US EPA community noise standard Leq(24) at 70 dBA is usually adopted as the standard in noise assessment. The findings from the many studies undertaken in OECD countries on the effects of noise and its wider repercussions point to the fact that in order to comply with desirable limits for well-being indoor, the outdoor level should never exceed 65 dBA (Leq by day). In the case of new residential areas, the outdoor level should never exceed 55 dBA (Leq by day) (OECD, 1985).

9.4 KEY ISSUES

Acid Rain

"Acid rain" is the term commonly used to describe the deposition of acidic or acid-forming compounds in either their dry or wet forms. These compounds are derived primarily from natural and man-made emissions of sulfure dioxide (SO_2), nitrogen oxides (NO_x) and hydrocarbons (OECD, 1985).

Every year, large quantities of SO_2 and NO_x are discharged into the atmosphere from the combustion of fossil fuels such as coal, lignite and oil. In Thailand about 48 percent of the SO_2 is emitted by electricity-generating power plants and another 34 percent from other industrial sources. Industrial and utility boilers emit about 44 percent of the NO_x and transportation vehicles generate another 23 percent (Table 9.5). Since large numbers of industrial plants and transportation vehicles are found in Bangkok, large proportions of the country's overall SO_2 and NO_x emissions are from Bangkok (one third of SO_2 and a quarter of NO_x emissions).

Usually, much of the sulfur and nitrogen emitted is deposited within a short distance. Effects on local areas include material corrosion and crop damage.

A portion of SO_2 and NO_x emissions may be transported several hundred kilometers by prevailing winds. After being chemically transformed into sulfates and nitrates, the acidic compounds may be deposited as dry or wet particles. This has become an international issue in Northern America and Europe.

It is important to note that normal rainfall is slightly acidic, with a pH sometimes as low as 5.0. However, low pH in rainfall does not automatically mean that the water in lakes and streams will become acidic. Many watersheds have a natural ability to buffer acidity. As the acid rainfall moves through the watershed, alkaline soils can neutralize the acidity. However, some watersheds, particularly those at high altitudes and with thin soils, have less ability to buffer deposited acids.

Table 9.19 Comparison of Ambient Air Quality Standards

Pollutants	Time average	Thailand (mg/m^3)	US EPA (mg/m^3)
Carbon monoxide (CO)	1 hour 8 hour	50 20	40 10
Hydrocarbon (HC)	1 hour (6-9 am)	-	0.16
Photochemical oxidants (O_3)	1 hour	0.2	0 24
Sulfur dioxide (SO_2)	24 hour 1 year	0.3 0.1	0.365 0.080
Total suspended particulates (TSP)	24 hour 1 year	0.33 0.1	0.26 0.075
Nitrogen dioxide (NO_2)	1 hour 1 year	0.32 -	- 0.1
Lead	24 hour 3 month	0.01 -	- 0.0015

There is very little information on the background pH values of rainfall or water resources to indicate the present situation regarding acid rain in Thailand. The potential for acid rain however, is small since the amount of SO_2 and NO_x emission is relatively small. The acidic compounds are mostly deposited within a short distance due to the fact that only a few tall stacks are in operation in the country.

Lead in Gasoline

There is a trend towards the reduction of lead in gasoline worldwide. While lead-free gasoline is used in USA, the amount of lead allowed in gasoline varies from country to country. In Thailand, the Ministry of Commerce lowered the limit of lead in gasoline from 0.84 mg/l to 0.45 mg/l in 1984.

After combustion, about 75 percent of the lead additives in gasaline are emitted in the car's exhaust. Most of the lead is emitted as particulates, mainly smaller than 10 µm. Due to its size, only 6 percent of lead is deposited within 30 meters from roadways and much of lead emission remain in the air for a longer period. Concentrations of lead in ambient air range from 1 to 5 $\mu g/m^3$ at curb side to around 0.1 to 0.5 $\mu g/m^3$ further from the traffic. The level of lead is within the standard limit of 10 $\mu g/m^3$ for 24-hour average values.

Annual lead concentrations found at Samrong (MPH/CU Network) fell from 0.914 $\mu g/m^3$ to 0.072 $\mu g/m^3$ between the years 1979 and 1984, due to the partial substitution of leaded gasoline by the increasing demand on LPG and diesel oil. The reduction of lead in gasoline also caused a significant drop in lead-in-air concentration in 1984. The concentrations of lead in Bangkok were found to be well within the safety limit. The contribution of lead from gasoline of the transportation sector to overall health impact should be minimal in comparison to other pollutants and other sources.

Air and Noise Pollution from Transportation

Transportation is the leading cause of complaints about air and noise pollution in Bangkok and other major cities. With rapid modernization and expanding urbanization, the number of vehicles has increased at 10 percent annually. These emission sources have encroached on people both at work and at home.

High levels of CO concentration, often exceeding the relevant standard, were found in major cities (Table 9.12). While congested traffic and wind dispersion are also important factors, a large percentage of cars were found to violate the emission standards (Table 9.13). However, it was found that new cars produced less emissions, due to better engine design. Replacement of the stock of motor vehicles should progressively reduce the average CO emission from cars.

Noise of motorcycles from assembly lines is within set standards. Noise violation by motorcycles in actual use is due to tampering with exhaust pipes. Although an industrial

Box 9.2 Turning a Deaf Ear to Noise

One of the first things a newcomer to Bangkok notices is the high noise level in the city streets. Buses, trucks and motorbikes all seem to compete to break the sound barrier. And visitors are not the only ones who find the constant blare of the traffic unacceptable; most of the complaints made to the authorities about air and noise pollution focus on road traffic. The increasing pressures are indicated by the fact that the number of road vehicles has been increasing at a rate of about 10 percent a year in Thailand. The number of vehicles nearly doubled in six years, growing from 1.5 million in 1978 to 2.7 million in 1983.

If you ask the average person in Bangkok to pinpoint the worst offenders, he or she will almost certainly mention motorcycles. Of the estimated 1.2 million vehicles in Bangkok in 1986, around 560,000, or nearly half, were motorcycles. And their number has been increasing by over 10 percent a year.

For all types of vehicles, research has shown that they generally meet the relevant noise standards when they first leave the assembly line. But follow-up surveys have shown that some 20 percent of the vehicles on the road exceed the noise standards, either because they have been poorly maintained or because,in the case of many motorcycles, their exhausts have been tampered with, specifically to increase their noise output. An ONEB survey in 1977 found that 16 percent of motorcycle exhausts studied had been tampered with.

Trucks and buses, meanwhile, tend to be more significant in terms of vibration, although they also make an important contribution to the dark smoke and other air pollutants which blight city streets. The Police Department is responsible for onstreet enforcement of the appropriate standards, but its resources are simply not up to the task.

Given that the traffic forecasts suggest that Thailand will have around 6.5 million vehicles in the year 2000, with 2.5 million of those in Bangkok, it is clear that steps will have to be taken to contain the problem. The real human health impact is perhaps best illustrated by the "drivers" of Bangkok's motorized (and very noisy) "long-tailed" boats. A study of 85 boat-owners found that 82 percent had hearing loss, with the extent of hearing loss reflecting the number of years they had been in the business. All those who had been in it for 15 years or more were suffering from hearing loss. But because the hearing frequencies used in everyday conversation are among the last to go, the victims generally fail to realize what is happening until it is too late.

Clearly, the problem is an enormous one. But immediate steps could be taken to cut down on gratuitous noise pollution. Tougher enforcement of noise laws against motorcycles, for example, could be coupled with efforts to encourage manufacturers to make their exhaust systems tamper-proof. Bangkok and Thailand's other major cities would not become silent overnight, but even the longest journeys start with a first step.

standard for exhaust pipes (TIS 340-2528) has been set, a careful examination is needed on the problem of after-use practice. The major causes of noise problems arising from vehicles can be summarized as three-fold: (1) tampering with exhaust pipes or mufflers to deliberately increase the noise emission level; (2) lack of attention in maintaining worn-out exhaust systems; and (3) inadequate enforcement, either through on-street checks or annual inspection during registration renewal.

If noise abatement is the objective, then drastic and strict measures will have to be undertaken to ensure a quieter environment. The measures will have to be directed against the three major causes mentioned above. Judging from past performance in the enforcement of standards, it is not expected that enforcement will get any better in the near future, although an action plan has been proposed by ONEB (1985e) to strengthen the manpower and resources needed to enforce the emission regulation. As to the problems of tampering and maintenance, the solution will lie in the design of tamper-proof and maintenance-free exhaust systems, such as the use of stainlesssteel and permanently welded inner tubes. This is especially the case for motorcycles and public transport, where the vehicles are normally poorly maintained.

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10 Water Quality Management

10.1 OVERVIEW

Urbanization and industrialization are basic causes of Thailand's growing water quality problems, but population growth is an even more fundamental problem. More people need more food, more energy, more materials, and more waste disposal facilities, including more sewerage facilities. The rapid growth of Bangkok and the industrialization of outlying areas are producing many signs of stress in terms of water quality, even well out into the Gulf of Thailand. But the most dramatic example of deteriorating water quality remains the Chao Phraya, the river which flows through the heart of Bangkok itself.

Normally, when a river receives regular inputs of organic matter, it can naturally cleanse itself over time. As the amount of input grows, however, these natural cleansing mechanisms become overloaded. If a river or other body of water ultimately arrives at the stage where it is stripped of the oxygen which beneficial microorganisms need to break down pollution, the entire system can turn anaerobic. To oversimplify, the river dies. The outlook for a number of Thailand's major rivers is reviewed later in this chapter, while the state of the Chao Phraya is summarized in Box 10.1.

This first section will review the current status of: (1) urban sewerage in Thailand; (2) rural sanitation; (3) industrial wastes and pollution; and (4) agricultural wastes. Then the data on water pollution are reviewed, both for inland waters and coastal and marine waters. Later sections focus on the emerging water quality trends, the legal and institutional background, and the key issues which emerge from the discussion.

Urban Sewerage Systems

The term "sewage" normally means the liquid wastes emerging from homes, schools, commercial and institutional buildings, hotels, hospitals, and industrial plants. In addition to human excreta, it generally contains industrial wastes, including effluents from slaughterhouses, breweries, food processing and chemical plants.

The basic approach to getting rid of sewage has been fairly elementary in Bangkok. The storm-water drainage system in urban areas was originally planned on the basis of conveying storm water to the nearest canal, or "khlong". The system is composed of U-shaped open channels, concrete boxes and pipe drains. The drains, which usually are built into the pavements on both sides of the main streets, were not designed as part of any coherent, overall approach to solving Bangkok's sewage problems. Often, they were built with both ends open, so the flow can go in either direction. In densely populated areas, these drains and channels have been converted into combined storm-water and sewage systems, even though they were not designed for this purpose.

Sullage water from sinks, laundries, baths and kitchens is generally collected separately from toilet waste and excreta, and is discharged into the nearest storm drain or channel. Excreta and toilet wastes are discharged into privies, or flushed into cesspools or septic tanks. The idea is that the liquid effluents soak away into the ground, while the accumulated sludge is collected by municipal tankers and usually dumped into a lagoon or, more rarely, taken to waste treatment plants.

Box 10.1 When will the Chao Phraya Die?

Like England's Thames or the Rhine running through the heart of Europe, the Chao Phraya River can be seen as a litmus test of the environmental standards of those living and working within its enormous watershed area. The results are far from reassuring.

The Rhine, which flows through many countries on its way to the sea, still has a long way to go before it can be restored to health, particularly now with the severe damage caused by the Sandoz spill. But the Thames has been resurrected. In the 1940s, it was technically dead; now even salmon swim in it. Unfortunately, the evidence suggests that by the year 2000 the lower reaches of the Chao Phraya, Thailand's most famous river, will be in an even worse state than the Thames was at its lowest point. Taking into account the sewerage systems installed in the 19th century, it took nearly 100 years to cleanup the Thames, so what are the prospects for the Chao Phraya?

To get an idea of what the Chao Phraya might look like in 20 years, consider the khlongs, or canals, of Bangkok. With less than 2 percent of the city's population currently linked to the sewers, many of the khlongs have effectively become open sewers. Measurements taken of the water in Khlong Rajabopit, for example, showed that its properties were almost identical to domestic sewage. The Chao Phraya is a large river, draining an area of 177,000 square kilometers, but its ability to assimilate the discharges from the septic khlongs and sewers, and the effluents from industrial areas like Samut Prakan, is already at the breaking point in some areas.

These problems are considerably aggravated during the low water flow conditions experienced in the dry season. Indeed, the prospect is that an anaerobic, or completely deoxygenated, area will develop. During low water periods, this anaerobic zone could eventually stretch from above the Memorial Bridge to Phra Pradaeng. If there is no oxygen in the water, most of the microorganisms which normally break down the pollution load will be unable to operate. And if the fate of the Thames was anything to go by, the water will become black and foul-smelling.

A mathematical model developed by the Japan International Cooperation Agency (JICA) confirms that if effective wastewater control measures are not soon adopted in the Bangkok Metropolis, anaerobic conditions will become commonplace in the lower Chao Phraya in low water conditions. JICA has recommended that Bangkok should install a new sewerage system and sewage treatment plants, estimating the cost at nearly 37 billion baht (roughly US$1,400 million), a huge sum by anyone's standards.

It seems highly unlikely that Thailand will be able to raise this level of funding in the foreseeable future. Other, more limited, schemes designed to treat domestic or industrial waste will probably stand a better chance of being implemented. One option would be to install smaller treatment plants for highrise buildings, university campuses, big hotels, schools and other institutions, given that treatment is generally much cheaper than installing complete sewerage systems. Meanwhile, the Chao Phraya will continue to die.

Where houses are built densely together, however, the solids may gradually block up the soil structure, preventing further dispersion of the liquids. In some cases, too, owners may decide to avoid paying the tanker charge by connecting their cesspool effluent outlets direct into the storm drains.

Where new, higher cost residences are being built, a small aerated tank unit may be installed to treat sewage, although the effectiveness of such systems is rarely guaranteed. The sludge which accumulates in the tank bottoms is emptied every few years, depending on the capacity and the number of people using the system. In Bangkok, the desludging service costs around 250 baht for each cubic meter of sludge removed, and the resulting sludges are taken to sludge disposal sites by the Bureau of Sanitation.

What Sort of Sewerage for Bangkok?

Currently, 100,000 people — or a mere two percent of Bangkok's population — are connected to the city's existing, limited sewers. Apart from the Bangkok Metropolitan Administration (BMA), a number of other agencies have responsibilities for various aspects of sewage management. For example, the first sewage treatment plant in Bangkok was constructed by the National Housing Authority (NHA), at Huay Khwang, in 1975. The NHA now has a total of 11 plants in Bangkok of which five are activated sludge plants, three oxidation ditches, one is an aerated lagoon and one is an oxidation pond, in total serving just over 73,000 people.

Other agencies include the Department of Health (DOH), which oversees the construction and operation of wastewater treatment plants for Thailand's 47 hospitals, and the Public Works Department (PWD), which handles some of the smaller municipal sewage treatment projects (like that for Pattaya, see Box 10.2).

Over the years, many consultants' reports have been commissioned on how Bangkok should deal with its sewage problems. The Bangkok Metropolitan Administration (BMA) has used such firms as Litchfield, Whiting, Bowne & Associates to prepare the *Greater Bangkok Plan 2533* (1960); Husband

Box 10.2 Pollution and Pattaya

Pattaya is one of Thailand's most important tourist attractions, second only to Bangkok in terms of foreign exchange earnings. In 1985, the town had an estimated resident population of 46,000, expected to grow to 95,000 by 1990. The number of hotel rooms in Pattaya is increasing at 10 percent a year, with some 594,000 overnighting tourists recorded in 1983, a number expected to increase to nearly 1.9 million by 1990. As a result, there is now growing concern among government agencies and local business leaders that the town's very success will undermine its future as a major tourist attraction.

Already, these pressures have been showing up in the quality of the beach environment. Pattaya, it is generally accepted, is not what it was. Sewage and other forms of pollution are in increasing evidence. In 1981, therefore, the City of Pattaya submitted a proposal for the construction of an intercepting sewer to take sewage to a new treatment plant. The following year, an intercepting sewer and wastewater treatment plant were built. They service a small, but densely populated, area of Pattaya, the beach-front strip, at a cost of some five million baht.

Unfortunately, this investment did not significantly reduce the pollution load discharged into the local environment because the new facilities serve such a small proportion of the total community. The conclusion: If Pattaya is to protect the environmental quality on which its original reputation was built, and protect the revenues which stream into the local economy each year, a much greater level of investment is likely to be needed. Tourism, experience has shown, can be a fickle industry. The key question is whether Thailand in general, and Pattaya in particular, can manage their environmental resources in such a way that tourism becomes a truly sustainable form of development.

Co. to prepare its *Report on Sewerage and Sewage Disposal for the Central Area of Bangkok* (1962); Tholin to prepare *A Study of Drainage and Sewerage for Bangkok* (1962); Camp, Dresser & McKee (CDM) to prepare Master Plan volumes on *Sewerage, Drainage and Flood Protection Systems* (1968); and, most recently, the Japan International Cooperation Agency (JICA) to prepare its *Report for the Master Plan of Bangkok Sewerage System Project* (1981). Due to the BMA's limited budget, however, few of their proposals have been fully implemented.

There are a number of reasons for this slow pace of progress. One is that sewerage systems have to be built as a whole. There is no point in building a sewage collection facility, for example, if the trunk sewers do not exist to carry the sewage to a treatment plant. At the same time, however, the population of Bangkok has not been vociferously unhappy with the existing system of septic tanks and cesspools, which has meant that there is less momentum behind the project. And, aggravating this problem, the BMA has made flood control its top-ranking priority. Flooding problems are much more obvious to the average Bangkokian, even if the causes are not (see Box 3.2), so the city's sewerage plans have experienced a further setback.

The JICA proposals, which update and further develop those first put forward by CDM in the late 1960s, recommend a disaggregated sewerage system, rather than a centralized one. The system would cover an area of 370 square kilometers, divided into 10 district zones. That area contained some 5.17 million people in 1980, and is expected to contain 7.89 million by the year 2000. The total cost of the proposals would be some 36,671 million baht, with the largest single element (37.4 percent) being for the construction of the sewers themselves (Table 10.1). As Box 10.1 suggests, this price tag makes it highly unlikely that even the full disaggregated system will be built in the foreseeable future.

Other Towns and Cities

With the continuing growth of urban populations and industrial output, the pressure on water quality is becoming intense in some areas of Thailand. The need to upgrade sanitation and sewerage systems can scarcely be overstressed, although it is recognized that there are many other competing priorities, and budgets are limited. It is worth stressing, however, that deteriorating water quality not only has an impact on public health, but also may affect income from industries which depend on environmental quality, including fisheries and tourism.

Table 10.1 Estimated Construction Cost for Bangkok Sewerage System

	Million baht (at 1980 prices)	% of total
Sewers	13,701.0	37.36
House Connection	9,409.0	25.66
Pumping Stations	188.3	0.51
Treatment Facilities	2,796.7	7.63
Land Aquisition	2,226.5	6.07
Engineering Fee and Contingency	8,349.6	22.77
Total	**36,671.1**	**100.00**

Source: JICA, 1981.

The situation in Bangkok is repeated throughout the towns and cities of Thailand, albeit on a smaller scale. Cities like Chiang Mai, Khon Kaen, Khorat and Songkhla all use the same basic sanitation system, based on cesspools and septic tanks. These work fairly well in many areas, but need frequent pumping in areas where the water table is high.

The Ministry of the Interior (MOI) assigned two of its departments, the Department of Local Administration (DOLA) and the Department of Public Works (DPW), to be responsible for the Regional Cities Development Project (RDCP), funded by the World Bank in 1982. Waste disposal and sewage collection and disposal are featured in the project, and Khon Kaen has been given priority treatment. Construction of intercepting sewers was due to have started in October 1986, laying the foundations for a drainage and sanitation program designed to serve about 118,000 people.

Within the past ten years, many of the larger hotels, shopping centers, multi-story buildings, hospitals, university campuses and other major institutions, have built their own sewage treatment plants. Due to the limited space generally available for such systems, the majority are packaged activated sludge plants. It is estimated, for example, that such plants serve a population of about 100,000 in Bangkok alone. The operation of such plants is not easy, however, due to the considerable fluctuations in waste loading, and the changes from one type of business to another, e.g., from discotheque to restaurant. Unless an operator is available to monitor the system's performance, the overall value of such treatment may be limited.

Rural Sanitation

In the rural areas of Thailand, there are very few types of sanitation facilities currently in use. They include pit latrines, pour-flush (PF) latrines, double-vault composting pourflush (DVCPF) latrines, and biogas digesters. The Sanitation Division of the Department of Health has reported that in 1983 there were about 2.8 million installed PF latrines (Table 10.2), serving approximately 44 percent of rural households. In addition, there were about 400 DVCPF latrines. Biogas digesters came to Thailand as early as 1971. They are fed with animal excreta, and there were some 2,500 of them in Thailand in 1983.

It has been reported that 61 percent of the total rural population already are familiar with the use of latrines (Santad, 1982), while the rest continue to do without them altogether. As far as latrine technologies are concerned, the pit latrine has tended to become much less popular, because of the problems of hygiene and smell, while the PF type is preferred. There is a trend for more Thais to install PF latrines in their own houses, both for convenience and privacy.

Statistical data from the Ministry of Public Health reveal that water and excreta-related diseases rank high on the list of common diseases, and are underlying causes of other forms of morbidity, including malnutrition. Diarrheal disease is the third most common cause of deaths for all ages, for example, and the second most common cause of death for children under the age of six.

Therefore it is the government policy to promote safe disposal of human excreta through low-cost, easily maintained facilities, with the target of equipping 75 percent of rural households by the end of the Decade Plan in 1991 (Table 10.3). Improved excreta disposal methods must be provided along with improved water supplies if the chain of transmission for certain diseases is to be fully broken. Investment in sanitation will inevitably have incidental implications for water quality in the wider environment, with the precise impact depending on the technology used.

Industrial Wastes

There are estimated to be more than 90,000 legal factories in Thailand. Wastes discharged from these plants and works are mainly in the form of air pollution and wastewater. A large part of the country's manufacturing activity is located in the Bangkok Metropolis and the surrounding provinces.

All private polluting factories have to install suitable wastewater treatment facilities in order to obtain their annual operating permits from the Department of Industrial Works (DIW). New factories need to get approval of their proposed treatment facilities before they receive their initial permits. The wastewater plant must treat effluents to a standard of effluent quality defined by the MOI. Some government-owned factories are also in the process of installing treatment facilities. Smaller factories typically do not have their own treatment facilities, due to a lack of space, a lack of funds, or both.

Table 10.2 Distribution of Sanitation Facilities in Rural Areas of Thailand by Region, 1983

Region	No. of Households Outside Municipalities	No. of Biogas Digesters	No. of DVCPF Latrines	PF Latrines	
				No.	%
North	1,645,372	-	-	800,309	48.6
Northeast	2,308,022	-	-	910,763	39.5
Central	1,526,273	-	-	864,380	56.0
South	798,531	-	-	217,210	27.2
Whole Country	6,278,198	2,455	400	2,782,662	44.3

Source: Sanitation Division, DOH, Annual Report 08 R-Ng 514.

Table 10.3 Number of Latrines to be Constructed, 1985-1991

Region	Number of Households By the end of 1991	Number of Latrines Needed to Reach 75%
North	1,853,500	590,000
Northeast	2,662,087	830,000
Central	1,741,138	570,000
South	929,022	500,000
Whole Country	7,185,747	2,490,000

Source: Asian Institute of Technology, 1985.

The DIW commissioned Stablex Canada in 1984 to prepare a feasibility study for the construction of inorganic waste treatment facilities in Bangkok (Stablex Canada, 1984). A few salient findings can be noted here. For example, the study concluded that the 862 factories identified as possible producers of toxic inorganic wastes were generating an estimated 29,000 tons of waste a year, plus 171,000 cubic meters a year of wastewater. By 1995, the study forecast, the respective figures could be 50,000 tons and 236,000 cubic meters. A central treatment plant was proposed.

Although materials like heavy metals and pesticides are clearly important as far as water quality is concerned, the main problem in most of Thailand's rivers is the biochemical oxygen demand (BOD) imposed by organic effluents. Some of the more significant industrial sources of BOD are highlighted in Table 10.4. One of these sources, the distillery sector, is discussed further in Box 10.3. Table 10.4 also shows that nearly half of the BOD loading from these six industries is produced in the Central region. And much of that will find its way directly into the Chao Phraya.

The DIW has recently published three reports on the results of surveys of the industrial wastes being produced in the basins of the Chao Phraya, Thachin, Mae Khlong and the rivers of the Southern region (DIW, 1985a; 1985b; 1985c). The purpose of the surveys has been to evaluate the BOD potential of industrial wastes discharged to these rivers following waste treatment, and the information will be used to help set future effluent discharge conditions. It is apparent, however, that the much higher BOD loading coming from domestic sewage is the main problem.

Industrial Estates

The Industrial Estate Authority of Thailand (IEAT) is responsible for developing areas for industry and for providing infrastructure, including water supply and wastewater treatment plants. At present, IEAT owns the Lad Krabang, Bang Poo, Lamphun, and Bang Chan industrial estates. Nawa Nakhon is owned by private enterprise. Each estate has to provide a central wastewater treatment plant to treat industrial wastes. Lad Krabang and Nawa Nakhon seem to operate their plants satisfactorily, using an activated sludge process. Most of the industrial operations can discharge their waste directly to the treatment system, but some of them have to adjust the pH or subject their wastes to chemical treatment before they can discharge them.

At the Bang Poo estate there are some problems relating to the central waste treatment plant. Earlier factories on the estate did not have their wastewater connected to the treatment system, so the wastes are discharged to the nearest khlongs or canals. Only the new factories which have recently been set up on the estate will have their wastes connected to the system. At the Bang Chan estate, there is no central waste treatment plant, because most of the industries in this estate do not produce wastewater.

Table 10.4 High Organic Pollution Effuents from Seven Typical Industries in Thailand, 1986

Regions	Industries													
	Sugar		Tapioca		Distillery Brewery Ehtyl Alcohol		Pulp and Paper		Mono Sodium glutamate flavor		Rubber		Total	
	No. of factories	BOD_5 kg/day	No. of factories	BOD_5 kg/day	No. of factories	BOD_5 kg/day	No. of factories	BOD_5 kg/day	No. of factories	BOD_5 kg/day	No. of factories	BOD_5 kg/day	No. of factories	BOD_5 kg/day
North	8	9,946	4	40,120	4	27,270	1	31	-	-	-	-	17	77,367
Northeast	6	10,859	14	181,130	4	38,290	1	98,939	-	-	-	-	25	329,218
East	9	15,244	25	300,940	3	18,330	1	63	-	-	8	5,360	46	340,937
Central	22	61,763	4	49,560	15	98,928	37	268,834	3	218,400	1	705	82	698,190
Southern	-	-	-	-	1	11,972	-	-	-	-	69	159,040	70	171,012
Subtotal	**45**	**97,812**	**47**	**571,750**	**27**	**194,790**	**40**	**367,867**	**3**	**218,400**	**78**	**166,105**	**240**	**1,616,724**
% of total	**18.80**	**6.05**	**19.6**	**35.36**	**11.3**	**12.05**	**0.17**	**22.75**	**1.2**	**13.51**	**32.5**	**10.27**	**100**	**100**

Box 10.3 A BOD Hangover from Thai Distilleries

Liquid wastes from alcohol distilleries represent some of the worst industrial effluents discharged into Thailand's surface waters, at least as far as their biochemical oxygen demand (BOD) is concerned. There are about 20 distilleries and two alcohol production plants in Thailand, all of which use sugar cane molasses as their main raw material. The wastewater discharge from the distilling column is known as the spent wash or stillage, or simply as "slop". Typically, the slop emerges as a dilution of the molasses in three times its volume of water, stripped of its sugar content, but containing yeast cells and ammonium sulfate.

Before 1978, most spent wash was discharged untreated into rivers, or sometimes stored in a lagoon. River discharges killed fish and most other aquatic organisms almost instantaneously, while the resulting deoxygenation and foul odor rendered the river water unfit for any other purpose. Increasingly, however, the nation's distilleries have been installing pollution control equipment. And, as the following examples show, some of the resulting by-products are finding profitable applications.

In 1982, for instance, two full-scale evaporation and incineration plants were installed at the Bangyikhan distilleries in Bangkok and Prathum Thani. Following separation of the yeast, the spent wash is concentrated to about 60 percent solids (compared with an original concentration of 9-10 percent) and incinerated. The heat generated in the process is used to generate steam which, in turn, is used to evaporate raw spent wash, to power the injection of thickened liquor into the incinerators, and to supplement the steam requirements of the fermenter and distillation columns. It has been estimated that about 70 percent of the distilleries' steam requirements are now met in this way.

Bangyikhan recently moved its Bangkok fermentation and distillation processes to Pathum Thani, to cut air pollution problems in the city center. The Bangyikhan waste heat boilers are fitted with electrostatic precipitators, to arrest the fine ash particles before they are vented to the atmosphere. The total cost of the waste recovery plant at the Bangkok distillery was about US$10 million, to provide treatment capacity suitable for 1,200 cubic meters of slop a day. If the price of fuel oil, used in starting up the incinerators, does not exceed 6 baht per liter (US24 cents per liter), the payback period will be about thirteen years. The Bangkok operation produces 18 tons of ash a day, with an average potash content of about 31 percent (as K_2O) or 65 percent (as K_2SO_4). If the ash is eventually marketed as a fertilizer, which is conceptually possible, the payback period could be shorter.

Elsewhere in Thailand, the high BOD loading imposed by distillery effluents is being tackled in different ways. Twelve new distillery plants owned by the Excise Department began commissioning early in 1985, in Chiang Mai, Ratchaburi Uttaradit, Nong Khai, Chachoengsao. Buri Ram, Suratthani, Khon Kaen, Nakhon Sawan, Prachinburi, Ubon Ratchathani and Kanchanaburi. The first six are operated by Surathip Co., Ltd., and the second six by Sukomaharas Co., Ltd. Since these plants are in rural areas, there are no problems in acquiring land for waste storage, and the spent wash is treated by anaerobic digestion, followed by storage lagooning and composting.The methane generated in the process is fed into the distillery boilers, and it is calculated that the digester costs can be recovered within 3 to 4 years.

The composting technique used involves spraying the raw slop onto a heap of bagasse, the sugar cane fiber waste, and adding bacteria and urea. The heap is turned by tractor, to ensure uniform mixing, ventilation and drying. The quality of the final product is low, however, and is more suitable for use as a soil conditioner than as an organic fertilizer. But the dried solids which accumulate at the bottom of the lagoon can be collected and sold as an organic fertilizer, with each ton of spent wash producing 10 to 20 kilograms of dry solids. When combined with final application to farming land, this approach can reduce the BOD input to nearby rivers by almost 100 percent.

Agricultural Wastes

Agricultural waste includes organic matter, such as animal manure, fish faeces, poultry wastes or drainage water from plantations, and other substances such as fertilizer and pesticide run off. Most of these agricultural activities are performed in rural areas. These wastes have often undergone a certain degree of natural aerobic or anaerobic treatment by soil adsorption before they reach water courses.

A study in 1982 (TISTR,1982) showed that the wastewater or drainage water from a highland paddy field in the Thachin River Basin contributed 0.0144 kg BOD/rai/day (1 acre = 2.5 rai) and 0.54×10^{-6} kg/rai/day of pesticide. For lowland paddy fields, the unit emission rate was 0.00035 kg BOD/rai/day and 0.0089×10^{-6} kg/rai/day of pesticides. After a four month retention period of this drainage water in the paddy field, the corresponding BOD and pesticide loadings will be 1.73 kg/rai and 64.8×10^{-6} kg/rai, respectively. However this drainage water is generally not discharged to the water course at the same time from different plots so the pollution load may not reach its peak. For the crop plantation land, the unit emission is 0.00626 kg BOD/rai/day and 0.387×10^{-6} kg pesticides/rai/day. The degree of pollution to the water course depends

Table 10.5 Unit Emission Rates and Loadings from Different Agricultural Wastes Discharged in the Thachin River Basin

Type of Agriculture		Unit Emission Rates (kg/rai/day)			Total Estimated Loadings to Thachin River Basin (kg/day)		
		BOD_5	Pesticides	Hg	BOD	Pesticides	Hg
1) Paddy Field	Low Land	0.00035	0.0089×10^{-6}		4,858	0.1424	
	High Land	0.0144	0.5385×10^{-6}				
2) Crop Plantation Land		0.00626	0.3868×10^{-6}		9,804	0.6086	
3) Pig Farm[a]		0.10336	0.0076×10^{-6}	0.0332	28,869	0.00119	0.0052
4) Striped Snake Head Fish Farm	Upper Part of river	20.58	126.25×10^{-6}		9,644	0.0254	
	Mid and lower part of river	9.67	20.93×10^{-6}				
5) Shrimp Farm		0.233	0.712×10^{-6}				
6) Non protein feeding fish farm		1.88					
7) Chao Phraya River Inflow					24,036	2.424	
				Total	**77,211**	**3.2**	**0.0052**

Note: a Unit emission rate in kg/pig/day
Source: TISTR, 1982.

on the dilution factor. If the waste is discharged when the river flow rate is high, the pollution effect may be negligible (TISTR, 1982).

The same study showed that floor washing waste from a pig farm will contribute mercury (Hg), BOD, and pesticide loadings of 0.103 kg BOD/pig/ day, 0.02 mg/pig/day and 0.44 µg/pig/day, respectively. Pig manure is collected separately and can be sold as an organic fertilizer at a rate of 20 baht per 20 kg bag. The BOD_5 loading from all pig farms in the Thachin River Basin is estimated at 28,869 kg BOD/day and this may be equivalent to a population of 10.5 million people (use 20 g BOD/capita/day). Although it looks as though the organic pollution load is high, these farms are spread out through an area of 12,000 square kilometers in six provinces.

For striped snake head fish farms, nonprotein feeding fish farms and shrimp farms, the unit emission rates are given in Table 10.5. Small biogas digesters may sometimes be used for the treatment of animal wastes, with more than 2,500 digesters in operation in Thailand (UNESCO, no date). The effluent from digesters can be used as organic fertilizer, reducing BOD_5 loading in nearby canals or rivers. The annual savings achieved by such a digester range between 500 and 1,500 baht, compared with a digester cost of 6,000-10,000 baht.

Oil Pollution

The pollution of the Thai marine environment by industry and shipping activities is causing a great deal of concern. The effects of the pollution are evident in the poor quality of the water in the rivers such as the Chao Phraya, deterioration in the fish catch, and beach pollution. Oil pollu[illegible] remains a major concern.

There are three sources of oil pollution that can be clearly identified, two related to chronic pollution and the third to massive pollution (Aqua-Guard, 1984). Chronic pollution results both from oil discharges from ship breaking activities along the Eastern Seaboard, and from the discharge of oily ballast, tank washings and bilge oil from shipping operations. The estimated annual worst case spillage is in excess of 35,000 tons of petroleum related products. Based on recorded accidents in Thailand this figure would appear to be high. The total from all three sources would be approximately 45,000 tons/year. However, this does not take into account the numerous sources of oil draining into storm drains, khlongs and sewers from petrol stations and other sites. Old lubricating oil is a major source in this category.

The primary environmental concerns focus on coral reefs, mangroves and birds. The first two provide bases for extensive ecosystems which support a wide variety of fish flora and

fauna. Secondary environmental concerns focus on beaches and marine parks, which form increasingly important components of the Thai tourist industry.

Oily waste management for chronic spills includes the signing of the MARPOL Treaty and measures should be taken to comply with the stipulated requirements. For massive spills, a Thai oil spill contingency plan must be established to ensure efficient use of present resources and to provide a basis for developing a non-redundant inventory and distribution of equipment.

An oil spill from Si Racha refinery of Thai Oil Co., Ltd. on 20 September 1986 hit Pattaya beach. The spill was caused by an overflow from the oil holding pond to the sea during heavy rainfall. The oil was absorbed by the sand. Moreover, the slick covered swimmers and their costumes with smears of oil, driving them ashore. Pattaya City Administration had cleaned up the oil slicks at the cost of the refinery.

Mining Pollution

Sediments entered Thailand's river systems at a rate of 47 million m^3 in 1978. Sediment from tin mining has also resulted in damage to the marine environment of Phuket, Ranong and Phangnga provinces. It is estimated that 40 million tons of sediment have been added to the nearshore area in Southern Thailand during the past 20 years (Carter 1979). Supan Bay, Ranong Harbor and Bang Thao Bay are areas of severe damage resulting from tin mining. A study by the NEB, shows that 60 percent of coral reefs in the Southern Bang Thao Bay have been destroyed with consequent effects on other marine life (NEB 1984b). Effluents of potential concern are also generated by such activities as barite, lignite and tungsten mining.

10.2 EMERGING TRENDS IN WATER QUALITY

The following section briefly reviews the water quality data for the urban khlongs, three out of Thailand's four major rivers (the Bang Pakong is considered relatively clean), groundwater, estuaries and coastal waters, the Gulf of Thailand and the Andaman Sea. The number of quality parameters which could be reviewed is very considerable. The Office of the National Environment Board, for example, has river quality monitoring stations which regularly check water temperature, pH, conductivity, salinity, chloride, dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), coliform bacteria, total phosphorus, nitrate nitrogen, ammonia nitrogen, total Kjeldahl nitrogen (TKN), phenol, cyanide, heavy metals and pesticides. For the purposes of the present discussion, however, three key indicators will be covered: the levels of dissolved oxygen (DO), heavy metals and pesticides.

The City Khlongs

In the lower reach of the Chao Phraya where Bangkok is located, there are many khlongs, or canals, some of which are natural. Most, however, are manmade. Most of these khlongs are used for drainage, irrigation and navigation, as well as for fire fighting purposes. In the central area of Bangkok, the khlongs receive all surface runoff, as well as sullage, garbage, industrial wastes, and the effluent from septic tanks and cesspools, ultimately conveying all of these inputs to the Chao Phraya.

Not surprisingly, many of the khlongs in the central area of Bangkok have become heavily polluted. In 1980, the BMA Bureau of Drainage and Sewerage conducted a survey of different khlongs, concluding that for most of the time the dissolved oxygen content was zero, while the BOD_5 values were equivalent to sewage, rather than to those for normal water (JICA, 1981). The khlongs in other cities, such as Samut Prakan, Chiang Mai or Khon Kaen, have also been used as sewers. In the dry season, these khlongs become septic and produce an offensive smell.

The Chao Phraya River

The Chao Phraya drains an area of about 177,000 square kilometers, including the most heavily populated and industrialized areas of Thailand. As a consequence, it is heavily polluted (see Box 10.1). The river is the country's largest: its minimum width when running through Bangkok is 180 meters, with depths of 20 meters and more, while 10 kilometers from the Gulf it broadens to 500 meters — and to 1,000 meters near the mouth. The river's minimum discharge rate is less than 50 cubic meters per second, in the low water period which runs from April to June. From August to December, by contrast, the flow normally exceeds 1,000 m^3/sec, while the maximum flow rate is in excess of 4,000 m^3/sec.

Given the quantities of sewage and industrial effluent being discharged into the Chao Phraya, the dissolved oxygen (DO) level is probably the best single indicator of the state of the river's health. The recorded DO levels have shown depressed sag curves for nearly 20 years, with the area affected showing a tendency to spread. Despite the somewhat higher DO curves recorded for 1979 and 1980, the evidence suggests that DO levels will remain depressed during low flow conditions for the foreseeable future. During high flow conditions, the area of depressed DO levels is shifted downstream.

Since the 1960s, there has been concern that these low DO levels would finally result in the formation of anaerobic conditions in extended lengths of the river. In fact, it is likely that anaerobic conditions already result in the river when the first major rainfall occurs following the dry season, flushing organic deposits into the river from the khlongs and drains. But the DO record suggests that there may have been a number of competing trends at work. Since the river has not yet turned anaerobic for significant periods of time, it may

well be that the increasing treatment of high-BOD industrial effluents has to some extent compensated for the growing volumes of untreated sewage discharged by Bangkok's rapidly growing population.

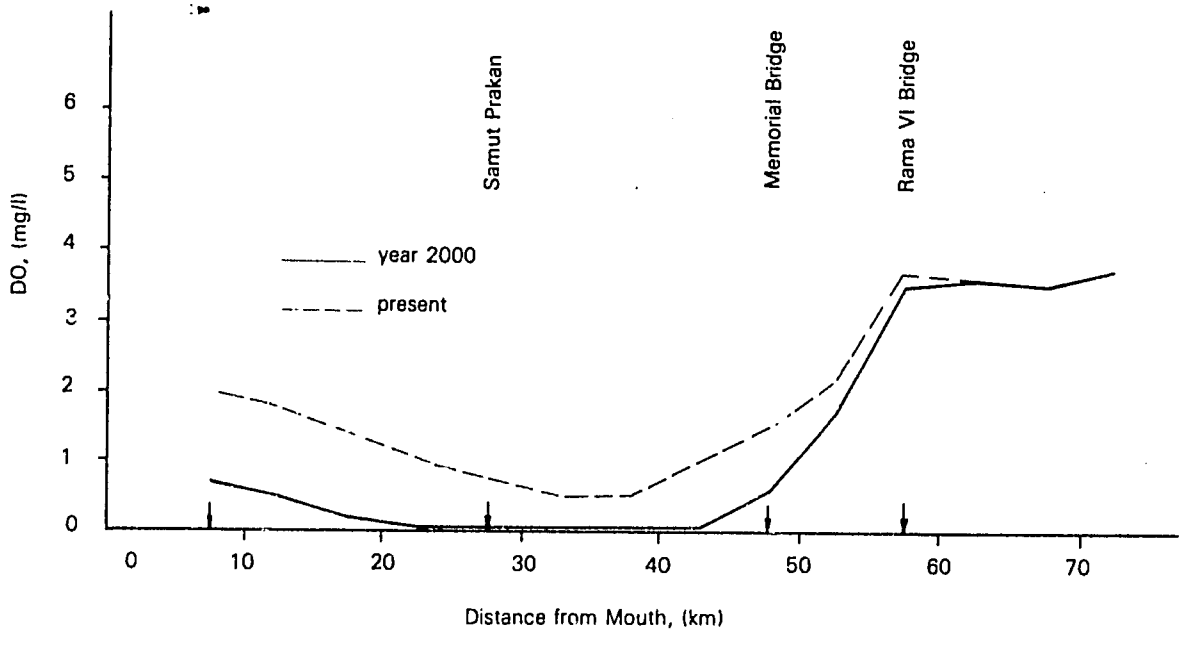
Nonetheless, the latest report on Bangkok's sewerage needs (JICA, 1981), forecasts that much of the river between the Rama VI Bridge (58 kilometers from the river's mouth) and Samut Prakan could become anaerobic in low flow conditions by the year 2000 (Figure 10.1). DO concentrations fluctuate from 1 to 4 mg/l, with an average value of 2.0 mg/l in the lower reaches (below km 50). It has been estimated that 364,900 kg/day of BOD loading is discharged into the river, including 355,000 kg/day in the form of untreated domestic sewage and 9,900 kg/day of treated industrial wastes (Table 10.6).

As far as heavy metal contamination of the Chao Phraya is concerned, Table 10.7 shows some recorded levels in water and sediment. Copper concentrations fluctuated between 4.8 and 66.9 µg/l (or parts per billion) in water and between 10.4 and 41.7 µg/kg in sediment, but were within the 100 µg/l standard for good quality water. Nickel concentrations ranged from 2.72 to 137.5 µg/l, implying some breaches of the 100 µg/l standard for good quality water, although the average value of 18.6 µg/l was acceptable. The reported levels of lead, cadmium and mercury were all within acceptable limits, as were chromium, manganese and zinc concentrations. Heavy metal contamination in water reflected the areas of peak discharges (Figure 10.2), while sediment contamination seems to be most pronounced in the lower stretches of the river (Figure 10.3).

