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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

DEPARTMENT OF PUBLIC WORKS AND TRANSPORT
MUNICIPALITY OF PHNOM PENH
THE KINGDOM OF CAMBODIA

THE STUDY ON DRAINAGE IMPROVEMENT AND FLOOD CONTROL IN THE MUNICIPALITY OF PHNOM PENH

FINAL REPORT

VOLUME 2

MAIN REPORT

AUGUST 1999

CTI ENGINEERING INTERNATIONAL CO., LTD.
NIPPON KOEI CO., LTD.

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SSS
JR
99-115

ESTIMATE OF PROJECT COST

Price Level : As of July 1998
Exchange Rate : US$ 1.00 = Yen 138 = Riel 3,880

PREFACE

In response to a request from the Government of the Kingdom of Cambodia, the Government of Japan decided to conduct the Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Kingdom of Cambodia a study team headed by Mr. Keiji Sasabe, CTI Engineering International Co., Ltd. and constituted by members of CTI Engineering International Co., Ltd. and Nippon Koei Co., Ltd., four times between February 1998 and August 1999.

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

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

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

August 1999

Kimio Fujita
President
Japan International Cooperation Agency

August, 1999

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

Letter of Transmittal

We are pleased to submit to you the final report on the Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh in the Kingdom of Cambodia.

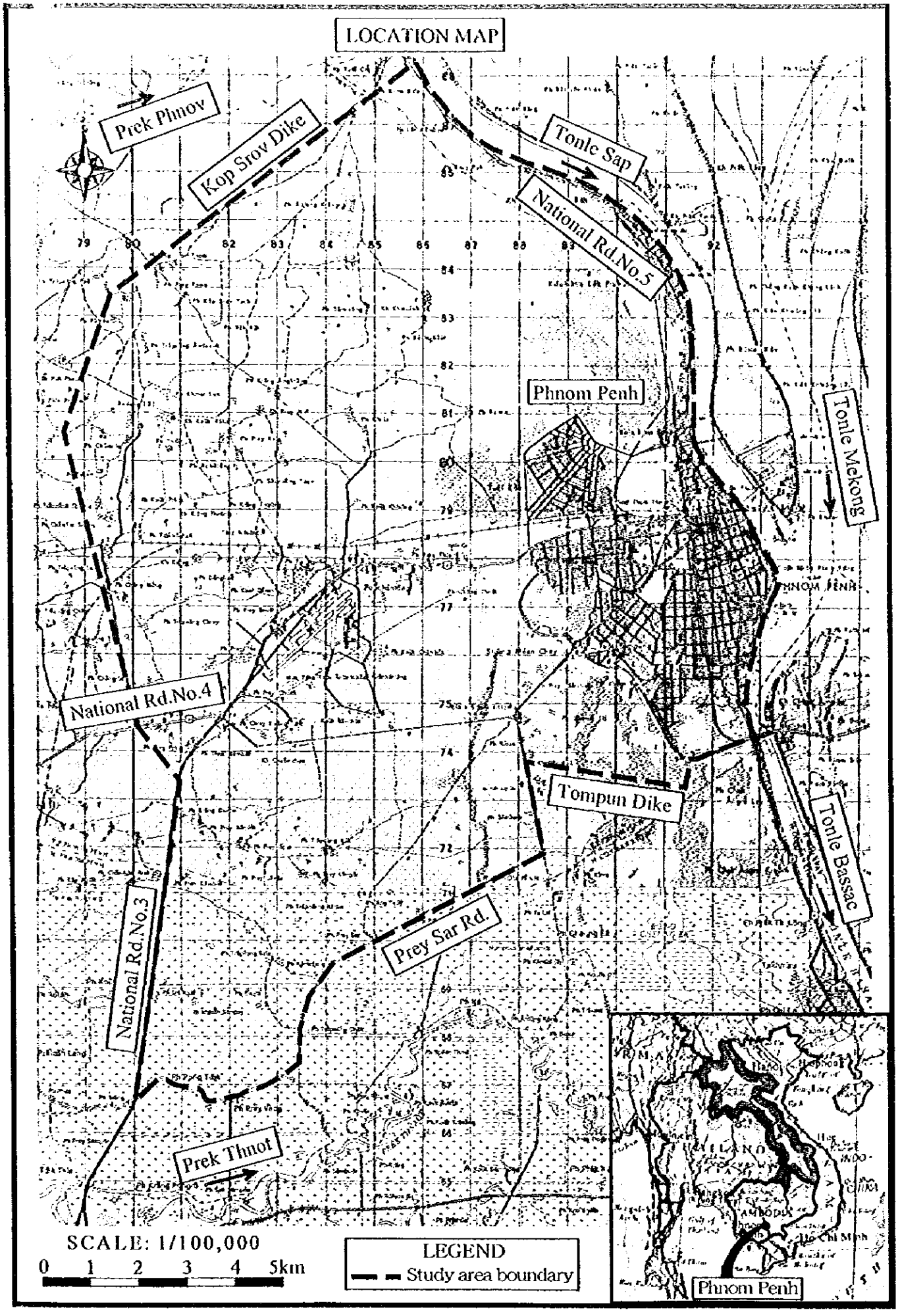
This study was conducted by CTI Engineering International Co., Ltd. and Nippon Koei Co., Ltd., under contracts to JICA, during the period February 1998 to August 1999. In conducting the study, we have paid much attention to formulate a realistic master plan with the target year 2010 with due consideration to the present situation of Cambodia and to formulate the most appropriate plan in the feasibility study.