Organochlorine pesticides such as Aldrin, BHC, DDD, DDE, DDT, Dieldrin, Heptachlor and Lindane were all found in the city khlongs and the Chao Phraya. Levels of Aldrin, BHC and Dieldrin in water collected in April of 1984 were 0.126, 0.002 and 0.080 µg/l, respectively. These concentrations were between three and ten times greater than those measured in October, during the rainy season (Table 10.8). The peaks in organochlorine pesticide contamination were found at three different locations, 300, 170 and 60 kilometers from the river's mouth, indicating the discharge of pesticides in significant quantities at three different points along the river. Concentrations of these pesticides were found to be 10 to 100 times greater in sediments than in water (Figure 10.4 and 10.5), indicating that there is long-term accumulation in sediments.

Overall, the available data show that there is a heavy pollution load in the lower reaches of the Chao Phraya, with DO levels dropping to near zero in places. The levels of such

Figure 10.1 Forecast Dissolved Oxygen in the Chao Phraya in Year 2000



Source : JICA, 1981

Table 10.6 Sources of High BOD Loadings in Three Areas of the Chao Phraya River Basin, 1984-1985

Region and Purpose of Survey	No. of Factories Surveyed	Total Waste Flow Rate (m^3/day)	Total Influent BOD_5 Loading (kg/day)	Total Effluent BOD_5 Loading (kg/day)	Total BOD_5 Removal by Waste Treatment (kg/day)	Treatment Efficiency (%)	Estimated Domestic Sewage Loading (kg/day)
1. Northern Region, 14 Provinces to observe pollution problems on the Ping, Wang, Yom, Nan Pasak, Mae Kok river basins. (Kamphang Phet, Tak, Lampang, Lamphun, Chiang Mai, Chiang Rai, Phayao, Nan, Phrae, Uttaradit, Sukhothai, Phitsanulok, Phichit, Phetchabun)	76	766,945	99,119	18,087	81,032	82	485,203
2. Upper Chao Phraya River, 8 Provinces to observe pollution problem on Lopburi and Pasak River basins (Nakhon Sawan, Singhburi, Ang Thong, Ayutthaya Lopburi, Saraburi, Phetchabun Chainat)	84	97,739	78,217	11,004.8	67,213	86	197,281
3. Lower Chao Phraya River, Provinces to observe raw water intake for city water supply Pathum Thani, Nonthaburi, Bangkok, Thonburi, Samut Prakan)							
3.1 Nonthaburi-Pathum Thani including Samlae Water Intake	40	33,263	93,094	4,268	88,826	95	44,791
3.2 BMA area at Khlong Phasi Charoen	52	26,401	14,430	2,763	11,667	81	276,007
3.3 Left hand side of Samut-Prakan at Khlong Samrong	43	31,510	20,574	1,957	18,617	91	23,257
3.4 Right hand side of Samut-Prakan at Khlong Bang Phueng	70	5,465	8,781	972	7,809	89	11,035
Total Lower Chao Phraya	**205**	**96,639**	**136,879**	**9,960**	**126,919**	**Avg.93**	**355,090**

Source: DIW, 1985.

Table 10.7 Some Heavy Metals in the Water And Sediment of Chao Phraya River, September 1984

Metals	River Water (μg/l)		Sediment (mg/kg)	
	Average	Range	Average	Range
Cu	16.0	4.81-66.9	22.2	10.4-41.7
Ni	18.6	2.75-137	21.8	13.8-32.9
Pb	2.07	ND-4.05	22.6	8.9-92.0
Cd	2.52	ND-4.29	0.4	ND-0.92
Total Hg	<0.2	ND-0.43	.00116	ND-.00218

ND = Not Detectable
Source: Onodera, 1985, p. 78 and 83.

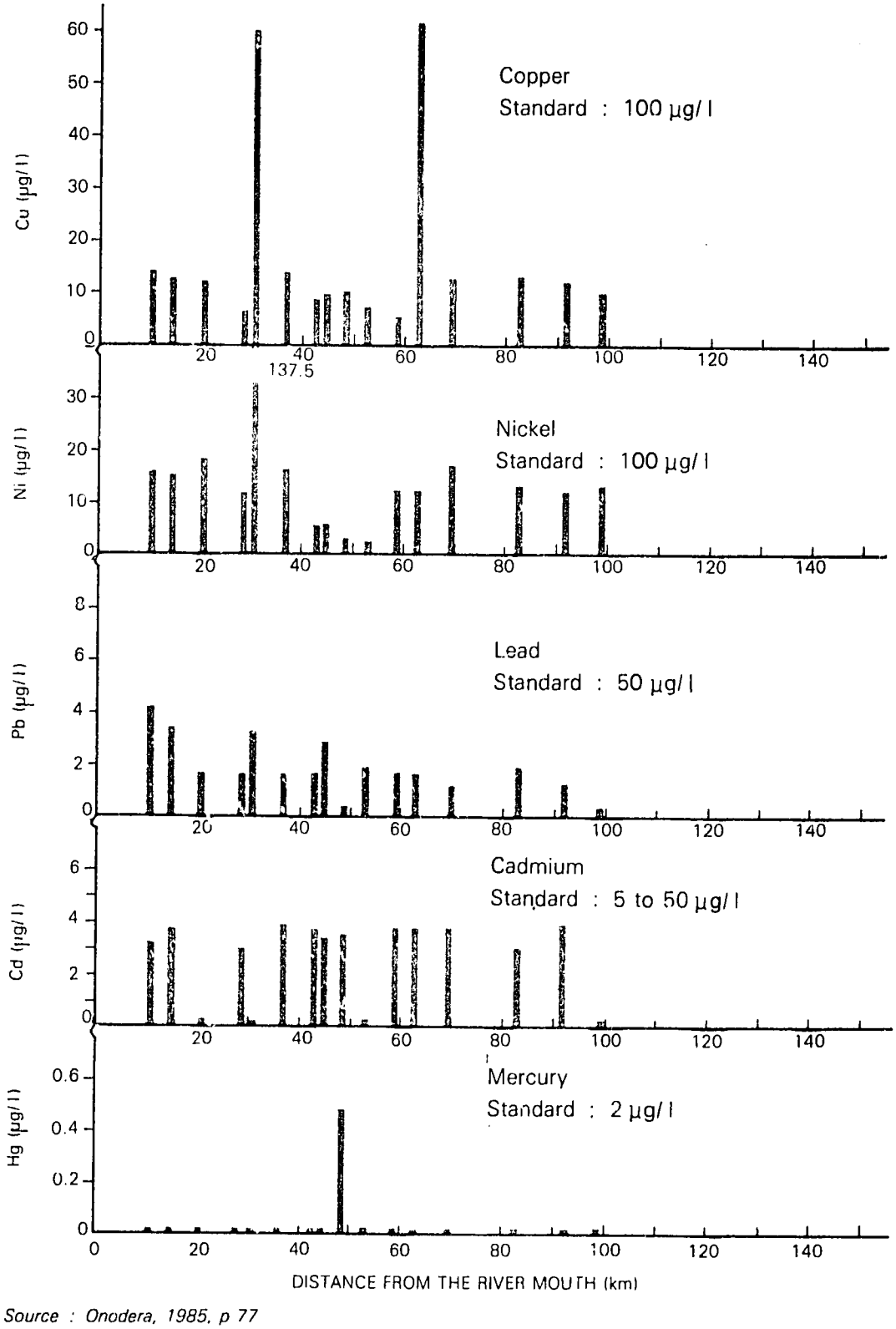
toxic substances as heavy metals and pesticides have not yet reached critical levels, although monitoring should continue as the urbanization and industrialization of the Chao Phraya watershed proceeds.

The Thachin River

The Thachin River also receives a considerable BOD loading from ssewage and industrial effluents. The flow of the Thachin fluctuates between 28 m^3/sec in the dry season (January-July) and about 200 m^3/sec in the wet season (August-December), at the Phophaya Gate.

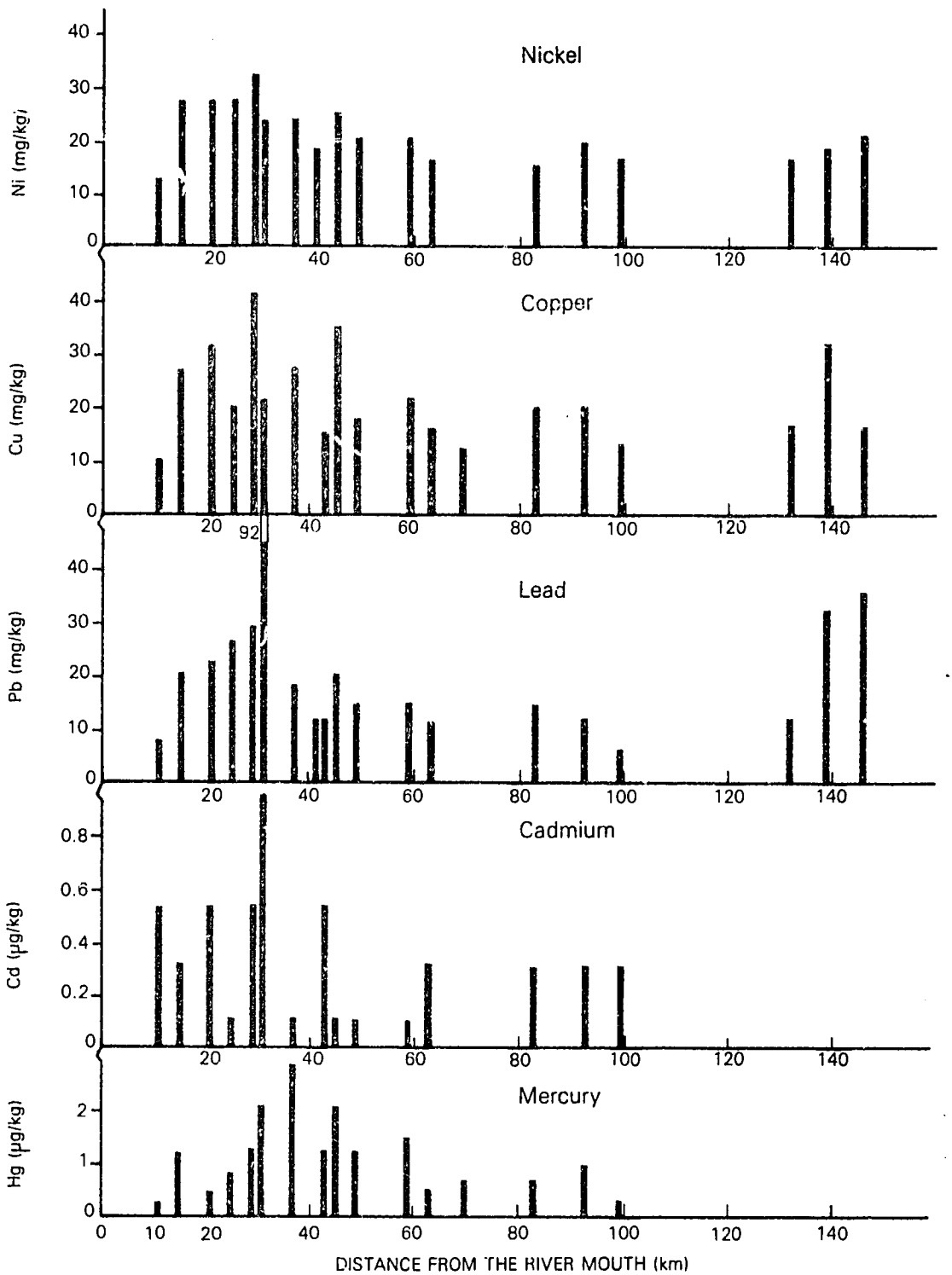
Around the river's 12,000 square kilometer water catchment area, it is estimated that about 20 communities with a population of nearly 200,000 discharge about 3,700 kg BOD_5/day to the lower reaches of the river. Moreover, 160

Figure 10.2 Distributions of Heavy Metals in the Water of Chao Phraya River, September 1984



Source : Onodera, 1985, p 77

Figure 10.3 Distribution of Heavy Metals in the Sediments of Chao Phraya River, September 1984



Source : Onodera, 1985, p 82

Table 10.8 Concentrations of Organochlorine Pesticides in the Chao Phraya River in April and October 1984[a]

(µg/l)

Organochlorine pesticides	April			October			ONEB Std.
	Freq.[b]	Max.	Med.	Freq.[b]	Max.	Med.	
α BHC	95	0.056	0.002	100	0.035	0.007	0.02
β BHC	5	0.024	-	0	-	-	
γ BHC (Lindane)	27	0.021	-	72	0.032	0.003	
Heptachlor	41	0.015		27	0.166	-	0.2
Heptachlor epoxide	32	Trace	-	18	Trace		0.2
Chlordane	0	-	-	0	-	-	
Aldrin	100	0.284	0.126	100	0.028	0.008	0.1
Dieldrin	100	0.289	0.080	88	0.442	0.029	0.1
Endrin	0	-	-	0	-	-	0
p,p'-DDE	36	0.031		18	0.030	-	
o,p'-DDT	0	-	-	0	-	-	1.0
p,p'-DDD	9	0.025	-	18	0.03	-	
p,p'-DDT	13	0.015	-	9	0.271	-	1.0

- = Non detectable
Notes: a. The survey extended from the river mouth to 340 km.
b. Frequency of occurrence in %
Source: Onodera, 1985, p.65

Table 10.9 Comparison of BOD Loads by Source in the Maeklong, 1976

Source	BOD Load kg/d	Percentage
Domestic	8,375	7.50
Other Industries	9,005	8.20
Sugar Industries	92,940	84.20
Total	**110,320**	**100.00**

Source: Visuthirungsiuri, 1976.

industrial concerns, mainly involved in food and textile manufacture, discharge about 5,600 kg BOD_5/day to the upper reaches, 120 kg BOD_5/day to the middle reach and 4,800 kg BOD_5/day to the lower reaches. Agricultural inputs include drainage water from paddy fields (about 15,000 kg BOD_5/day), pig farm wastes (16,500 kg BOD_5/day), fish and prawn farms (9,600 kg BOD_5/day), and pesticides (about 0.15 kg BOD_5/day). Moreover, the upper reaches of the river receive a diversion flow from the Chao Phraya which includes a BOD load of about 27,000 kg/day and mercury contamination in the order of 2.26 kg/day.

Heavy metals do not exceed the standards for good quality water. Mercury and lead concentrations are 0.62 µg/l, compared with the allowable limit of 2 µg/l, while average lead concentrations are also less than the good water quality standard of 5 µg/l. There was one sample, near km 240, at Samchook, Suphanburi, where the mercury level was relatively high, however, at 14.6 µg/l.

As far as pesticides are concerned, the average Heptachlor concentration is somewhat higher, at 0.08 µg/l, than those for Aldrin (0.06 µg/l), BHC (0.013 µg/l), DDT (0.004 µg/l) and Dieldrin (0.063 µg/l). Pesticide concentrations increase towards the mouth of the river, but the reported concentrations are well within the permissible limits.

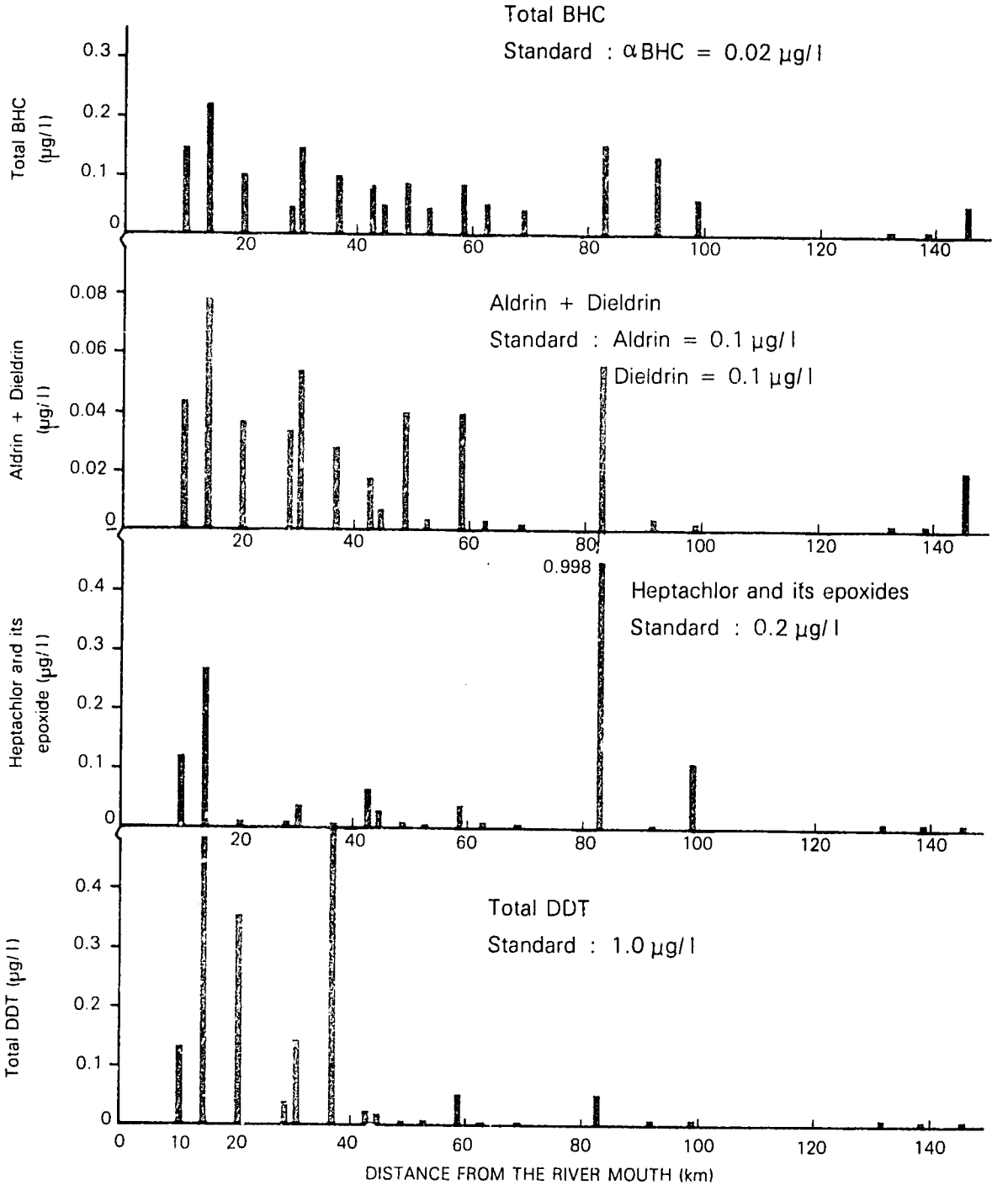
The Maeklong River

The Maeklong is one of the most important rivers of western Thailand. Along its 140 kilometer course, it drains an area inhabited by several hundred thousand people and, more importantly, supports the largest concentration of sugar cane plantations in the country. By the 1970s, there were 17 sugar mills in the area, which together accounted for over 60 percent of Thailand's total sugar processing capacity.

In 1976, the total estimated BOD discharges into the river during the dry season was estimated at 110,320 kg/day (Table 10.9). As a result, there was widespread pollution in the lower part of the Maekhlong and in the estuary. Cockle farms in particular, were hard hit by the deteriorating river quality.

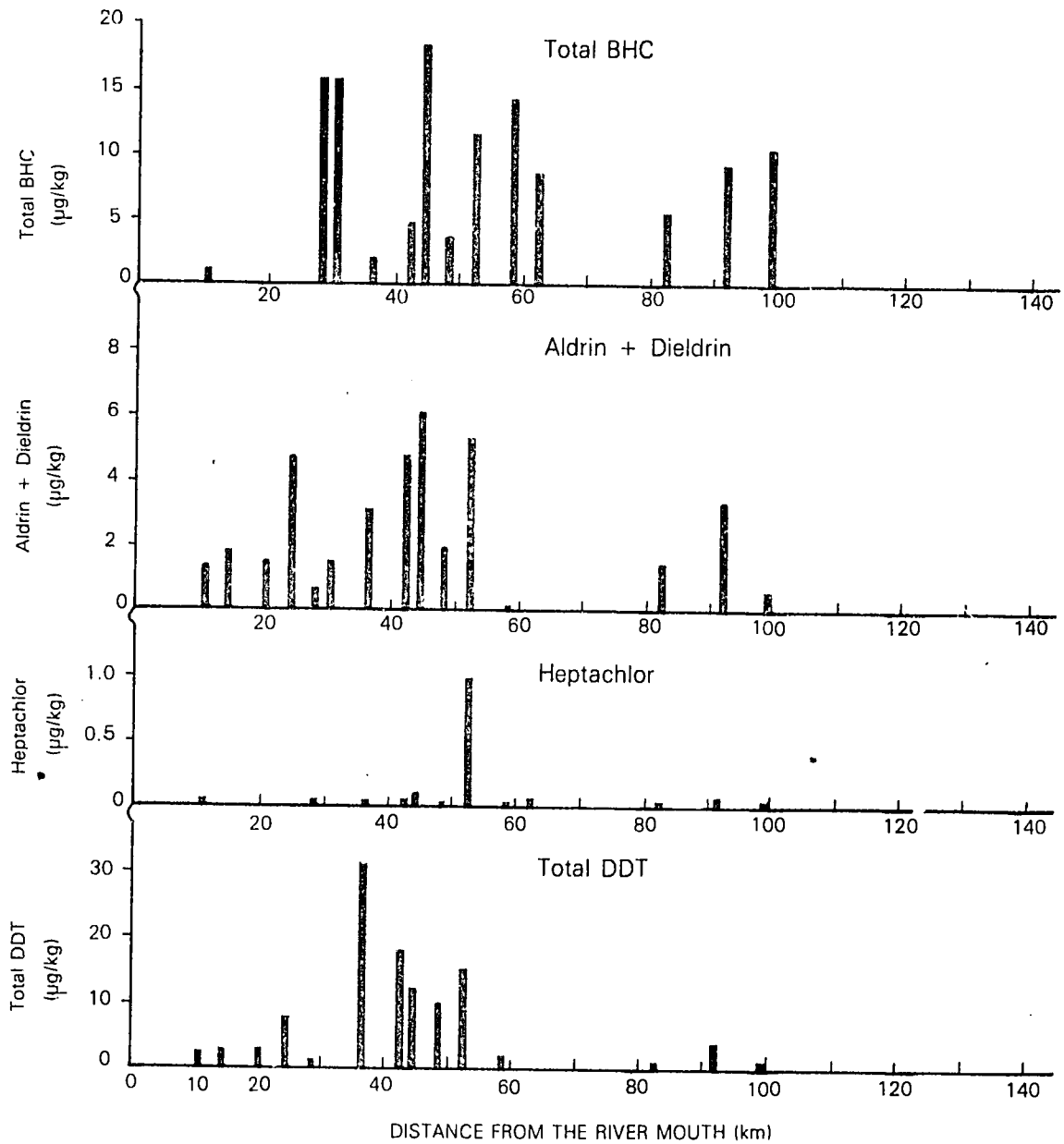
In July 1974, therefore, the Ministry of Industry launched a project designed to solve the problem. Wastewaters from the sugar mills were to be pumped to a central treatment plant, consisting of a series of equalization ponds and anaerobic lagoons, followed by oxidation ponds. The water from sugar mill condensers continued to be discharged into the river, however. Where such waters were recirculated through a sugar mill, their BOD content (caused by a rising sugar content) was considerably enhanced. Whereas the acceptable

Figure 10.4 Distribution of Organochlorine Pesticides in the Water of Chao Phraya River, September 1984



Source : Onodera, 1985, p. 68

Figure 10.5 Distribution of Organochlorine Pesticides in the Sediments of Chao Phraya River, September 1985



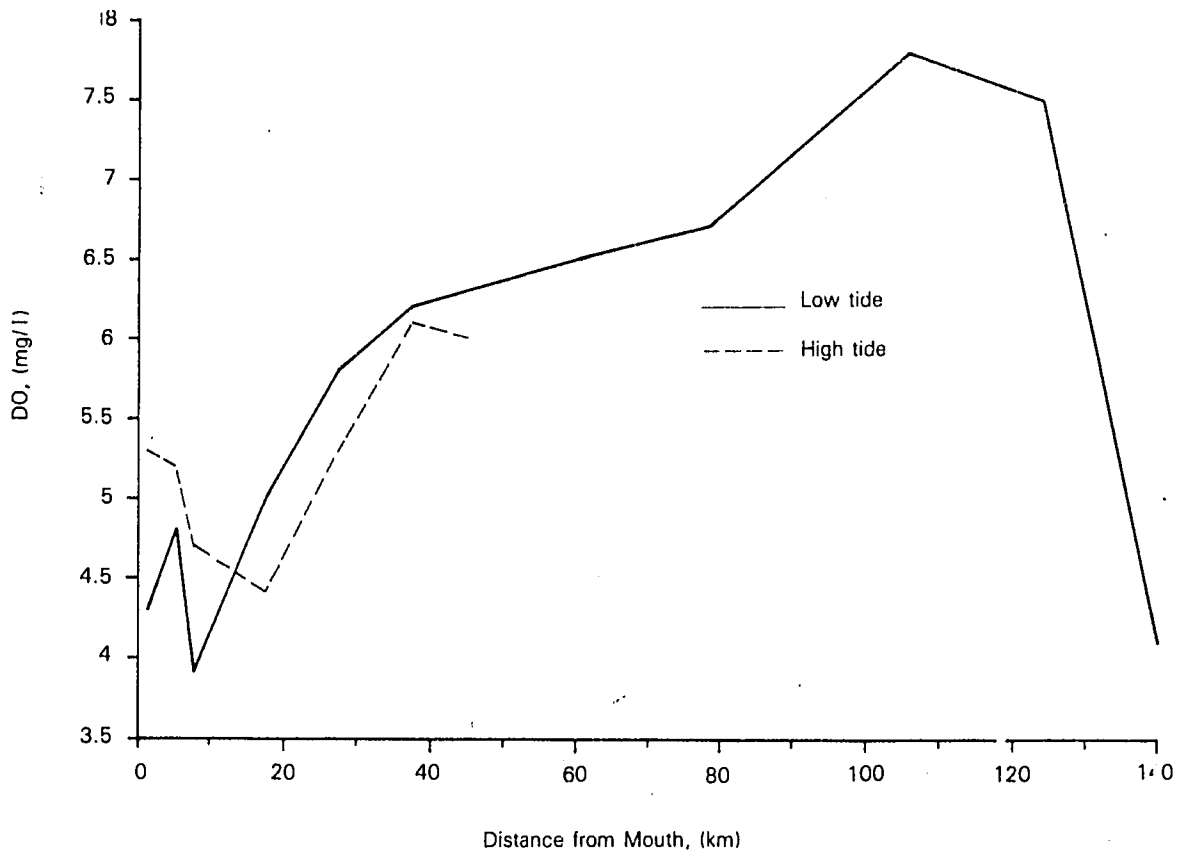
Source : Onodera, 1985, p.69

level of BOD was about 40 mg/l, the recirculated condenser water picked up about 30 to 60 mg/l with each pass through the system.

The treatment facilities are reported to have cost about 32 million baht (US$ 1.6 million, @ 20 baht to the US dollar in 1979-80).The cost of the land occupied by the facilities was about 8 million baht, bringing the total initial capital cost to 40 million baht (US$2 million). The operating costs were reported to be around 3.2 million baht (US$400,000) per year in the early 1980s, excluding power costs.

The environmental quality of the Maeklong River has now greatly improved (Figure 10.6), thanks to the treatment system installed by the industries unloading their effluents to the river. Table 10.10 shows that only 13.6 percent of the BOD_5 load is now directly discharged to the river. Maeklong could, in fact, serve as a successful example of how concerted efforts

Figure 10.6 Dissolved Oxygen in the Maeklong River, April 1986



Source : NEB, 1986, p. 64.

between government, industry and the effected communities can restore the health of a sick river.

Groundwater

Groundwater is increasingly important as a source of drinking water, as Chapter 3 explains. The data are fairly sparse on groundwater contamination in Thailand. The most immediate problems revolve around saltwater encroachment into aquifers beneath the Bangkok region. In areas where groundwater pumping has been particularly heavy, saltwater encroachment in the 150 meters aquifer has been taking place at the rate of around 500 meters a year. The encroachment is slower, at around 100 m/year, where there is a lower rate of groundwater extraction.

In the extraction wells which have been most seriously affected, chloride concentrations have risen from 10 mg/l to more than 600 mg/l over the past nine years. In the case of one well, in Thonburi, the chloride content increased steadily from 40 mg/l in 1963 to more than 1,000 mg/l in 1969. As a result of this process a number of public supply wells are known to have been abandoned.

Table 10.11 gives some indicative figures for heavy metal contamination of groundwater in the land-subsidence control zone of Bangkok, during 1982 to 1985. Despite some relatively high samples, the average concentrations for all these compounds were within the drinking water standards. The manganese level, however, was relatively high in 1982. No testing was carried out for other heavy metals, such as lead, nickel and mercury, or for pesticides. Given the levels at which such materials are used in Thailand, and the increasing importance of the groundwater resource, more effort should be devoted to groundwater quality monitoring. This will be particularly important, as Chapter 11 notes, where solid waste or hazardous waste disposal facilities are in operation or planned.

The Estuaries, Coasts and Seas

Following concern about deteriorating conditions in Thailand's estuaries and coastal waters, the Subcommittee for

Table 10.10 BOD_5 Loadings from Various Industries Dischaged to the Maeklong

Areas	Total BOD_5 generated		Treated by Ponds		Agri. Use		BOD_5 Dischaged into Maeklong		Treated by Treatment Plants	
	(kg/day)	%	(kg/day)	%	(kg/day)	%	(kg/day)	%	(kg/day)	%
Kanchanaburi										
Tha Muang	56,545	100	13,942	24.6	4,640	8.2	19,803	35.0	18,160	32.2
Tha Maka	36,249	100	12,797	35.3	1,622	4.5	186	0.5	21,644	59.7
Muang	53	100	41	77.4	-	-	12	22.6	-	-
Subtotal	92,847	100	26,780	28.8	6,262	6.7	20,001	21.5	39,804	43.0
Ratchaburi										
San Pong	53,640	100	26,622	49.6	2,240	4.2	1,154	2.2	23,624	44.0
Photharam	404	100	402	99.5	-	-	2	0.5	-	-
Muang	9,184	100	113	1.2	-	-	9	0.1	9,042	98.7
Damnoen Saduak	3	100	3	100	-	-	-	-	-	-
Subtotal	63,211	100	27,140	42.9	2,240	3.5	1,165	1.8	32,666	51.8
Samut Songkhram										
Muang	128	100	1	0.8	-	-	122	95.3	5	3.9
Grand Total	**156,186**	**100**	**53,921**	**34.6**	**8,502**	**5.4**	**21,288**	**13.6**	**72,475**	**46.4**

Source: NEB, 1986, p.34

Table 10.11 Heavy Metals in Groundwater, 1982-1985[a]

(mg/l)

Year	1982	1983	1984	1985	Drinking Water Standard[b]	
					(1)	(2)
Copper	ND-0.13 (0.007)	ND-0.25 (0.0033)	ND-0.12 (0.0026)	ND-0.03 (0.0021)	1.0	1.5
Zinc	ND-19 (0.333)	ND-8.4 (0.380)	ND-3.1 (0.263)	ND-8.8 (0.284)	5.0	15.0
Manganese	ND-22 (0.389)	ND-7.4 (0.376)	ND-6.1 (0.276)	ND-6.7 (0.297)	0.3	0.5
Number of samples	248	384	437	284		

ND = non-detectable level; figures in parenthesis are average values.
Notes: a. in the land-subsidence control zone, namely Bangkok, Samut Prakan, Samut Sakhon, Nortaburi, Pathum Thani and Ayutthaya.
b. Groundwater Division, MOI Notification No. 4 (B.E. 2521).
(1) Highest desirable level (mg/l)
(2) Maximum permissible level (mg/l)
Source: Groundwater Division, 1986.

Table 10.12 Heavy Metals in Estuaries in the Gulf of Thailand
(μg/l)

Estuaries		Fishery Dept. year 1979-80				
		Pb	Zn	Cu	Cd	Hg
Thachin	Avg	10.72	3.44	17.11	1.91	0.24
	Min	6.50	0.11	2.70	0.90	0.10
	Max	22.00	14.50	94.00	2.45	0.50
Maeklong	Avg	9.65	5.76	22.96	2.01	0.38
	Min	4.00	0.10	3.10	1.10	0.08
	Max	24.00	25.00	150.00	2.55	1.25
Phetchaburi	Avg	11.97	3.13	14.61	2.01	0.27
	Min	3.50	0.08	3.20	1.15	0.08
	Max	28.00	12.50	94.00	2.55	0.88
Bang Pakong	Avg	11.78	2.20	27.14	1.88	0.30
	Min	4.00	0.07	2.00	1.20	0.10
	Max	26.00	10.57	124.00	2.35	1.24
Pranburi	Avg	11.00	4.29	19.52	1.94	0.28
	Min	6.00	0.17	1.00	0.75	0.08
	Max	24.00	28.00	160.00	2.50	0.12
NEB River Standard		**50.00**	**1,000.00**	**100.00**	**5.00 to 50.00**	**2.00**

Research on the Quality of Water and Living Resources within the Natural Resource Council was formed in 1973, and the resulting research program was essentially completed by 1984. The purpose of the exercise was to gather data which would serve as a baseline for future environmental management. The study area included estuarine areas near the mouths of major rivers, the upper and lower areas of the Gulf of Thailand, and the Andaman Sea.

The results, as the previous discussion would lead one to expect, show that the estuaries of the Chao Phraya and Thachin rivers are characterized by relatively low DO levels. Other estuaries, including those of the Phetchaburi Chanthaburi, Tapi, Lang Suan, Pak Phanang and Chumphon, also show evidence of some pollution, but at a much lower level than either the Chao Phraya or the Thachin. Generally, the DO levels were high, with an average value of 7.15 mg/l along the East Coast of the Gulf of Thailand, and a minimum value of 2.3 mg/l. These results suggest that the current organic load discharged by the major rivers is being assimilated quickly into the marine environment.

Heavy metals are a different matter, since they do not break down like BOD. Some results for heavy metals are given in Table 10.12, all of them within the National Environment Board's standards for river water. The concentrations were generally considerably higher in river sediments, however. Lead, for example, was 1,000 to 2,000 times more concentrated in the sediments of the Bang Pakong, Maekhlong, Phetchaburi, Pranburi and Thachin rivers than in their waters, while zinc was 6,000 to 20,000 times as concentrated in the sediment. The differences were lower for some other heavy metals, such as copper (300-600 times), cadmium (60-130 times) and mercury (20-80 times). In general, heavy metal concentrations are still within the safety limits, although occasional local "hot spots" of mercury have been found, probably because of dumping activities.

The mercury concentrations found in marine animals are generally below the safety limit (0.5 mg/kg) set by the US Food and Drug Administration (FDA). Of 221 specimens collected, only two showed the highest mercury value of 0.227 mg/kg, and only 3.6 percent of the samples showed mercury levels higher than 0.1 mg/kg.

As far as pesticide concentrations in the Gulf of Thailand are concerned, the results from the river mouths were generally very low. However, one value for DDT was observed which was 1,400 times the safety limit. Again, it is thought that this may result from illegal industrial dumping. DDT was detected in 12 samples out of 100 at the level of 0.002 to 0.003 μg/l, exceeding the standard of 0.001 μg/l.

The situation could easily have been worse than the present data show it to be. But there is no room for complacency. One phenomenon which has been of particular concern in coastal areas, has been the "red tide" condition, thought to result from the excessive nutrients and inorganic pollutants which wash down into the estuaries and coastal areas. Red tides have been a major problem for the mariculture industry, which is described in Chapter 8, and are considered to be the major cause of the mass mortalities affecting green mussel farms.

As far as the Andaman Sea is concerned, there is even less in the way of concrete information about the prevailing pollution levels. In part, however, this reflects the fact that the pollution problems here are essentially very localized, including sediments and slimes from the tin mining industry in the Phuket region and a certain amount of sewage and oil pollution.

10.3 LEGAL AND INSTITUTIONAL FRAMEWORK

A considerable number of Acts and other forms of regulation have some bearing on water quality management in Thailand, and some of the more important pieces of legislation are briefly reviewed below.

Public Health Act, 1941

This Act is fairly comprehensive, regulating the disposal of rubbish, filth and dirt, and authorizing local authorities to issue bylaws or rules stipulating the methods and procedures to be used in such disposal. The local authorities are also empowered to control commercial undertakings which are likely to be injurious to health, and insanitary dwelling places, latrines, night soil receptacles, urinals, and other sites, facilities or water courses likely to represent a hazard to health. The Act also prescribes penalties, although the fines are minimal, not exceeding 50 to 100 baht.

Act for the Cleanliness and Tidiness of the Country, 1960

This Act regulates and controls public offences, including disturbance and anti-aesthetic activities. It specifically prohibits the dumping of waste into rivers or canals.

Building Control Act, 1979

This Act, and its Municipal Bylaw of 1979, updated an earlier Act and Bylaw of 1936 and 1940, respectively. The local authority is empowered to issue bylaws controlling the number and type of bathrooms and toilets, for example. It can also control storm water and wastewater drainage under the Act.

Factories Act, 1969

This Act imposes certain duties on industrial concerns using processes which will lead to the discharge of defined levels of effluent with a high BOD, or containing potentially polluting chemicals or heavy metals.

Navigation in Thai Waters Act, 1913

This Act, later amended by a Revolutionary Council Announcement, bans the dumping of stone, gravel, sand, clay, sludge, decaying matter, garbage oil or chemical products into canals, rivers, lakes or coastal waters. Permission for such activities must be sought from the Harbor Department.

Enforcement of Environmental Regulations

Thailand's present pollution control system still relies on the establishment of effluent standards. This approach implies end-of-pipe treatment, rather than specifying changes in the source technology. Moreover, emission standards can only control the degree of pollution in effluents, rather than their total volume. Industries which consume a large quantity of water can thus continue to discharge large volumes of pollutants in their wastewater discharges.

Again, the existing standards do not distinguish between large and small companies, which can lead to difficulties, since the type of treatment required is likely to be the same in every case, regardless of the organization's ability to pay for treatment technology. But, perhaps most important of all, such regulatory measures require stringent enforcement if they are to succeed, yet developing countries like Thailand simply do not have the enforcement resources needed to ensure full compliance.

Two main governmental organizations are directly responsible for domestic and industrial pollution control, the Department of Industrial Works (DIW), under the Ministry of Industry (MOI), and the National Environment Board (NEB), under the Ministry of Science, Technology and Energy (MSTE). The DIW has authority to monitor and enforce established standards. It can revoke the operating license of a factory found guilty of violating the relevant standards. The NEB, by contrast, is responsible for formulating government environmental protection policies. It has been playing a leading role in ensuring that other government agencies adopt and follow appropriate environmental standards. But, with a total of some 90,000 industrial establishments needing monitoring and enforcement activity, both the DIW and NEB are severely overstretched.

Overall, regulation is only one element of a successful environmental protection strategy. Enforcement is also needed, as are programs designed to encourage industrial concerns to adopt newer, more efficient, "cleaner" technologies.

10.4 KEY ISSUES

Management of Domestic Wastewater in Urban Areas

Almost universally, urban domestic wastewater disposal is dealt with by means of on-plot, squat-plate, pour-flush cesspools or septic tanks for human excreta, and by means of street drains for kitchen and laundry waste (or sullage). It is estimated that the present use of cesspools and septic tanks for excreta reduces the overall BOD of sewage (excreta plus sullage) to about 50 percent. So the remaining 50 percent of BOD goes to sewers, drains, khlongs and rivers. The proportion of Bangkok's population currently connected to main sewers is very small indeed, at around two percent.

The total BOD_5 imposed by discharges of domestic sewage and industrial waste to Bangkok's sewers, drains, and waterways is estimated at 365,000 kg BOD/day, with 355,000 kg/day coming from domestic sources and 10,000 kg/day from industrial sources. Such high BOD loadings have already created insanitary or obnoxious conditions in all the city's khlongs, and also result in the low dissolved oxygen content of the Chao Phraya during dry weather flow conditions. Eventually, as Box 10.1 describes, the result will be to turn long stretches of the river anaerobic.

To reduce the overall pollution load and avoid such anaerobic conditions, Bangkok needs a new sewerage system and sewage treatment plants, as proposed in the report prepared by the Japan International Cooperation Agency (JICA, 1981). But this must be a long-term measure, partly because such systems take a long time to build, but also because Thailand will find it difficult to raise the necessary funds for such a large investment program. Although the total program cost is high, at 36.7 billion baht, it is worth noting that this approach represents 1,270 to 4,933 baht per capita, of providing appropriate disposal.

As far as shorter-term measures are concerned, an immediate priority should be to use existing treatment plants to the full. Existing sewage treatment and industrial waste treatment facilities, both in Bangkok and elsewhere, should be evaluated with a view to transferring additional loads of domestic or industrial wastes to those facilities found to have excess capacity.

High-rise Buildings

Large-scale developments, such as high-rise buildings, university campuses, big hotels, government institutions, schools, housing villages, or large department stores should be provided with sewage treatment plants. There may be problems, due to the limited space available, unless such requirements are designed into the project from the earliest stages.

Sewage Pumping Stations

The Bangkok Metropolitan Administration (BMA) has received complaints from people living downstream of Krung Kasem and Chong Nonsri, where its two sewage pumping stations continue to pump raw sewage into the Chao Phraya during low flow periods and at low tide. Measures should be taken to ensure that sewage discharge only takes place at high tide, which will afford much greater dilution and reduce the prospect of septic or anaerobic conditions forming in the river.

Monitoring of Waterborne Diseases

There should be a monitoring station a few kilometers downstream from the Rama IV sewage pumping station at Chong Nonsri to study the role of sewage discharges in the transmission of key waterborne diseases, such as acute dysentery, cholera and typhoid.

Operator Training

It is essential that those treatment plants actually installed should operate as efficiently as possible. Plant operators should have sufficient technical knowledge to monitor the effluent and seek appropriate help from sanitary experts and the responsible authorities. The present operator training period of 3 to 5 days seems much too short. A longer period of 3 to 6 months would be more suitable.

Analysis and Research

The effluents to be treated, including sullage or "grey water", should be analysed to ensure that cesspools, septic tanks and other treatment facilities are operating at a reasonable efficiency. Further research is needed to identify the most appropriate alternatives to conventional sewerage and sewage treatment.

Industrial Waste Management

Although industrial effluents and wastes are less of a problem than domestic sewage discharges, a great deal more must be done to ensure that industrial water pollution is identified and effectively controlled. Most large industrial concerns already have their own wastewater treatment systems, many of them relatively sophisticated, activated sludge treatment plants. However, many of these plants are reported to have sludge bulking problems, such that the effluent quality is sometimes worse than the quality of the incoming materials.

Activated sludge sustems are complicated and need professional handling, particularly where there are constant changes in the nature and volume of the incoming waste streams. What is needed is a willingness on industry's part

to explore ways of improving its current environmental performance, coupled with the use by industry of suitably qualified and trained personnel.

It will still be difficult for medium and smaller-sized factories to invest in treatment facilities, which suggests that one of three options might be adopted in such cases: (1) wastes can be tankered to nearby treatment plants, provided that they are organic and can be treated biologically; (2) if the waste is inorganic, chemical and/or toxic, it may be possible to transport it to a central treatment plant, such as those currently planned for Bang Khun Tien, and elsewhere. The private sector should be encouraged to invest in such facilities, in part by ensuring that the relevant pollution control regulations are fully enforced; and (3) if the Bangkok sewerage system is finally built, industrial effluents can be discharged to sewer for treatment at a central works, on payment of the relevant charges or effluent taxes.

Appropriate Waste Treatment Technologies

In rural areas, where land is not at a premium, appropriate low-cost waste treatment technologies may include stabilization ponds and lagoons. Waste utilization should also be encouraged, wherever feasible. The aim should be to use by-products, such as biogas or organic fertilizers, to offset some of the costs of waste treatment. Since most Thai industry is agroindustrial in nature, the potential for such an approach should be fairly good. In some cases, too, it may make sense to encourage the location of industries producing organic effluents in areas of the country where the natural cleansing abilities of the local rivers has not been exploited.

Cleaner Technologies

Cleaner, or low-waste, technologies are designed to generate less pollution and waste than conventional technologies, rather than simply treating pollutants at the end of the process. Clean or cleaner technologies may include recycling, process and product reformulation, substitution of less hazardous feedstocks, and/or the installation of more efficient equipment.

Industrial Inventory

A nationwide survey of industrial activity would provide extremely useful information for those involved in planning, regulation and enforcement activities. The sort of information which needs to be collected includes locational details, type of industry, scale of operations, production rate, number of employees, raw materials used, and waste flow and characteristics. This inventory approach has already been pioneered by the Department of Industrial Works (DIW), but the work should be extended.

Protection of Drinking Water Intakes

Drinking water for Bangkok is abstracted from the Chao Phraya at Sam Lae, Pathum Thani, some 90 km from the river's mouth. Water quality in the area is deteriorating, with increasing bacterial contamination and BOD values, in part because of the new industries moving into the area. One consequence is that increasing volumes of chemicals have to be used to treat water intended for drinking purposes. The National Environment Board (NEB) has suggested three guidelines designed to protect the quality of water in the region of these intakes. First, the NEB suggests that industries producing heavy metals, pesticides, polychlorinated biphenyls or other such toxic products or wastes should not be permitted to locate in sensitive areas of the water catchment. Second, factories producing more than 50 cubic meters per day of wastewater, not including cooling water, should not be permitted. Third, this second type of operation, however, may be permitted by the responsible authorities in particular cases.

Control of Waste Disposal Sites

The open dumping sites at Soi On Nuj, Nong Khaem and Ram Intra have generated significant quantities of leachate during heavy rainfall. This leachate can now be a major source of water pollution unless it is properly controlled. It should be treated prior to being discharged into canals or rivers.

Agricultural Waste Treatment

A survey of the geographical distribution of pesticide and fertilizer applications would help in identifying actual or potential pesticide pollution problems in major river basins. Wherever possible, animal wastes should be treated anaerobically, to recover biogas and organic fertilizer, and to cut the BOD potential of such materials. Farmers should be given appropriate instruction to ensure that they do not over-apply or otherwise misuse agrochemicals, resulting in runoff into local water courses.

Integrated Estuarial and Coastal Zone Management

The pollution monitoring programs already underway in major estuaries, coastal areas and the Gulf of Thailand should be continued in order to detect any emerging trends. Given their critical role in underpinning major commercial fisheries, the estuaries and coastal seas should be properly protected. Illegal dumping of industrial and other wastes in the sea should be totally prohibited by the Harbor Department and other responsible agencies.

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11 Solid Waste and Toxic and Hazardous Substances Management

Solid wastes are those wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted, regardless of their toxicity or hazard potential. Toxic substances are those that pose a threat to human health or living organisms due to their non-biodegradability, accumulative ability and lethality.

In Thailand, most solid wastes are discarded into the community collection system, resulting in the contamination of community garbage by industrial toxic wastes. Meanwhile, the solid wastes generated in remote areas, are usually simply piled up together and burned in the open air.

In this chapter, solid wastes and toxic substances are treated as two different subjects and, as a result, are discussed in two separate sub-chapters, with solid wastes covered in Sections 11.1—11.4, and toxic substances and hazardous wastes in Sections 11.5—11.8.

SOLID WASTES

11.1 OVERVIEW

Data on solid waste management practices and infrastructure in small to medium sized communities, as well as in Bangkok, have been compiled by the Office of the National Environment Board of Thailand (ONEB, 1986a, 1986b; Thongkaimook 1986). Most of the basic information presented here derives from ONEB reports.

In Thailand, solid wastes generated from any community, industry or in urban areas are currently collected by governmental agencies. In Bangkok, the responsible agency is the Department of Public Cleansing (DPC) which is administratively under the Bangkok Metropolitan Administration (BMA) and local district offices. DPC is also responsible for the haul-away and subsequent treatment of the nightsoil (which is considered to be a type of solid wastes) taken from septic tanks.

In other urban areas where garbage collection is provided, the local administration office, namely the Public Health Section is normally assigned to take the responsibility (ONEB 1986).

Recycling Systems

Residents separately store and sell the most valuable items in their waste stream (e.g., large intact bottles). Once wastes are collected, there are two further recycling stages, performed by the collection crew (primarily the worker within the refuse truck body) and by scavengers at the disposal sites. Indeed, in the larger municipalities, recycling revenues represent an important incentive for collection workers to service their routes. It has been reported that each collection worker receives a supplementary income of about 1,500 baht/month from recycling. Scavengers reported (and probably underestimated) their incomes as 300-500 baht/month/worker. Kitchen wastes from large restaurants and hotels are typically given daily to farmers for use as pig feed.

As a result, the characteristics of the solid wastes arriving at a final disposal site may not represent those originally generated at the community.

Characteristics and Quantity of Solid Wastes

If one looks at the composition of the solid wastes emerging from major communities in Thailand, such as Bangkok, Chiang Mai, Pattaya, Khon Kaen and Songkhla, it turns out that the largest proportion of these wastes is garbage (vegetable and putrescible fraction). Paper is usually the second largest category. Moisture content measures about 55 percent of the total wet weight, with little difference observed between dry and wet seasons, so the waste is not suitable for self-sustaining combustion.

The specific density of wet refuse within collection vehicles was estimated from observations of the volume loaded into each truck upon completion of its route and measurements of load weights. The average density within collection vehicles was 335 kg/m^3. (All of the vehicles assessed were of the non-compaction type). However, the density at the dump sites is only about 200 to 250 kg/m^3.

The per capita production of solid waste is estimated to range from 0.4 to 0.56 kg/day for small communities; from 0.66 to 0.85 kg/day for larger urban areas; famous tourist spots such as Chiang Mai and Pattaya produce higher quantities of 0.92 and 1.27 kg/day respectively. Most Bangkokians produce about 0.85 kilogram per capita per day (kg/c/day), but people in out lying areas of Bangkok produce much less. It has been estimated that daily overall production at present is about 3,600 tons. About 95 percent of these are collected and disposed of.

Chiang Mai, another main tourist location in Thailand, ranks second in terms of its solid waste generation per capita per day. It produces 0.92 kg/c/d, resulting in about 138 tons of waste per day. With the population served of 70 percent

Table 11.1 Summary of Solid Wastes Management of Some Cities in Thailand

Description	Unit	Bangkok[a]	Chiang Mai[a]	Nakhon[a] Ratchasima	Khon Kaen[a]	Hat Yai[a]	Chonburi[a]	Pattaya[a]	Rayong[a]	Songkhla[b]
Population	1000 prs	5,300	150	90	115	113	48	43	39	76
Population served	%	80	70	80	60	90	98	95	90	75
Waste generation	kg/c/d	0.85[c]	0.92	0.64	0.56	0.66	0.8	1.27	0.85	0.67
No. of Collection trucks	trucks 1000 prs/truck	606 8.75	23 6.52	13 6.92	8 14.38	19 5.95	9 5.33	7 6.14	6 6.5	11 6.91
Trucks in operation	%	80	80	80	75	97	90	90	80	64
Average trip	trips/d trips/truck/d	1,010 2.08	53 2.88	23 2.21	16 2.67	42 2.28	16 1.98	17 2.7	15 3.12	18 2.56
Average collection	ton/d	3,420	96.7	53.5	36.4	67.7	37.5	51.2	30	41.1
Uncollected percentage[d]	%	5	15	5	20	10	5	15	20	ND
Disposal system	-	Composting 17.5% Open dumping 82.5%	Open dumping and occasional burning	Open dumping and occasional burning	Open dumping and occasional burning	Open dumping and occasional compacting and burning	Open dumping and occasional burning 80% sea dumping 20%	Mainly sanitary landfill	Open dumping and occasional burning	Open dumping
Personnel	prs per population	7,125 1:745	340 1:440	233 1:385	161 1:715	315 1,360	195 1:245	210 1:205	98 1:400	105 1:725
Expenditure	baht/ton baht/prs/yr	450 112	367 86	504[e] 109	409[f] 47	349 76	332 95	316 137	194 54	291 57

prs = persons; c = capita; d = day; yr = year; ND = no data; kg = kilogram

Notes: adapted from a. ONEB, 1985a
b. Sinclair Knight, et al., 1983c
c. For most of Bangkok excluding out-lying areas
d. Uncollected percentage of the solid wastes produced in the area under service.
e. Sinclair Knight, et al., 1983a
f. Sinclair Knight, et al., 1983b

and with the collection efficiency of 85 percent, the average collection comes to around 94 tons per day.

Among the major cities surveyed and reported here, Nakhon Ratchasima and Khon Kaen produce the lowest quantities of waste per capita per day: 0.64 and 0.56 kg/c/d, respectively.

Collection Systems

Communities perform a combination of "station", "door-to-door", and "block" collection. "Station" collection is by far the predominant system, wherein residents bring their wastes to a communal container (various containers of different sizes are used, such as steel drums, masonry containers, plastic bags and bamboo baskets). In neighborhoods where residents put their own containers on the curbside for collection, this is the "door to door" system. At the entrance to inaccessible neighborhoods, the "block" system involves the truck arriving at a scheduled time, the driver ringing a bell, and residents coming to the truck with their parcels of waste. This last method is practiced for a small number of households, however. The collection vehicle most often used is a non-compaction, side-loading tipping truck of 7.5 - 12 m^3 capacity.

A number of markets pile refuse on the ground and in baskets at a designated collection area. This is unsightly, and unsanitary. Although sites are serviced several times a day, cleanliness cannot be maintained.

11.2 TRENDS

In any community, the characteristics and quantity of solid waste do not stay unchanged. The plastic portion tends to increase as living standards rise, for example. The percentage of paper may dwindle in some cities as plastic starts to replace it.

The Composition of Urban Waste

Data on the changing composition of wastes in provinces other than Bangkok are not currently available. As far as Bangkok's wastes are concerned, between 1980 and 1985, paper dwindled from 21.9. to 18.4 percent, while the plastic and rubber portions increased from 8.9 to 14.5 percent. Wooden material decreased from 23.2 to 8.9 percent, probably due to the increasing scarcity and price of such materials. The garbage or vegetable/ putrescible fraction increased by about 25 percent, from 29.9 to 39.9 percent while incombustible materials such as glass, bottles and metal fell from 10.1 to 6.0 percent.

The moisture content almost did not change; ash content dropped by about 30 percent over a five year period. By contrast, volatile or combustible solids increased from 27.2 to 31.9 percent. The calorific value dropped slightly from 1,130 to 1,120 kcal/kg. This trend, however, does not make the wastes suitable for incineration, due to the still high energy requirement.

Different agencies have different forecasts of Bangkok's future population, partly depending on whether the nonregistered population and migration were taken into account. The data supplied by the Population Policy and Planning Division of NESDB are used here. Based on the projected population, the waste production of 0.85 kg/c/d, the population to be serviced of 80 percent and the collection efficiency of 95 percent, the overall collection can be expected to grow from 3,860 in 1987 to 4,220 tons/day in 1991 (Table 11.2). Considering a scavenged volume of about 100 tons/day, as estimated by BMA Division of Policy and Planning, the corresponding disposal volumes then become 3,750 and 4,120 tons/day respectively.

The uncollected volume is mostly dumped onto vacant areas nearby, while some is directly dumped into canals and/or rivers, or discharged into drainage systems. One way or another, there will be an ultimate impact on the quality

Table 11.2 Forecast of Bangkok Solid Wastes Production, 1987-1991

Year	Total Population[1] (million)	Estimated volume of solid wastes (ton/day)				
		Produced[a]	Collected[b]	Uncollected	Scavenged[2]	To be[c] disposed
1987	5.972	5,076	3,860	1,216	110	3,750
1988	6.115	5,198	3,950	1,248	110	3,840
1989	6.256	5,318	4,040	1,278	100	3,940
1990	6.396	5,437	4,130	1,307	100	4,030
1991	6.527	5,548	4,220	1,328	100	4,120

Notes: a. based on 0.85 kg/c/d
b. based on 80% of population to be serviced and 95% collection efficiency.
c. to be disposed = collected−scavenged

Sources: 1. Subcommittee on Population Policy and Planning, NESDB 1985 (including non-registered population).
2. Policy and Planning Division I, BMA. 1986.

of the receiving water resources. The collected volumes also need to be disposed. This can create water pollution problems, as described later in this chapter.

Cost Accounting

Solid waste management can be seen as a "thankless task", with no end nor fixed, lasting accomplishments. And yet it consumes large portions of community revenues, costing anywhere from 200 to 500 baht/ton of waste material handled, or from about 47 to 137 baht/resident/ year.

In general, about 10 percent of the costs of solid waste management are covered by the direct user charges collected. One household with six people produces about 0.7 tons/year and yet they pay only about 48 baht/year (only 70 baht/ton). Markets are particularly problematic. One private market in Chonburi generates at least 3,300 tons/year of waste, but pays a fee of only 36,000 baht/year to cover all municipal services provided (less than 11 baht/ton). Similarly, hotels often generate large amounts of waste. One large hotel in Pattaya produces about 350 tons/year, yet pays a solid waste fee of only about 1,100 baht/year (less than four baht/ton). And to compound the problem, collection of fees is incomplete, with many households not paying their dues.

For the service to be performed well, it needs a reliable, adequate budget: one which could be more assured if special revenues earmarked for solid waste service were being collected. For example until this year, fees for a household of less than 20 l/day were stipulated by law at only 4 baht/household/month. A new (1985) Ministry of Public Health Notification now enables all communities to raise their fees to about 10 to 15 times depending on the type of establishment and quantity of wastes.

With these raised fees, it is expected that solid waste collection may become profitable in the near future and private companies will be interested in the potential. At present, BMA is already contracting private enterprises to collect solid wastes from selected residential areas. If this proves successful, it is highly likely that more contracts will be granted to private companies in the future.

11.3 LEGAL AND INSTITUTIONAL FRAMEWORK

All community waste is managed under the Public Health Act of 1941 and later amendments. This Act briefly states that local administrations have full responsibility for developing ordinances and regulating solid waste management; providing communal solid waste management; providing communal solid waste containers as needed; providing collection and transportation of solid waste; and for collecting fees. The local administrations are also empowered to plan and manage some or all of these operations through private contract. Citizens are prohibited from littering or dumping waste at clandestine sites, subject to the penalty of a fine (not exceeding 50 baht per offence).

Experience throughout the world has clearly demonstrated that the only way to obtain public cooperation is through continued strict enforcement of the law for a period of time long enough to change behavior patterns. While public education, especially of children, is also needed, it is not enough on its own. Unfortunately, community officials can not easily enforce the existing laws. While they have local Public Health Inspectors who make note of violations, but to make arrests and impose penalties is a police matter.

11.4 KEY ISSUES

Solid wastes from hospitals and medical clinics, as well as from industry, are collected together with other community wastes. It appears that most of the establishments do not separate potentially pathogenic wastes (e.g., spent bandages, laboratory cultures, or surgical wastes) or toxic substances (e.g., mercury or lead) from the normal wastes. This leads to contamination of the domestic solid wastes and may result in complications in waste handling and management.

Most Thai communities rely on open dumping and occasional open-air burning as their disposal technique. Only Bangkok, thanks to its better financial status, can use composting processes and small incinerators for solid waste treatment and disposal. Table 11.3 summarizes the current overall capacity of Bangkok's solid waste disposal facilities. Overall disposal capacity amounts to 1,480 tons/day.

However, only approximately half of wastes are presently processed by the above-mentioned facilities (ONEB 1985a). This is due to an unusually high downtime at some of the facilities. Regardless of the downtime of the disposal facilities, the present capacity cannot cope with the volume of already collected wastes. This necessitates additional disposal capacity. At present, four dump sites are in use: at On-Nuj, Nong Khaem, Ram Intra and Rajburana.

Partly due to the high investment cost involved, and partly due to the high energy requirement because of the moisture content of the wastes, incineration processes have not been effectively used in Thailand. Sanitary landfill practice, in which the solid wastes are covered with soil, is also practically non-existent. Open dumps are widely employed by Thai municipalities, resulting in public health hazards such as disease transmission, vector breeding, foul odors, and surface and groundwater contamination.

Where burning is used, the waste is typically burned on-site during the dry season to control vectors and reduce volumes. During the rainy season, insecticides are sprayed on-site to control vectors. Certain communities own machines for spreading and covering refuse at the disposal site, while other communities intermittently rent equipment. Overall, however most communities are simply concerned to get solid wastes "out of town" as fast as possible. Little thought is given

Table 11.3 Overall Capacity of Bangkok Solid Wastes Disposal Facilities, 1985 (tons/day)

Facilities	Site				Total
	On-Nuj 1	On-Nuj 2	Nong Khaem	Ram Intra	
1. Composting	320	320	160	320	1,120
2. Small incinerators	100	100	60	100	360
Total	**420**	**420**	**220**	**420**	**1,480**

Source: Suttapreeyasri, 1985.

Table 11.4 Characteristics of Solid Waste Leachate (stored in dump-site ponds) (mg/l except pH)

Description	Dump Site			Typical[3] Sewage
	Nong Khaem[1]	On-Nuj[1]	On-Nuj[2]	
pH	8.2-9.0	7.6-9.1	7.9-8.6	
Alkalinity[a] as $CaCO_3$	6,126	3,225	1,000-8,900	100
BOD[b]	590	312	150-1,230	150-200
COD[c]	14,260	3,300	1,930-8,820	-
TKN[d]	570	222	575-1,700	50
Phosphate	21.5	7.8	22.5	-
Suspended solids	146	109	110-2,410	300
Colour(Pt-Co)	-	-	3,500-22,500	-
PCB	-	-	0.6-0.7	-
Chromium VI	-	-	1	-
Mercury	-	-	3.8-4.5	-

Notes: *a. Alkalinity is the capability to buffer changes of pH.*
b. BOD (Biochemical Oxygen Demand) denotes the organic content readily digestable by organisms.
c. COD (Chemical Oxygen Demand) is the equivalence of oxygen used for the chemical oxidation process. It represents both biologically and chemically digestable parts of organic matters present in a sample.
d. TKN (Total Kjeldahl Nitrogen) is the sum of organic and ammonia nitrogen content. It is also used for organic matter measurement, especially that of protein type.

Sources: *1. Panswad 1982, Annual average of 1979-1980.*
2. Pattamapirat 1986a.
3. McGauhy 1986. 'Engineering Management of Water Quality'

to suitable treatment or disposal processes. At present, the most promising potential approach would seem to be sanitary landfill, especially in upcountry provinces. This technique offers both relatively low investment costs and a useful potential for land reclamation projects.

Water Pollution

The wastes generated from all sources are collected and disposed of together by the relevant authorities. Toxic chemical and pathogenic wastes can therefore contaminate domestic solid wastes. These wastes, when dumped, stored in open areas and rained upon, can cause water pollution due to their high organic content leachate. Its typical characteristics are shown in Table 11.4.

The data show the high water pollution potential of such leachate (Table 11.5). If discharged into waterways, it can cause problems such as low dissolved oxygen (DO) levels, septic conditions, and algal blooms. Such high alkalinity values (of 1,000 to 8,900 mg/l as $CaCO_3$) make the water unsuitable for

Table 11.5 Potential Water Pollution Load from Solid Wastes

Year	Total Population (million)	Uncollected portion		Dumped portion		% Population equivalence
		(ton/day)	P.E. (million)	(ton/day)	P.E. (million)	
(1)	(2)	(3)[1]	(4)[a]	(5)[1]	(6)[b]	(7)[c]
1987	5.972	1,216	0.834	3,750	1.837	44.7
1988	6.115	1,248	0.856	3,840	1.882	44.8
1989	6.256	1,278	0.876	3,940	1.931	44.9
1990	6.396	1,307	0.896	4,030	1.975	44.9
1991	6.527	1,328	0.911	4,120	2.019	44.9

P.E. = population equivalence

Notes: a. *(4) = (3) x 0.06 x 0.4/35*
based on 0.06 g BOD per gm garbage (Panswad 1982), 40% of wastes being 'garbage' type, population equivalence (P.E.) of 35 gm BOD_5/c/d
b. *(6) = (5) x 0.049/100*
based on 0.049 gm COD per gm solid wastes (Panswad 1982), population equivalence of 100 gm COD/c/d
c. *(7) = ((4) + (6)) x 100/(2)*

Source: 1. *from Table 11.2.*

various industrial processes, while the high content of organic matter (COD of 1,930 to 14,260 mg/l and BOD of 150 to 1,230 mg/l) makes such leachate much more polluting per unit volume than domestic wastewater (COD of about 600 mg/l and BOD of 150-200 mg/l).

The concentration of color present in the leachate is very high (3,500 to 22,500 units), it is possible to create problems arising from leachate discharges. At present, there is a continuous outcry from people living along canals which receive the discharge of leachate from both the On-Nuj and Nong Khaem dump sites. The BMA has begun to realize the seriousness of the problem and has currently conducting a treatability test of the offending leachate.

At On-nuj 2, the Polychlorinated biphenyl (PCB) content of 0.6 to 0.7 mg/l found in the leachate is relatively high. A high dilution ratio is essential once the leachate is discharged into rivers if safety limits are to be safeguarded. The high insecticide content may be attributed to the pesticide sprays used on the waste piles to control vectors in the rainy season. This high content of insecticides can be a bacterial inhibiting factor, which could be significant if a biological process were to be selected to treat the leachate.

PCBs are now proving to be a more severe environmental problem than initially envisaged. When compared with similar compounds such as DDT, the residence time of PCBs in the environment is much longer. The estimated inputs of PCBs are currently many times those of DDT. There are no technical or economic reasons why the use of PCBs in transformers, large and small capacitors, and heat-transmitting fluids should not be prohibited in new equipment. The use of PCBs as a chemical feedstock or as intermediates in synthesis processes should be prohibited (Lack T.J., 1984). The US Food and Drug Administration (FDA) has issued an interim safety standard of 5.0 ppm PCB in any food. The Environmental Protection Agency (EPA) has imposed limits on PCB discharges, deciding that environmental levels should remain below 0.01 ppm at all times (Waite T.D. 1984).

Of equal concern is the total concentration of heavy metals, namely chromium VI (1 mg/l) and mercury (3.8 to 4.5 mg/l). The Ministry of Industry requires that the discharged effluent contents of insecticide, chromium and mercury should be nil, 0.5 and 0.005 mg/l, respectively. The high content of these two heavy metals may be from the leachate effect of certain discarded items, such as fluorescent lamps and dry cell batteries.

Due to their non-biodegradability, one way to bring these metals down to acceptable standards is dilution. However, the dilution ratio to achieve this would be very high for the mercury case (1:800), rendering the method next to impossible in practice. A chemical coagulation or precipitation approach followed by sedimentation is therefore also likely to be required to treat the waste leachate.

Composting

In Bangkok, up to 17.5 percent of the solid wastes collected are sent to four composting plants, at three different locations, while the rest is piled in open dump areas. It takes about six months for the composting process to yield a soil conditioner with a fertilizer value (expressed as %N : %P : %K available) of 1.5:1.3:1.5 and pH of eight (Suttapreeyasri, 1985). This product, if mixed with dried nightsoil, will produce another type of soil conditioner with an N:P:K ratio of 1.8:2.5:1.0 and the same pH value.

People are misled if they try to rate these products based on only the N:P:K ratio, which incidentally is rather low in both cases. Their soil conditioning capability is virtually ignored by local farmers. So, coupled with the fact that additional synthetic fertilizer is still needed when the composted product is applied on the field. The composted solid wastes tend to be noncompetitive in price terms and are not at all popular among users.

The picture is somewhat discouraging. But a new conceptual approach is needed in this important area. The responsible organizations should look at the situation from another angle. Besides providing more publicity on the soil

conditioning value of the products to the public, the assigned staff should bear in mind that it is their duty to treat the wastes (or to turn them into valuable products, no matter how low the value is), not to produce a fertilizer product as their main aim. Whatever comes out of the process should be regarded as a by-product, not as a product, and be priced accordingly.

Management Considerations

For solid waste disposal to be performed efficiently, the costs need to be carefully monitored. With little or no cost accounting performed, it is difficult for community officials to feel justified in charging a specific fee — even though a recently amended fee structure enables them to cover all, or at least most, of their costs. Authority expenditures range, from only 194 to 504 baht/ton of wastes (see Table 11.1). In developed countries, up to 10 times this expenditure is needed (and used) for solid waste disposal programs. The poor level of collection and disposal of waste in Thailand may be attributed to this single fact.

In a community where residents and visitors are considerate in placing their wastes in litter bins and well-designed household bins, sweeping would be a minor part of the solid waste management service. However, within the urban communities served, the sweeping cost surprisingly comprises a significant 35-55 percent of total solid waste management costs. Because public cooperation is so conspicuously lacking, assignments to sweepers are for only 200 to 500 meters of street length. This short length is cleaned and re-cleaned continuously throughout the day. (Thongkaimook, 1986). Public cooperation and a good publicity program are clearly essential.

Due to the lack of good record keeping, it is difficult to disaggregate the data by activity and thereby evaluate its meaning in terms of the efficiency and effectiveness of solid waste collection and disposal. New procedures for record keeping, monitoring and cost accounting are strongly recommended.

Typically, local communities have no technical data (e.g., loaded weights, densities), costing data (e.g., maintenance, repair and operating costs), productivity data (e.g., weight litted/work shift, available loading time/shift), nor trained staff and qualified personnel to do the necessary planning. It is again recommended that engineering and economics-oriented training and technical assistance be made available.

TOXIC AND HAZARDOUS SUBTANCES

11.5 OVERVIEW

Toxic substances are those which pose a threat to human health or living organisms because they are: (1) non-biodegradable or slow to biodegrade; (2) biologically accumulated or "magnified" in living tissues as they move up the "food web"; (3) lethal; and/or (4) capable of posing other detrimental threats to living systems. This second part of Chapter 11 will concentrate on two main types of toxic substance: pesticides and heavy metals. It will also focus on the nature and location of some of Thailand's more significant producers of hazardous wastes.

The subject of toxic and hazardous substances in the riverine and marine environments has been treated in Chapter 10, whereas the impact of these substances to the welfare of the workers will be treated in depth in Chapter 12. It is thus recommended that readers who are interested in the full picture of the use of toxic and hazardous substances and their impacts in Thailand should read all three chapters (i.e. 10, 11, 12) in toto.

Pesticides

Of all the chemical products in extensive use in Thailand, pesticides probably have the greatest potential for damaging both people and their environment (see Box 11.1). Total consumption of pesticides in Thailand grew from 30,000 tons in 1981 to over 38,000 tons in 1984 (Figure 11.1), representing fairly rapid market growth.

The pesticides which make up these annual totals come from three different sources: (1) from other producing countries, as imports of final products; (2) from other producing countries, as imports of active ingredients, to be locally formulated into final products; and (3) from local manufacturing plants.

Pesticide imports have fallen from the 50 percent share of the market they enjoyed in 1980, partly because their cost has encouraged increased local formulation of final products from imported active ingredients, and partly because Thailand has begun to build up its own pesticide manufacturing base. Figure 11.2 shows the total quantity of pesticides imported between 1976 and 1985, whether as finished products or as technical grade materials. It also reveals that, while insecticides accounted for the major proportion of pesticide imports during the 1970s, growing volumes both of herbicides and fungicides have been consumed in Thailand through the 1980s.

Insecticides have also dominated the local pesticide formulation business in recent years, although Table 11.6 shows broadly the same trend here as in pesticide imports: herbicides have been enjoying a rapidly growing market, while insecticides have not regained the dominant market share which they held in the late 1970s.

Two factories started producing paraquat in Thailand during 1982, with a total average annual production capacity of 4,500 tons. The significance of this local production was greatest in 1982, when it accounted for about a third of the combined output of locally formulated and manufactured pesticides. As the local formulation of herbicides from imported materials has grown in subsequent years, so local production's share of the market has slipped, accounting for 19 to 20 percent in 1984 and 1985.

Due to commercial secrecy problems, the amount of locally formulated pesticides had to be estimated using the known figures for imports of active ingredients and conversion factors recommended by the ESCAP Agricultural Division

Box 11.1 The Pesticides Picture

Used carefully, pesticides can play an important role in boosting agricultural productivity. Used carelessly, they have the potential for causing more damage to people and their environment than almost any other single class of chemicals. Even when properly managed, their long residence time in human tissues and in the open environment makes it essential that their levels are monitored wherever they may end up. Like most other developing countries, Thailand has benefited from the availability of the growing spectrum, of pest control chemicals (some 2,000 brands are sold in the country), and has also produced its share of pesticide poisonings and wider environmental contamination.

The statistics for pesticide poisonings and deaths among farm workers are reported in Chapter 12. Broadly, they show that the annual rate of reported pesticide poisonings more than tripled between 1974 and 1983, from 725 to 2,353. Reported pesticide-related deaths fell from 34 in 1974 to 17 in 1983, albeit by way of a peak figure of 53 in 1976. On the basis of these figures, it has been calculated that the average annual pesticide poisoning rate between 1974 and 1983 was 9.2 cases per 100,000 agricultural workers, with an average annual death rate of 0.17 per 100,000 workers. However, these figures probably represent a severe underestimate of the scale of the problem.

A survey of 10 villages in Rayong Province, described in Chapter 12, found well over 8,000 cases of pesticide poisoning per 100,000 agricultural workers. Of these cases, only about 2 percent actually went to a hospital for treatment, suggesting that the official figures are likely to be overly optimistic. A random sample of workers was tested for pesticide exposure, and 37 percent proved to have been exposed, with 0.8 percent of the sample showing early warning signs of pesticide poisoning. It was also concluded that the death rate was likely more like 1-2 per 100,000.

One of the best ways of determining whether someone has been exposed to pesticides is to test the levels of the enzyme cholinesterase in their blood. The greater the pesticide exposure, the lower the cholinesterase level. The available evidence, some of which is reviewed in this chapter, tends to suggest that workers in pesticide factories are less exposed than they were in the past, that a proportion of those working in pesticide retail outlets are affected, and that the number of farmers with depressed cholinesterase levels is on a rising trend. This last fact points to continuing ignorance among pesticide users of the potential risk they are running.

Meanwhile, testing of pesticide residues in food has shown, in the very small number of vegetable samples tested, that anywhere between 40 and 90 percent contained detectable levels of pesticide. Although a small proportion of the samples tested were over the limit, the danger to consumers was thought to be marginal. At the same time, research on the pesticide contamination of rivers and of the Gulf of Thailand has found such contamination in places, but no conclusive evidence of major pollution problems.

One reason for this state of affairs may be that action has already been taken to control some of the most persistent pesticides, particularly the organochlorines. The volume of organochlorine pesticides imported into Thailand has dropped sharply, from 3,592 tons in 1978 to 323 tons in 1985 (see Figure 11.3).

Meanwhile, there has been a significant shift in the structure of the Thai pesticides industry. There are three main options in this area: (1) import pesticides as final products; (2) import only the active ingredients, and formulate the products locally; or (3) manufacture pesticides locally. Option (1) accounted for just over half (53 percent) of Thailand's total pesticide consumption of around 30,000 tons in 1980, with option (2) making up the balance. By 1984, however, imports had slipped to around 37 percent (of an admittedly larger total consumption figure of over 38,000 tons). Local formulation had grown significantly in volume, accounting for 51 percent, and the balance was made up by two new Thai factories which have a manufacturing capacity of some 4,500 tons per year of the herbicide paraquat.

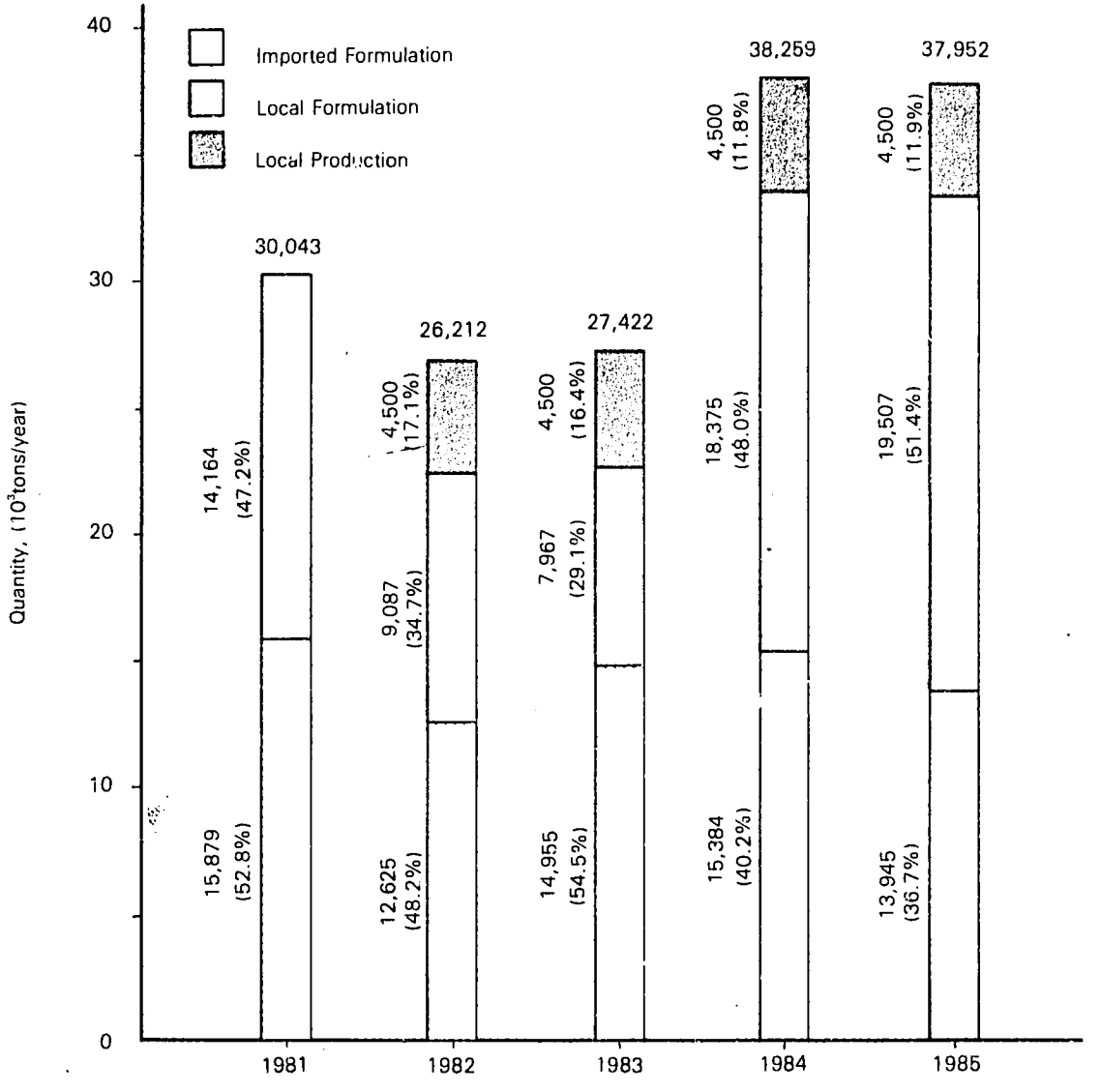
The overall picture, then, is one of growing pesticide manufacture in Thailand, with local formulation and production jointly totaling nearly 13,600 tons in 1982 and just over 24,000 tons in 1985. The cost advantage of local formulation over imports has fuelled the growth of the local formulation industry, with the 10 plants operating in 1982 having more than doubled to 26 by 1985. Given the toxicity of these products, a careful eye must be kept on their production, distribution and use. It is also essential that pesticide research and monitoring continue, to provide a picture of where these products and their breakdown products finally end up (e.g., in workers, the public or the open environment), and of what impacts they have along the way.

(ESCAP, 1982). The number of local formulation plants grew from 10 in 1982 to 26 in 1985 (Chuapanich, 1986). Further information on the trends in pesticide consumption and the related impacts can be found in Section 11.6.

Other Toxic Chemicals

And what about imports of other toxic chemicals? The definition of toxic substances with which we began is relatively broad. The U.S. Environmental Protection Agency (EPA) is

Figure 11.1 Estimated Domestic Supply of Formulated Agropesticides in Thailand, 1981-1985



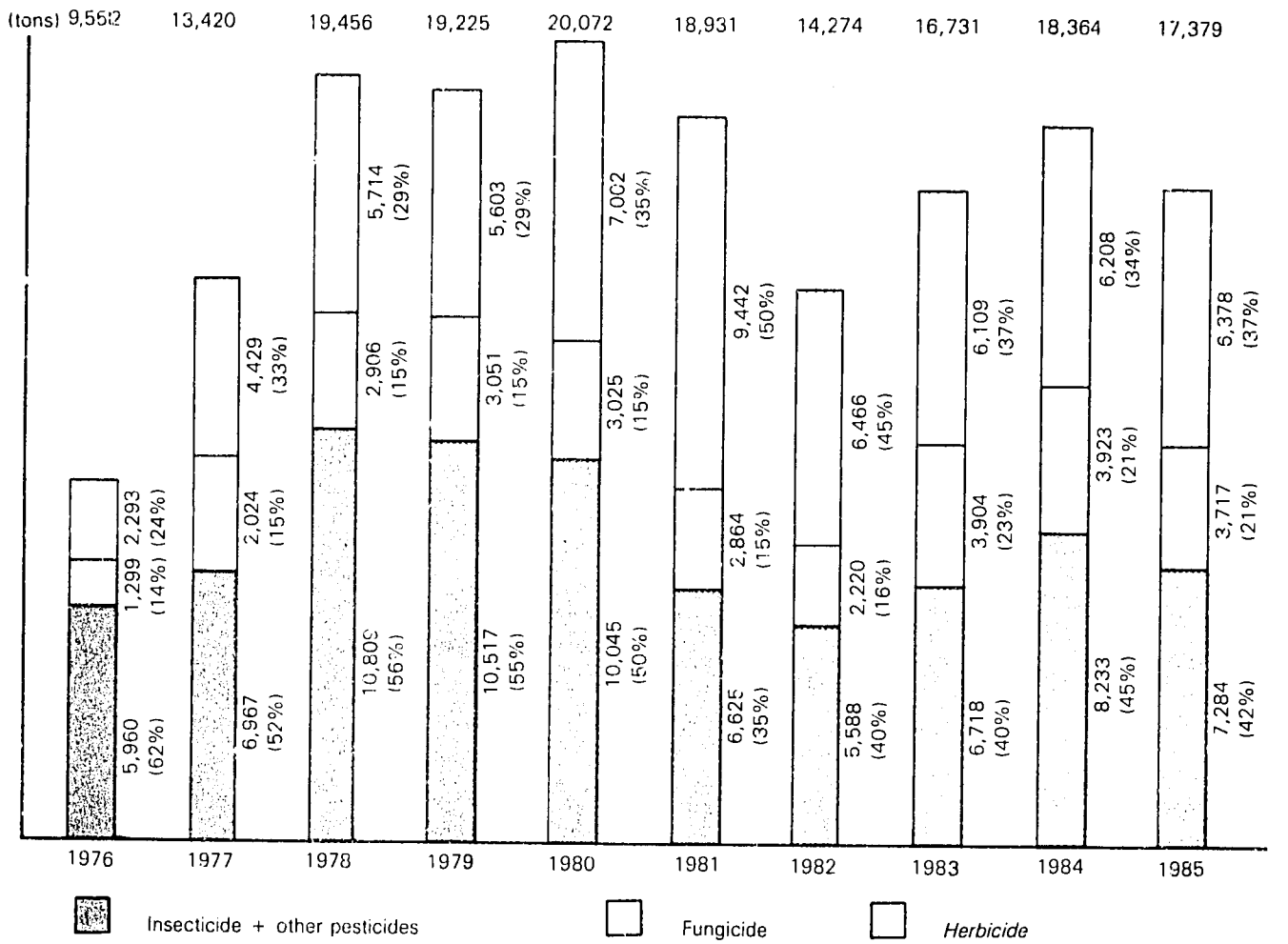
Source : Adapted from Chuapanich (1986) & BOI (1986)

more specific, listing several hundred materials, including even methanol and saccharine, as toxic or hazardous substances (EPA, 1985). The EPA uses five main codes when classifying such materials: I (ignitable), C (corrosive), R (reactive), E (uncertain toxicity, so must be tested under EPA-defined extraction procedures) and T (toxic). This chapter concentrates on the last three types.

Many of the materials listed by the EPA are not currently used in Thailand. Those that are imported and registered by the Customs Department are listed in Table 11.7, under three broad headings. Group 1 covers inorganic chemicals, and inorganic or organic compounds of precious metals and rare earth metals, imported in tons per year. Group 2 covers organic chemicals, also imported in tons per year. And Group 3 covers those organic chemicals which are imported as cubic meters per year. As the notes to the table explain, a number of the chemicals shown therein appear on the EPA list, but are not currently controlled either by the Ministry of Industry or by the Ministry of Public Health.

Imports under Group 1 fell from 25,821 tons in 1977 to 18,099 tons in 1978, before rebounding to 43,623 tons in 1979. In following years, the total volume fluctuated somewhat between 1980 and 1983, before growing rapidly in 1984 and 1985 (Figure 11.3). Imports of Group 2 materials ranged between 15,932 tons and 32,537 tons a year, with the lowest figure in 1977 and the highest in 1982 (Figure 11.3). Imports

Figure 11.2 Total Quantity of Imported Pesticides both as Finished Products and Technical Grade Ingredients, 1976-1985



Source : Chuapanich, 1986

of Group 3 chemicals peaked at 16,804 cubic meters. in 1984, before falling back to a more typical figure of 11,172 cubic meters. in 1985 (Figure 11.4).

Location of Toxic Waste Producing Plants

Thailand's heavy manufacturing industry is mainly concentrated in Bangkok and the nearby provinces of Samut Prakan and Samut Sakhon (see Table 11.8). Samut Prakan, nicknamed the "Industrial City", has one private industrial estate and the highest number of factories per hectare in the country.

The overwhelming bulk of the toxic organic chemicals used in manufacturing processes in Thailand consists of solvents, most being used up in the process. While such materials can certainly cause problems when released into the environment, the evidence suggests that, so far at least, they are not a major problem as far as the pollution of the atmosphere or rivers is concerned. But their concentrations should be carefully monitored in groundwater underlying major industrial plants.

The wastes which cause greater immediate concern in Thailand are thouse in the inorganic chemical or heavy metal categories. Five out of the country's seven lead smelting plants are found in and around Bangkok, along with 83 percent of fluorescent lamp manufacturing plants, and between 90 and 97 percent of chemical, dry cell battery, paint, pharmaceutical and textile manufacturing plants. Clearly, any attempt at the national level to identify and control major industrial hazards needs to start in this area of the country.