We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs, and the Ministry of Construction. We would also like to express our gratitude to the officials concerned of the Department of Public Works and Transport of the Municipality of Phnom Penh, the JICA Cambodia Office, the Embassy of Japan in Cambodia for their cooperation and assistance throughout our field survey.

Finally, we hope that this report will contribute to drainage improvement and flood control in the Municipality of Phnom Penh.

Very truly yours,

Keiji Sasabe
Team Leader
Study Team on
Drainage Improvement and Flood Control
in the Municipality of Phnom Penh
CTI Engineering International Co., Ltd.


LOCATION MAP
Prek Phnov
Kop Srov Dike
Tonle Sap
National Rd.No.5
Phnom Penh
Tonle Mekong
National Rd.No.4
Tompun Dike
Tonle Bassac
National Rd.No.3
Prey Sar Rd.
Prek Thnot
SCALE: 1/100,000
0 1 2 3 4 5km
LEGEND
Study area boundary
Phnom Penh

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Outline of the Study

Part I: Master Plan for Drainage Improvement and Flood Control in the Municipality of Phnom Penh

Part II: Feasibility Studies on Reinforcement of Kop Srov and Tompun Dikes and Tompun Watershed Drainage Improvement

VOLUME 2. MAIN REPORT

Part I: Master Plan for Drainage Improvement and Flood Control in the Municipality of Phnom Penh

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Sector A: Land Use and City Planning

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Sector C: Topography and Geology

Sector D: Plan and Design

Sector E: Organization and Institution

Sector F: Socioeconomy

Sector G: Environment

VOLUME 4. DATA BOOK

ABBREVIATIONS

1. ORGANIZATIONS

ADB	:	Asian Development Bank
APUR	:	Atelier Parisien d'urbanisme (Town Planning Agency for Paris)
BAU	:	Bureau des Affaires Urbaines
CATUC	:	Comité de l'Aménagement du Territoire, d'Urbanisme et de Construction (Committee for Planning, Urbanization and Construction)
CDC	:	Council for the Development of Cambodia
CNATUC	:	Comité National de l'Aménagement du Territoire, d'Urbanisme et de Construction (National Committee for Country Planning, Urbanization and Construction)
COM	:	Council of Ministers
CRDB	:	Cambodian Rehabilitation and Development Board
CTA	:	Cambodian Telecommunications Authority
DPWT	:	Department of Public Works and Transport
DSD	:	Drainage and Sewerage Division
EdC	:	Electricité du Cambodge
EU	:	European Union
GDIMH	:	General Directorate of Irrigation, Meteorology and Hydrology of MAFF
GOJ	:	Government of Japan
JICA	:	Japan International Cooperation Agency
MAFF	:	Ministry of Agriculture, Forestry and Fisheries
MEF	:	Ministry of Economy and Finance
MFAIC	:	Ministry of Foreign Affairs and International Cooperation
MOE	:	Ministry of Environment
MOP	:	Ministry of Planning
MPP	:	Municipality of Phnom Penh
MPWT	:	Ministry of Public Works and Transport
MWRM	:	Ministry of Water Resources and Meteorology
NORAD	:	Norwegian Agency for Development Cooperation
PMU	:	Project Management Unit
PPWSA	:	Phnom Penh Water Supply Authority
TdC	:	Telecommunication du Cambodge
UNDP	:	United Nations Development Program
UNESCO	:	United Nations Educational, Scientific, and Cultural Organization
UNICEF	:	United Nations Children's Fund
UNTAC	:	United Nations Transitional Authority in Cambodia
USAID	:	United States Agency for International Development
WB	:	World Bank
WHO	:	World Health Organization