Table 11.6 Estimated Local Formulation and Production of Pesticides

(ton/year and percent)

Pesticides	Formulation Volume				
	1981	1982	1983	1984	1985
Insecticides	12,797 (90.3%)	8,302 (91.4%)	6,307 (79.2%)	9,583 (52.2%)	10,689 (54.8%)
Fungicides	294 (2.1%)	144 (1.6%)	- (-)	20 (0.1%)	18 (0.1%)
Herbicides	729 (5.1%)	355 (3.9%)	1,392 (17.5%)	8,378 (45.6%)	8,487 (43.5)
Miticides	349 (2.5%)	286 (3.1%)	268 (3.3%)	394 (2.1%)	313 (1.6%)
Sub-Total	14,164 (100%)	9,087 (100%)	7,967 (100%)	18,375 (100%)	19,507 (100%)
Local production of herbicide	-	4,500	4,500	4,500	4,500
Total	**14,169**	**13,587**	**12,467**	**22,875**	**24,007**

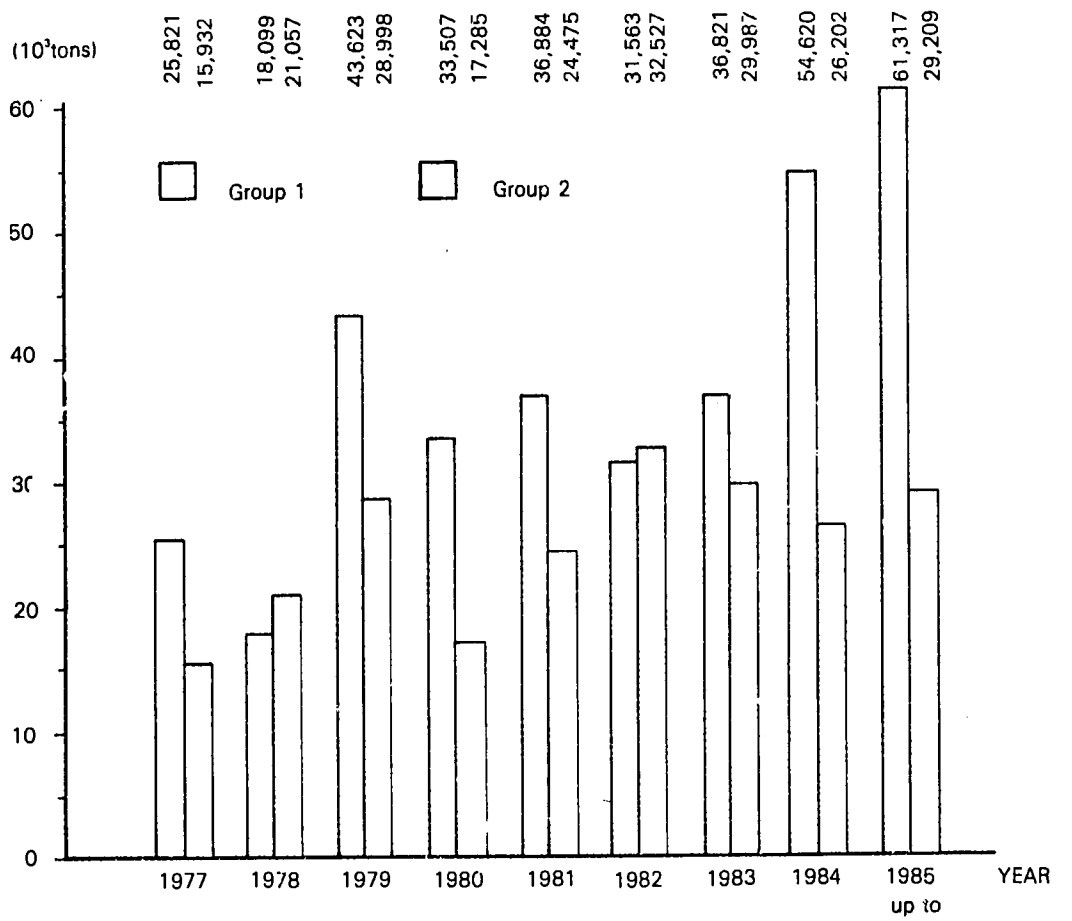
Source: Adapted from Chuapanich (1986) & BOI (1986).

Table 11.7 List of Imported Toxic Chemicals

Group 1	Group 2	Group 3
Inorganic chemicals, organic and inorganic compounds of precious metals or of rare earth metals (tons/year)	Organic chemicals (imported as tons/year)	Organic chemicals (imported as cu.m./year)
Chlorine	Cyclohexane	Chloroform[a]
Mercury	Benzene	Carbon tetrachloride
Hydrochloric acid	Toluene	
Sulfuric acid		Bromoform[a]
Oleum	Xylene[a]	Methyl alcohol (methanol)
Nitric acid		
Phosphorus pentoxide	Naphthalene[a]	Propyl and isopropyl alcohols[a]
Phosphoric acids	Vinyl Chloride	
Arsenic trioxide, arsenic pentoxide and acids of arsenic	Tetrachoroethylene	
	Phenol	Butyl alcohols (butanols)[a]
Sulfuric anhydride	Cresols[a]	
Ammonia anhydrous	Formaldehyde	
Ammonia in solution		
Sodium hydroxide, solid	Saccharin[a]	
Sodium hydroxide, in aqueous solution	Soluble saccharin powder[a]	
Potassium hydroxide	Organic--arsenic compound[a]	
Chromium oxide[a]	Organo--mercury compounds[a]	
Chromium hydroxides[a]		
Manganese dioxide		
Sodium chlorate		
Arsenite and arsenates[a]		
Potassium cyanide[a]		
Complex cyanide		
Other cyanides		

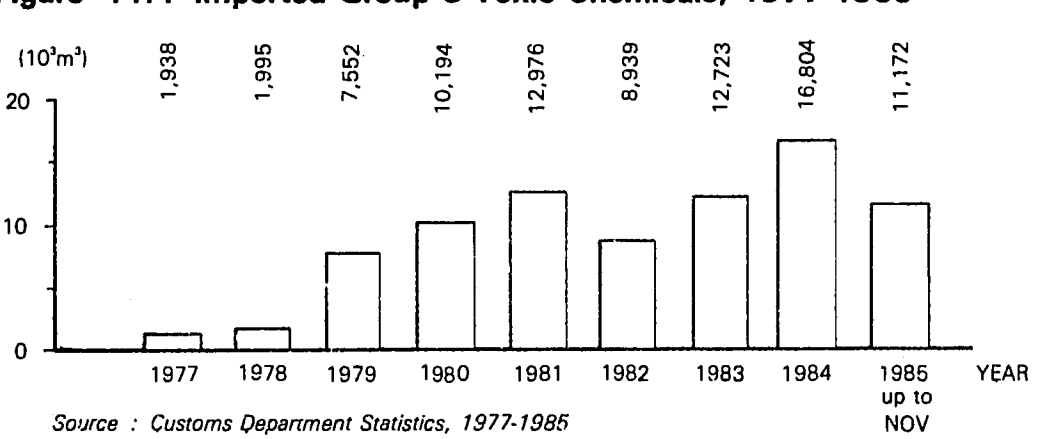
Note: a. Toxic chemicals not currently controlled by MOI or MPH.
Source: Information compiled from the Customs Department, MOF, 1970-1985.

Figure 11.3 Imported Group 1 and 2 Toxic Chemicals, 1977-1985



Source : Statistic files 1977-1985 of the Customs Department, Ministry of Finance.

Figure 11.4 Imported Group 3 Toxic Chemicals, 1977-1985



Source : Customs Department Statistics, 1977-1985
Ministry of Finance

Table 11.8 Locations of Toxic Wastes Producing Registered Factories
(as of 1985)

No. Province	Number of Registered Factories								
	Lead Smelting	Fluorescent Lamps	Car Batteries	Drycell Batteries	Electro plating	Paint	Pharmaceutical	Chemical	Textile (Dyeing) (Printing)
1. Bangkok Metropolis	3	3	5	13	94	67	184	25	46
2. Samut prakan	2	2	8	2	16	29	16	11	32
3. Samut Sakhon	-	-	-	-	2	-	1	-	12
4. Other Provinces	2	1	2	1	23	5	1	4	3
5. **Total**	**7**	**6**	**15**	**16**	**135**	**101**	**202**	**40**	**93**

Source: Industrial Control Division, MOI.

11.6 EMERGING TRENDS

A number of trends can be discerned in Thailand's use of toxic substances and production of hazardous wastes. First, the volumes of toxic substances being imported do not suggest that there is any need for drastic action. Localized problems have emerged and the mismanagement of pesticides, particularly in the agricultural sector, underlines the need for improved controls, more vigorous enforcement of the legislation, and better education of pesticide users on the hazards involved in using these materials.

The total amount of pesticide supply is clearly on a growth trend, as Figure 11.1 confirms. If there is a drive to improve the efficiency of Thai agriculture in future years, because the total area of land available for conversion to farming is constantly shrinking (see Chapters 2 and 4), then the use of crop protection chemicals is likely to grow. The most buoyant demand has been for the relatively safe pyrethroid group of insecticides, although to date the total quantities involved are much smaller than for the organochlorine, organophosphate or carbamate groups. So far, at least, demand for the more problematic compounds (e.g., the organochlorines) has been contained, as Figure 11.5 illustrates. DDT has been detected in a small number of environmental samples, but at extremely low levels, considerably less than one part per billion. The Ministry of Health is the only current user of DDT.

Although the levels of pesticide found in rivers are not yet particularly pronounced, concern has been expressed about the level of pesticides found in food in Thailand. Figures 11.6 and 11.7 show the pesticide levels reported as remaining in such important foods as vegetables, peanuts, fish, meat, eggs and milk. The diagrams show the number of samples taken, the percentage found to contain pesticide, and the percentage of the samples found to contain pesticide levels in excess of the maximum residues limit.

The total number of samples involved was very small indeed (around 45 vegetable samples, for example, in a year, of which three were over the maximum residue limit), so it is impossible to draw any overall conclusions. But, while it is also worth noting that residue limits are typically set to ensure a considerable margin of safety, it is at least suggestive that a small percentage of the samples of vegetables, peanuts, sesame seed, fresh milk and lard were found to be over the limit.

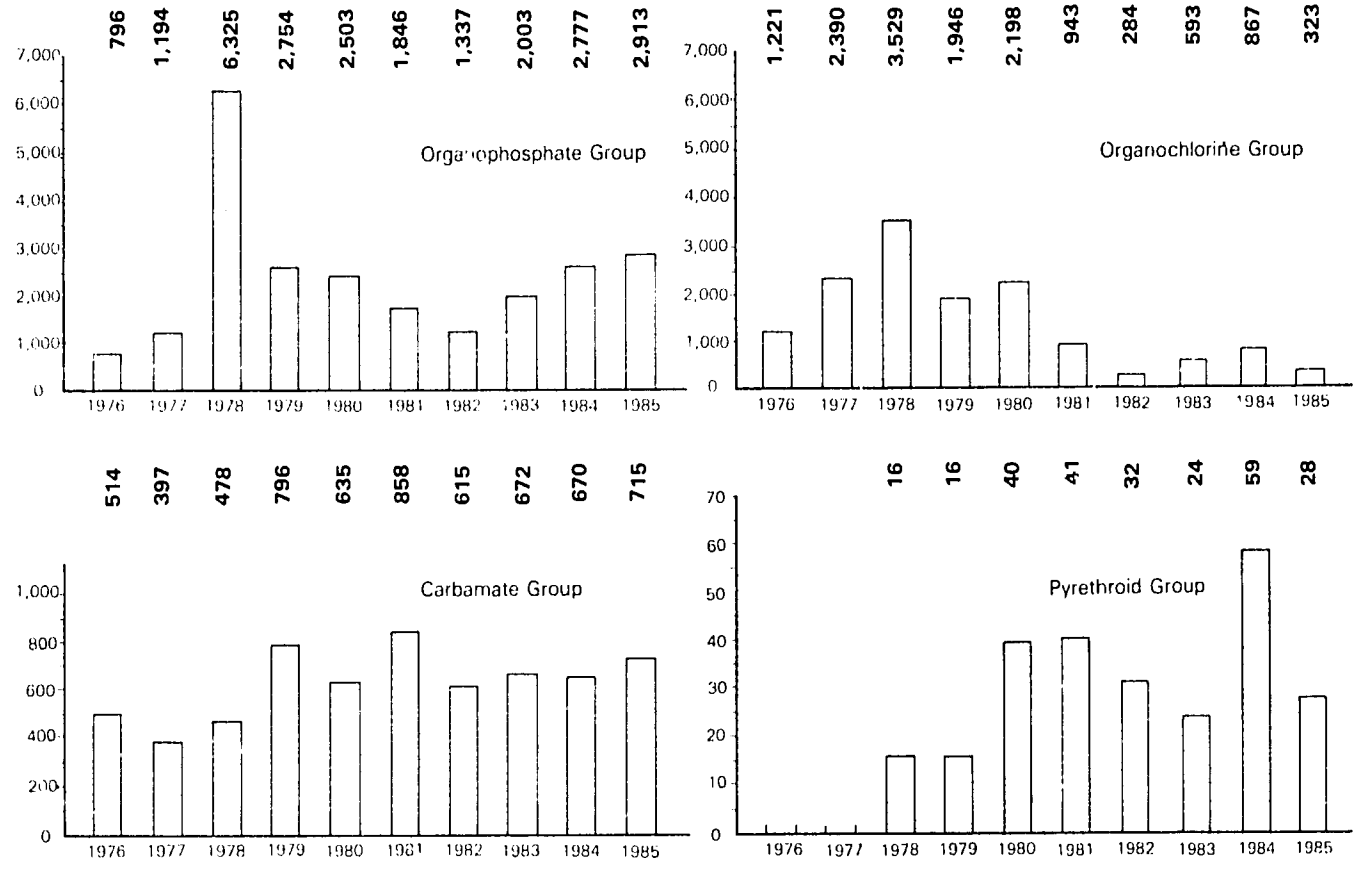
Herbicides are gaining growing acceptance among farmers, as shown in Table 11.6. Although herbicides are certainly toxic, they tend to be very much less toxic than most insecticides and are also much less likely to cause long-term environmental pollution problems. But like all agricultural chemicals, their formulation, distribution and use may lead to problems and should be closely monitored. The human health and ecological problems alleged to have been associated with dioxin contamination of the herbicide 2,4,5-T underline the need for careful quality control in the production of such materials.

As far as major hazard industrial plants are concerned, Figure 11.8 shows that there was almost a sevenfold growth in the number of industrial plants using and disposing of toxic chemicals registered with the Ministry of Industry's Industrial Control Division during the 1970s, although the number of new registrations has tapered off during the worldwide recession. As Section 11.5 argues, one of the key issues in this field is that there is a worrying lack of the sort of survey data on which a comprehensive picture of the major hazards situation might be built up, both for particular localities and for Thailand as a whole.

11.7 LEGAL AND INSTITUTIONAL FRAMEWORK

An array of regulations and agencies is involved in dealing with toxic substances, pollution control and the disposal of hazardous wastes in Thailand. A summary of some of the

Figure 11.5 Total Quantity of Imported Active Ingredients for Some Major Pesticide Groups (ton/year)



Source: Division of Agricultural Regulatory, Department of Agriculture

important responsibilities and linkages is provided in Figure 11.9. Some of the key Acts are discussed below.

Poisonous Substances Act, 1967

The Poisonous Substances Act dates from 1967 and was amended in 1973. It controls the import, export, manufacture, marketing, storage, transport, and use of poisonous substances. Under the Act, these substances are broadly described as " active ingredients" with properties that may endanger human and/or animal health, crops or property. Controlled substances which are used in agriculture, industry and public health come under the joint control of the Ministry of Agriculture (MOA), the Ministry of Industry (MOI) and the Ministry of Public Health (MPH).

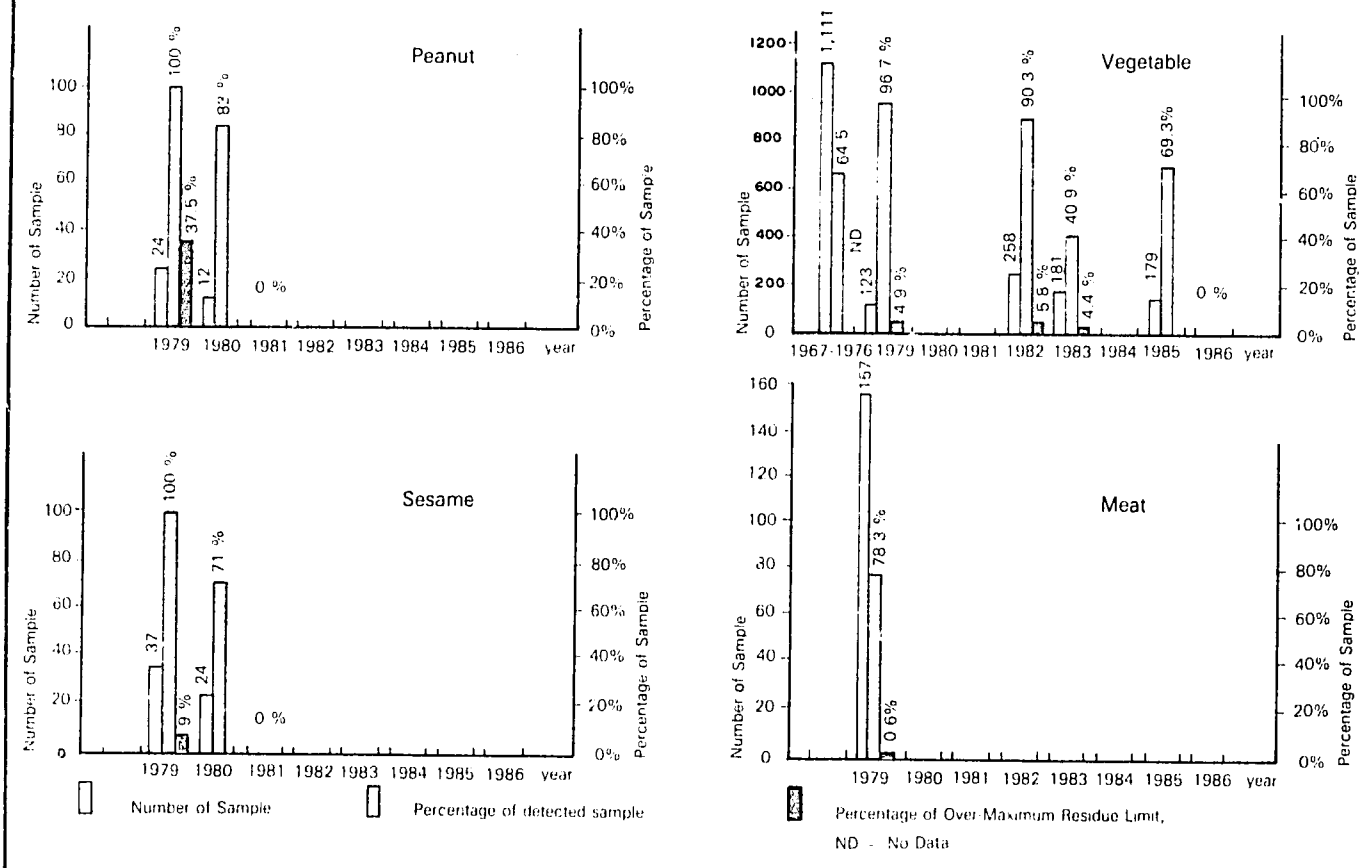
The respective ministries are empowered to include a chemical on the list of poisonous substances. Once a chemical has been listed, it is subject to the provisions of the Act. Permission must be obtained from the respective ministries prior to the import, export or manufacture of listed chemicals. The ministries can issue ministerial regulations governing the storage, transportation, manufacture, use, labelling, and disposal both of poisonous substances and of their containers. At present, 367 chemicals are listed (Pairojboriboon, 1986).

Factories Act, 1969

The Factories Act empowers the Ministry of Industry (MOI) to control the establishment and operation of factories. The MOI can issue regulations imposing limits on discharges of air pollutants, effluents or wastes from factories, and set occupational health and safety standards for the working environment. Government-owned factories and other facilities are exempt from the provisions of the Act, however.

Section 39 of the Factories Act specifically empowers the MOI to issue regulations relating to pollution, occupational safety and accident prevention. Regulations issued under this section, such as the MOI's Notification No. 4 of 1971, deal with toxic substances only in very general terms. The issue of public safety is not directly addressed.

Figure 11.6 Pesticide Residues in Vegetable, Peanuts, Sesame and Meat



Source Deema (1980), DOA 1980 (a), DOA 1982 (a), (c), DOA 1983 (a), (b), (c), (d), (e), (f), (g), (h) DOA 1985 (a), (b)

The MOI has also established the Office of Hazardous Substances, assigned to work solely on toxic and hazardous materials. Moreover, the Office of Industrial Services and Waste Treatment was also set up to provide hazardous waste treatment services to the private sector. This service has yet to come into operation, however, because problems have been encountered in setting up the planned central treatment facility (Box 11.2).

National Environmental Quality Act, 1975

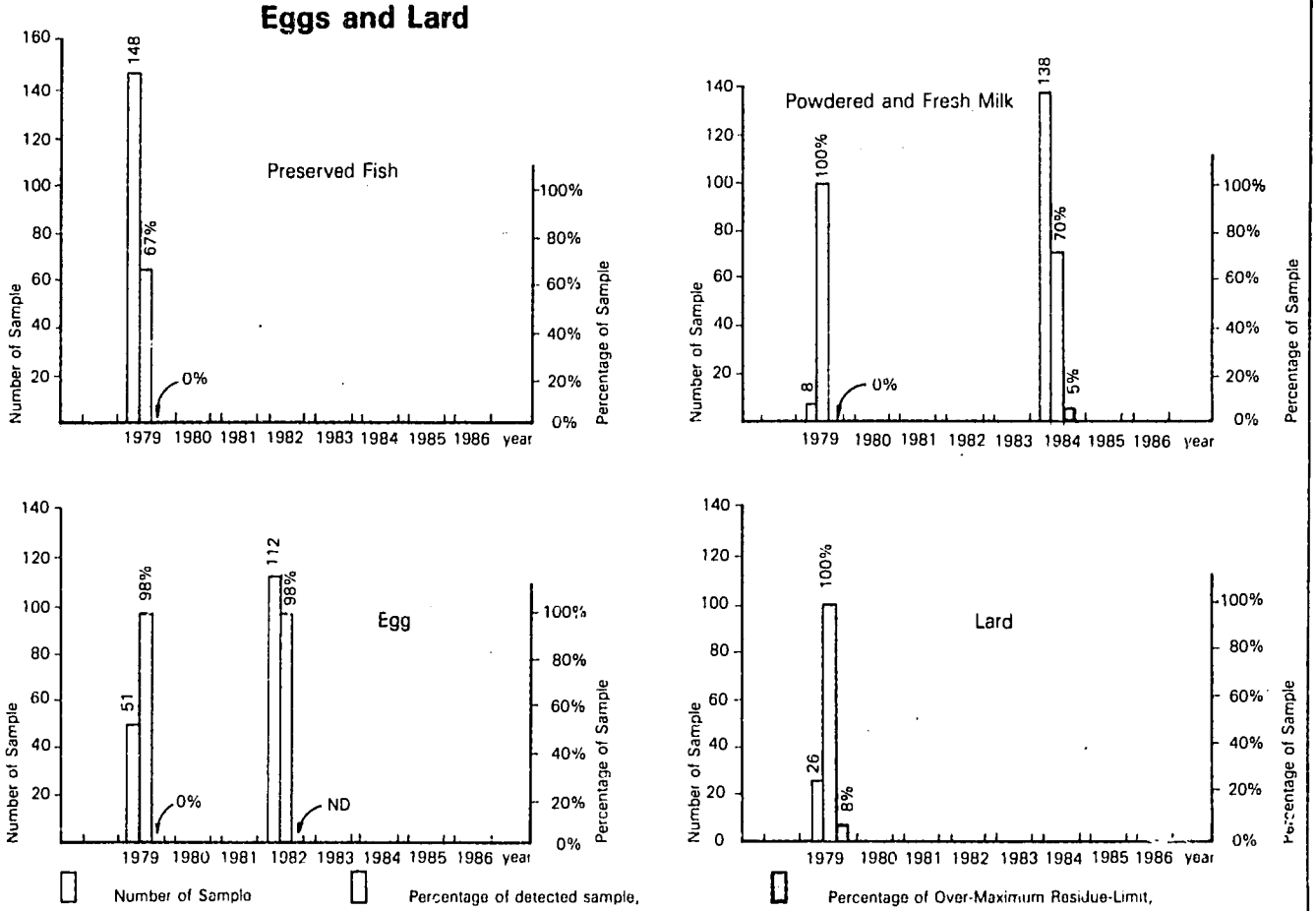
The National Environmental Quality Act, amended in 1978, created the National Environment Board (NEB) and the Office of the National Environment Board (ONEB). It authorizes the NEB to perform functions, which are mostly concerned with policy development and coordination with other government agencies in matters relating to environmental quality.

The 1978 amendment empowers the NEB to issue ministerial regulations covering certain designated projects for which the submission of an Environmental Impact Assessment (EIA) is a precondition of NEB approval. Presently, ten project types are covered, including chemical plants, oil refineries, pulp mills, and smelters. Several committees have been formed under the NEB umbrella, with those responsible for various aspects of hazardous waste management including the Committees on Air Quality, Water Quality and Toxic Substances. They provide technical advice to the NEB on, for example, the establishment of priorities, the formulation of action plans, and the setting of ambient standards.

Regulation of the Office of the Prime Minister on Accident Prevention, 1983

The Regulation of the Office of the Prime Minister on Accident Prevention created the National Safety Council of Thailand (NSCT), which is chaired by a Deputy Prime Minister and

Figure 11.7 Pesticide Residues in Preserved Fish, Powdered and Fresh Milk, Eggs and Lard



Sources : Deema (1980), DOA 1982 (b), DOA 1984 (a)

consists of representatives from other government agencies. The Council's primary duties are to advise the Council of Ministers in matters related to accident prevention, to propose new laws or regulations to the Council of Ministers, and to promote public awareness and public relations.

Other Acts

A number of other Acts touch on this area to a greater or lesser extent. The Land Transportation Act makes (general) provision for the control of hazardous materials. The Minerals Act of 1967 governs the development and operation of mines, including pollution control and safety aspects. The Public Health Act of 1941 covers the handling of refuse and solid wastes, nuisance, and food sales. The Navigation Act of 1913 includes regulations covering the transportation of dangerous substances within Thai waterways. With the exception of the regulations which are needed to control toxic waste disposal, the existing legal framework should be adequate to the task, provided the political will exists.

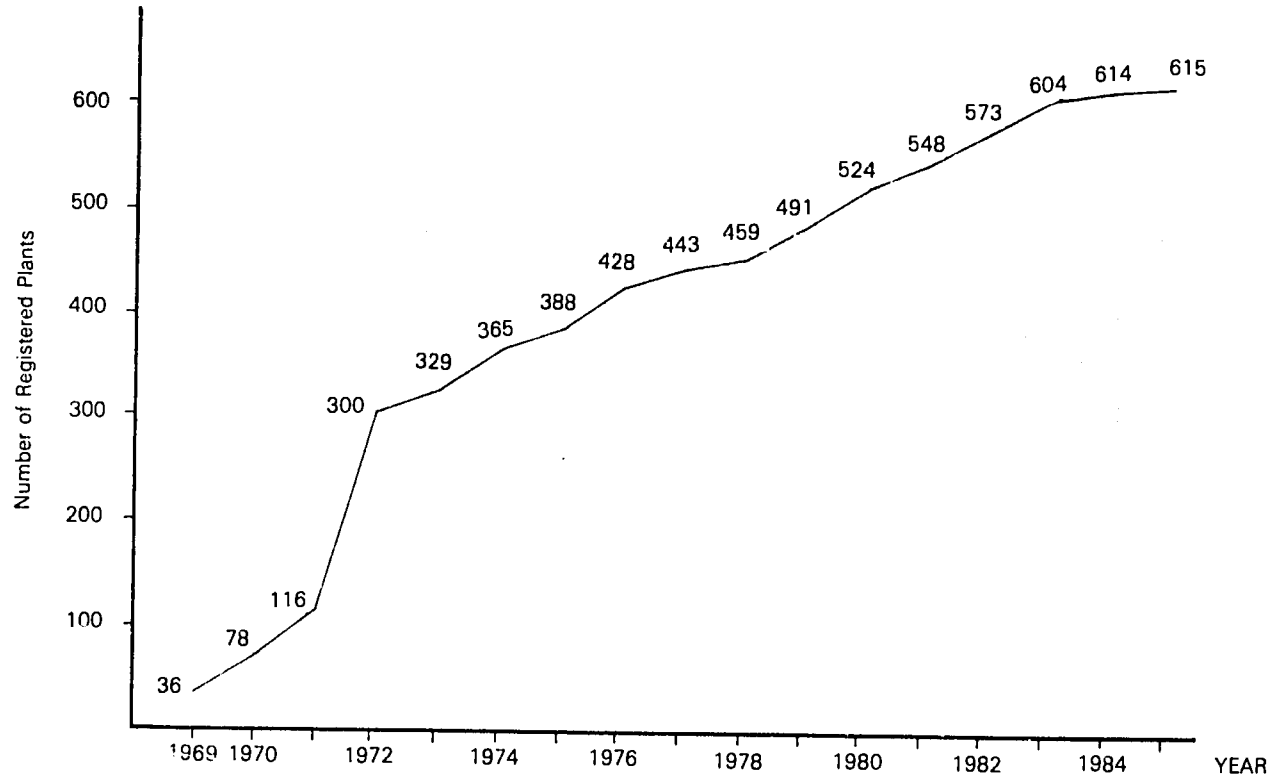
11.8 KEY ISSUES

Three major issues have emerged. First, there is the question of what can be done to ensure that Thailand's growing consumption of pesticides does not buy increased agricultural productivity at ther expense of human health and environmental quality (Box 11.1). Second, there is the question whether sufficient information is known about the country's growing number of major hazard industrial plants. And, third, what can be done to ensure that all hazardous wastes are identified and properly treated, where necessary, and disposed of in a safe fashion. An example of one possible solution to some of these problems is described in Box 11.2.

Pesticides

The evidence reviewed in the preceding sections suggests that, while the number of pesticide poisonings is falling in pesticide plants, the local production of these compounds is increasing and new factories are coming into the business. Pressure must

Figure 11.8 Registered Plants Using and Disposing Toxic Chemicals



Source : Industrial Control Division, MOI

be maintained, and in some cases increased, on such operations, to ensure that they achieve acceptable standards.

At the same time, while there is considerable variance in the estimates of pesticide poisonings and deaths reported by different researchers who have studied the agricultural sector, the trend here is certainly an adverse one. More must be done to ensure that those pesticides that are used are used safely and that the containers in which they are shipped are disposed of in an acceptable manner. Pesticide users at the farm level clearly need more education on the health and environmental impacts associated with such materials.

New pesticide formulation and production plants should generally require EIAs before they are given the go-ahead. Meanwhile, however, the Bhopal disaster underscores the necessity of using zoning and other town planning controls to ensure that such plants are not constructed in unduly sensitive places. One company recently got BOI approval to build a pesticide factory in Pathum Thani, a small town north of Bangkok. The company plans to produce 300,000 liters/year of glyphosate and 600 tons/year of carbofuran. In the event of a major accident, the plant could possibly discharge either of these products, or intermediates like dimethyl sulfur, into the Chao Phraya River—upstream from the main water intake for Bangkok's Metropolitan Water Works Authority. Fortunately, the company did not receive approval from other government agencies.

Toxic Substances and Hazardous Wastes

The number of registered factories using toxic or otherwise hazardous materials is growing. The volume of potentially hazardous materials used in the Thai economy as a whole is also growing. Yet there is a severe shortage of reliable information on who is using what, where, and what is being done with such materials once their working life is finished.

If experience elsewhere is anything to go by, pressures will continue to build on this front because of three mutually reinforcing factors: (1) growing quantities of pesticides and other synthetic organic chemicals are being produced, transported, used and disposed of; (2) many are hazardous and some are long-lived, whether in human tissues or in the open environment; and (3) the analytical techniques used to detect concentrations of such substances are constantly evolving, and their sensitivity is increasing dramatically.

It is worth pointing out, too, that even normal garbage can produce toxic leachates which may percolate down into groundwater used for drinking water purposes. The garbage which Thais throw out each day tends to end up in waste dumps which have not been designed with groundwater protection in mind. Yet these materials include such everyday — and potentially hazardous substances — as nail polish

Box 11.2 Suitable Case for Central Treatment?

Hazardous waste disposal is a subject of considerable concern in Thailand, despite the fact that some industries have spent millions of baht on the installation of treatment facilities for their liquid wastes. The treated effluent may or may not meet the standards imposed by the Department of Industrial Works (DIW), but the chemical precipitation techniques generally used result in chemical sludges or solids which themselves require disposal. Often they are passed on to private contractors, who may dump them in sites unknown either to the industrial waste producer or to the authorities.

At the same time, many smaller companies do not have the know-how to treat or adequately dispose of the wastes they produce. The DIW has therefore decided to initiate a joint treatment program for handling toxic liquids, sludges and solid wastes from all industries situated in and around Bangkok (Lohwongwatana, 1986).

A prefeasibility study was conducted in 1984 and revealed that as many as 682 factories were regarded as definite generators of toxic wastes, out of 862 possible producers in the study area. The annual volume of hazardous wastes produced in 1984 by the factories in the study area was estimated at 22,100 tons of solids and slurries, in addition to 84,000 cubic meters of wastewater. These volumes are expected to double by the year 2000.

Three treatment centers are planned by the DIW, to be located in the western, northern and eastern suburbs, where some of the major generators of hazardous wastes are located. The aim is to minimize the cost of collecting and transporting the waste. The toxic, inorganic wastes will be converted into an environmentally inert substance using a solidification process which encapsulates the waste in a cement-like agent. The original idea was that the resulting material might be sold as a filler for use in road-making, although the disposal of the fixed wastes in a landfill site is another option.

The first treatment complex will be situated on a large plot of land in the western suburbs of Bangkok, at Samea San, Bangkhuntian district. There will be a 200 cubic meters per day chemical treatment plant for treating electroplating wastewater, an 800 cubic meters per day chemical treatment plant and polishing lagoons for treating textile dye wastewater, and chemical detoxification and cement mixing facilities for handling sludges and solid wastes. The center is expected to begin operations early in 1988.

A program of public hearings is under consideration by the government and, if the scheme is accepted by local people, about 160 hectares of land will be secured. In order to reduce the administrative burden on the government, the operation of the center, including the transportation of treated sludge, will be handled by a private contractor. Besides providing some 30 million baht to cover the initial investment cost, the DIW will also play a supervisory role. It hopes to recover some of its costs by sharing the profits generated in the process.

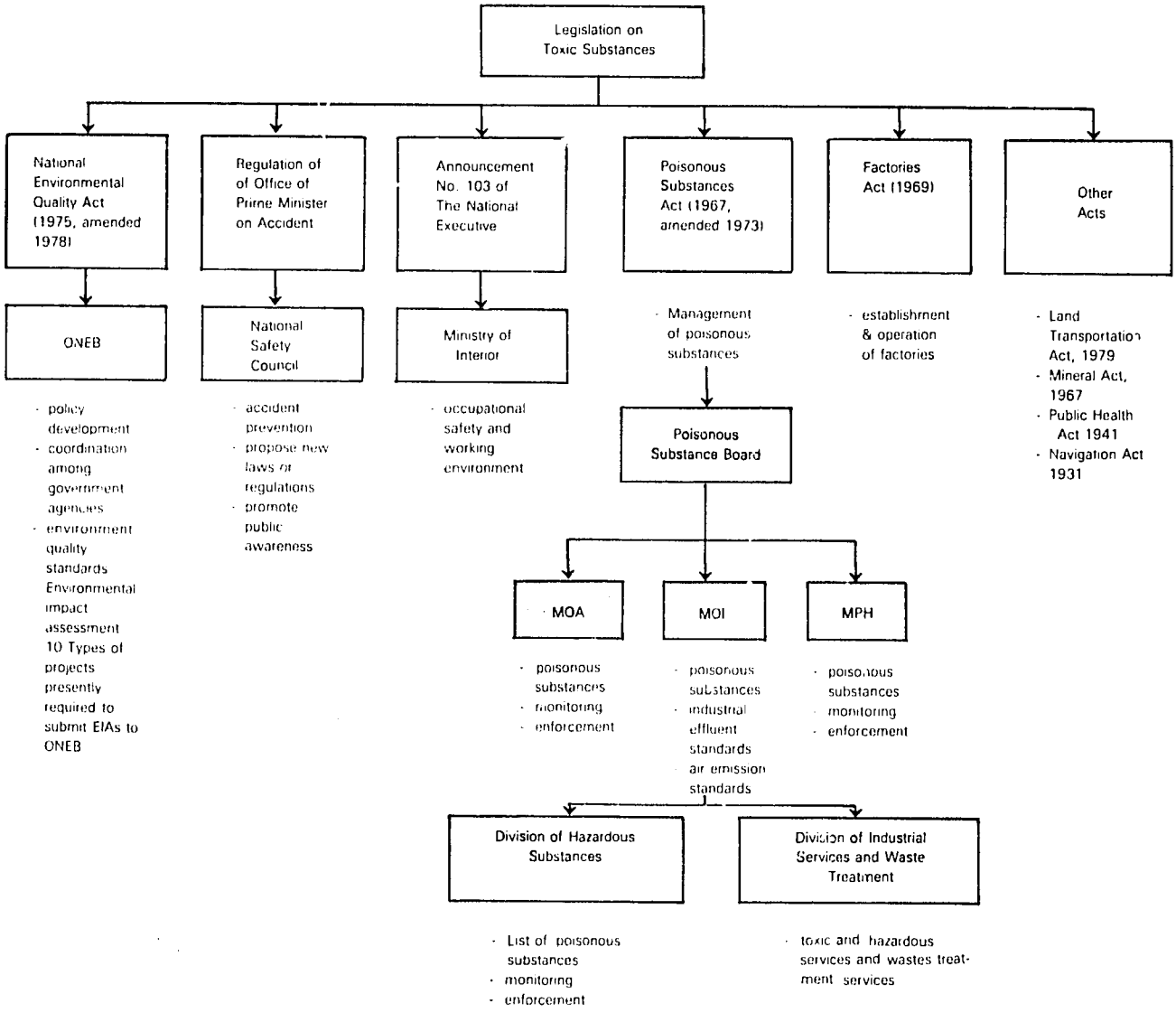
remover, bleach, domestic pesticides and PCBs from old television sets and other equipment. What is needed is a review of the current situation in the waste disposal sector, together with the formulation of a strategy designed to ensure that Thailand's future needs for hazardous waste disposal are met.

The quality of groundwater resources will need careful monitoring, to ensure that Thailand does not repeat the problems experienced even in such technologically sophisticated countries as the United States.

Another urgent priority is the updating of the list of substances prepared under the Poisonous Substances Act. Currently, only substances that have been specifically named in ministerial regulations under the Act are subject to control. Since the process of listing such substances is extremely slow in Thailand, the result is that a considerable number of potentially dangerous substances are being used without any control. The updating of the list should be complemented by the introduction of new procedures designed to ensure that new toxic threats can be identified and controlled in a much shorter time-scale.

Another line of development would be to ensure that the issues related to the management of toxic substance and hazardous waste are properly addressed in the EIAs prepared for the National Environment Board. Ultimately, too, the list of project types for which EIAs are required should be extended. The controversy over the proposed tantalum plant at Phuket (see Box 12.2) illustrates what can happen if the public believes that it has not been properly informed about the impacts likely to be associated with a proposed development. Public education and awareness programs, together with measures designed to ensure real public participation in major planning decisions, are both essential in a democracy which aims to pursue a vigorous program of industrial modernization.

Figure 11.9 Legislation on Toxic Substances in Thailand



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12 Accident Prevention and Occupational Safety and Health

12.1 OVERVIEW

Many studies have revealed that Thai workers are generally exposed to poor working environments and have poor welfare facilities, especially in small and medium-sized undertakings (e.g., Wongpanich, no date). Records available from the Workmens's Compensation Fund (WCF) show that, nationwide, occupational injury rates have been on the rise since the Fund's establishment. Occupational accidents and diseases impose a burden on workers both directly in terms of material damages and medical costs, and indirectly, in the form of intangible costs such as the misery inflicted on workers and their families, loss of future earnings, loss of normal advancement, mental changes, need for retraining, and so on.

Major factors that contribute to work-related injuries have often been attributed to dangerous working conditions, lack of efficient production machinery and safety equipment, inadequate attention given by both the employers and employees to safety, and the shortage of government safety inspectors (Thosuwonchinda, 1985).

An accident may be defined as an unintended event that may involve injury, loss or damage. Accidents may happen in every aspect of our daily lives, while we are at home, travelling, at play or at work. However, this Chapter only deals with accidents at work. Such events are usually unforeseen and are therefore commonly regarded as the result of chance or ill-luck. However, this negative attitude has gradually given place to a more positive one. It is now recognized that most accidents are foreseeable and that many can therefore be prevented. This can be effected by the introduction of protective measures in the form of safety engineering and protective equipment.

With progress in the development of industrial and other occupations, new problems relating to working conditions and the working environment emerge that call for new forms of intervention. These gradually evolved into what is called occupational health. Occupational health is concerned with health in its relation to work and the working environment. It includes studies on all factors relating to work: working methods, conditions of work and aspects of the working environment that may cause disease, injuries or ill-health, chemical and physical hazards such as intoxication from inhaled dusts, fumes, gases or vapors, silicosis from inhaled quartz dust, skin diseases from irritating substances, deafness from noise, physical or mental strain from heavy or monotonous work. Furthermore, poor human relations at work may lead to stress and other nervous symptoms. However, occupational health concerns not only focus on health protection, but also on the promotion and maintenance of the physical, mental and social well-being of workers in all occupations. It is clear from the foregoing that occupational health calls for special knowledge drawn from many disciplines, including medicine, engineering, chemistry, toxicology, psychology, physiology and statistics.

It is important to distinguish occupational health from public health. The latter is concerned with the relation of man to his environment in society outside the workplace, where factors such as air and water pollution, nutrition and infections may influence his health.

New industrial substances and processes are being introduced into the developing countries in ever-increasing amounts, and many of these substances are flammable,

Table 12.1 Coverage of Workmen's Compensation Fund

Year	No. of Provinces	No.of Employers	No. of Establish-ments	Contribution (Million baht)	No. of Employees	No. of Injuries	No. of Injuries per 100,000 workers	Compensation paid (Million baht)
1974	1	2,492		24.20	272,848	3,200	1,173	16.40
1975	1	2,794		34.77	349,814	4,605	1,329	23.50
1976	6	3,605		54.25	496,700	10,136	2,041	52.05
1977	12	4,382		74.75	570,000	16,537	2,901	51.04
1978	17	5,403		90.71	590,640	20,135	3,376	62.17
1979	22	6,101		114.62	659,041	24,366	3,697	75.22
1980	25	7,337		152.15	745,513	26,034	3,494	98.27
1981	30	8,465		186.80	797,270	28,374	3,559	148.17
1982	33	9,286		203.55	824,565	29,974	3,635	151.28
1983	33	10,047		224.06	873,059	34,252	3,923	205.44
1984	36	11,133		248.99	994,190	39,798	4,003	247.19
1985[a]	56		13,580	268.30	1,091,318	39,500	3,625	232.61

Note: a. 1985 figures from private communication, starting from 1985, the number of establishments will be given instead of the number of employers.
Source: DOL, 1984a, p.26

explosive, or toxic. These substances create major new hazards not only for workers but also for the environment and the public arising from handling, processing, production or disposal. A very general definition of a major hazard could be an event which has the potential to kill or injure large numbers of people. Each year around the world, there are a significant number of such serious accidents. Examples include the recent disaster in Bhopal, where the leakage of methyl isocyanate (MIC) from the Union Carbide plant in December 1984 caused over 2,000 deaths and tens of thousands of injuries, and the explosion at a liquefied petroleum gas (LPG) facility in Mexico City in 1984, which caused an estimated 650 fatalities, with thousands more seriously injured.

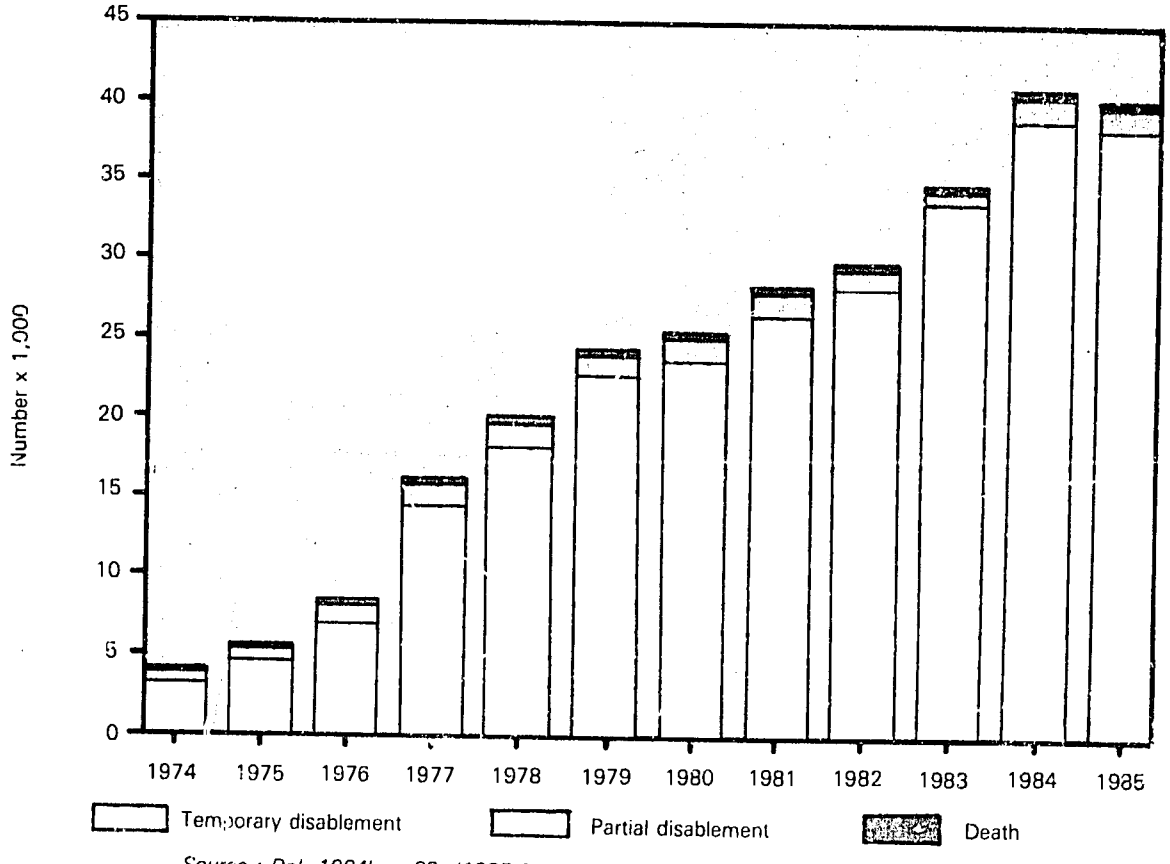
The population of Thailand in 1986 is about 52.5 million. The total number of people in the labour force was estimated to be approximately 24.9 million. About 64.5 percent of the labour force are in the agricultural sector, 29.8 percent are in nonagricultural sector, the rest being unemployed. Factory workers and laborers comprise about 9.8 percent of the total labour force (DOL, 1985b). Because of rapid industrial development and the rising number of occupational injuries, the government set up the Workmen's Compensation Fund (WCF) in 1972, by the National Executive Council Decree No. 103. The purpose of this Fund is to ensure that workers injured at work will be compensated fairly and speedily.

All establishments in designated provinces of the country having 20 or more employees are required to join the Fund, except agricultural and fishery establishments, schools and some governmental enterprises, which have their own employee benefits. Table 12.1 shows the coverage and the compensation paid out from the Fund between 1974 and 1985. In order to compare the yearly figures, the number of injuries per 100,000 workers are also computed and given in the same table. It can be seen that the WCF is now in force in 56 provinces out of the total of 73 provinces, and covers about 1.1 million employees. The rate of injuries and the amount of compensation paid have increased rapidly in the last ten years. The rate of injuries has increased from 1,173 per 100,000 workers in 1974 to 4,003 per 100,000 in 1984. In 1984 alone, there were 39,798 reported injuries, representing a 16 percent increase in the number of injuries over 1983. Fortunately, the number of fatal injuries in 1985 decreased somewhat. However, because of the incomplete coverage achieved by the WCF, the actual number of injuries has been estimated to be three to five times higher than the reported figures (TDRI, 1986). The compensation paid out in 1985 was 232 million baht. Although much has been said about other indirect costs of injuries, their estimates are not available. It is often asserted that the indirect costs of accidents (in lost output, lost wages or damage to property) average four times the direct costs (medical treatment and compensation) (ILO, 1976, p.2).

In terms of severity, data from the Labour Studies and Planning Division of DOL was used to prepare Figure 12.1. It should be noted that the data as reported by the Labour Studies and Planning Division differ slightly from those produced by the WCF. No explanation for the discrepancies has been given in either report. But the differences are slight and do not affect the overall picture. It can be seen from Figure 12.1 that about 5 percent of the injuries are severe injuries, resulting in permanent disability or death. But most of the injuries are not of the severe type, resulting in only temporary stoppage of work. Note that each year there are also about 30 to 40 cases of permanent disablements which are not shown in Figure 12.1.

To compare the number of injuries in various forms of employment, the rates of injuries per 100,000 workers in a number of industries are computed and shown in Figure 12.2. It can be seen from these figures that the industries that are

Figure 12.1 Number of Occupational Injuries in Thailand, 1974-1985



Source : DoI, 1984b, p.83, (1985 figures from private communication)

most injury-prone are the basic metal industry, the manufacturing of transportation devices and construction, respectively.

The fatality rates for various industries are shown in Figure 12.3. It can be seen that the industries with the highest fatalities are construction, transportation and mining respectively. The chemical industry is also of special concern. Although ranks sixth in the injury rating, it has the potential to inflict a large number of injuries if a major accident takes place.

Table 12.2 gives the causes of injuries in 1984. It is interesting to note that the most common causes of accidents are due to simple actions like being struck by objects, struck by flying pieces of objects, or struck by falling objects. The fourth major cause of injury is machinery. But the deadliest causes are vehicles, fall from high places and electrical failure, respectively.

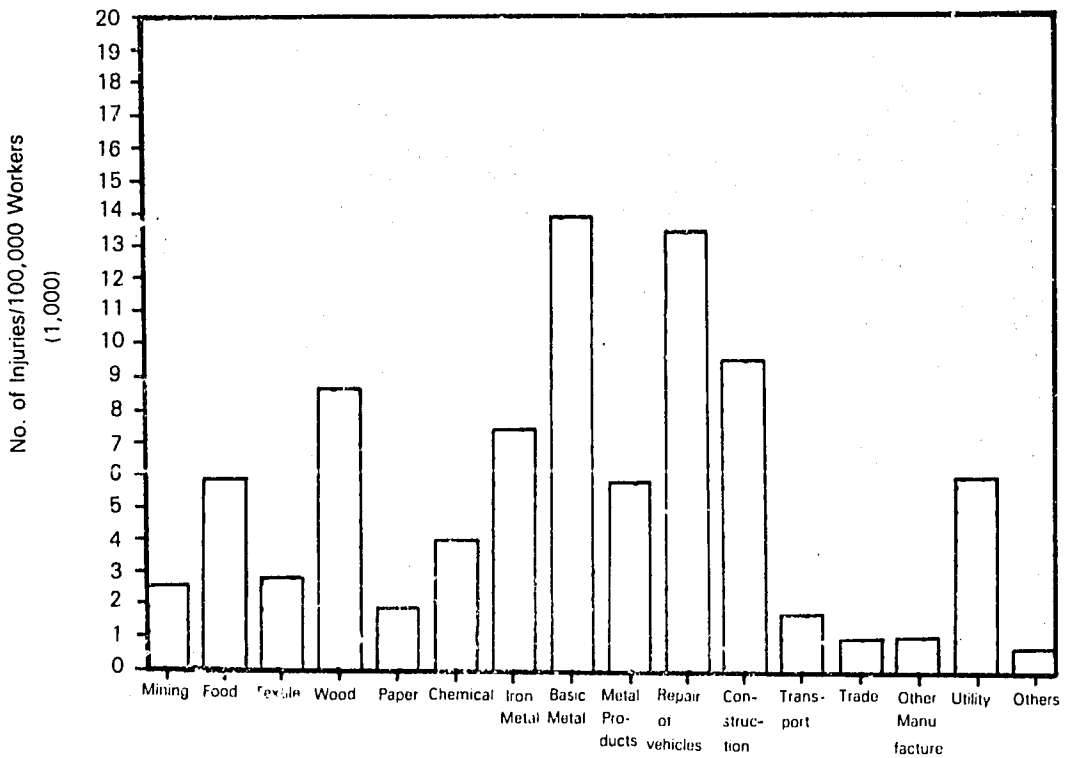
Factory Working Conditions

Occupational health problems caught much public attention in 1964 when 41 workers in a dry-cell manufacturing plant in Thonburi became severely ill from inhalation of manganese dusts. By 1984 all these victims were reported dead (Husbumrer, 1985). Several other cases that received much press coverage have also been reported by Wongpanich (1984). Although some progress has been achieved since then, dangerous working conditions are still prevalent. In order to give an indication of the working conditions of the workers, the results from a 1983 DOH survey are summarized as follows.

Dry-cell battery plants

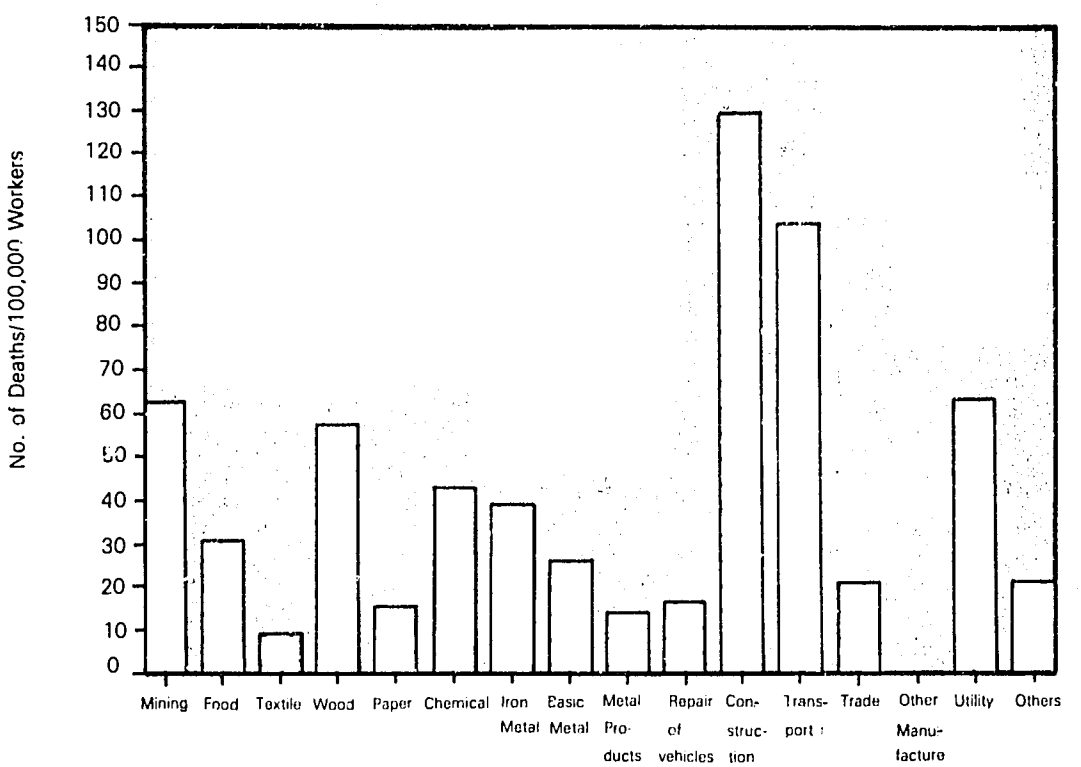
Manganese has three principal uses: in the production of steel, in the manufacture of dry-cell batteries, and in the production of potassium permanganate and other manganese chemicals. Intoxication by manganese is reported in mining and the processing of manganese ores, and in the production of manganese alloys, dry-cell batteries, welding electrodes, varnishes, and ceramic tiles. Manganese poisoning may be present in two forms: nervous and pulmonary. Manganese can be measured in blood (MnB), urine (MnU), stools or hair. But estimation of the extent of exposure by means of manganese in the blood or urine does not prove to be of great value, because the average manganese-in-blood level in exposed workers seems to be of the same order as that in non-exposed workers. Our present knowledge does not include any other reliable biological parameter which might be used as an indicator of exposure. Thus the assessment of workers' exposure to manganese still has to rely on manganese-in-air levels. The mean concentration of manganese in the urine

Figure 12.2 Number of Injuries/100,000 Workers in Various Industries, 1984



Source : DoI, 1985c, p. 47-48

Figure 12.3 Average Fatality Rates of Workers in Various Industries, 1983-1984



Source : DoI, 1985c, p. 47-48

Table 12.2 Causes of Injuries, 1984

Causes of Injuries	Total	Deaths	Perm. Disability	Number of Partial Disability	Loss > 3 Work Days	Loss < 3 Work Days
1. Vehicles	2,000	153	8	45	1,275	518
2. Machines	4,463	8	0	779	2,538	1,138
3. Tools	1,295	1	1	52	575	666
4. Fall from high place	1,330	34	5	13	778	500
5. Fallen upon by heavy object	5,590	22	4	156	2,815	2,593
6. Slip and fall	1,088	2	0	6	576	504
7. Heat	1,408	13	0	5	658	732
8. Electricity	446	30	1	6	215	194
9. Chemicals and toxic substances	1,609	0	0	1	343	1,265
10. Explosion	164	11	0	6	85	62
11. Chips and pieces of objects	6,370	1	0	28	1,445	4,896
12. Physical assault	102	19	0	0	62	21
13. Noise	7	0	0	1	0	6
14. Hit by objects	6,769	12	1	125	3,038	3,593
15. Lifting heavy objects	1,433	1	0	2	618	812
16. Occupational diseases	390	2	0	0	83	305
17. Others	4,718	6	0	80	1,832	2,800
Total	**39,182**	**315**	**20**	**1,305**	**16,936**	**20,606**

Source: DOL, 1984a, p.32

of non-exposed people is usually estimated to be between 1 and 8 µg/l, but values of up to 21 µg/l have been reported. Manganese in hair is normally below 4 µg/kg (ILO, 1983, p. 1280-1281). But, like manganese in blood and in urine, Mn in hair cannot be used in the assessment of individual exposure. It can be used only as an indicator of the mean level of exposure.

For Thais, the average manganese-in-blood level has been reported to be 8 µg/100ml, the manganese in urine 25 µg/l (DOH, 1983). Table 12.3 gives the manganese concentrations found in the air of three dry-cell manufacturing plants. From this table it can be seen that the air quality in these plants does not exceed the present DOL air quality standards for the working environment. However, examination of blood and urine samples in these factories have shown that the manganese levels for many workers are above normal levels (Table 12.4). As mentioned earlier, although MnB and MnU cannot be used as measures of exposure for individuals, they can be used as group indicators of exposure.

Lead-acid battery factories

The primary health hazard of lead is toxicity, which leads to adverse neurophysiological effects. Lead poisoning has always been one of the most important occupational diseases. The main route of entry in industry is through the respiratory tract,

Table 12.3 Manganese Concentrations in the Air of Three Dry-cell Plants in Samut Prakan

No. of Workers	No. of Air Samples	Mn (mg/m^3)	No. of Samples Exceeding Standard	Remark
40	4	0.01 -0.22	0	DOL Standard
64	6	0.024-1.056	0	of Mn in Air
99	7	0.016-0.303	0	is 5 mg/m^3

Source: DOH, 1983, p. 136-147

Table 12.4 Manganese Concentrations in the Blood and Urine of Workers in Three Dry Cell Plants, Samut Prakan

Blood			Urine		
Concentration (µg/100ml)	No. of Samples	No. of Samples > Normal	(µg/l)	No. of Samples	No. of Samples > Normal
1.82-4.55	38	0	9.06-32.51	38	10
0.82-9.21	6	0	9.08-32.51	6	2
4.54-7.31	81	2	4.08-62.44	81	22

Notes: Normal Mn in blood is 8 µg/100ml.
Normal Mn in urine is 25 µg/l.
Source: DOH, 1983, p. 136-147

Table 12.5 Concentration of Lead in Air at Five Lead-Acid Battery Plants in Samut Prakan

No. of Workers	No. of Air Samples	Pb (mg/m^3)	No. of Samples Exceeding Standard
26	6	0.060-0.225	1
33	7	0.013-0.049	0
56	8	0.033-1.437	1
62	4	0.01 -1.23	2
62	4	0.014-0.117	0

Note: DOL Standard for Lead in Air is 0.20 mg/m^3
Source: DOH. 1983, p. 136-147.

and the main portion is taken up by the blood-stream. The degree of absorption depends on the proportion of particles less than 5 um in size. Poor personal hygiene may increase exposure by the oral route. The lead-in-blood level (PbB in ug/100ml) is the best indicator of exposure. In non-occupationally exposed adults, the PbB levels usually do not exceed 25 to 30 µg/100ml. The lead-in-urine level (PbU) normally does not exceed 65 µg/l (ILO, 1983).

For Thai adults, the average normal PbB is 80 µg/100ml, and the average normal PbU is 150 µg/l (DOH, 1983). Tables 12.5 and 12.6 give the concentration of lead in air and the concentration of lead in blood and urine at five lead-acid battery manufacturing plants. It can be seen that some air samples are exceeding the air quality standard DOL, and the blood and urine samples of many workers have higher than normal concentrations of lead.

Pesticide formulation plants

Almost all pesticide plants in this country are pesticide formulation plants. They import technical grade pesticides from abroad and dilute, mix or coat the pesticides onto sand or dust particles, according to a particular formula. These products are then packaged or bottled for sale. Table 12.7 gives the blood cholinesterase in workers at three pesticide formulation plants. Cholinesterase is an enzyme in the blood. Organophosphorus pesticides, when ingested or inhaled, can inhibit the activity of this enzyme, resulting in functional disorders of several physiological systems, in particular the central and autonomous nervous systems. The principal diagnostic sign of poisoning by organophosphorus pesticides is the pronounced decrease—by 50 to 60 percent or more—of the blood cholinesterase activity. Thus from the table it can be seen that some workers have shown signs of organophosphorus poisoning.

Noisy factories

Noise is often described as unwanted sound. Exposure to noise may interfere with speech communication, causing annoyance and distraction. It has been reported that noise may also reduce output and efficiency, causing fatigue, and various health disorders unrelated to the effects on hearing. Noise consists of sounds of various frequencies. To describe noise, it is necessary to state its sound pressure level and its frequency. The sound pressure level defines the noise intensity and is measured in decibels (dB). The frequency is measured in cycles per second (Hz). The ear's perception of loudness when exposed to sounds of the same intensity but different frequency is not the same. Therefore frequency-weighted sound pressure levels are used. The weighting dBA is the closest to the perception of the human ear. Whether a noise is harmful depends mainly on its level, its duration and the frequencies it contains. Prolonged exposure to excessive noise can cause hearing impairment. The definition of hearing impairment is based on the ability to understand spoken sentences in quiet surroundings. This ability is measured at pure frequencies. The accepted criterion for the beginning of impairment is an average hearing level of 25 dB at 500, 1,000, and 2,000 Hz (ILO, 1983, p. 1464-1467). Tables 12.8 and 12.9 give the noise level in five factories and the hearing loss of workers in four factories. These tables show that, at many locations in these factories, the noise levels have exceeded the DOL standards. And a number of workers are clearly suffering from hearing losses.

The results from this DOH survey, as presented in Tables 12.3 to 12.9, provide some examples of working conditions

Table 12.6 Concentration of Lead in Blood and Urine of Workers at Five Lead Acid Battery Plants in Samut Prakan

Blood			Urine		
Concentration (µg/100ml)	No. of Samples	No. of Samples > Normal	Concentration (µg/l)	No. of Samples	No. of Samples > Normal
12.43-142.37	26	1	74.53-487.01	26	25
35.71- 90.50	33	1	39.46-316.59	33	22
31.75-108.52	23	6	59.14-422.42	23	17
15.78- 99.55	49	1	39.46-293.72	49	20
19.73- 55.16	61	0	-	-	-

Note: Normal Pb in blood is 80 µg/100ml; normal Pb in urine is 150 µg/l
Source: DOH, 1983, p. 136-147

Table 12.7 Blood Cholinesterase in Workers in Three Pesticide Formulation Plants in Samut Prakan

No. of Workers	Blood Cholinesterase (Unit)	No. Samples < Normal
71	66-131	5
7	71- 99	1
34	84-133	0

Note: Normal Blood Cholinesterase is more than 74 Units.
Source: DOH, 1983, p. 136-147

Table 12.8 Noise Level in Five Noisy Manufacturing Plants

No. of Workers	Noise Level dBA	No. of Sampling Locations	No. of Location > 90 dBA
224	88-105	22	17
304	81-108	19	14
88	80-101.5	10	7
31	82-101.5	31	23
45	68-107.5	36	35

Note: DOL standard for noise is 90 dB(A) in 8 Hours.
Source: DOH, 1983, p. 136-147

Table 12.9 Hearing Loss of Workers in Four Noisy Manufacturing Plants in Samut Prakan

No. of Workers Examined	No. of Workers with Hearing Loss		
	Both Ears	Left Ear	Right Ear
21	3	4	5
38	4	7	12
24	0	2	3
16	2	9	

Note: Normal hearing at 500, 1,000 and 2,000 Hz not greater than 27.5 dB on average
Source: DOH, 1983, p. 136-147

in factories in this country. They confirm that workers are still exposed to dangerous working conditions. Similar conclusions have also been reported by other researchers (Wongpanich, 1985, Wongpanich, 1984-1985).

Occupational Diseases

Table 12.10 gives the number of occupational diseases from 1981 to 1984. It can be seen that the number of occupational diseases in each year is relatively small when compared to the total number of injuries. But may be a reflection of the difficulty of linking a disease to working conditions rather than indicating a satisfactory condition. Moreover, the record of the WCF reveals that most reported occupational diseases are dermatitis arising from direct contact with chemicals or heat

Table 12.10 Number of Occupational Diseases, 1981-1984

Year	Number
1981	240
1982	508
1983	214
1984	390

which can be diagnosed readily, whereas diseases due to chronic exposure to chemicals are rarely reported. Presently, there is no systematic recording of the working history of the employees, therefore establishing a disease's cause is very difficult especially if the exposure took place long ago.

Agricultural Workers

The control of crop pests and disease vectors has relied increasingly on the use of pesticides. In 1984, Thailand imported 18,363 tons of pesticides, costing 1,495 million baht (DOA, 1985). The amount of active ingredients in these pesticides is about 12,702 tons. In addition, 6,000 and 66 tons were produced domestically by ICI Asiatic and Agrochemical, respectively (private communication). Assuming that 50 percent of these quantities represents active ingredients, the domestically produced active ingredients total 3,033 tons. Knowing that the amount of land area under cultivation in 1984 was about 18.5 million hectares (DOA, 1985b), the average amount of active ingredient per hectare used in Thailand can be roughly computed to be 850 grams per hectare. It would be better to use actual consumption figures, but these are not available because they are rarely recorded. Thus, the average is only a rough national average to indicate the general level of usage. Considerable differences certainly exist among the various regions of the country. Use per hectare on various crops also differs considerably. Table 12.11 shows the estimated share of pesticides used in various crops. Table 12.12 shows the estimated extent of pesticide usage in major crops in Thailand. From these two tables the quantity of pesticides used, the cultivated land area for each kind of crop and the amount of pesticide use per hectare can be computed as shown in Table 12.13.

The use of pesticides, even under good management practices, can cause undesirable effects. In Thailand, pesticides are openly on sale with no restrictions on who buys them or how they should be used. The knowledge needed for proper use by farmers is often lacking. In 1984, DOH reported the number of pesticide poisonings and the number of deaths. Using these figures and the number of agricultural workers in the country, the rate of pesticide poisoning and deaths per 100,000 agricultural workers can be computed as shown in Table 12.14. The average pesticide poisoning rate from 1974 to 1983 was 9.2 cases per 100,000 agricultural workers. The average death rate was 0.17 deaths per 100,000 agricultural workers.

However, Wongpanich (1984-1985) reported very much higher figures from a survey of 10 villages in Rayong Province. She found 8,268 pesticide poisoning cases per 100,000

Table 12.11 Estimated Shares of Pesticide Used in Various Crops

Crop	(%)
Rice	27
Vegetables	23
Cotton	11
Citrus	7
Other fruit trees	6
Tobacco	5
Watermelon	4
Bean	4
Rubber	0.1
Others	12.9

Source: Wongpanich, 1984-1985, p. 10

agricultural workers, but only 169 in 100,000 would go to a hospital, and the number of fatalities was between one and two deaths per 100,000 farm worker. A tintometric test for cholinesterase activity was also conducted for a random sample of 381 individuals. It was found that 37 percent of that group had been exposed to pesticides, and 0.8 percent were in the first stage of danger. There is considerable difference between these two sets of figures. Apparently the number of poisoning incidents can vary widely between different localities.

Construction Workers

As mentioned earlier, construction is one of the most dangerous activities. But apart from the injury statistics of the WCF, very little information regarding the general working conditions at construction sites has been reported. Petchpaiboon (1985) gave the following as major factors causing injuries: (1) fall into holes or other openings in buildings; (2) fall from high places; (3) struck by falling objects; (4) incorrect use of tools or machines; (5) fires; (6) electric shocks; (7) employee brawls; (8) pollution such as noise, and odours from heavy machinery; and (9) incorrect design of falseworks, scaffoldings, and so on.

Project owners are often reluctant to bear the costs of safety provisions. For a typical large construction project, the provision of hard hats, safety shoes, gloves, insurance, and contributions to WCF costs about 4 to 5 hundred thousand baht (Anon., 1985). These items are almost always left out in construction contracts.

Miners

Poopaiboon (1985, p.21) reported that miner injury statistics also come from the WCF. The number of injuries and the rate of injuries are shown in Table 12.15. It can be seen that from 1977 to 1984, the number of mines in operation and the number of miners fluctuated somewhat depending on the price of minerals. But the number of injuries and the rate of injuries have been on the rise. This, he reasoned, could be due to the improvement in the collection of injury data. He reported the following as the main causes of injuries: (1) about 70 to 80 percent of mines in this country are small operations,

Table 12.12 Estimated Extent of Pesticide Usage in Major Crops in Thailand

Major crops	Percent of cultivated area under pesticide usage
Cereal crops	
Rice	30
Corn (sweet corn)	90
(field corn)	75
Sorghum	5
Oilseed and legume crops	
Soybean	20
Mung bean	30
Peanut	15
Cowpea	15
Castor	5
Fiber Crops	
Cotton	90
Sunn hemp	5
Kenaf	2
Kapok	none
Root crops	
Sweet potatoes	20
Cassava	none
Fruit crops	
Mango	50
Banana	negligible
Rose apple	60
Durian	80
Rambutan	90
Longan	50
Guava	60
Jujube	95
Citrus	80
Vegetable crops	
Chinese kale	95
Chinese mustard	95
Cabbage	95
Squash	80
Tomato	80
Shallot	95
Morning glory	20
Miscellaneous crops	
Sugarcane	20
Tobacco	90
Rubber	45

Source: Banpot Napompeth, 1981.

Table 12.13 Estimate of Pesticide Usage in Some Crops, 1985

Crop	Cultivated Area (rai)	Estimated Area that uses Pesticide (%)	Active Ingredient Usage (gm/ha/year)
Rice	62,329,000	30	1,420
Vegetable	343,023	90	73,112
Cotton	450,847	90	26,711
Citrus & fruit tress	11,906,487	70	1,571
Tobacco	194,900	90	28,018
Beans	5,353,000	20	3,676
Rubber	10,254,000	45	22

Sources: 1. DOA, 1985b
2. See Table 12.14

Table 12.14 Number of Pesticide Poisonings, 1974—1983

Year	Number[1]		No. of Agricultural Workers[2]	Number per 100,000 agri. workers	
	Poisoning	Deaths	(million)	Poisoning	Deaths
1974	725	34	11.23	6.5	0.30
1975	518	18	13.27	3.9	0.14
1976	860	53	13.95	6.2	0.38
1977	1,013	32	14.92	6.8	0.21
1978	876	25	16.02	5.5	0.16
1979	1,835	18	15.02	12.2	0.12
1980	1,851	15	15.94	11.6	0.09
1981	2,159	17	17.53	12.3	0.10
1982	2,187	10	16.98	12.9	0.06
1983	2,353	17	16.68	14.1	0.10
		Average		**9.2**	**0.17**

Sources: 1. DOH, 1984, and DOH, 1985
2. DOL, 1984b.

Table 12.15 Injuries in Mines, 1977—1984

Year	No. of Mines	No. of Miners	No. of Injuries	Injuries per 100,000	Injuries per 10^6 hr.	No. of Deaths	Deaths per 100,000
1977	778	58,613	77	131	0.65	7	12
1978	857	84,713	57	67	0.33	0	0
1979	1,003	93,222	126	135	0.67	9	10
1980	1,044	90,813	239	263	1.31	14	15
1981	960	70,218	249	55	1.76	5	7
1982	1,149	68,240	273	400	1.98	5	7
1983	1,154	65,124	294	451	2.24	10	15
1984	1,088	54,458	278	510	2.53	15	28

Source: Poonpaiboon, 1985, p. 23

with small numbers of workers, making the improvement of working conditions difficult; (2) most mines are in remote and isolated areas, which makes communication and inspection difficult; and (3) mining concessions generally last only 3 to 5 years. The short concession period makes the mining companies reluctant to invest in good facilities.

Major Hazard Installations

As a result of strong governmental promotion, Thailand has undergone very rapid industrialization in the past two decades. The number of registered factories increased from 1,655 in 1969 to 91,214 in 1983. The number of factories producing chemicals has been estimated at about 2,023. As a consequence of these developments, many hazardous chemicals are finding their way into the country in increasing amounts. The dire consequences of the Bhopal and Mexico disasters have elevated the issue of major hazards to national status. This is especially relevant to Bangkok and its neighboring provinces, where 20 percent of the country's factories are situated.

In 1984, there were about 2,023 factories falling within Standard Industry Code (SIC) 35, including manufacturers of chemicals, petroleum, coal, rubber and plastic products. Of the total, 1,483 are located in Bangkok and the five neighboring provinces. Table 12.16 shows the number of chemical factories in Bangkok and the five surrounding provinces and the number of employees in these factories. The concentration of factories in and around Bangkok is natural, since Bangkok is the center for industry and commerce. However, this is a point of concern because Bangkok is also densely populated, with an average of about 3,000 persons per square kilometer. The impact of an accident from the manufacture or transportation of chemicals is bound to be very severe.

Table 12.16 Distribution of Factories and Number of Workers According to the Size of Factory in Bangkok and the Five Surrounding Provinces

SIC No.	Type of Factory	Total		1-9 Emp		20-49 Emp		50-99 Emp		>100 Emp	
		Ent[a]	Emp[b]	Ent	Emp	Ent	Emp	Ent	Emp	Ent	Emp
351	Industrial chemicals	119	5,718	60	411	33	974	14	974	12	3,359
352	Other chemical products	416	22,647	208	1,736	103	3,307	50	3,376	55	14,228
353	Petroleum refineries	6	831	1	7	1	52	2	121	2	651
354	Miscellaneous petroleum & coal products	4	173	1	9	1	20	2	144	-	-
355	Rubber products	331	16,407	197	1,561	66	1,974	33	2,230	35	10,642
356	Plastic products	607	16,378	444	3,142	87	2,504	41	2,951	35	7,781
35	**TOTAL Manufacturer of chemicals & products**	**1,483**	**62,154**	**911**	**6,866**	**291**	**8,831**	**142**	**9,796**	**139**	**36,661**

Notes a. Ent = No. of factories
b. Emp = No. of employees
Source: TDRI, 1986, p. 47

In 1986, the Thailand Development Research Institute (TDRI) conducted a study of 27 chemical factories in Thailand. It was found that 20 of these factories used chemicals classified as major hazards if the World Bank's *List of Hazardous Substances Requiring a Major Hazard Assessment* is followed. The proportion is alarmingly high and must be a cause for concern.

It was also found in this survey that safety practices vary widely among the factories surveyed. Only a few well established large factories were found to have reasonably good safety measures, while most still need improvement.

Some obvious examples of potentially unsafe conditions or practices were found during the survey, including the following: no safety regulations available in the plant; unsafe methods of loading or unloading of chemicals; improper storage of chemicals or the storage of chemical drums in the open exposing them to rain; improperly designed ventilation systems; absence of labels on chemical drums and packages; naked electrical switches; insufficient attention to the maintenance of fire fighting facilities; no color codes on pipes; no containment structures around large liquid containers to contain accidental spills; and no alarm systems to warn workers or the public in case of emergencies. Accident recording and reporting varies considerably among the factories. Most of the smaller factories have no recording system at all.

Although Thailand has been fortunate in that Bhopal-scale accidents have never occurred, several accidents involving hazardous chemicals have happened in the past. These are listed in Table 12.17.

The Workmen's Compensation Fund

The WCF was established in 1972. The purpose of the Fund is to provide compensation to employees who are injured at work or who become ill with occupational diseases. The Fund is now (1986) in force in 56 provinces. All undertakings having 20 or more employees, except undertakings in agriculture, fishery, governmental enterprises and nonprofit organizations, are required to join the WCF. The contribution rate to the WCF by employers varies from 0.2 to 4.5 percent of the employee's income, depending on the type of undertaking. Undertakings with good performance records are entitled to reductions in contribution rates.

Currently there are four types of compensation: (1) medical expenses in which employees can be reimbursed the full amount of medical expenses up to the maximum of 30,000 baht; (2) funeral expenses in which the legal heir can be reimbursed up to three times the monthly salary, but it must not be less than 5,000 or more than 10,000 baht; (3) injury compensation in which employees receive monthly compensation at rates set by DOL, according to the severity of the injury; and (4) rehabilitation expenses where monthly rehabilitation expenses range from 1,000 to 6,000 baht.

In 1985, the DOL classified a number of substances as contributions to occupational diseases, as those arising from the following: (1) arsenic or its compounds; (2) lead or its compounds; (3) manganese or its compounds; (4) phosphorus or its compounds; (5) halogen or derivatives of the hydrobenzene groups; (6) benzene or similar substances; (7)

Table 12.17 List of Recorded Hazards from Chemicals in Thailand

Date	Description of Hazard
Nov., 1980	Explosion at an arms depot in Bang Sue, Bangkok killed 35 persons. 600 families near the plant had to be relocated due to home and property damage.
6 April, 1983	"Siam Mira", a 3,000 ton oil tanker exploded 10 miles off shore from Srichang Island, 2 persons were killed and 19 persons missing.
16 April, 1983	Explosion from an LPG-leak in restaurant in Soi Nana, Bangkok killed 5 persons.
16 August, 1983	A 10-ton oxygen tank exploded in the Sahapan Steel plant in Pra Pradaeng, Samut Prakan. The explosion killed 4 persons passing by in a small bus.
30 Jan., 1984	An LPG tank for cooking exploded at a house on Bangkok Street, Phuket. Nine persons were killed, five injured, and 50 houses destroyed.
20 Feb., 1984	Ammonia gas leaked from a refrigerator under repair in a seafood processing plant in Hatyai, 35 persons were injured, one killed while fleeing the scene and fell from a building.
23 June, 1986	Tantalum riot in Phuket, a tantalum production plant (not yet in operation) and a hotel were set ablaze by a mob of local residents, out of unfound fear of accidents arising from the use of hydrofluoric acid in the production process.

derivatives of nitro and amino benzene groups; (8) mercury or its compounds; (9) chromium or its compounds; (10) carbondisulfide; (11) anthrax; (12) asbestosis; (13) nenmochoniosis; (14) biscinosis; (15) berylium or its compounds; (16) radiation; (17) wood alcohol; (18) carbontetrachloride or its compounds; (19) other chemicals or their compounds; (20) dermatitis from contact with chemical substances; (21) heat, cold, noise, light, vibration or air pressure at work; or (22) other workplace conditions.

12.2 HISTORICAL DEVELOPMENT AND FUTURE TRENDS

Historical Development

Industrial accidents first began to occur in large numbers in Europe during the 18th century as the industrial revolution made possible the use of large-scale mechanized production. In Thailand, it is not clear when the problems of accident prevention and occupational safety and health really began. But the problem was probably not a new one. During the reign of King Rama IV (1851-1868), when Khlong Dumnernsaduak was being built, His Majesty the King, when seeing workers become ill during work, ordered a Salaya (Medical Center) built to treat the workers who were ill or injured. A Salasop (Corpse Center) was also constructed by order of His Majesty to hold funeral services for those who were less fortunate. To this day the place where the Medical Center was is still named Salaya District.

In modern times, occupational safety and health management can be said to have begun in 1928, when an Act to control businesses that are a nuisance or dangerous to the public was enacted by King Rama VII. The first Public Health Act of the country was enacted by the Parliament in 1934, two years after the changeover from the absolute monarchy system to the parliamentary system as we know it today. This Act was soon repealed and replaced by the Public Health Act of 1941, which is still in force today. The Public Health Act is concerned with the control and management of primary public health, such as garbage disposal, and other sanitary matters.

The first piece of labour legislation was introduced in 1956. This legislation contained provisions for the compensation of workers who became ill or were injured during work. The responsibility was primarily placed upon the employer. In 1964, when 41 workers in a dry-cell manufacturing plant were overcome by manganese intoxication, the occupational health problem had received much public attention. Consequently in 1972, the Department of Health (DOH), which was the main government agency responsible for the general health of the public at that time, established the Division of Occupational Health. Subsequent efforts to upgrade this Division into an Institution of Occupational Health failed. In the same year the Division of Occupational Health was established, the Revolutionary Council Decree No. 103 was announced. This decree is a comprehensive labour code, launching labour management in Thailand into a new era. The Decree covers many aspects of labour management, including labour welfare, wages, child labor and occupational health. The WCF was also established by this Decree.

Many ministerial regulations regarding occupational health have since been announced under Decree 103. In 1981, the National Institute for the improvement of working Conditions and Environment (NICE) was established, with assistance from UNDP/ILO. The objective of NICE is to improve the protection of workers from occupational accidents and diseases through research, training, proposing of standards, dissemination of information and other related activities.

Box 12.1 Where are the Major Hazard Plants?

In the wake of the disasters in Bhopal and Mexico City, there has been growing interest in finding out how many major hazard plants there are in Thailand, where they are, what they are doing, and what potential risks are being imposed on their workers, the communities in which they are located, and the natural environment.

The total number of factories registered with the Ministry of Industry's Industrial Control Division as generators of toxic waste grew from 78 in 1970, through 524 in 1980 to 615 in 1985. Currently, the records on major hazards and toxic waste generation are patchy. Some toxic waste producing plants do not register with the Department of Industrial Works (DIW), while financial and personnel constraints slow the process by which the responsible agencies visit major hazard plants, advise their management on how to tackle particular problems, and enforce the relevant standards.

But where are these factories located? The answer seems to be that the overwhelming majority are to be found in and around Bangkok, including nearby Samut Prakan and Samut Sakhon provinces. Five out of seven of Thailand's lead smelters are found in the area, together with over 80 percent of the country's fluorescent lamp manufacturers, and over 90 percent of its chemical, dry-cell battery, paint, pharmaceutical and textile manufacturers. So, while problems undoubtedly exist elsewhere in the country, the immediate need is for a thorough review of the situation in and around the nation's capital.

This is confirmed by the study conducted by Thailand Development Research Institute in early 1986. In cooperation with the Department of Labor, an intensive survey of 27 chemical plants producing pesticides basic chemicals explosives, LPG and paints was undertaken. Using the World Bank criteria, it was found that 20 of the 27 plants visited possess hazardous substances in sufficient quantity to be classified as major hazard installations. In most of the plants, emergency and contingency plans for hazard control are totally absent.

Aside from potential hazards from chemical processes, the study has pointed out similar dangers associates with the storage of large quantities of hazardous chemicals. In addition, the transportation of hazardous substances has complicated the issue. Without proper protective measures, the potential hazards have become mobile depending on the transportation routes. This is of particular concern in crowded cities such as Bangkok.

With industrial hazards now becoming a recurrent crises in all parts of the world — Bhopal, Mexico City, Chernobyl and lately the deaths in the Rhine from the Sandoz spill — when will the next industrial accident strike? Can it happen in Thailand next? Past studies have uncomfortably confirmed that Thailand is not immune from similar manmade disasters.

From another direction, the occupational health of factory workers is also the concern of the Ministry of Industry. King Rama IV was the first Thai Monarch openly receptive to western influences and ideas. This period saw the introduction of steam engines into rice mills and lumber mills, bringing Thai industry into the age of modern mechanization. Large factories began to appear after World War I, during the reign of King Rama VI (1910-1925). During this period factories producing, cement, cigarettes, soft drinks, soap and other goods were set up. Originally the Division of industry was established in the Department of Commerce in 1930 for the control of factories. Later, in 1941, this Division was upgraded into a Department. In 1942, during World War II, the Ministry of Industry was established to deal with wartime conditions. The first Factory Act was promulgated in 1939. This Act contained provisions for the welfare and safety of workers. Later revisions of this Act in 1969, 1975, and 1979 retain these provisions.

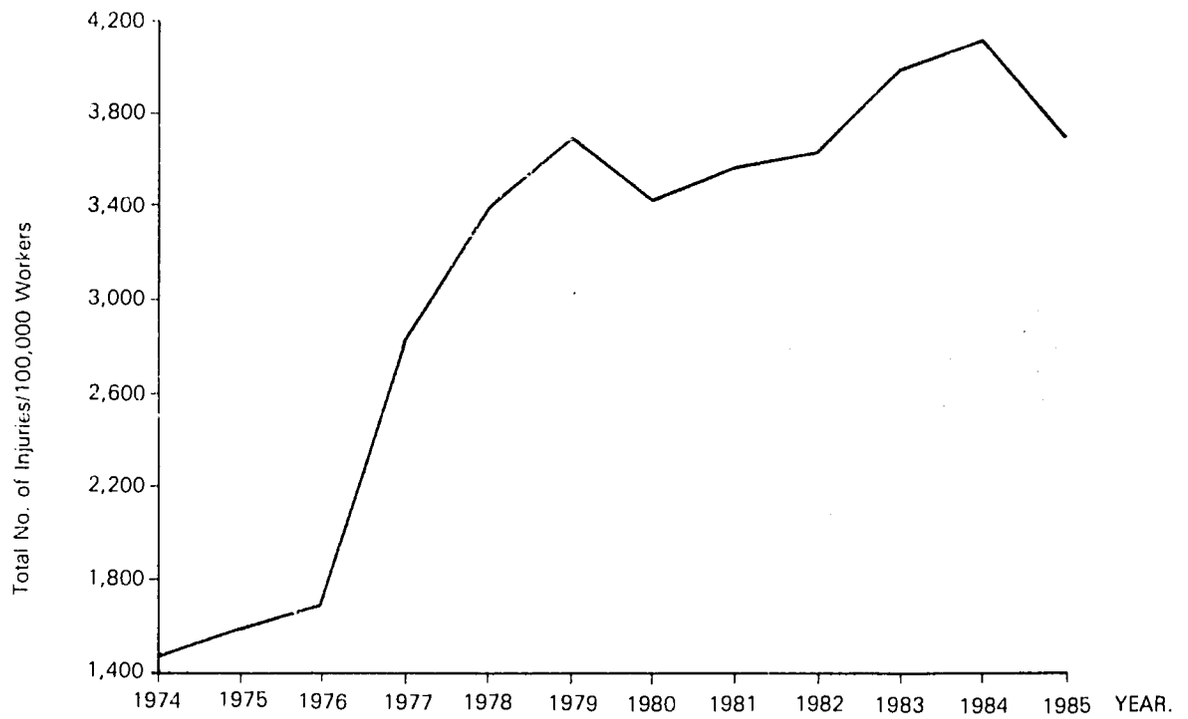
In 1983, the National Safety Council of Thailand (NSCT) was established, mainly due to the concern about the increasing number of traffic accidents. NSCT is a policy and advisory agency attached to the Prime Minister's Office. It is responsible for proposing national policies to the Council of Ministers and for coordinating the many agencies dealing with accidents. The present brief of NSCT includes all types of accidents, however.

Accident prevention at major hazard installations is a relatively new area of activity. Although major accidents, such as the explosion of the Bangsue Arms Depot in November 1980, have occurred in Thailand, the Bhopal tragedy in India has proved an unparalleled spur. In 1986, TDRI, in cooperation with NICE/ILO, conducted an investigation and prepared some initial groundwork for establishing a major hazard control system. The several recent international industrial accidents such as the explosion of an LPG facility in Mexico City, the leakage of methyl isocyanate (MIC) from a pesticide manufacturing plant in Bhopal, and the accident at the Chernobyl nuclear power plant in USSR, have all made the Thai public increasingly concerned about of major hazard installations.