2. OTHER TERMS

BOD	:	Biochemical Oxygen Demand
BOT	:	Built, Operation and Transfer
COD	:	Chemical Oxygen Demand
CUDSS	:	Cambodian Urban Development Strategy Study

CUEIP	:	Cambodian Urban Environmental Improvement Project
DO	:	Oxygen Demand
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
GRDP	:	Gross Regional Domestic Product
EPNRM	:	Law on Environmental Protection and Natural Resources Management
NR	:	National Road
PAP	:	Project Affected Persons
PIP	:	Public Investment Plan
SEDP	:	Socio-Economic Development Plan
SS	:	Suspended Solid
TA	:	Technical Assistance

3. UNITS OF MEASUREMENT

(Length)

mm	:	millimeter(s)
cm	:	centimeter(s)
m	:	meter(s)
km	:	kilometer(s)

(Weight)

mg	:	milligram(s)
g, gr	:	gram(s)
kg	:	kilogram(s)
ton	:	tonne(s)

(Area)

mm^2	:	square millimeter(s)
cm^2	:	square centimeter(s)
m^2	:	square meter(s)
km^2	:	square kilometer(s)
ha	:	hectare(s)

(Time)

s, sec	:	second(s)
min	:	minute(s)
h(hrs)	:	hour(s)
d(dys)	:	day(s)
y, yr(yrs)	:	year(s)

(Volume)

cm^3	:	cubic centimeter(s)
m^3	:	cubic meter(s)
ℓ	:	liter(s)

(Concentration)

mg/ℓ	:	milligram per liter

(Speed/Velocity)

cm/sec, cm/s	:	centimeter per second
m/sec, m/s	:	meter per second
km/hr, km/h	:	kilometer per hour

(Stress)

kg/cm^2	:	kilogram per square centimeter
ton/m^2	:	ton per square meter

(Flow/Discharge)

ℓ/sec, ℓ/s	:	liter per second
m^3/sec, m^3/s	:	cubic meter per second
m^3/yr, m^3/y	:	cubic meter per year

(Electrical Units)

W	:	watt(s)
kW	:	kilowatt(s)
MW	:	megawatt(s)
kWh	:	kilowatt-hour
MWh	:	megawatt-hour
GWh	:	gigawatt-hour
V	:	volt(s)
kV	:	kilovolt(s)

(Note: Other combined units may be constructed similarly as above)

4. MONETARY TERMS

¥	:	Japanese Yen
US$	:	United States Dollar
Riel	:	Cambodian Riels

5. CAMBODIAN TERMS

Boeng	:	Lake
Prek	:	River/Stream
Stoeng	:	River (medium)
Tonle	:	River (large)

Part I

Master Plan for Drainage Improvement and Flood Control in the Municipality of Phnom Penh

THE STUDY ON
DRAINAGE IMPROVEMENT AND FLOOD CONTROL
IN THE MUNICIPALITY OF PHNOM PENH

MAIN REPORT - PART I

MASTER PLAN FOR
DRAINAGE IMPROVEMENT AND FLOOD CONTROL
IN THE MUNICIPALITY OF PHNOM PENH

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II. INTRODUCTION

1.1 Background of the Study

After the Paris Peace Agreement in 1991, the Government of the Kingdom of Cambodia has been promoting reconstruction and rehabilitation of the country exhausted by the long civil war. The First Socio-Economic Development Plan (SEDP) 1996-2000 was announced in 1996. The prime objectives of the plan are "Poverty Alleviation and Rural Development" to achieve a fair, just and peaceful society and to raise the living standards of all Cambodians through the acceleration of economic growth. Implementation of concrete measures to realize these objectives is now important.