Future Trends

Although the occupational injury rate has risen in the last ten years, there is as yet no explanation being put forward to

Figure 12.4 Total Number of Injuries/100,000 Workers, 1974-1985



Source : DoI, 1984 b, p.83

explain this trend. In part this is due to the lack of adequate studies or research in these problem areas. The only reliable source of injury statistics available is the WCF. But the statistics collected by the WCF are inadequate, firstly because the data are collected primarily to satisfy the legal requirements for granting of compensation claims, and secondly because the Fund only covers about 40 percent of industrial workers. Therefore it is difficult to predict whether the rising trend will continue in the future, because we do not know the underlying mechanism for the trend.

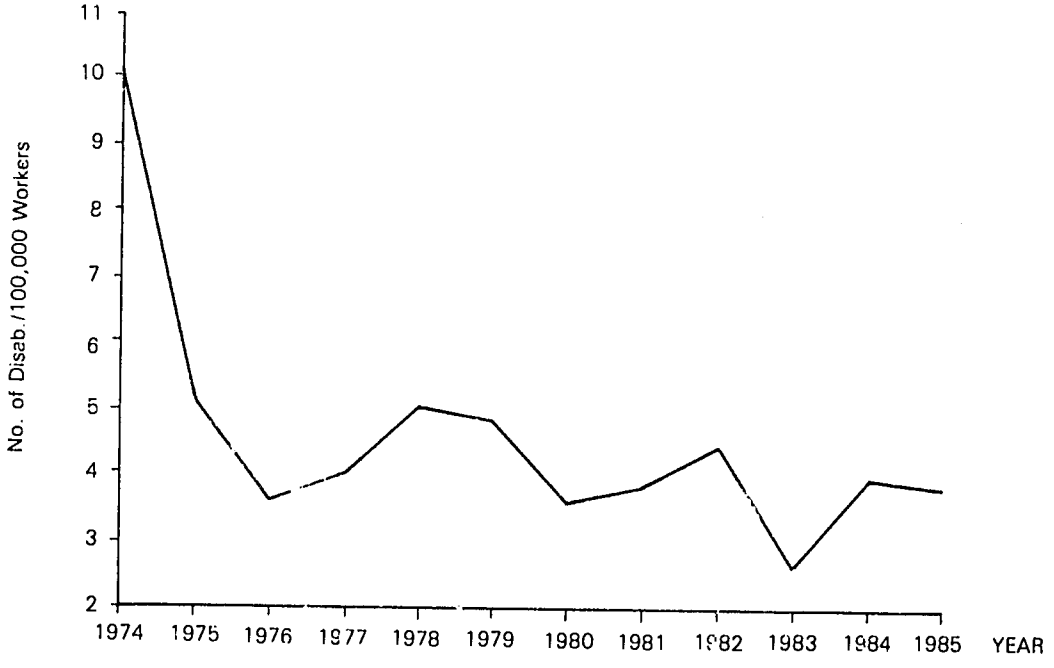
Consider the rates of various types of injuries as classified by the severity of injury. If we separate the various types of injuries in Figure 12.1 and replot them as shown in Figures 12.4 through 12.8, it can be seen that severe injury rates (those resulting in death, permanent disability or partial disability) have all shown decreasing trends. Only injury rate from the temporary disability category has been rising.

Therefore, the increasing trend in the past could have been due in part to the expansion of the WCF itself. As more employees are covered by the Fund and as more employees become aware of the Fund, more workers begin to file for claims. Again from Figure 12.4, we can see that the rate of increase was most rapid during the initial five years after the establishment of the Fund. The rate then levels off in the last five years.

Although the fatality rate has shown a decreasing trend in the past, this does not necessarily indicate that the situation is satisfactory. If we compare the fatality rate of Thailand to those in the Nordic countries (Finland, Norway, Denmark, or Sweden), the fatality rate here is still more than an order of magnitude higher (DOL, no date, page 8).

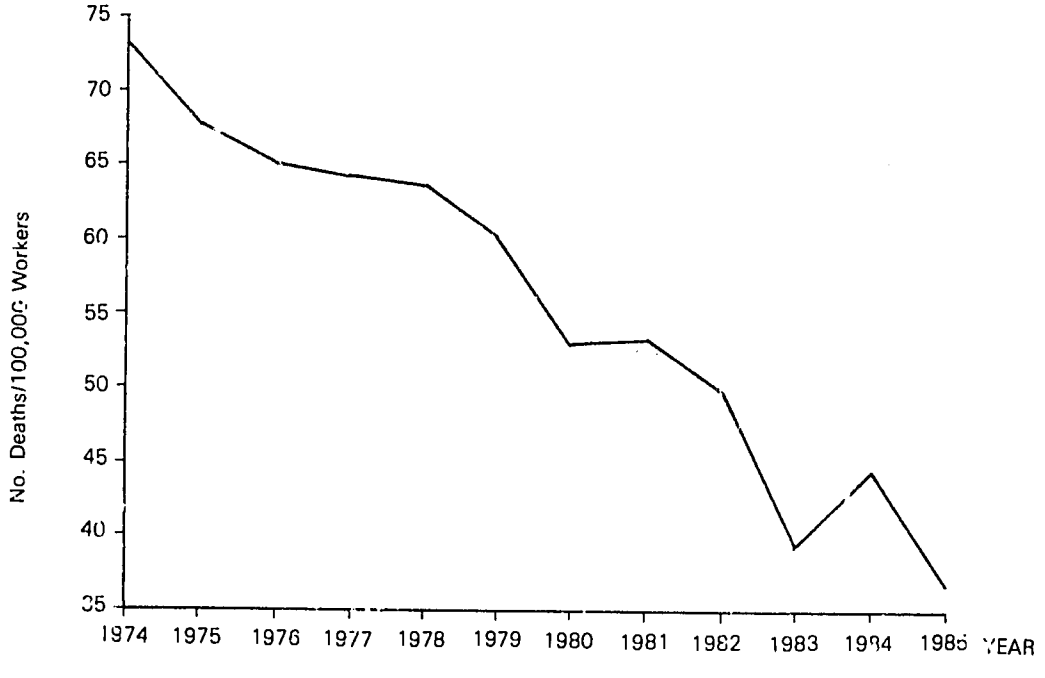
As far as the trend in pesticide poisonings is concerned, we have seen that one of the most effective ways of detecting potential problems is to measure the cholinesterase levels in human blood. The Department of Agriculture internally specifies a minimum level of 54 Ch-E per unit, whereas the Department of Health's minimum value is 71 Ch-E per unit. From the data presented in Figures 12.9 and 12.10, it would appear that while the proportion of pesticide factory workers with unacceptably low cholinesterase levels has declined significantly, from a peak figure of 47 percent of the 1982 sample to just one percent in 1985, the number of farmers with depressed cholinesterase levels has shown a tendency to increase slowly in recent years.

Figure 12.5 Number of Permanent Disablements/100,000 Workers, 1974-1985



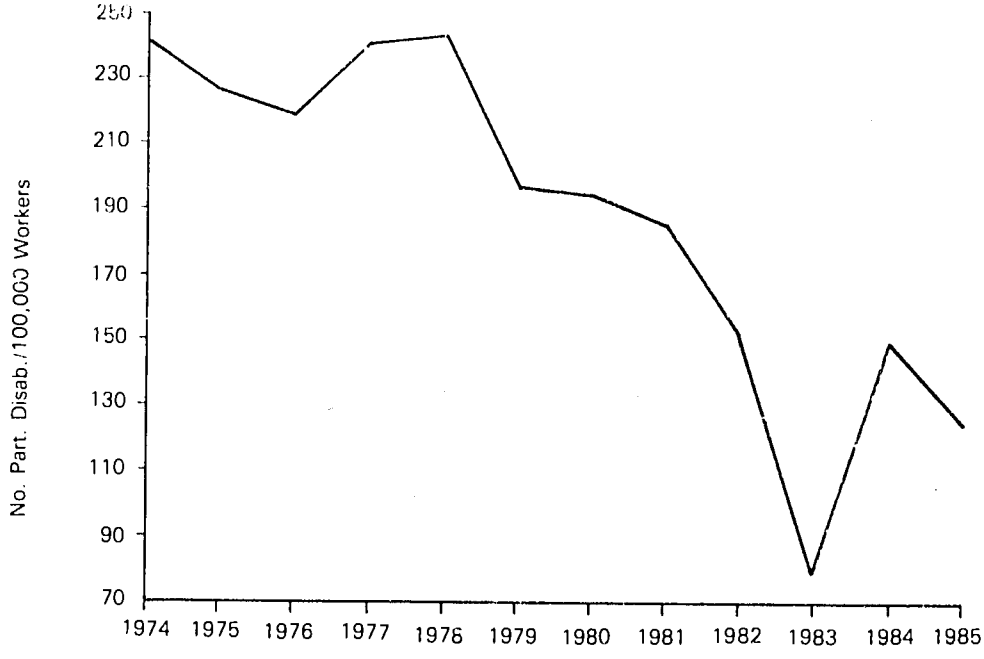
Source : Same as Figure 12.4

Figure 12.6 Number of Deaths/100,000 Workers, 1974-1985



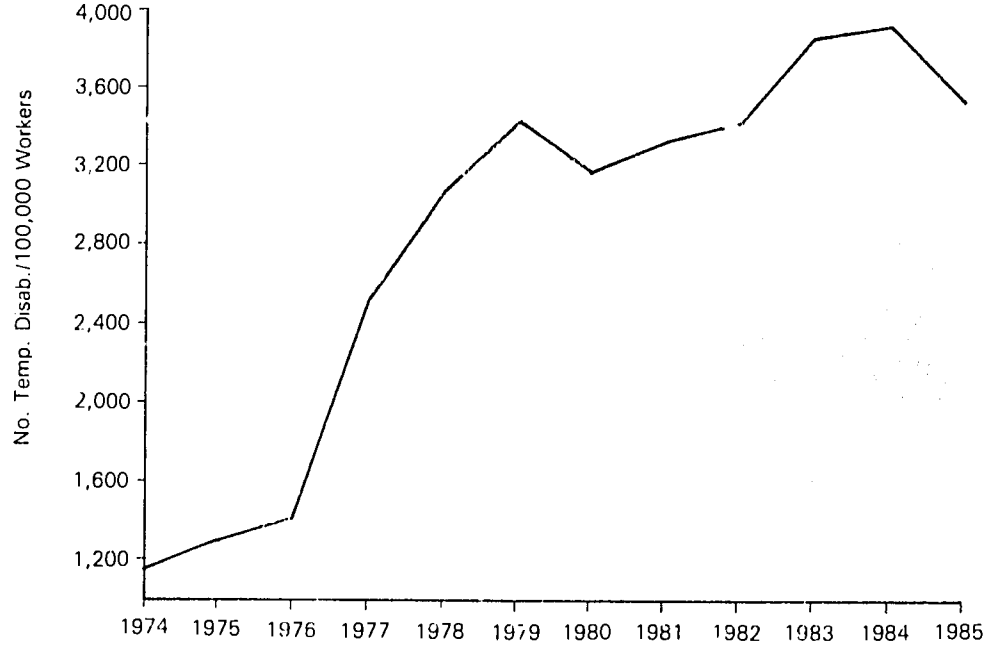
Source : Same as Figure 12.4

Figure 12.7 Number of Partial Disablements/100,000 Workers, 1974-1985



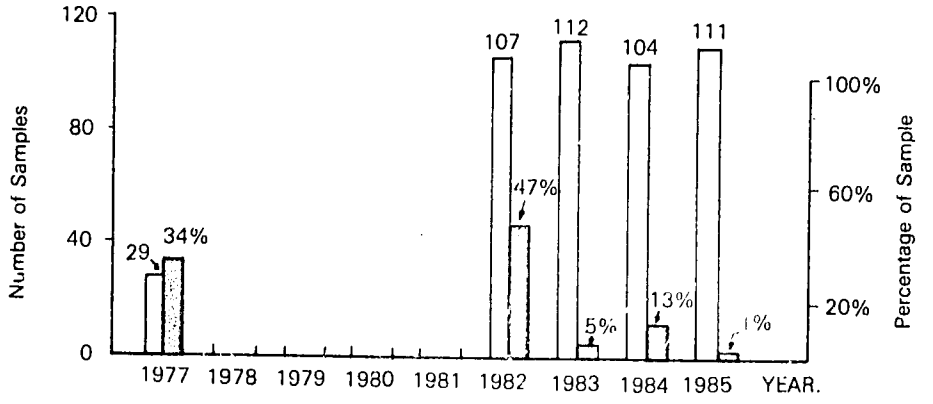
Source : Same as Figure 12.4

Figure 12.8 Number of Temporary Disablements/100,000 Workers, 1974-1985



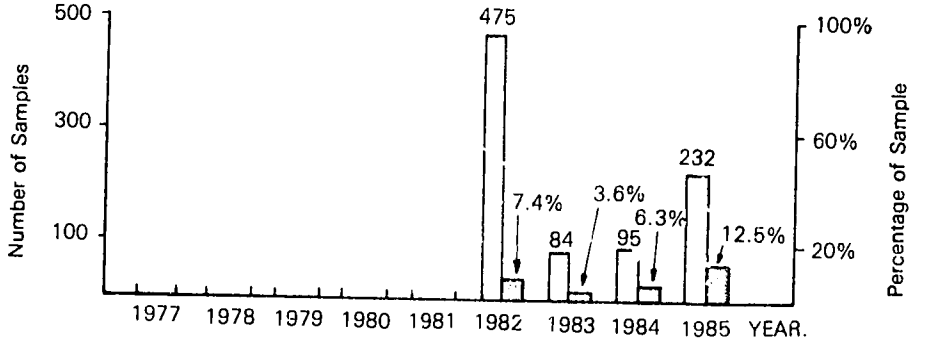
Source : Same as Figure 12.4

Figure 12.9 Cholinesterase Level in Blood of Workers in Pesticide Factories



Sources : Division of Occupational Health (1977-79B), 1982, 1983, 1984 (D), 1985 (C).

Figure 12.10 Cholinesterase Level in Farmers' Blood



Sources : DOA 1982, 1983, 1984, 1985

Legends : number of samples.

percentage of samples with low cholinesterase level.

As far as heavy metals are concerned, the results are somewhat contradictory in places. For example, manganese concentrations in factories have shown a slight rising trend from zero in the 1982 samples to 8 percent in 1985 (Figure 12.11). Yet, while manganese levels in the blood of workers in thesefactories have fluctuated between peaks of 11 percent in 1981 and 1984 and a low of zero in 1985 (Figure 12.12), manganese concentrations in the urine samples leapt from 31 percent in 1983 to 95 percent in 1985 (Figure 12.13). It is thought that the manganese may be transferred in drinking water. The pattern for manganese miners was somewhat similar (Figures 12.14-12.16)

With lead, a higher proportion of samples exceeded the relevant safety limit (0.20 mg/m^{3}of working area air volume for a continuous eight hour shift) than was the case for manganese, with a peak proportion of 22 percent of over-the-limit samples in 1984 falling to 19 percent in 1985 (Figures 12.17-12.19). Yet the percentage of blood and urine lead levels exceeding the relevant safety standard was lower than for either the manganese factory workers or manganese miners.

Given the fact that mammals tend to excrete heavy metals through the urine, the high metal-in-urine levels for these three cases is not surprising. What should cause concern, however, is the considerable proportion of workers apparently carrying unacceptably high heavy metal burdens in their bodies. An improved toxic substances management program is clearly needed in all these cases.

Figure 12.11 Manganese Concentration in Working Environment of Factories in Thailand

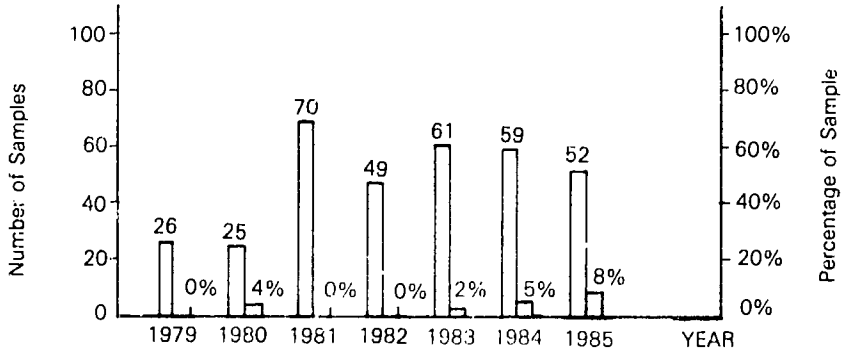


Figure 12.12 Manganese Concentration in Urine of Workers in Thailand

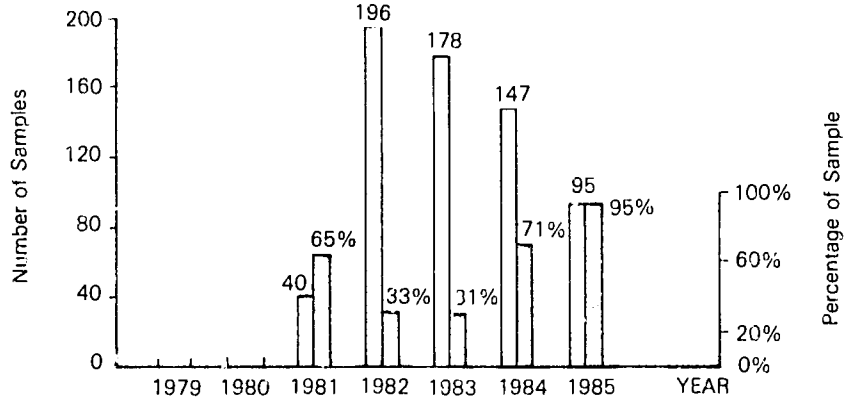
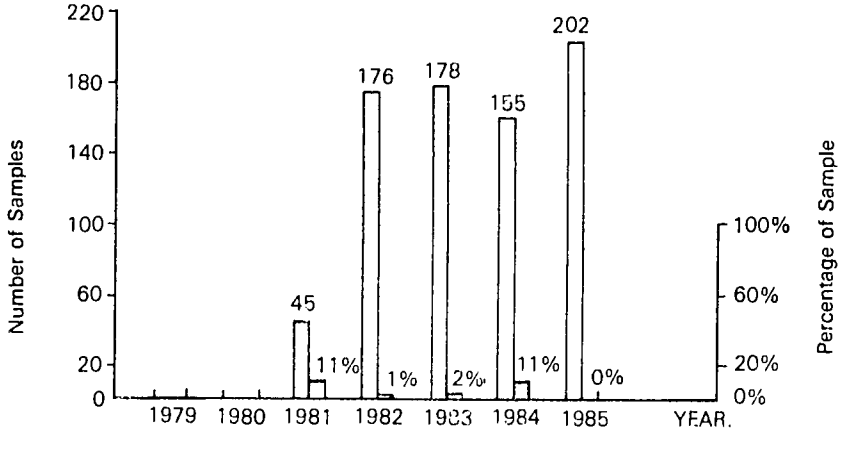


Figure 12.13 Manganese Concentration in Blood of Workers in Thailand



Sources : Division of Occupational Health 1982, 1983, 1984, (A), 1984 (D), 1985 (B), 1985 (D).

Legends : number of samples

percentage of samples with manganese exceeding recommended level

Figure 12.14 Manganese Concentration in Working Environment of Mines in Thailand

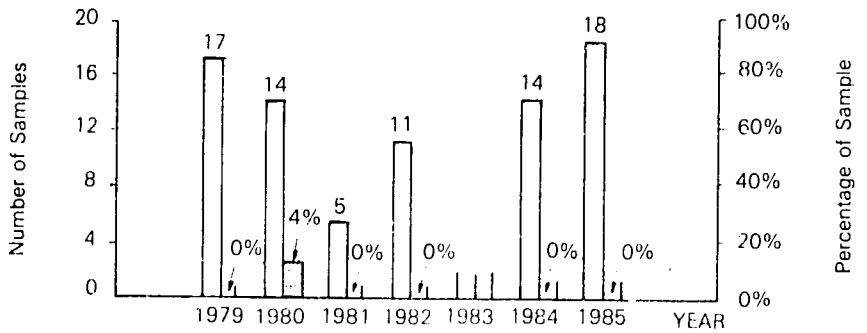


Figure 12.15 Manganese Concentration in Urine of Miners in Thailand

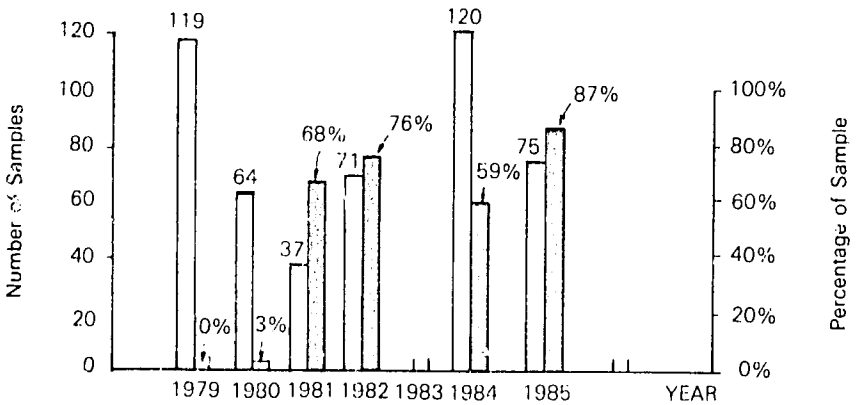
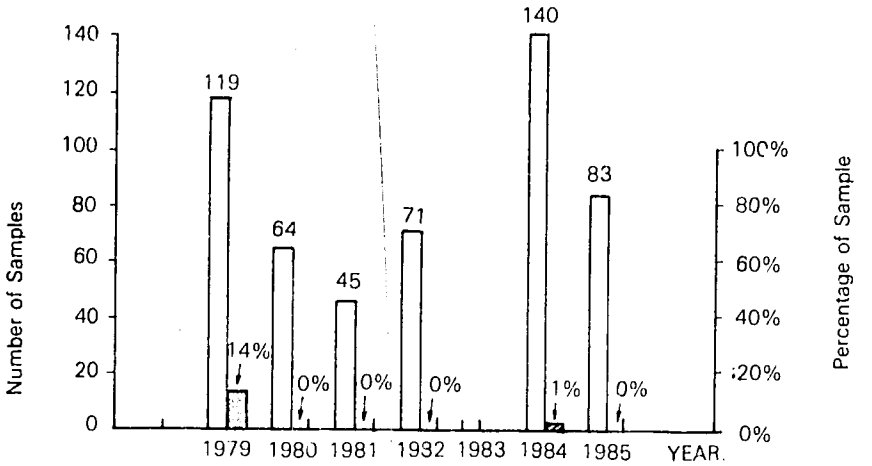


Figure 12.16 Manganese Concentration in Blood of Miners in Thailand

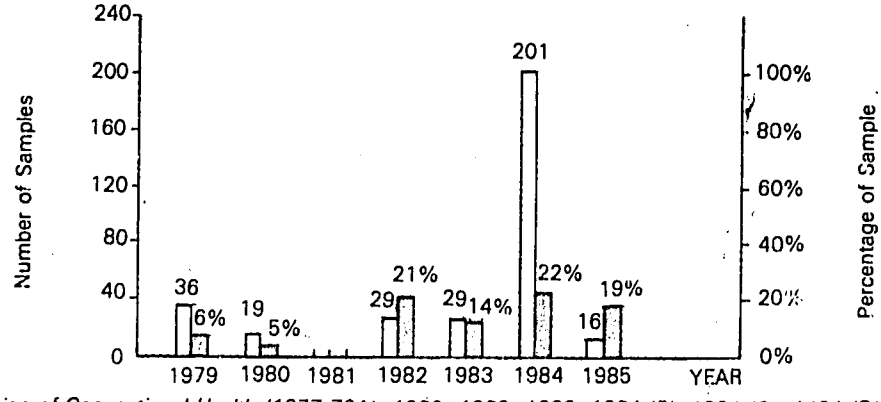


Sources : Division of Occupational Health 1984 (A), 1985 (D)

Legends : number of samples.

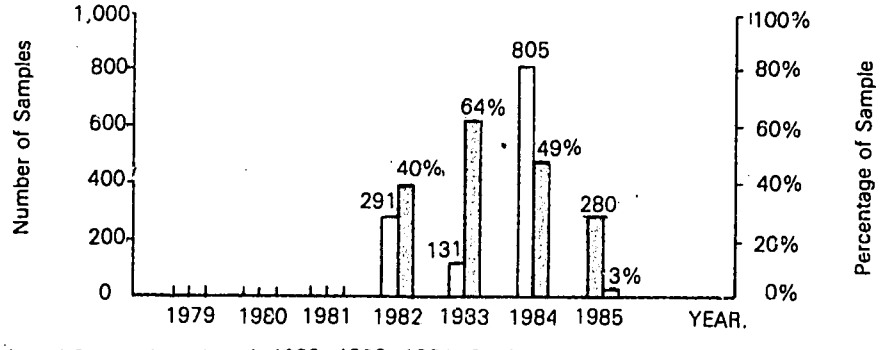
percentage to samples with manganese exceeding recommended level.

Figure 12.17 Lead Concentration in Working Environment of Factories and Mines in Thailand



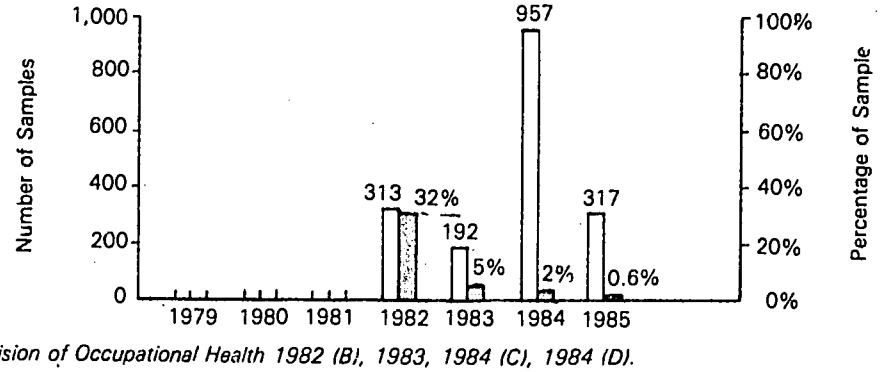
Source : Division of Occupational Health (1977-79A), 1980, 1982, 1983, 1984 (B), 1984 (C), 1984 (D).

Figure 12.18 Lead Concentration in Urine of Workers and Miners in Thailand



Sources : Division of Occupational Health 1982, 1983, 1984 (C), 1984 (D)

Figure 12.19 Lead Concentration in Blood of Workers and Miners in Thailand



Sources : Division of Occupational Health 1982 (B), 1983, 1984 (C), 1984 (D).

Legends : number of samples.

percentage of samples with lead concentration in blood exceeding recommended level.

On the positive side, many forces are being exerted to ameliorate the situation, including the actions of NICE. In 1985, DOL required that all undertakings having 100 or more employees should appoint a safety officer. NICE is the agency responsible for the training of these officers. NSCT has also been actively promoting occupational safety through the mass media.

Mahidol University has been advocating the setting up of provincial occupational health centers. All these actions will help to improve future conditions. But judging from past performance, it is fair to say that the statistics of occupational injury will probably continue to increase during the Sixth Plan, mainly because of the expansion of the coverage of the WCF.

12.3 LEGAL AND INSTITUTIONAL FRAMEWORK

Legislation

Presently there are several laws and regulations related to occupational safety and health. There are Acts passed by parliament and there are Announcements promulgated by the Revolutionary Council or by the National Executive Council (NEC).

Incidentally, these Announcements have the same status as Acts passed by the parliament. Passing a law through parliament is very laborious, and consequently there is a tendency to draft laws containing only general principles and a list of subjects on which the respective ministers have power to issue ministerial regulations. A brief summary of the important laws and regulations follows.

Announcement No. 103 of the National Executive Council, 1972

Announcement No. 103 provided the basic framework for comprehensive labour regulations, including the creation of the Workmens' Compensation Fund. The Ministry of the Interior is empowered to issue notifications which are administered by the Department of Labour. A number of safety related notifications have been issued and are described as follows:

Safety and the Work Environment, 12 November 1976

This Notification estaeblishes standards in the work environment with regard to temperature, illumination, noise levels, and personal protective equipment (PPE).

Safety in the Use of Machinery, 23 July 1976

Prescribes the general safety requirements in the use of machinery, boiler safety, provision of PPE, and standards of PPE related to the use of machinery.

Safety at Construction Sites, 10 June, 1976

Governs the design of scaffoldings, and the use of PPE in construction works.

Safety with Electricity, 7 March 1976

Stipulates the provision of safety equipments, wiring procedures, transformer design, earthing, installation of lighting arrestors, and the use of PPE in electrical work.

Safety in Diving, 17 September 1980

Governs safety and the use of equipments in diving.

Safety in the Use of Temporary Lifts at Construction Sites, 29 January 1981

Governs the design and loading of lifts used at construction sites.

Safety in Chemical Handling, 30 May 1977

Governs the handling of chemicals, including the use of PPE. This Notification also contains air quality standards for the workplace.

Factories Act 1962, as amended in 1972, 1975 and 1979

The construction, operation, and expansion of factories are governed by this Act. It is administered by the Department of Industrial Work (DIW), which is part of the Ministry of Industry (MOI). A factory is defined as any premise or vehicle

which uses machinery of 2 horsepower or more or which employs seven or more workers for manufacturing, producing, assembling, packing, repairing, maintaining, testing, improving, processing or destroying anything or materials. Presently, there are 99 classes of factories listed in the Ministerial Regulations. Because of this definition of a factory, many establishments that are not factories by definition do not fall within the jurisdiction of DIW.

The Act does not apply to government-owned and operated factories which are for the purposes of national security, except that such factories must comply with Ministerial Regulations concerning location, safety, prevention of nuisance, refuse disposal, effluent treatment and ventilation. The MOI is authorized to publish a listing of types of factories which it will not approve for establishment or enlargement.

Applications for the establishment of a factory require information on the amount of investment, construction and operation, the number and duty of workers, details of production, drawings or plans showing the nature and location of machinery, effluent treatment systems, and other necessary details. For certain projects, the applicant must also file an Environmental Impact Assessment (EIA) to be approved by the Office of National Environment Board (ONEB). The DIW may not issue the factory establishment license until ONEB has approved the EIA.

A factory operation license must be obtained prior to the factory start-up. Operational licenses are renewable every three years. Also an application must be filed with the DIW prior to any factory expansion.

The Factories Act contains a number of provisions relating to safety and the prevention of public nuisance. The DIW is authorized to inspect factories and to issue orders requiring a factory to modify, repair or cease operations. Ministerial regulations have provisions regarding emergency exits alarm signals, fire-fighting equipment, ventilation, wastewater effluent standards, illumination, first-aid facilities, clean drinking water for workers, and refuse disposal.

Public Health Act, 1941

Parts 1, 2, 3 and 5 of the Public Health Act are related to occupational safety and health as follows: (1) Part 1 relegates the responsibility of refuse collection and disposal to the local municipalities. (2) Part 2 regulates the operation of certain commercial activities deemed objectionable to the public. Local municipalities are authorized to issue regulations regarding the issuing of permits to these activities. (3) Part 3 regulates establishments that may jeopardize the health of the public. Health officials are authorized to issue orders requiring owners to modify their operations, to remove certain goods or to close establishments that are deemed unfit for human occupation. (4) Part 5 governs the regulation of public nuisance. Health officials are authorized to issue orders to establishments causing public nuisance to modify or take remedial measures to remove the nuisance. The courts are authorized to close down any operations causing public nuisance.

Poisonous Substances Act (PSA) 1967, as amended in 1973

The PSA provides the basic framework for the regulations of poisonous substances. Under this Act, poisonous substances used in agriculture, industry, and public health are the jurisdictions of the Ministry of Agriculture and Cooperatives, the Ministry of Industry and the Ministry of Public Health, respectively. The ministers are empowered to issue ministerial regulations governing the storage, transportation, manufacture, use, labelling, and disposal of poisonous substances and their containers. However, the ministers must publish the listing of the poisonous substances that they wish to control first. Substances not on the list are not subject to control under this Act. This aspect of the Act has been regareded by many as a worrying loophole.

The National Environmental Quality Act, 1975, as amended in 1978

This Act created the National Environment Board (NEB) and the Office of the National Environment Board (ONEB). It authorizes the NEB to perform functions which are mostly concerned with policy development and coordination with other government agencies in matters relating to environmental quality.

The amendment empowers the NEB to issue ministerial regulations to list development projects that are required to submit an Environmental Impact Assessment (EIA) to the NEB for prior approval. Presently, 10 types of project are required to submit EIA to the NEB for approval.

Regulation of the Office of the Prime Minister on Accident Prevention, 1983

This regulation created the National Safety Council of Thailand (NSCT). The Council, consisting of representatives from various government agencies, is chaired by a Deputy Prime Minister. The primary duties of the NSCT are to advise the Council of Ministers on matters related to accident prevention, to coordinate the works of various government agencies, to propose new laws or regulations to the Council of Ministers, and to promote public awareness and public relations.

Institutional Framework

Table 12.18 summarizes the functions of major government agencies in Thailand that deal with occupational safety and health, pollution control and accident prevention. It can be seen that the responsibilities are fragmented among several agencies, often with overlapping authorities. A brief description of these agencies follows.

The National Environment Board (NEB)

The NEB is primarily a policy and advisory agency responsible

for formulating policies for the conservation and enhancement of the environment. It is also responsible for coordinating various government agencies involved with matters related to the environment. The NEB has appointed a Toxic Substances Committee which assists the NEB to formulate policies regarding the use of toxic substances. The NEB is empowered to require an Environmental Impact Assessment (EIA) from developers of 10 major types of development projects including petrochemical, oil refinery, natural gas separation, chlor-alkali, iron and steel, cement, smelting and pulp production. Unfortunately, accident prevention related to the use of chemicals is not yet one of the requirements in the EIA. Within the ONEB, the Toxic Substances Section is responsible for research, monitoring and proposal of policies.

Table 12.18 Functions of Governmental Agencies Involved in Occupational Health, Pollution Control and Accident Prevention in Thailand

Functions	Agencies					
	DOL	NEB	DIW	DOA	DOH	NSCT
Policy formulation	o	o	o	o	o	o
Coordination		o				o
Enforcement	o	o	o	o		
Research	o	o	o	o	o	
Standard setting	o	o	o	o	o	
Monitoring	o	o	o	o	o	

Note: a. DOL - Department of Labor
NEB - National Environment Board
DIW - Department of Industrial Works
DOA - Department of Agriculture
DOH - Department of Health
NSCT - National Safety Council of Thailand

The Department of Industrial Works (DIW)

The DIW is responsible for granting licenses for the establishment and operation of factories. The DIW is responsible for the enforcement of the Factories Act and the PSA which include pollution control from industries, including wastewater, air pollution, noise pollution, solid wastes, toxic wastes and workplace environment and safety.

The Department of Health (DOH)

The DOH is responsible for primary public health. The Occupational Health Division of the DOH is responsible for research on occupational health problems, establishment of occupational health standards, monitoring of occupational diseases, training and dissemination of information. The DOH Food and Drug Administration (FDA) is responsible for poisonous substance control under PSA. Its functions include the inspection of undertakings producing or storing poisonous substances.

The National Safety Council of Thailand (NSCT)

The NSCT is primarily a policy and advisory agency in matters related to accident prevention. It has been effective in mass media campaigns, particularly in using TV and radio. NSCT has established a Toxic Substance Committee dealing with toxic substances.

The Department of Agriculture (DOA)

The DOA Agricultural Regulatory Division is ressponsible for the registration of pesticides for agricultural use. This Division also issues permits for the import, manufacture and sale of pesticides. Presently more than 200 pesticides have been registered. The Division publishes annual reports of pesticides imported in the country.

The DOA Agriculture Toxic Substances Division is responsible for research on toxic substances, certification of pesticide residues in agricultural products, and other quality control activities. The Division's formulation control laboratory regularly monitors pesticide formulations on the market, while the pesticide residue laboratory conducts analyses of pesticide residues in export crops. The DOA Entomology and Zoology Division is responsible for making recommendations for the use of pesticides.

The Department of Agricultural Extension (DOAE)

The DOAE gives away free pesticides during pest outbreaks. DOAE also provides training to licensed pesticide retailers at the village level.

In 1968, a National Committee for the Coordination of Occupational Safety and Health, chaired by the Minister of Public Health, was established to coordinate the work of the various related agencies. The efforts of this Committee have not been very successful. Some attribute this to the fact that this Committee does not have a permanent secretariat. In 1986, a similar coordination committee chaired by the Minister of Interior was established.

12.4 KEY ISSUES

Poor Working Conditions

Poor working conditions have often been reported as a major factor causing occupational accidents (e.g., Thosuwonchinda, 1985, p 109). Except in a few modern factories, working conditions in most factories are still not entirely satisfactory.

This situation exists because about two-thirds of the factories in the country are small family enterprises, the management of which may be ignorant about safety and health hazards in the workplace. The problem is compounded by the generally low educational levels of the workers. They are often unaware of the dangers or risks involved in working with certain chemicals or processes.

In a recent survey of 107 enterprises in Bangkok by the DOL (Hasle et al., 1986, p. 30), it was found that although most enterprises provide basic welfare facilities like toilets, washing facilities and drinking water, many of them are of low standard. Problems related to ergonomics and accident hazards were found in nearly all enterprises. Personal protective equipment was only occasionally provided and used.

For agricultural workers, there is a general agreement that pesticides are being overused and misused. Pesticide poisoning of farmers is a matter of great concern, although the extent of poisoning incidents has not yet been adequately explored. Agricultural workers in general still have the wrong perception of the danger of pesticides. These misconceptions have resulted in widespread carelessness in the use of pesticides. Many farmers do not wear any protective devices while spraying pesticides.

Inadequate Data Collection, Research and Monitoring

Present statistics of occupational accidents are obtained mainly from the WCF The statistics are inadequate because the WCF only covers 40 percent of the total industrial workforce. Secondly, the data compiled by the WCF are primarily gathered for the purpose of determining the eligibility of compensation claims. They are not collected for accident analysis in the interest of accident prevention. An accident is reported as a simple phenomenon arising from a single and direct cause. The working conditions conducive or leading to accidents are generally not reported.

Other agencies often collect information for their own internal use, and tend not to publish or share such information. Information on occupational accidents should be compiled into one or more data banks that are accessible by all agencies concerned.

In the area of occupational safety research, there is little current activity. One of the main obstacles in developing realistic programs and policies in accident prevention is the lack of adequate baseline data concerning existing working conditions. There has never been a comprehensive baseline survey of the health and safety aspects of the working environment, especially in the agricultural sector.

Insufficient Number of Government Inspectors

In order to enforce safety regulations, it is important that the government conduct frequent inspection of the factories and other undertakings. It is commonly acknowledged that the present level of factory inspection is inadequate. For example in 1985, the DOL conducted safety inspections in 2,638 undertakings (DOL, 1985b, p. 20), whereas the total number of factories is about 90,000. The shortage of experienced inspectors has been described as severe (Chalvalitnitikul, 1985, p. 47). It has been suggested that, as far as possible, every establishment should be inspected once a year, and that unsatisfactory or unhealthy establishments should be inspected much more frequently (ILO, 1976, p. 142). It is evident that safety regulations will be ineffective unless they can be rigorously enforced through inspection.

Inadequate Training Activities

Accidents often occur because workers are not aware of the risks involved, or do not know how to prevent them. Training in safety is therefore vital to promote awareness and to help eliminate accidents.

Although some training activities are being carried out by various public and private organizations, the present level of safety training activities has been judged inadequate (Joungtrakul, 1985, p. 185). The DOL Labour Training Division conducts many training courses, but most of them focus on the labour relations area. NICE has conducted some training courses, especially the training of labour inspectors and of safety officers.

In 1985, the DOL required that undertakings having 100 or more employees appoint a safety officer. A six-week training program series was conducted in 1985 to train approximately 1,500 safety officers and should have a major influence on working conditions in medium and large sized undertakings in the future.

Other organizations, such as the Occupational Health Division of DOH, Employers' Confederation of Thailand and some workers organizations also give training courses, but very few of these courses are in occupational safety and health.

Training is a long-term solution to the problem of improving working conditions, and merits more support.

Lack of a Major Hazard Control System

The increasing use of hazardous chemicals in industry has created situations where the safety of a large number of the general public can be endangered. The recent international tragedies in Mexico, India and the Soviet Union clearly indicate that the establishment of a major hazard control system is necessary (see Box 12.1).

Accidents involving hazardous substances can happen at an installation or during transportation of raw materials intermediates or products by road or rail. Adequate hazard assessments will be needed to insure the safety of the public. There is also a need to develop contingency plans in case an accident involving hazardous substance occurs.

Box 12.2 The Tantalum Riot: Some Lessons Learned

It would have been one of only five tantalum processing plants in the world, and the only one in Asia. Designed to produce 600,000 pounds of tantalum pentoxide (Ta_2O_5) a year, or approximately a quarter of the current world demand of 2.5 million pounds, it would also have produced an equivalent quantity of niobium pentoxide. The entire production of tantalum would have been exported, earning an estimated 1,100 million baht a year. Claimed to incorporate the latest pollution control technology, the plant was shortly to open. But then, on 23 June 1986, a mob broke in and burned the 600 million baht plant virtually to the ground. What had gone wrong?

The first problem was that the authorities had badly underestimated how far the public might go to stop a project with which it was not in sympathy. In retrospect, the planning of the project had not been sufficiently sensitive to public feelings at a time when the reverberations of the Bhopal disaster were still being felt and the Chernobyl disaster was headline news. Among their worst fears: the hydrofluoric acid used by the plant might leak, causing another Bhopal, or the sheer environmental impact of normal operations would undermine the booming local tourism industry.

The residents of Phuket first began to voice their concern in May of 1986, culminating in mass demonstrations by about 50,000 people in June. Local community leaders were threatening to boycott the national election on 27 July, but the real surprise was the mass break-in on 23 June, the day that a public hearing was meant to begin, with the Minister of Industry present.

On the surface, things seemed to be going well. The Thailand Tantalum Industry Corporation (TTIC) had received considerable support from the Board of Investment, with the bulk of the project's financing coming from a US$53.5 million package arranged by the International Finance Corporation (IFC), the World Bank's investment arm. The project's original proponent, S.A. Minerals, was the largest investor, holding 45 percent of the equity, with the IFC, three Thai banks, the quasi-governmental Industrial Finance Corporation of Thailand and local tin-mining families holding the rest.

Tantalum is very much a high technology metal, exploited for its high tensile strength and heat resistance. It is used to make capacitors, special alloys, aerospace components and nuclear reactor equipment. It is normally derived either from tantalite ore or from tin slag, the major source in Thailand. The tin slags have a tantalum content varying from 2.5 percent of Ta_2O_5 in low grade ores to 14 percent in high grade ores. The original plan for the Phuket tantalum plant called for two components: an enrichment plant to produce slag with a 20-30 percent Ta_2O_5 content (later deferred because of falling tantalum prices), and an extraction plant using hydrofluoric acid, to dissolve the tantalum in the ground ore or slag, and methyl isobutyl ketone, a common solvent, to extract the tantalum-rich material.

The wastes from the plant would have included 380 cubic meters per day of acidic and wastewater. The plan was that the acidic wastewater and ammoniacal digestion residues would be neutralized with lime, and the resulting 48 tons per day of waste would be filtered and the solids landfilled. The treated wastewater would be discharged to a canal in the rainy season, and to an abandoned mine during the dry season. Air pollutants, it had been promised, would be collected and treated.

One problem, however, was that an Environmental Impact Assessment (EIA) was only prepared late in the day, and then somewhat reluctantly, following government pressure on TTIC. The EIA was completed shortly before the plant was burnt down, and was not used as a means of promoting public participation. The TTIC plant was also approved before the World Bank issued its post-Bhopal guidelines for assessing the major hazards associated with industrial development projects in developing countries. The TTIC plant would now come within those guidelines, since they cover any plant handling more than 10 tons of hydrogen fluoride. Such assessments are not a legal requirement under Thai law, but the lack of such an assessment can leave the door open for rumour and speculation.

The plant was located on the northern outskirts of the city, just a few hundred meters from a teacher training college. The site was apparently chosen because of its proximity to the tin smelter that produce the tantalum-rich slags, but the siting of such plants in residential areas is questionable at the best of times. Even if local people had read and understood the EIA report which concluded that the plant could be run safely (if sufficient effort was devoted to making sure that it was), the lack of effective enforcement of pollution control standards in Thailand would have raised question marks over the apparently satisfactory picture painted in the EIA.

The tantalum riot, reprehensible though it may have been, underscored a number of points about the planning requirements for such projects. The local public remained grossly ignorant throughout the project of what was likely to be involved. But the facts that did percolate through, for example that tantalum is used in nuclear warheads, simply fanned the flames. The fact that the public could be gradually swayed into staging a riot should be a lesson to us all.

Given that there were probably other deeper-rooted political forces at work, too, it is impossible to guarantee

Box 12.2 (contd.)

that a developer who does his homework, basing it on a thorough environmental assessment of the major hazard potential involved, and who does his best to ensure that the local community is involved in the decision-making process, will succeed. But TTIC's experience confirms that if he does not do these things, he will certainly increase his chances of failure.

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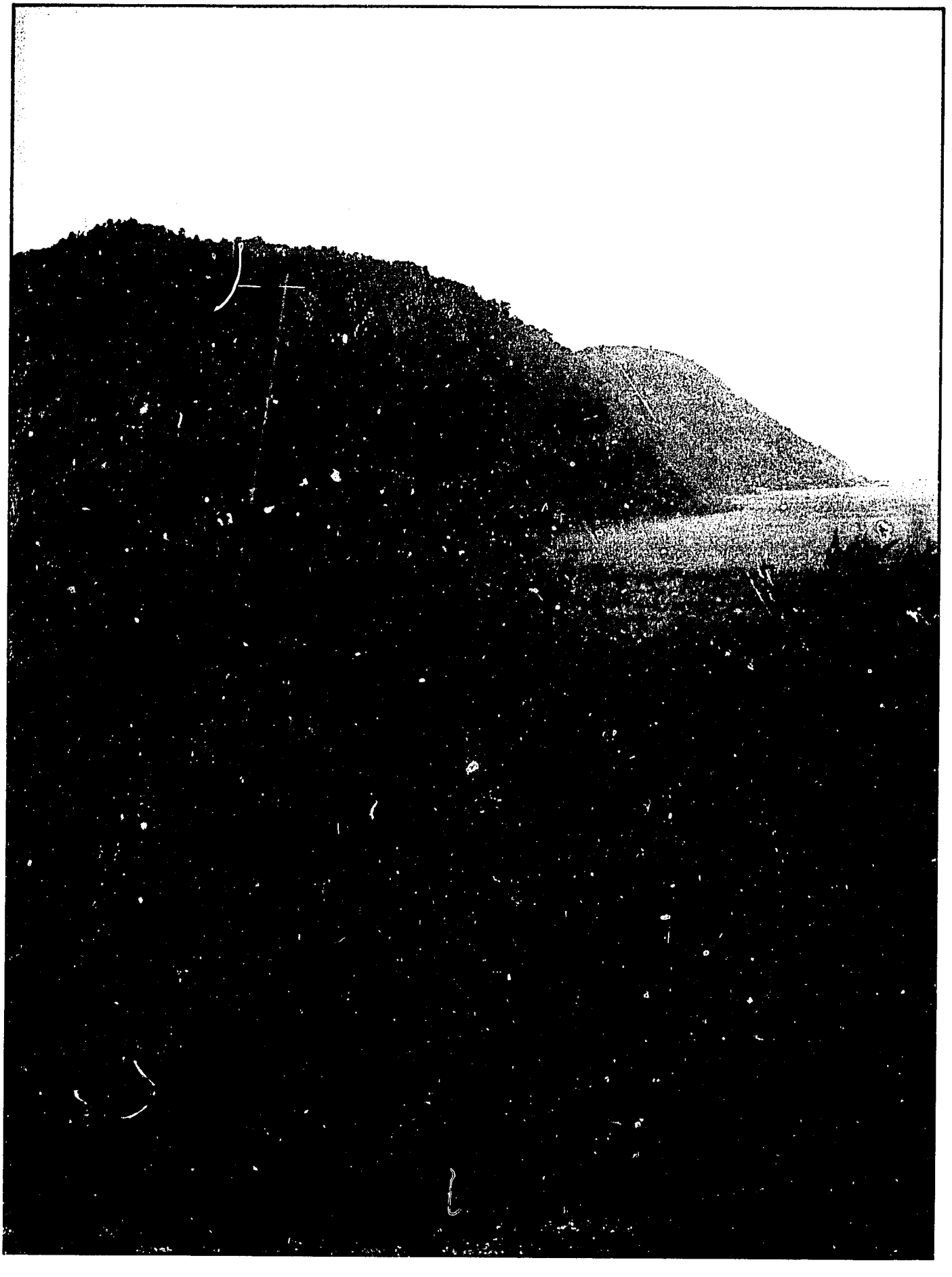


Recommendations and Strategies PART IV

13 Recommendations and Strategies

13.1 THE TRENDS

The Thai standard of living owes much to the country's generous endowment of natural resources. Thailand's once-tranquil pace of development accelerated considerably in the 1960s, and today's economy is both stronger and more resilient. Indeed, it has maintained an overall pattern of growth throughout the vagaries and turmoil of world affairs over the last 25 years. Between 1960 and 1985, based on current prices, Thailand's GDP expanded more than 18-fold, with a buoyant 7.5 percent average annual growth rate through the period. The country's population has also grown rapidly, of course, but economic growth has so far more than kept pace.

If you look at per capita GNP, this has also grown steadily, although there are marked imbalances in the distribution of the resulting wealth between sections of society and between regions. The biggest gains, unquestionably, have been in the Central Region, and particularly in the Bangkok Metropolis. This phenomenal pace of development is now weakening somewhat, however, due to a host of internal and external events and trends. Economic growth dropped below the five percent mark in 1985.

There are now signals that changes are needed in the way that Thailand's development is directed and managed. Previous chapters of this Profile have focused on some of the key emerging trends and issues in particular sectors of the economy. This concluding section will pull together some of these threads, review the overall situation, and suggest areas in which Thailand needs to rethink and remodel its approach to development.

The evidence marshaled in Parts II and III points to one inescapable conclusion: Thailand's current development strategies need overhauling in a number of areas, because they are leading to an unsustainable pace of natural resource consumption and destruction. The fate of countries which have run up such a natural resource deficit is evident enough of the need for more sustainable styles of development, throughout the world. So, before reviewing the sort of adjustment process which Thailand now needs to embark upon, it may help to briefly review some of the trends in natural resource utilization. These trends have contributed to Thailand's current economic strength, and we need to consider how our natural resources can sustain the economic development and growth needed to provide a satisfactory standard of living not only for today's Thais, but also for tomorrow's.

Resources for Development

Minerals, fishes and forest are just some of the natural resources which have helped power the growth of Thailand's economy in recent decades. Unfortunately, there has been no reliable and regularly updated index of the contribution which these resources have made -- and continue to make -- to the economy. To fill this gap, TDRI has evaluated the contributions of four natural resource-related sectors (agriculture, forestry, fisheries, and mining and quarrying) to Thailand's GDP since 1975. The results, shown in Table 13.1, and summarized in Figures 13.1 to 13.3 are very interesting indeed.

The first thing that the analysis shows is that the contribution of the agricultural sector has grown significantly, from

Table 13.1 Contribution of Natural Resource-Related Sectors to Gross Domestic Product[a] in 1972 Prices

Sectors	1975		1976		1977		1978		1979	
	million baht	% of GDP	million baht	% of GDP	million baht	% of GDP	million baht	% of GDP	million baht	% of GDP
Agriculture[c]	53,016	26.0	55,457	25.1	54,104	22.9	62,098	23.8	60,735	21.9
Forestry and Related Industries	4,861	2.4	5,115	2.3	5,121	2.3	4,898	1.8	5,540	2.0
Forestry[d]	3,330	1.6	3,380	1.5	3,205	1.4	3,001	1.1	3,392	1.2
Wood Industry[e]	1,212	0.6	1,282	0.6	1,319	0.6	1,165	0.4	1,306	0.5
Pulp and Paper Industry	319	0.2	453	0.2	597	0.3	732	0.3	842	0.3
Fishery and Related Industries	6,065	3.0	6,207	2.8	6,688	2.9	7,783	2.9	7,652	2.7
Fishery[f]	5,734	2.8	5,898	2.7	6,324	2.7	7,414	2.8	7,281	2.6
Fishery Product Industry[g]	331	0.2	309	0.1	364	0.2	369	0.1	371	0.1
Mining and Quarrying[h]	2,485	1.2	2,906	1.3	3,534	1.5	4,104	1.6	4,531	1.6
Other Sectors	126,703	62.0	140,290	63.4	155,244	65.2	169,533	65.2	185,257	67.1
Total GDP	**204,056**	**100.0**	**221,297**	**100.0**	**236,500**	**100.0**	**261,097**	**100.0**	**276,907**	**100.0**

Notes: *a. Gross Domestic Product is defined as the total market value of final goods and services produced during a given period of time with factors of production located in the country.*
b. 1985 figures are preliminary as compiled by NESDB.
c. Agricultural sector comprises only crops and livestock.
d. Forestry sector comprises all timber production, fuelwood and minor forest products but excluding sawmills and other wood processing operations.
e. Wood Industry comprises saw mills and plywood factories, wood preserving mills, manufacture of wooden doors and windows, basketry, lacquer ware, tread-plates and other products.
f. Fishery sector includes both fresh water and marine fisheries as well as aquaculture.
g. Fishery Product Industry comprises preservation of fish, seafood and fish sauce making.
h. Mining and Quarrying sector comprises all mineral resources production including natural gas and crude oil.

Source: National Accounts Division, NESDB.

Figure 13.1 Natural Resource-Related Sectors Contributions to GDP, 1975-1985 (1972 prices)

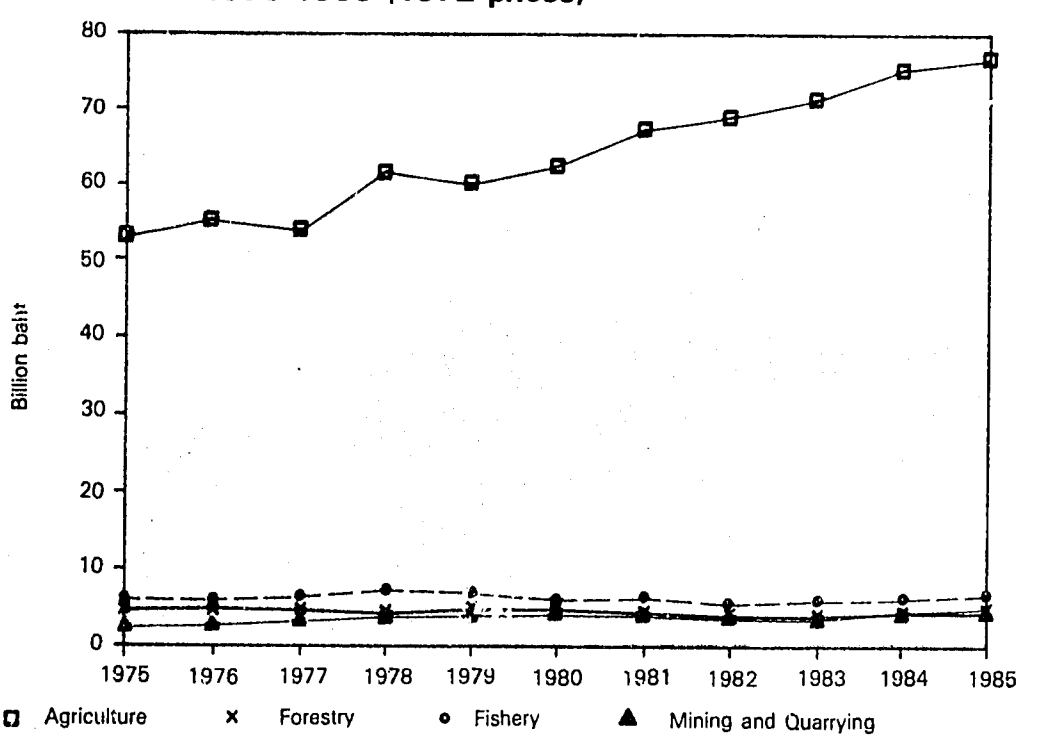
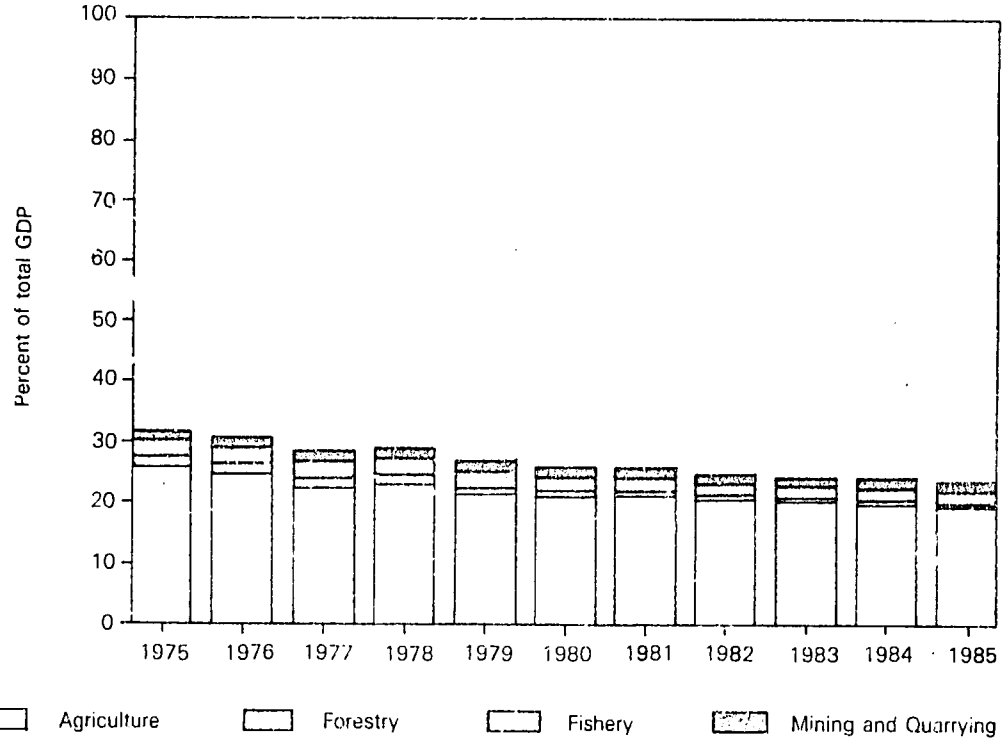


Table 13.1 (contd.)

1980		1981		1982		1983		1984		1985[b]		1985 (current prices)	
million baht	% of GDP	million baht	% of GDP	million baht	% of GDP	million baht	% of GDP	million baht	% of GDP	million baht	% of GDP	million baht	% of GDP
63,190	21.6	68,028	21.9	69,901	21.5	72,251	21.1	76,299	20.9	77,784	20.5	182,779	17.4
5,455	1.8	5,136	1.6	4,874	1.5	5,009	1.5	5,340	1.5	5,571	1.4	21,035	2.0
3,318	1.1	2,896	0.9	2,682	0.8	2,630	0.8	2,741	0.8	2,823	0.7	13,165	1.3
1,178	0.4	1,257	0.4	1,217	0.4	1,342	0.4	1,496	0.4	1,568	0.4	5,559	0.5
959	0.3	983	0.3	975	0.3	1,037	0.3	1,103	0.3	1,180	0.3	2,311	0.2
6,661	2.2	7,178	2.3	6,437	2.0	7,011	2.0	7,383	2.0	7,865	2.1	13,940	1.3
6,276	2.1	6,777	2.2	6,019	1.9	6,568	1.9	6,862	1.9	7,290	1.9	12,651	1.2
385	0.1	401	0.1	418	0.1	443	0.1	521	0.1	575	0.2	1,289	0.1
4,780	1.6	4,623	1.5	4,431	1.4	4,414	1.3	5,415	1.5	6,012	1.6	29,279	2.8
200,650	68.8	213,991	68.8	227,178	70.1	242,241	70.6	257,046	70.6	268,088	71	765,606	73.2
292,852	**100.0**	**311,270**	**100.0**	**324,032**	**100.0**	**342,946**	**100.0**	**364,206**	**100.0**	**378,756**	**100.0**	**1,047,564**	**100.0**

Figure 13.2 Percentage of Resource-Related Sectors to Total GDP, 1975-1985 (1972 prices)

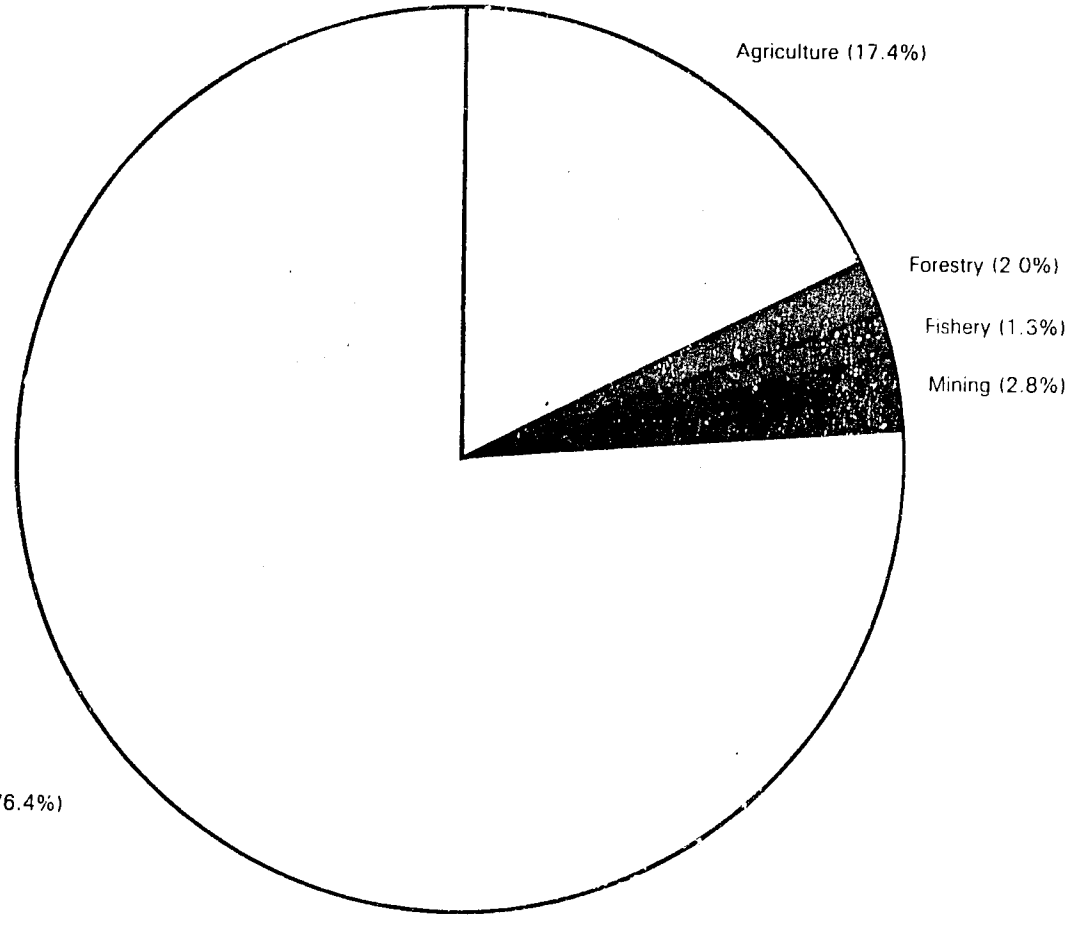


53 billion baht in 1975 to 77.8 billion baht by 1985, with both figures expressed in terms of 1972 prices. While the pace of growth may have been somewhat slower in some of the other sectors, it has been significant, too. The forestry sector grew from 4.9 billion baht in 1975 to 5.6 billion baht; the fisheries sector from 6.01 billion baht to 7.9 billion baht; and the mining and quarrying sector, showing a faster pace of growth, from 2.5 billion baht to 6.0 billion baht.

Judging from the latest figures (Figure 13.3), we can see that the resource and related sectors contribute as much as 23.5 percent of the total GNP. If agriculture is taken out of the picture, the other three sectors still account for 6.1 percent in 1985 (current price) or the equivalence of 64,254 million baht.

These are major contributions in any terms, but this index is still incomplete in that it only takes into account contributions which are formally entered in the national GDP accounts. The tremendous uncosted service provided by forests in the area of watershed management are completely ignored, for example. But, even allowing for this narrow focus in the eco-

Figure 13.3 Natural Resource-Related Sectors Contributions to GDP in 1985 (current prices)



nomic analysis, the contribution of these natural resource-related sectors begins to look very much healthier when you consider their contributions in terms of export values and employmlent.

Export-led Growth

The contribution of Thailand's natural resources to the nation's economic state of health is nowhere clearer than in the export statistics, which are presented in Table 13.2, and summarized in Figures 13.4 and 13.5. The forestry, fisheries and minerals sectors bring in over 16.5 percent of Thailand's export earnings, and agriculture alone accounted for 49 percent of the country's exports in 1985.

Agriculture's share of Thai exports may have slipped from 55 percent in 1980 to 49 percent in 1985, but the absolute value of agricultural exports has increased significantly, from 73.3 billion baht to 94.8 billion baht, via a peak contribution of 96.5 billion baht in 1984. The forestry sector accounts for a much smaller proportion of exports. Between 1980 and 1985, the absolute value of forestry exports has grown from 1.9 billion baht to 3.4 billion baht. Even more significant has been the growth in fishery exports, which rose from 7.3 billion baht (5.4 percent of total exports) in 1980 to 18.5 billion baht (9.6 percent of total exports) in 1985. Meanwhile, mining and quarrying went in the opposite directions: a contribution of 14.9 billion baht in 1980, representing 11.2 percent of total exports, fell sharply to 9.8 billion baht by 1985, representing just five percent of total export.

While the contribution of these four natural resource-related sectors to Thailand's exports may have slipped from three-quarters (73 percent) in 1980 to two-thirds (65.5 percent) in 1985, their contribution to the country's much-needed export earnings are clearly very considerable indeed.

It hardly needs stressing that the productivity of these sectors depends on the health of renewable natural resources and the continued, uncosted contributions made by environmental systems in terms of air quality and water quality, for instance. If greater attention can be paid to the concept of maximum sustainable yield, and to the development of value-added industries in all four sectors, their contribution to

Table 13.2 Export Values of Key Products from Natural Resource-Related Industries[a], 1980-1985

Sector/Product	1980		1981		1982		1983		1984		1985	
	million baht	% of total export	million baht	% of total export	million baht	% of total export	million baht	% of total export	million baht	% of total export	million baht	% of total export
Agriculture and related industries[b]												
Total Value	73,330	55.1	91,909	60.1	95,769	60.0	83,346	56.9	96,544	55.1	94,810	49.0
- rice	19,508		26,366		22,510		20,157		25,932		22,524	
- food crops	9,773		11,566		11,840		11,452		13,464		11,889	
- cassava products	14,887		16,447		19,752		15,387		16,600		14,967	
- raw sugar and products	3,357		10,311		13,807		7,878		6,111		7,060	
- rubber and rubber products	13,025		11,470		10,060		12,406		13,892		14,807	
- fruits and fruit products	2,123		2,974		3,120		3,032		4,206		5,114	
animal products	1,391		2,239		2,361		2,016		3,005		3,354	
others	10,657		10,536		12,319		11,018		13,334		15,095	
Forestry and related industries												
Total Value	1,928	1.4	1,931	1.3	2,018	1.3	2,130	1.5	2,648	1.5	3,446	1.8
Timber and wood products[c]	1,420		1,499		1,424		1,484		1,733		2,031	
- teak veneer	259		250		283		349		505		474	
- household utensils of wood	376		406		407		500		501		543	
- articles of wood furniture	234		183		230		215		176		267	
- others	551		660		504		420		551		747	
Minor forest products[d]	283		244		358		421		634		802	
Paper and products	225		188		236		225		281		613	
Fishery and some related industries[e]												
Total value	7,251	5.4	8,776	5.7	10,853	6.8	12,677	8.7	15,081	8.6	18,528	9.6
- fish (fresh, chilled, frozen)	381		767		689		715		1,017		1,377	
- cuttle fish (fresh, chilled, frozen)	1,300		1,334		1,738		1,637		1,693		2,121	
- shrimps, prawns, lobster (fresh, chilled, frozen)	1,961		2,136		2,764		3,164		2,799		3,440	
- fish (canned)	603		1,109		1,665		2,116		1,782		492	
- tuna in airtight containers	-		-		-		-		1,854		4,620	
others	3,006		3,430		3,997		5,046		5,936		6,478	
Mining and quarrying[f]												
Total Value	14,935	11.2	11,856	7.8	9,743	6.1	6,669	4.6	7,404	4.2	9,782	5.1
- primary tin metal	11,169		9,653		7,986		5,225		5,268		5,462	
- tin-lead-alloy	12		34		131		202		164		325	
- zinc	-		-		-		-		-		471	
- tungsten												
wolfram	577		320		165		88		159		85	
scheelite	62		64		48		41		46		48	
- fluorite												
metallurgical grade	186		205		190		198		246		276	
acid grade	114		122		125		90		110		86	
condensates	-		-		-		-		362		2,003	
- others	2,815		1,458		1,098		825		1,049		1,026	
Total exports of the whole country	**133,200**		**153,000**		**159,728**		**146,471**		**175,238**		**193,365**	**100.0**

Table 13.2 (contd.)

Notes: a. *Export value reflects changes in both volume of export and prices which depend upon foreign exchange rate. Two major devaluations of baht currency in 1981 and 1984 coupled with fluctuations of some major currencies such as Yen and US dollars also significantly contribute to changes in export values.*

b. *Consists of rice products, food crops, cassava products, raw sugar and products, oil seeds, vegetable oils, fiber crops, garden crops and products, fruits and products, other food products, rubber and products, live animals, animal feed, animal products, dairy products, fertilizer and pesticides.*

c. *Consists of teak, yang, teak veneer, other veneer sheets, plywood, block and strips for parquet and other flooring assemblies, particle board, hardboard, soft board and other boards, blockboard, drawn wood, reconstituted wood, wooden frames, household utensils of wood, doors, wooden windows, articles of wood furniture, articles of personal clothing,adornment of wood,fork and spoon, other household utensils of wood, fuel wood, wood charcoal*

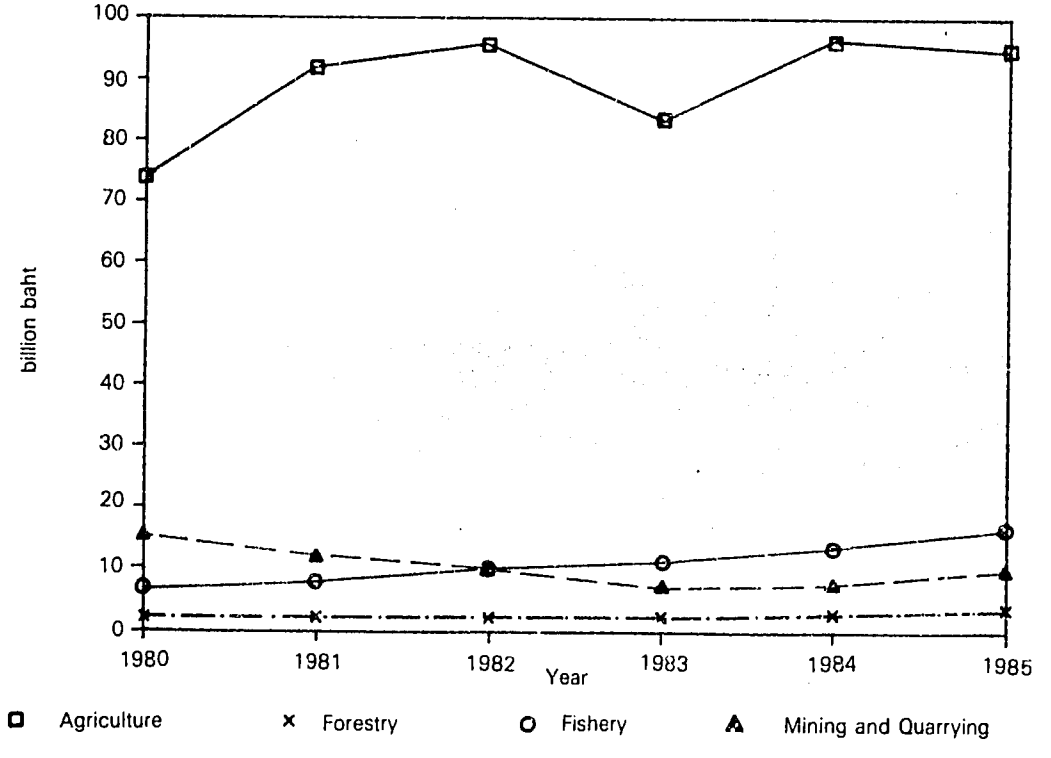
d. *Consists of bamboo stalks, bamboo in the rough, bamboo for plaiting reeds, vegetable materials in brushes or in brooms, vegetable materials used primarily for boating, sea weed, other vegetable products, yang oil, seedlac and sticklac, shellac, nutural gum rasins, vegetable saps and extracts, medicinal plants, other forest by-products.*

e. *Consists of products of fish, crabs, cuttle fish, shrimps, prawns, lobsters, jelly fish, molluscs, crustaceans, squids, octopuses; also fish sauce, oyster sauce, fish meal, and seaweed*

f. *Consists of exports of mineral products namely tin, tungsten, antimony, barite, calcite, columbite, tantalite dickite, dolomite, feldspar, ball clay, columbium, tantalum, fluorite, gypsum, ilmenite, kaolinite, lead, lignite, limestone, manganese, marble, monazite, pyrophyllite quartz, struvenite, xenotime, talc, zinc and condensates.*

Sources: *Office of Agricultural Economics, Ministry of Agriculture and Co-operatives; Foreign Trade Statistics of Thailand, 1980 to 1985, Department of Custom, Ministry of Finance; Fishery Statistics Division, Department of Fisheries, Ministry of Agriculture and Co-operatives, Mineral Statistics, 1985, Department of Mineral Resource, Ministry of Industry.*

Figure 13.4 Values of Natural Resource-Related Exports, 1980-1985



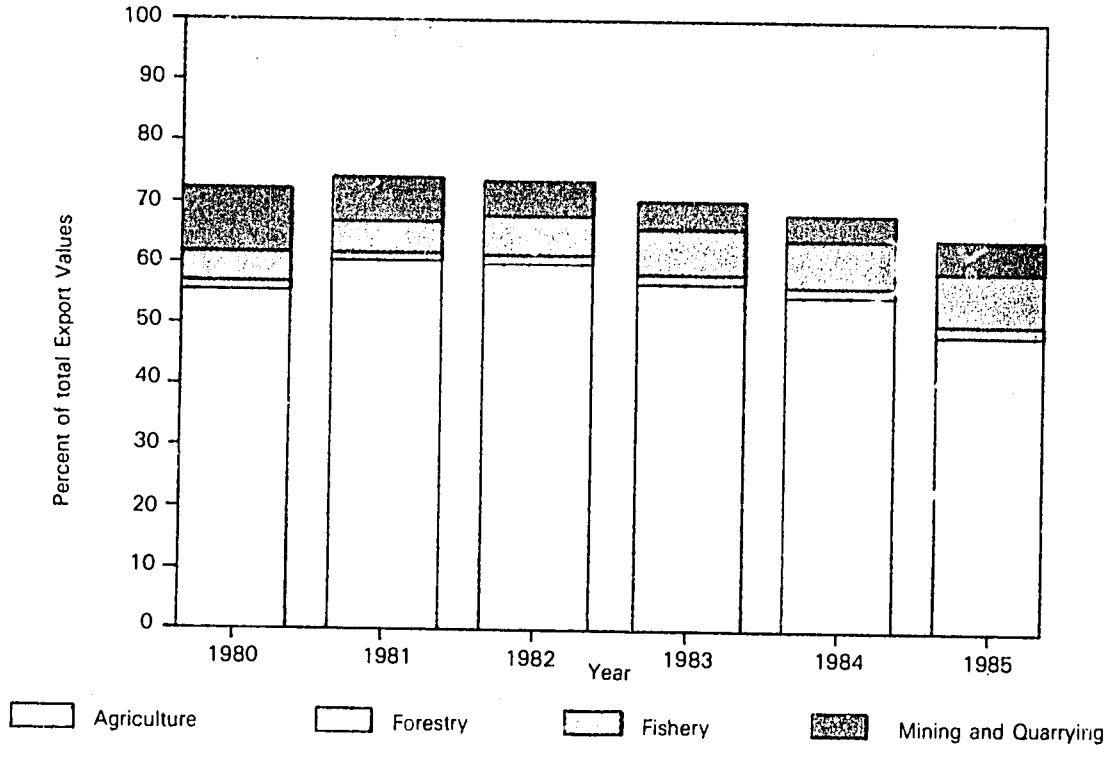
Thailand's future economic health stability could become increasingly significant.

Imports and the Trade Deficit

As Thailand's economy has expanded, however, so has the size of the trade deficit. The worst deficits were in the 1970s, when they reached nine percent of GDP. Since then, deficits have run in the range of 7-9 percent, roughly paralleling the economic growth rate. There was a marked drop to under five percent in 1982, but the deficit promptly rebounded to nine percent in 1983.

The OPEC "oil shocks" aggravated Thailand's trade deficits in the period following 1973, and then again after 1979. But

Figure 13.5 Percentage of Natural Resource-Related Exports, 1980-1985



the growing exploitation of indigenous energy supplies began to counterbalance the impact of oil prices, and the deficit shrank to seven percent of GDP in 1984 and down to 5.5 percent in 1985.

Clearly, these deficits reflected the influence of many different factors and trends. But there has been a strong pattern in the influence of the natural resource-related sectors. Prior to 1970, when the trade deficit was less of a problem, agricultural and mineral products held commanding shares of Thailand's GDP. Then, as industrial expansion took hold of the economy, it generated a growing demand for imports, producing widening trade deficits.

As shown in Table 13.3 and Figures 13.6 and 13.7, agricultural imports have grown considerably in terms of absolute value, from 19 billion baht in 1980 to 26.4 billion baht in 1985. Because of the size of the trade deficit, however, their share of the import bill grew only slightly, from 9.8 percent to 10.5 percent. Imports of forestry products have grown at a faster rate, meanwhile, from 4.5 billion baht in 1980 to 6.4 billion baht in 1985, with their share of imports remaining steady at around 2.5 percent.

The most dramatic growth of all has come in the fisheries sector, however. From a 1980 figure of just 483 million baht, imports in this sector grew eight-fold to 3.9 billion baht in 1985. Mineral imports, on the other hand, fluctuated considerably. From a figure of 41.7 billion baht in 1980, they hit a high of 48.6 billion baht in 1981, then a low of 36.4 billion baht in 1984, before rebounding to 40.2 billion baht in 1985.

Since 1983, as indicated in Table 13.4, the production of indigenous fuels, including lignite, natural gas and oil, has grown very considerably indeed. In the five years from 1981 to 1985, natural gas production increased nearly 13-fold, from 10.6 billion standard cubic feet to 132.3 billion standard cubic feet. Condensate production increased 10-fold, from 576,000 barrels to over five billion barrels. Lignite production more than tripled, from 1.4 million tons to 5.1 million tons.

Indigenous energy supplies met approximately 40 percent of Thailand's needs in 1985, and the prospect for further reductions in the country's energy deficit are good. Meanwhile, the country's natural resources make other contributions to the economy: we next look at the revenues contributed to government funds, the generation of wealth which powers other areas of investment, and the provision of jobs.

Contributions to the Treasury

The Royal Thai Government benefits from the country's natural resource wealth in many ways. For example, it charges royalties for the award of land, forest and mineral concessions. It collects duties on exports of agricultural products, including

Table 13.3 Import Values of Key Natural Resource-Related Products[a], 1980-1985

Sector/Product	1980		1981		1982		1983		1984		1985	
	million baht	% of total import	million baht	% of total import	million baht	% of total import	million baht	% of total import	million baht	% of total import	million baht	% of total import
Agriculture and some related industries[b]												
Total Value	19,048	9.8	21,479	9.8	17,552	8.9	22,739	9.6	25,204	10.3	26,361	10.5
- food crops	1,188		1,619		1,296		1,664		1,558		1,615	
- fiber crops	3,112		4,052		3,065		4,844		5,668		6,419	
- milk products	1,315		2,175		1,650		2,140		2,085		2,191	
- animal feed	1,306		1,368		1,540		1,511		2,224		1,247	
- fertilizers and pesticides	4,177		5,185		3,339		6,383		6,298		6,853	
- others	7,950		7,080		6,662		6,197		7,371		8,036	
Forestry and some Related Industries												
Total Value	4,479	2.3	5,911	2.7	5,046	2.6	6,208	2.6	5,784	2.4	6,394	2.5
Timber and wood products	1,186		1,831		1,783		2,366		2,388		2,223	
Paper and paper products	2,851		3,668		2,805		3,325		2,848		3,752	
Minor forest products[c]	442		412		458		517		548		419	
Fishery and some related industries[d]												
Total Value	483	0.2	550	0.3	726	0.4	1,093	0.5	2,119	0.9	3,857	1.5
- fish (fresh, chilled, frozen)	218		197		323		656		1,728		3,483	
- shrimps, prawns, lobsters (fresh, chilled, frozen	64		65		83		132		99		64	
- ark-shell (fresh, chilled frozen)	85		98		79		55		45		56	
others	116		190		241		250		247		254	
Mining and quarrying[f]												
Total Value	41,716	21.5	48,620	22.2	46,228	23.5	41,230	17.4	36,370	14.8	40,244	16.0
Metallic ore[f]	67		67		30		42		72		122	
Non-metallic ore[g]	2,345		1,312		1,145		1,213		1,263		1,596	
Crude oil	39,304		47,241		45,053		39,975		35,035		38,526	
Total Imports of whole country	193,618		219,026		196,616		236,608		245,155		251,169	100.0

Notes: a. *Import value reflects changes in both volume of import and prices which depend upon foreign exchange rate. Two major devaluations of baht currency in 1981 and 1984 coupled with fluctuation of some major currencies such as Yen and US dollars also significantly contribute to changes in import values*

b. *Consists of food crops, sugar products, cocoa and products, tea and coffee, spirits and beverages, oil seeds, vegetable oils, fibre crops, garden crops and products, fruits and products, other food products, tobacco, rubber and products, live animals, animal feeds, animal products, dairy products, fertilizers, pesticides, machineries and appliances for agricultural products*

c. *Consists of wood pulp, kraft paper, newsprint, printing and writing paper in rolls or sheets, corrugated cardboard, other paper and paper boards*

d. *Consists of hop cones and lupulin, medicinal plants, other vegetable products, lac and shellac, raw vegetable materials used primarily in dyeing or in tanning, tragacanth, arabic acid, agar-agar, vegetable saps and extracts.*

e. *Consists of fish (fresh, chilled, frozen), fish (live), fish (live for aquarium), cuttle fish (fresh, chilled, frozen), shrimps prawns, lobsters (fresh, chilled, frozen), fish (salted, in brine, dried), fish maws, cuttle fish (in brine, dried), shark fins (in brine, dried), ark-shells, (fresh, chilled, frozen) other crustaceans, fish and crustaceans preparation, fish (canned), products of crustaceans, shrimp paste, liver, fish oil and oyster sauce*

f. *Mainly consists of iron, copper, aluminium, chromite, titanium and antimony*

g. *Mainly consists of salt, sulphur, earths and stone, plastering materials, lime and cement*

h. *Consists of crude petroleum and shale oil imported for petroleum products refinery, does not include refined petroleum products*

Sources: *Office of Agricultural Economics, Ministry of Agriculture and Co-operatives Foreign Trade Statistics of Thailand, 1980-1985, Department of Customs, Ministry of Finance. Fishery Statistics Division, Department of Fisheries, Ministry of Agriculture and Co-operatives Mineral Statistics, 1985, Department of Mineral Resources, Ministry of Industry.*

Figure 13.6 Values of Natural Resource-Related Imports, 1980-1985

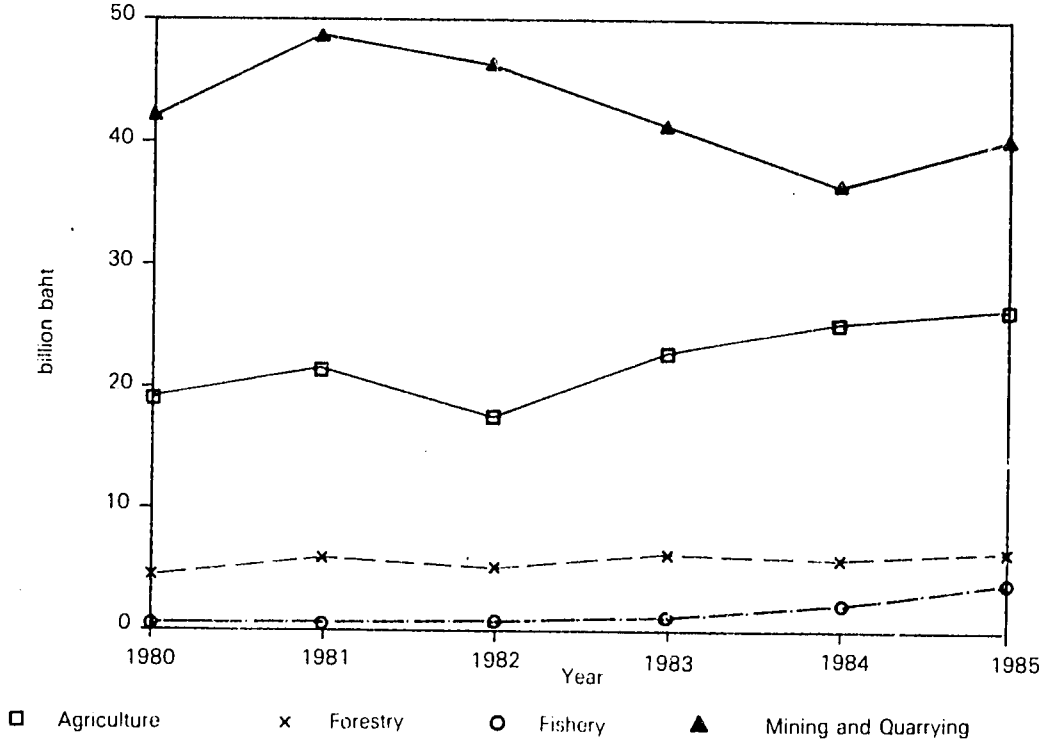


Figure 13.7 Percentage of Natural Resource-Related Imports, 1980-1985

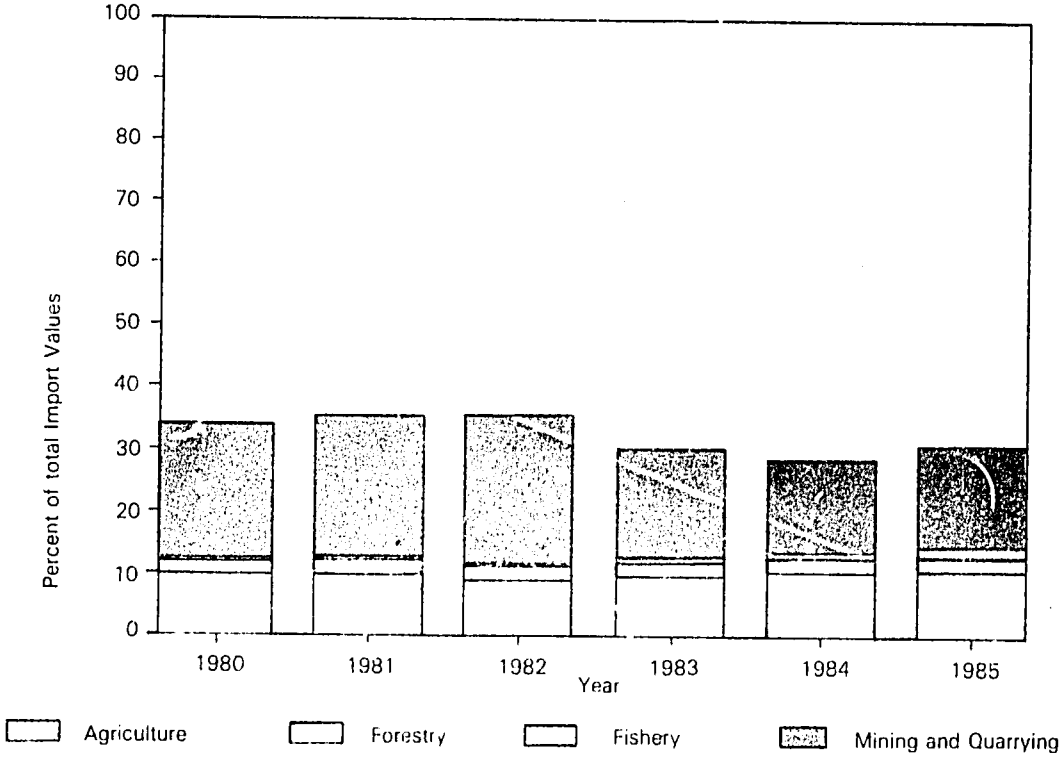


Table 13.4 Volume and Value of Natural Resource-Related Primary Products, 1980-1985

Products Year	1980		1981		1982		1983	
	Quantity	Value (million baht)	Quantity	Value (million baht)	Quantity	Value (million baht)	Quantity	Value (million baht)
Forestry (1,000 m³)								
teak	97	191	73	144	58	114	58	113
other timbers[a]	2,447	733	1,725	522	1,711	521	1,762	533
firewood and charcoal	870	76	900	79	1,198	105	1,064	93
Fishery (1,000 ton)								
marine fishery[b]	1,647	7,807	1,824	8,646	1,987	9,418	2,100	9,954
freshwater fishery[c]	145	1,360	165	1,548	134	1,257	155	1,454
Mining[d]								
tin (1,000 ton)	46	2,514	43	2,349	36	1,949	27	1,488
lignite (1,000 ton)	1,427	114	1,686	135	1,964	157	1,866	149
Crude Oil[e] (1,000 barrels)	na	na	na	na	na	na	2,218	94
natural gas[f] (1,000 MMSCF)	na	na	10.6	39	47.1	189	56.2	222
Condensates[f] (1,000 barrels)	na	na	576	30	2,026	108	2,268	125

na = not available

Notes: a. *Mainly consists of Yang, Teng and Rung, Takien, Daeng, Pluang, Pradu, Tabek and other kinds of timber. Production values of this sector were calculated by the NESDB based on average farm prices of 1972, except for firewood and charcoal, production values were based on market prices.*

b. *Includes marine prawns and shrimps. Production values of this sector were calculated based on average farm prices of 1972. Figures for 1985 were estimated by the NESDB.*

c. *Includes freshwater aquaculture. Production values of this sector were calculated based on average farm prices of 1972. Figures for 1985 were estimated by the NESDB.*

d. *Production values of this sector were calculated by the NESDB. For tin and lignite, production values were based on prices announced by the Department of Mineral Resources in 1972. For crude oil, natural gas and condensate, production values were based on well-head prices.*

e. *1972 prices of crude oil was calculated based on price index of arabian light imported crude oil.*

f. *1972 prices of natural gas and condensate were calculated based on the price index of liquefied petroleum gas (LPG). Natural gas production values are preliminariy figures from NESDB based on total production not sale volume.*

Sources: *National Accounts Division, NESDB; Forestry Statistics of Thailand, Royal Forest Department, Ministry of Agriculture and Co-operatives; Fishery Statistics Division, Department of Fisheries, Ministry of Agriculture and Co-operatives; Mineral Statistics of Thailand, Department of Mineral Resources, Ministry of Industry.*

rice and rubber. And it collects royalties on the production of energy minerals, such as natural gas and oil.

But recently, government revenues from the natural resource sector of the economy have weakened considerably. In 1980, the government earned export duty revenues of 3.4 billion baht, of which 2.4 billion baht (or some 70 percent) came from export duties on rubber. Its royalty income was 4.2 billion baht that year, of which 3.4 billion baht (or some 80 percent) came from tin concentrates. In 1985, by contrast, export duty revenues had dropped sharply to just one billion baht, less than a third of the 1980 figure, while the royalties received on tin concentrates had dropped to 1.2 billion baht – again less than a third of the 1980 figure.

In the energy sector, royalties on natural gas production rose from 422 million baht in 1983 to one billion baht in 1985, while those from condensate and crude oil rose from 340 million baht to 1.1 billion baht over the same period. But the most dramatic increase was in lignite royalties, which went from five million baht in 1980 to 104 million baht in 1985.

The point that should be made about these three, healthier sectors, however, is that they are all based on the exploitation of nonrenewable fossil energy resources. Efficient production may extend the life of these energy reserves, but ultimately they will be exhausted. We should be preparing for that day.

Wealth to Invest

In addition to their role in feeding, clothing and housing the population, Thailand's natural resources have also produced wealth needed to provide the capital for starting up new ventures in other sectors of the economy. Successful trading firms in the rice, teak, rubber and tin markets have often evolved into finance, banking and general trading groups.

The Siam Commercial Bank, founded in 1906, was the first modern Thai bank, and was capitalized by wealth derived from agricultural and other natural resources. Five major banks -- the Provincial Bank, Bangkok Bank of Commerce, Bangkok Bank, Bank of Ayutthaya, and the Thai Farmer's Bank -- were founded between 1942 and 1945 by different family groups, whose fortunes were derived from trading and manufacturing activities in the agricultural and mineral sectors. In this sense, logs, rice, tin, sugar and gunny sacks were the building blocks of Thailand's modern economy. These new ventures, in turn, made possible additional large-scale ventures in agribusiness and agro-industry, as well as in the wider manufacturing and service sectors.

1984		1985		1985 (current prices)
Quantity	Value (million baht)	Quantity	Value (million baht)	Value (million baht)
48	94	39	80	272
1,984	581	1,844	571	2,238
1,255	110	1,055	92	470
1,973	9,352	2,042	9,679	23,672
162	1,520	168	1,576	5,350
30	1,639	23	1,259	5,290
2,337	187	5,146	412	2,552
5,100	204	7,587	321	5,225
85.5	329	132.3	493	8,368
3,008	158	5,202	269	3,841

Clearly, the agricultural and mining industries are to be congratulated on their contributions to Thailand's economic growth, but later sections raise the question whether these achievements too often have been bought by an excessive exploitation of key natural resources. The evidence that we are seeing significant degradation of our land, forest, water and fishery resources is now overwhelming.

An Exploding Workforce

The trends in population growth, together with the changing age structure of Thailand's population, pose a number of difficult problems. For one thing, the number of people of working age has been growing much faster than the population as a whole. The number of Thais aged between 15 and 59 grew from 52 percent in 1960 to 56 percent in 1980, and is projected to reach 65 percent in the year 2000. But what does this mean in terms of absolute numbers? It has meant a doubling of the working-age population from 13.6 to 26.1 million between 1960 and 1980, and it will mean that there will probably prove to have been an overall tripling between 1960 and 2000. The beginning of stabilization cannot be expected until after 2010, and the working-age population may remain at about 68 percent of the total population for some time.

So, that is the supply side of the equation; what about the demand for labour? The evidence suggests that the Thai economy has done fairly well so far in absorbing and employing this doubled workforce. Employment in the urban and industrial sectors has expanded considerably, reaching an estimated 7.4 million jobs by 1985, with a projected expansion to 12 million jobs by 2000. The overwhelming bulk of the employable population, however, is employed in the agricultural sector, as indicated in Table 13.5. Figure 13.8 shows dry season and harvest season employment in a number of natural resource-related industries. Not surprisingly, there is a significant shift in the structure of employment in the agricultural economy between the two seasons.

Longer term, however, it looks as though the agricultural sectors of the economy are going to be faced with the prospect of having to more than double the number of people they employ. Already, the number of people seeking employment in these sectors, coupled with their relatively low-value output per capita, is aggravating the per capita income gap between the agricultural and nonagricultural sectors.

The real test will clearly come when the second and third waves of new working-age Thais start to look for work. It is projected that over 7.6 million more will be looking for work between 1980 and 1990, a further eight million between 1990 and 2000, and 6.3 million more between 2000 and 2010. These extraordinary statistics sum up one of the most important challenges which Thailand will face in the waning years of the twentieth century and beyond.

Natural Resources Mismanagement

Faced with ever-keener competition for jobs and for space to live, work and relax, Thais are beginning to confront a number of questions which hitherto seemed comfortably remote. There is a feeling that many economic development projects have paid too little attention to the long-term sustainability of their natural resource base; that laws and regulations have sometimes been weighted in favor of the unscrupulous, rather than the conscientious; and that a fair distribution of the wealth derived from Thailand's natural resources is as distant a prospect as ever.

Malpractices are certainly prevalent in some areas, reducing the potential wealth to be derived from natural resources. In the mining industry, for example, the encroachment of outsiders upon the extraction rights granted to legal concession holders was discussed in Chapter 6. Instances of this problem have been reported from Phangnga, in offshore tin mining; from Doi Ngom and Khao Soon, in wolfram ore mining; from Doi Mok, in scheelite ore mining; and from Chonburi, in antimony ore mining. The mob mining scene in some of these areas does not ensure equity of wealth distribution, but shortchanges the nation, in terms of lost royalties and other government revenues, and the reduced maximum ore recovery from affected concessions.

In the forestry industry, encroachment and poaching are very much the order of the day; even the national parks and wildlife refuges are not immune. In some areas, the thinking has changed from maximum sustainable yield to last-ditch protection. National policy calls for the preservation of 40 percent of Thailand's surface area under forest cover, yet the latest data show that only 29 percent remains under forest – and the downward trend seems set to continue. At the current rate of progress in reforestation, as Chapter 4 pointed out, making good that missing 11 percent of forest cover, which would involve rehabilitating over 35 million rai of deforested land, will take well over 115 years, always assuming that today's deforestation can be stopped in the meantime.

Table 13.5 Estimated Seasonal Employment in Natural Resource-Related Industries[a], 1980-1985

(persons)

Sector	1980		1981		1982		1983	
	Dry Season[b]	Harvest Season[b]	Dry Season	Harvest Season	Dry Season	Harvest Season	Dry Season	Harvest Season
Agriculture[c]	na	15,821,699	8,929,087	17,421,486	9,188,118	17,070,044	11,000,996	17,059,988
Forestry and Related Industries	na	378,699	615,290	398,608	772,825	442,568	763,555	342,429
- Forestry and Logging[d]	na	61,117	166,828	59,410	322,419	111,338	246,709	69,191
- Wood Industry[e]	na	282,059	424,516	312,639	422,045	297,647	483,162	231,577
- Pulp and Paper Industry[f]	na	35,523	23,946	26,559	28,361	33,583	33,684	41,661
Fishery and Related Industries	na	227,285	353,363	360,798	313,012	295,080	326,644	307,028
- Fishery[g]	na	199,023	305,462	314,062	272,706	238,432	274,507	262,433
- Fishery Product Industry[h]	na	28,262	47,901	46,736	40,306	56,648	52,137	44,595
Mining and Quarrying	na	35,598	74,252	61,021	101,493	64,672	69 145	50,836

na = not available

Notes:
a. Employment figures presented above refer to numbers of employed persons defined in the labor force survey as follows: Persons 11 years of age and over who during the survey week
1) worked for at least one hour for any kind of payment
2) had regular job (including those who had job but were temporarily absent).
b. Seasons are dry season (January to March) and harvest season (July to September).
c. Employment in the agricultural sector refers to those engaged in farm and animal husbandry including agricultural services but excluding fishery and forestry activities.
d. Employment in the forestry sector refers to those engaged in forest plantation, logging operation and wildlife capture.
e. Employment in the wood industry refers to those engaged in the sawmill industry and the manufacturing of wood and wood products such as plywood, veneer and furniture.
f. Employment in the pulp and paper industry refers to those engaged in the manufacturing of pulp and paper products such as kraft paper, sanitary paper, printing paper including paperboard, paper boxes and paper houseware.
g. Employment in the fishery sector refers to those engaged in inland, marine fisheries and aquaculture.
h. Employment in the fish product industry refers to those engaged in the manufacturing of fish products such as seafood canning and frozen seafood production.
i. Employment in the mining and quarrying sector refers to those engaged in mining and quarry operations including oil and natural gas exploration and drilling.

Source: Unpublished TDRI data based on Labor Force Survey statistics (1980-1985), the National Statistical Office.

In the Gulf of Thailand, too, the maximum sustainable yield (MSY) of major fisheries is clearly being exceeded, as we saw in Chapter 8. The MSY is being exceeded by 50 percent in some demersal and pelagic fisheries. Illegal fishery practices, including fishing out-of-season, in off-limits protected areas or with destructive methods, combine with the destruction of mangrove ecosystems and increasing pollution to threaten commercially important fish stocks. Pollution in the upper Gulf has crippled important mariculture operations: the production of bivalves by upper Gulf mariculture was cut by two-thirds between 1977 and 1983.

Inevitably, the rules and regulations designed to ensure the proper management of fishery resources, however well intentioned, will fail unless they have the active support of those who do the fishing. If they cannot be persuaded that today's over-fishing undermines tomorrow's yields, the yields on which their own children will depend, then there is little hope of arresting the process of decline.

Ultimately, Thais may have to accept that highly valued foods like fish roes and sea-turtle eggs, will have to be dropped from the menu, to ensure that future generations may harvest these species for food.

As far as our renewable land resources are concerned, as Chapter 2 explained, too many upland farmers are ignorant of - or ignore - the need for soil conservation. The loss of topsoil and the decline in soil productivity are real growing threats to our future security. Whereas slash-and-burn agriculture was once more closely attuned with the ecosystems exploited, it now causes untold ecological damages. In part this is because hill tribe and other upland farmers believe that they are immune from prosecution under the forest laws if no trees are left standing on the land they have cleared. The result is that natural regeneration is slowed, if it happens at all.

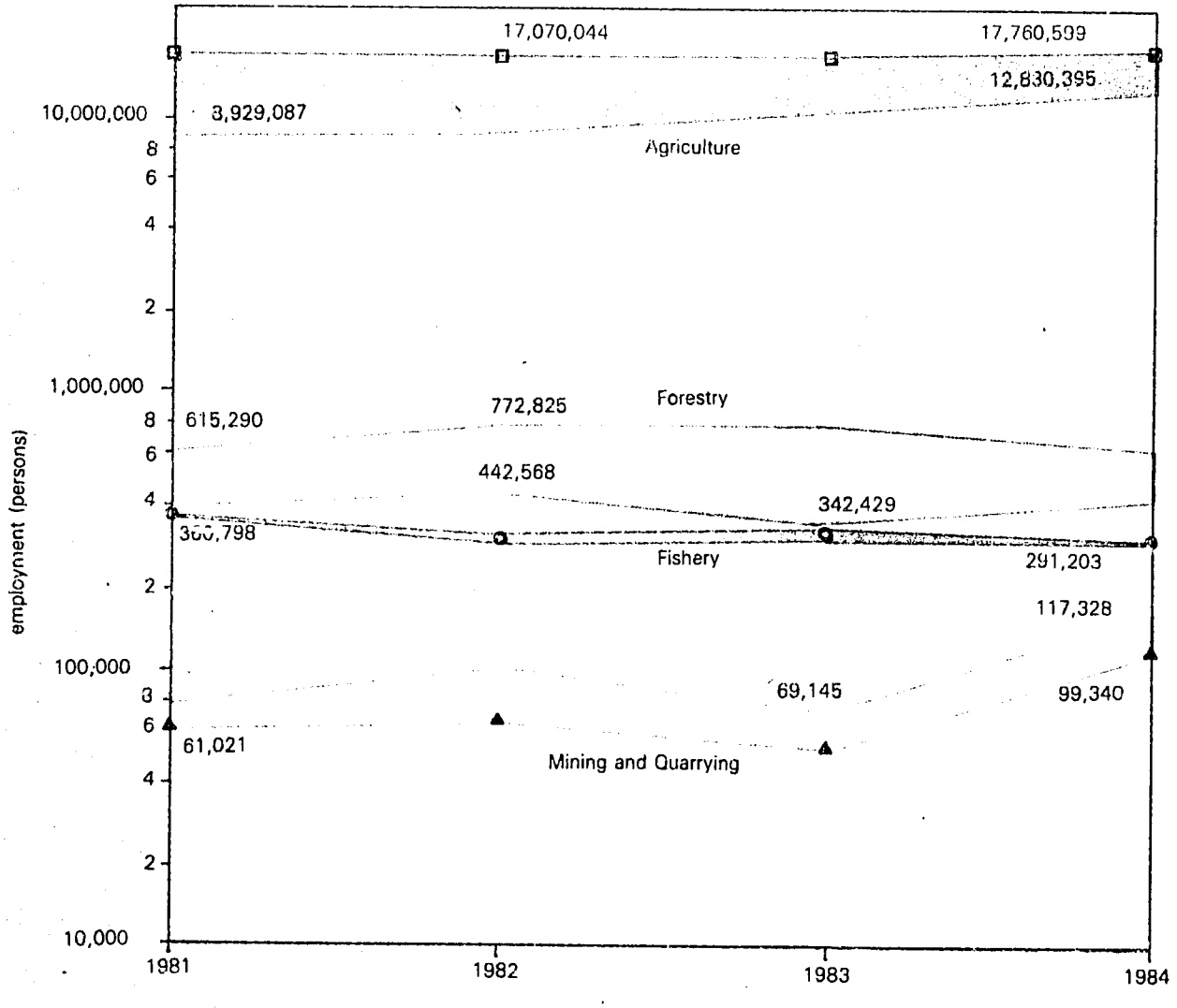
In the process, major watersheds are being denuded, with increasing silt loads washed down into the nation's rivers, silting up dams and causing extensive downstream flooding. Meanwhile, as Chapter 3 notes, the mistaken idea that abundant, clean water is a free resource still persists, discouraging investment in water-efficiency technologies and practices.

1984		1985	
Dry Season	Harvest Season	Dry Season	Harvest Season
12,936,857	17,760,599	12,850,395	na
622,567	426,128	733,316	na
193,059	109,673	257,520	na
404,583	291,377	448,950	na
24,925	25,078	26,846	na
291,203	296,358	301,303	na
255,308	257,921	269,018	na
35,895	38,437	32,285	na
160,235	117,328	99,340	na

The more water is used in Bangkok, where the rate of groundwater extraction is thought to exceed the safe limit by some 60 percent, the faster the nation's capital will sink. The more water we waste, the more areas have to be flooded by new dams, if suitable sites can be found (see Box 3.3). The more water we pollute, like the Chao Phraya with just one part million of dissolved oxygen left in low water conditions, the more we have to pay for water treatment chemicals to ensure a safe drinking water supply.

And who pays for all this? Make no mistake, we do. It is not just a question of having to put up with more noise as our cities and road traffic grow, with deteriorating air and water quality, or unsafe working conditions. There is a still more fundamental question that needs to be addressed: are we undermining the natural resource base in such a way that, at the very time when there is a growing population to feed, clothe, house and employ, the natural resource base which should sustain them will be becoming less—rather than more—productive?

Figure 13.8 Estimated Employment during Dry and Harvest Seasons in Natural-Resource-Related Industries, 1981-1985



Shortchanging Sustainability

The revenues generated by the exploitation of Thailand's natural resources are urgently needed, of course, but who bothers to cost the revenues foregone because of the short-sighted mismanagement of key resources? Clearly, some such work is done, but in a patchy, uncoordinated fashion. In the case of mining royalties, a proportion has been put aside to ensure land rehabilitation once the productive life of a mine is over. But no-one really knows how much such rehabilitation is going to cost, or whether sufficient funding will be available.

Take another example. Thermal power generation consumes oil, natural gas or lignite. The cost of oil and gas includes the full royalties and/or taxes paid to the Treasury, whereas the cost of lignite includes only the relevant royalties, not the full taxes, based on tons-of-oil-equivalent (TOE), which would ensure a fair basis for energy pricing. Hydropower generation, meanwhile, enjoys the lowest cost per kilowatt-hour, due both to heavy public sector investment and the fact that water resources are free. Rather than passing those savings directly on to the electricity consumer, should we not adopt a fair pricing approach across the board, designed to ensure a careful balancing of demand with appropriate supply –and the rehabilitation of areas damaged in the process of energy production?

Again, if we consider what is happening in the agricultural sector, the evidence suggests that rice farmers are effectively subsidizing the consumer. Their nationwide, inclusive costs of production of 2,972 to 3,287 baht/ton of paddy, as calculated by the Office of Agricultural Economics (OAE), were generally above the farmgate paddy price. Some farmers certainly make a profit, but according to a study by Chulalongkorn University's Social Research Institute (CUSRI) the actual net gain is often less than it appears, when interest on loans is taken into account. A profit is generally expected from export sales of rice, but this is not shared by the farmer. The converse is true with the sugarcane and sugar industries, where the domestic consumer subsidizes exports by paying roughly three times the world market price for sugar. Even so, small-holders selling sugarcane to sugar factories often do so at an effective loss.

Similarly, pararubber producers operating under the small plantation system, with 20 rai or so of traditional varieties, may gross an average family income of some 1,200 baht a month, but their net income, according to CUSRI, will be about two-thirds of that, once all their costs are taken into account. The huge amount of value eventually added to rubber as it moves through the production chain does not filter down to the smallholders.

The implication throughout is that small farmers will not be able to spare the resources needed for soil and water conservation. The way in which the production and trading systems have evolved legislates against the thinking and investment needed to ensure the sustainable development of key natural resources.

A Legal Straitjacket?

While the nation's lawyers cannot single-handedly solve our problems, legislation is an essential tool in environmental protection and the drive for sustainable development. However, as earlier chapters have shown, the evolution of Thailand's legal framework is lagging behind current needs.

As far as the management of land-based resources is concerned, there are 11 laws currently in force. The oldest of them is the Forestry Act of 1941, while the most recent at the time of writing is the Land Development Act of 1983. In addition, there are a number of other legal instruments governing land administration, including Revolutionary Party orders, Cabinet resolutions and Royal decrees. A total of 24 agencies, operating under six ministries, are involved. Confusion, not surprisingly, is often the order of the day. This leads to delays and to inequities, particularly in terms of the widely different land title documents that participants in different government-backed programs receive from the respective agencies.

At the other end of the spectrum, in the water resource management field, there is no direct legislation and no master plan, either. There are five laws that touch on, or are related to, surface water management, however, the oldest being the People's Irrigation Act of 1941. None of these laws specifies the rights and duties of water users, a glaring and increasingly problematic omission. There is a single law on groundwater, the Groundwater Act of 1977. There are 31 agencies and 17 committees involved in the development of Thailand's water resources, a state of affairs which effectively precludes the development of the sound, multipurpose projects which are so badly needed.

What all this suggests is that legislation is as often serving to impede progress as to drive it forward. No-one doubts, for example, that reforestation, watershed management and improved forestry practices are needed, but the 1941 Forestry Act seems to be operating as a legal straitjacket. Too often, whether one thinks of programs designed to protect mangroves, fisheries or mineral deposits, innovative approaches are being stalled by antiquated legislation. This whole area is in need of urgent review.

Competing Priorities and Responsibilities

Thailand's administrative structure and procedures could scarcely be better designed to impede progress in areas which, like natural resource management, demand an integrated approach. All the agencies whose activities are described in earlier sections of this Profile set out with the best of intentions, but their efforts are ultimately overwhelmed by the sheer number of policy bodies and executing units which have to be involved. The problem is further aggravated by the fact that, while there is now a National Forest Policy, there are no coordinated central policy guidelines covering other critical areas, such as land and water resources.

Each agency operates under its own mandate and with its own legal backstops. Each develops its own mission and sets its own yardsticks for rating achievement. So a situation develops where one agency gives away land free to illegal squatters, who qualify because they committed a breach of the law in the first place, while another insists that law-abiding citizens take up their land allocations on the basis of purchase, hire-purchase or rent. Both agencies can claim that they are fulfilling their mandated missions, and both can claim success, in their own terms, at the end of the day. Overall, however, the result is less than satisfactory.

Interagency disputes waste time and other resources. Of course, a dynamic individual or group of individuals can push a project ahead, even within the current administrative structures, but the waste of effort involved is generally prodigious. The only real way forward when dealing with such interrelated problems must be the formulation of coherent, integrated policy guidelines, carried through into a series of master plans targeted on particular resources. Table 13.6 and Figure 13.9 shows that seven percent of the 1986 national budget was devoted to environmental protection and natural resource development. While more money is always welcome, the evidence suggests that more could be done to ensure that the budget that has already been allocated is used efficiently and to the best effect.

13.2 THE AGENDA FOR ACTION

Previous chapters of this Profile have demonstrated that concerted action is now needed to ensure that future economic development does not unwittingly erode its own natural resource foundations. Sustainable development, which integrates economic and social objectives with a sound approach to the management of renewable and nonrenewable natural resources, is the key to ensuring a better quality of life for the country's growing population.

But, if we are to come to grips with the many complex and interrelated problems and issues discussed earlier, we need to develop a strategic perspective. The process of agenda-setting, the allocation of responsibilities, the drawing up of budgets, the design of programs and projects, and the whole process of implementation must be informed and shaped by a wide-angle vision of the country's natural resource problems and opportunities which we hope that this Profile begins to provide. In the process of preparing the Profile, a number of conclusions have emerged about what needs to happen next. These are summarized below.

Figure 13.9 Allocation of the 1986 National Budget for Natural Resource and Environment-Related Agencies

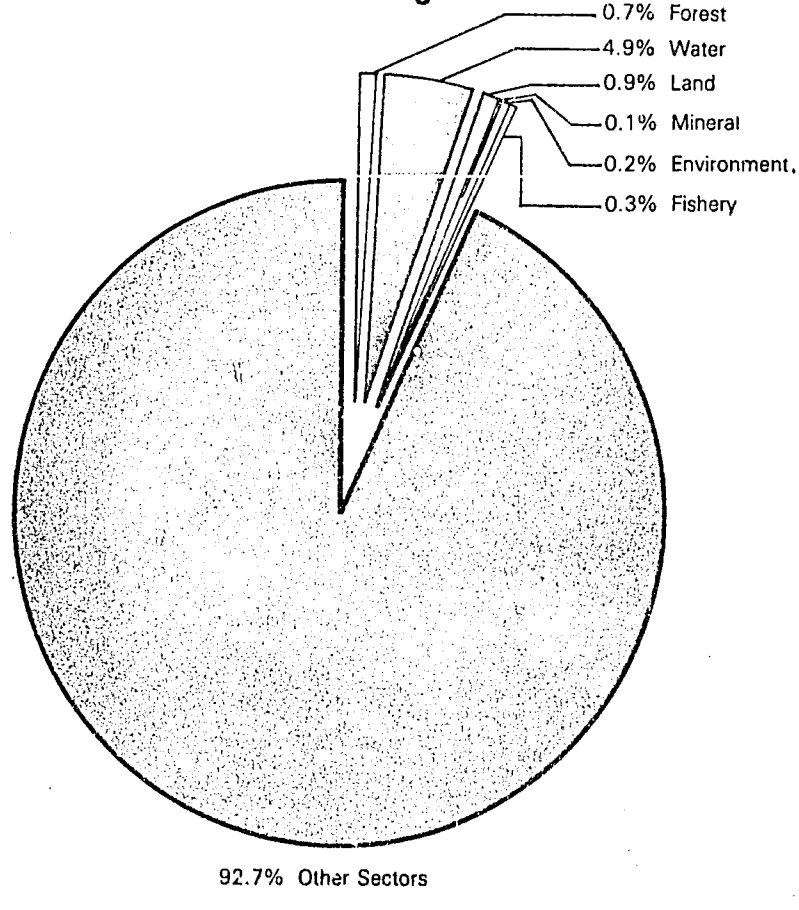


Table 13.6 Allocation of the 1986 National Budget for Natural Resource and Environment—Related Agencies[a]

Sector/Program/Project	Responsible Agency	National Budget (1986) (baht)
Land Resource		
1) Program to improve efficiency in land use	LDD, ALRO, RFD, DOL, Office of the Permanent Secretary (MOAC), TISTR	1,396,849,000
2) General administration for land right protection	DOL	36,136,000
3) Land administration sub-program	DOL	610,803,900
Land Resource Subtotal		**2,043,789,700**
Water Resource		
1) Water resource development for agriculture		
1.1) Administration of water resource development for agriculture program	The Secretariate of the Prime Minister, RID	2,544,350,200
1.2) Water resource for agriculture program	RID	7,049,729,000
2) Water transportation		
2.1) Administration of water transportation program	HD, MPC	81,559,900
2.2) Local water transportation development program	HD	212,659,600
2.3) Coastal transportation development program	HD	120,758,100
2.4) International sea transportation and mercantile marine promotion program	HD	136,610,600
3) Water resource for hydroelectric power generation	NEA	450,627,100
Water Resource Subtotal		**10,596,294,500**
Forest Resource		
1) Forestry administration program	RFD	361,665,500
2) Forestry research program	RFD	86,040,100
3) Forest conservation program	RFD	922,385,900
4) Hilltribes development program	DPW, PD	118,964,100
Forest Resource Subtotal		**1,489,055,600**
Fishery Resource		
1) Fishery administration program	DOF	116,772,300
2) Fishery research program	DOF	82,712,600
3) Fishery promotion program	DOF	494,048,400
4) Fishery resource conservation program	DOF	26,799,000
Fishery Resource Subtotal		**720,332,300**

Table 13.6 (contd.)

Sector/Program/Project	Responsible Agency	National Budget (1986) (baht)
Mineral Resource		
1) Mineral resource administration program	DMR	117,858,500
2) Basic geological survey program	DMR	80,370,500
3) Detailed geological survey for mineral resource development program	DMR	40,943,900
4) Development and promotion of mineral production program	DMR	40,254,200
Mineral Resource Subtotal		**279,427,100**
Environment		
1) Administration of environment development program	ONEB	21,760,100
2) Environmental quality control program	ONEB, DMR	25,446,100
3) Pollution control program	ONEB, DIW	26,400,300
4) Study on human settlement program	ONEB	2,358,100
5) Borrowed fund for Songkhla Lake Basin development project	ONEB	5,156,500
6) Sanitary program	DOH	185,601,100
7) Occupational health program	DOH	5,722,800
8) Conservation of national heritage sub-program	DFA	158,516,800
Environmental administration and development subtotal		**430,961,800**
Natural resource and environmental administration and development subtotal		**15,559,861,500**
Total		**218,000,000,000**
% of total 1986 national budget		**7.1%**

Note: a. *National budget for natural resource and environment figures was compiled based only on expenditure budget as classified by programs.*

Source: *Budget document No. 5: Expenditure Budget as Classified by Programs in budget year of 1986, The Budget Bureau.*

Natural Resource Master Plans

A more coherent, coordinated approach is clearly needed in the management of Thailand's natural resources and environment. It is probably too early to prepare a single, integrated master plan for all natural resources, but a set of master plans could be assembled, covering such critical areas as land use, water resource development, forest management, fisheries management, mineral resource development, and wildlife conservation. Each master plan should provide a proper framework for the various agencies working in the field, or in related fields.

The National Economic and Social Development Plan is already moving in this direction, and this process should be accelerated. Long-range, resource-specific master plans would feed into later versions of the Plan, but, as an insurance policy, a master plan for integrated natural resources and environmental management will be prepared concurrently.

The national plan on hydrology, currently being prepared, will throw up important lessons for other planning exercises. Reliable data are essential, and improved data collection procedures are a priority need. With numerous agencies likely to be involved in implementing such plans, most of them having limited resources, it is essential that areas of responsibility are made explicit from the outset. By encouraging long-term thinking, such plans can ensure that critical constraints do not come as a surprise. But, since surprise is almost guaranteed in this fast-moving world, such plans should also be flexible and interactive, so that they can respond to unforeseen circumstances.

The forest resource master plan already exists in embryo, with the new national forest policy. The supporting legal framework and detailed action plan are not yet in place, but a momentum is building. Areas suitable for the 15 percent protected forest and 25 percent managed forest must be identified and focused follow-up programs designed and implemented.

Land use and soil conservation, interlinked with water and forestry issues, represent the next urgent master plan priority. The plan must address outstanding questions about land classification, land rights, land allocation, land valuation and land use planning. Here, too, the legal framework must be disentangled and updated if the master plan is to have a real chance of getting to the roots of key problems.

Administrative Streamlining

Ultimately, even the best laid plans need to be implemented. A great deal can be done by ensuring closer working relationships between existing ministries and agencies. Lip-service is paid to the notion of multi-agency, multidisciplinary approaches, but while the idea of the four- or five-ministry action team is an attractive one, the reality is that the necessary integration is rarely achieved. Different agencies pursue their independent lines within the new context.

Therefore, the conclusion must be that key ministries and agencies will have to be restructured to ensure the necessary integration. This streamlining process will need to extend right down to the local level, which ultimately is the most important level of all. Most authorities and officials at this level are keen to achieve progress for the areas and populations within their jurisdiction. But their efforts will generally be more effective if their responsibilities are carefully defined, clear lines of communication established, and effective monitoring and accounting procedures are adopted. Pre-program budgeting can also help direct local efforts in appropriate directions, although the current system is in need of an overhaul.

Given that public participation is likely to be a critical factor determining the success or failure of such programs, a complementary approach may be to delegate more responsibility to the provincial level, with the requisite authority and funding. If all agencies investing or operating in a particular province were to coordinate their inputs in a single development package, the impact could be considerable.

An Area Focus

Past experience has shown that available resources can be most effectively deployed when the various agencies involved adopt an integrated, area-wide approach to a particular task. This is as likely to be effective in the field of sustainable development as in any other. This approach, as a minimum, should be adopted in the management of the resources briefly highlighted below. It is perhaps worth noting, however, that flexibility is likely to be a key factor when identifying the areas to be covered in such integrated program planning.

Coastal zone and marine resources

Many different interests share -- and compete for -- the coastal zone, including marine life spawning and nursery grounds, wood and charcoal production, brackish water aquaculture, tourism, mining, port and harbor development, road and rail networks, housing and agricultural land conversion. A collapse of the mangrove, for whatever reason, can destroy the delicate nutrient balance over wide areas, adversely affecting catches of important marine species.

While it would be inappropriate to declare a complete embargo on human activities in such areas, special management packages are undoubtedly needed to ensure that this zone can serve its multiple functions on a sustained basis. Sub-zones for development and conservation will need to be identified, an activity which will itself need careful planning and management.

Protected areas

There are many different types of protected area in Thailand, including watershed areas, national parks, protected forests and wildlife reserves. The highlands represent a critical watershed area for the whole country. Watersheds typically cover the broadest range of land types, from very steep slopes at higher elevations, where no settler is allowed, down to the flat terrain found at low elevations, where no restrictions are imposed.

The top watershed classes, Classes 1A and 1B, are in a specially protected category. Next comes Class 2, which is partly protected, but where commercial forestry is permitted. Classes 3 and 4 do not qualify for full protection, but specify the types of trees and crops which can be grown, and the conservation measures to be employed. The protected forests, whether they be parks or reserves, are defined by their legal boundaries.

Carefully integrated planning and management programs are a priority in these specially protected areas, with effective measures needed to deal with the problems of squatters and encroachment. Special consideration will also need to be given to long-established squatters and to the reforestation of areas which have already been cleared.

Irrigated areas

The country's comparatively small total area of irrigated land holds the potential for intensive production regimes, because of the availability and controllability of water supplies. There are a number of other factors which can affect agricultural production in such areas, however, with many water supply schemes increasingly needing to serve a number of purposes simultaneously. These might include irrigation, flood control and hydropower generation, for example. To accommodate these various uses, and their likely development over time, a comprehensive approach is needed, preferably focusing on the water basin as a whole.

Rainfed agricultural areas

Rainfed areas represent the overwhelming bulk of land currently under production and support the majority of the rural population. They share common requirements as far as their requirements for technological improvements, and land and water conservation measures, are concerned. Each region, even each sub-region, will need to meet its own specific requirements in its own way.

In these circumstances, it would clearly be advisable to tailor development plans to sub-regions having similar general features of physiography, climate and cultural background. The development package could then address all the major concerns identified by the government, including soils and water conservation, social forestry schemes, human resource development, and area-integrated agrobusiness and agro-industry projects.

Economic forestry lands

The forest lands falling under this crlassification include the commercial forest, the community forests and land to be returned to forest. Many of these forests are in watershed areas where economic forestry activities are permitted, within guidelines laid down by the Royal Forest Department. The commercial forest is destined for privatization, posing several knotty issues which will need to be resolved. The community forest, meanwhile, holds real promise in the reforestation of denuded watersheds.

Many of these areas, however, are coming under intense pressure from the activity of illegal squatters, illegal loggers, and shifting cultivators, Thai and non-Thai alike. To effectively address such a spectrum of pressures, broad-based management packages are, once again, urgently required.

Area-oriented integrated program planning has a great deal to offer in all the areas described above. But they should not be considered as a totally inclusive list. As our knowledge base grows, so new resource development areas will emerge as suitable candidates for this sort of approach.

Keeping the Public Informed

Public interest in environmental and natural resource management issues fluctuates considerably, although environmental awareness is much higher today than it was in the 1960s or even the 1970s. Periodically, however, an issue inflames public emotions, creating a frenzy of interest and concern. Recent examples in Thailand have included the tantalum riot in Phuket, described in Chapter 12, and the cable-car controversy at Doi Suthep, near Chiang Mai (see Chapter 5).

In both cases, the proponents of development were challenged by local conservationists and found themselves in the unfamiliar position of having to justify their plans not simply to bankers and government officials, but to the wider public as well. Experience in other countries suggests that this trend will probably strengthen. As population pressures build, the potential for environmental conflict becomes increasingly pronounced. The Nam Choan Dam project, also described in Chapter 5, shows how national and international concern about an issue, in this case the integrity of the world's tropical rain forests, can translate into local controversy.

Inevitably, however, while the public's conscience may be stirred on some issues, it is remarkably quiescent on others. One example might be the pollution of Thailand's premier river, the Chao Phraya. The canals of Bangkok (and many other cities) are now de facto open sewers, with only two percent of Bangkok's inhabitants connected to a sewerage system. Another example of an issue which has not yet had the attention it perhaps deserves is accident prevention of hazardous industrial plants, described in Chapter 12.

Without well-planned public education programs, a great deal of government money could be wasted on projects designed, for example, to clean up the Chao Phraya, slow the salinization of agricultural soils, protect major fisheries, or improve working conditions. All important objectives, of course, but in each of these areas, public support will be necessary to implement the solutions proposed in the respective master (and local action) plans.

Big budget public awareness campaigns have their place, of course, but low-key, sustained educational programs are likely to be at least as effective. Existing community leaders are often the best channel of communication in the vast rural sector, if they can be convinced that the programs directly relate to the future health, wealth and welfare of their people. They should be provided with the information and other resources needed to ensure that the message is communicated effectively – and continuously reinforced though an in tegrated information delivery approach.

Human Resource Development

People are the key to sustainable development. To ensure that their enthusiasm, commitment and ingenuity are harnessed, we need to capitalize on Thailand's healthy regionalism, ensuring that development planning is closely integrated with local priorities and resources. Sustainable development programs should be viewed not simply as a means for achieving environmentally sound economic development, but also as a means for achieving the strengthening of local communities and the upgrading of their skills-base and other *human* resources.

People want to improve their living standards, not undermine them. They must be shown how. Wherever possible, national programs should be brought into sharp focus, area by area. The active support of local community leaders, development workers, extension officers, teachers, nurses, housewives and youth leaders must be recruited. The effort required to mount this sort of program is clearly greater than that needed to issue a set of national guidelines, but the ultimate return on the investment of time and energy is likely to be that much greater.

Ultimately, the sustainable development of Thailand's natural resources is designed to insure that all Thais have a reasonable future to look forward to. Lowland farmers need to be assured that the destruction of watershed areas is not going to lead to extensive flood damage to their land and crops; fishing communities must see that the destruction of the mangroves, and of the fish nurseries which they sustain, is being brought under control; and communities living in or near forest reserves must be convinced that they have a real stake in the long-term survival of the forest ecosystem. Everyone must feel that miscreants will not go unscathed, whether they are dynamiting coral reefs, clearing unsuitable highland areas for opium poppy cultivation, or dumping toxic chemicals in the nation's rivers.

A Sustainable Future

Despite its acknowledged problems, then, Thailand has a real opportunity to pioneer in the emerging field of sustainable development. Much of the groundwork has already been laid, even though the country's legal and administrative framework cannot yet exploit the full potential of the investments already made.

Previous chapters have already highlighted some of the early examples of integrated planning. The Ministry of Industry, for example, helped establish centralized effluent treatment facilities for sugar mills on the Maeklong, as described in Chapter 10, and is now seeking to establish centralized treatment facilities for industrial waste generators in several areas of the Bangkok Metropolis, as described in Chapter 11.

Investment in cleaner and more resource-efficient technology need not represent a drain on the economy. Instead, the process of innovation can lead to unexpected improvements in the productivity, efficiency and competitiveness of industrial firms. Government can play an important role in this process, using tax incentives to promote the adoption of water-efficient practices by farmers (Chapter 3), for example, or to spur investment in appropriate technologies, whether in the form of tamper-proof motorcycle exhaust systems (Chapter 9) or improved biogas plants for use in rural areas (Chapter 10).

As the pace of development becomes more intense, and the implications of getting major decisions wrong become more serious, the importance of careful planning increases. Proper planning for major hazard or highly polluting industries, for example, will help minimize the risk of a Thai version of Bhopal, and also help identify cost-saving opportunities for centralized waste treatment

A country like Thailand, while it cannot afford disasters, is also hard pressed to find the resources to enforce the legislation already enacted. Wherever possible, then, every effort should be expended to ensure that potential future problems are identified and prevented at an early stage, rather than having to be cured later on by add-on technology, increased surveillance and politically sensitive enforcement actions. The introduction of the requirement for pre-project environmental impact assessments (EIAs) was a welcome step in this direction.

Whether it comes in the form of EIAs, natural resource profiles or computerized databanks, information will inevitably be a critical resource in the transition to more sustainable forms of development. Management proficiency will be a key factor in ensuring the success of the proposed programs and projects, and effective management depends on the ready availability of accurate, up-to-date information. Although this Profile has highlighted some of the most important links between the many areas which it has covered, it remains essentially a snapshot of the natural resource base of Thailand. A useful first step, certainly, but the next step must be to move towards an integrated, interactive national database on natural resources and the environment.

New developments in the field of geographic information system permit just such an approach. Many different kinds of data - from map data through to remote sensing data from the LANDSAT or SPOT Image satellites - can be assembled onto a common grid, and computers can begin to trace and analyze the web of interactions between, for example, forests and other natural resources, or superimpose the types of land title held in various areas on a map of the areas targeted for the 15 percent conservation forest - or the 25 percent productive forest.

Clearly, if such systems are to achieve their full potential, they must have access to the latest data on all the relevant areas, whether on land classoification and soil types, forest coverage, surface water status, groundwater status, the yield trends for key fisheries, and mineral reserves, or on the various schemes proposed by the private and public sectors in sensitive areas.

In a world where different agencies see themselves in competition for resources and influence, information is seen as power. To begin with, it may be difficult to persuade them to share the information they have and to coordinate the data they collect in future. But, in the final analysis, the wise use of information is the only guarantee of the survival of a thriving, independent Thailand, able to meet the increasing needs of its growing population. Where there is a will to succeed in sustainable development, there will be a way. Where there is no such will, many options will be foreclosed. The choice is still ours to make.

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