With an estimated population of approximately one million, Phnom Penh, the capital city, is the political, economic and cultural center of the country. It is located on the right bank of the confluence of the Tonle Mekong and Tonle Sap rivers and, accordingly, flood control and inland drainage are basically affecting urban development. The city has originally developed on the relatively high natural levees along the Tonle Mekong, Tonle Sap and Tonle Bassac rivers, and it has been expanding to the west and south with the construction of ring dike against river flood.

Urban drainage facilities developed gradually according to the development of the city are not functioning well due to the superannuated facilities constructed from the beginning of the 1900s as well poor maintenance in the 1970s. As a result, the city suffers from habitual flooding and inundation, which are serious constraints to social and economic development not only of Phnom Penh City but the whole country in general.

The Government of Cambodia had accordingly conducted measures for drainage improvement of the city through bilateral and international assistance. However, it has become recognized that the preparation of a master plan for drainage improvement and flood control covering the whole area of the city is needed for the expected future urban expansion. The Government of Cambodia accordingly made a request for technical cooperation from the Government of Japan. In response to the request, the Government of Japan dispatched a preparatory study team through Japan International Cooperation Agency (JICA), and the Scope of Work has been agreed between Municipality of Phnom Penh and JICA on March 18, 1997 (Annex-1 and Annex-2)

1.2 Objectives of the Study

The objectives of the Study are:

(1) to formulate a master plan of drainage improvement and flood control in the Municipality of Phnom Penh with the target year 2010;

(2) to conduct a feasibility study on drainage improvement and flood control for the priority project identified in the master plan study; and

(3) to transfer knowledge on method and management of drainage improvement and flood control to counterpart personnel in the course of the study.

1.3 Study Area

The study area principally covers the urban center of the Municipality of Phnom Penh (approximately 28 km^2). In addition, the surrounding areas and rivers that may influence inundation in the urban center shall also be covered. The study area is shown in the location map.

1.4 Implementation Organization of the Study

The Study has been conducted by a Study Team organized by JICA and consisting of nine experts. An Advisory Committee has also been organized to give technical advice to JICA.

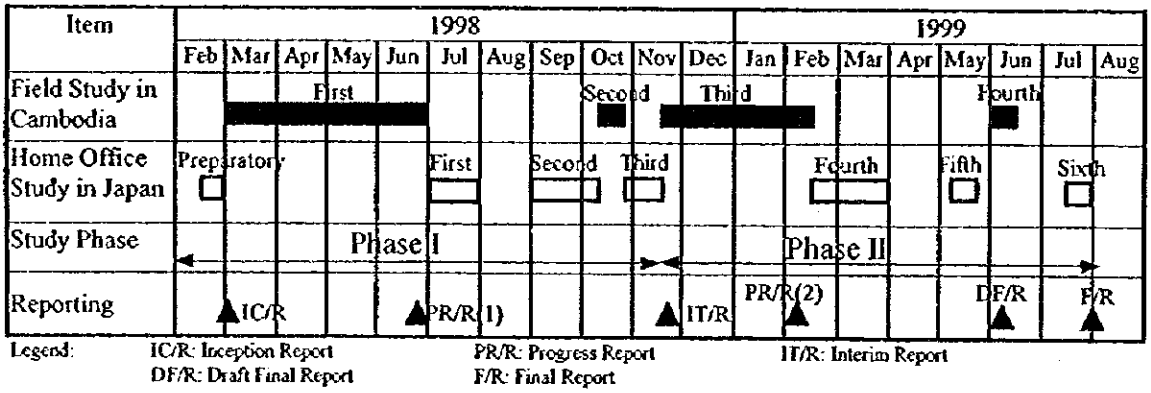
On the Cambodian side, Municipality of Phnom Penh was the counterpart agency for the Study. Municipality of Phnom Penh established a Steering Committee to assist the Study and to discuss various issues related to the Study.

List of members of Steering Committee, Advisory Committee and the Study Team is in Annex-3 of this report.

1.5 Study Flow

The Study has been conducted dividing it into two phases. In Phase I, from February to November 1998, a master plan study for drainage improvement and flood control in the Municipality of Phnom Penh with the target year 2010 has been conducted. In Phase II, from November 1998 to July 1999, a feasibility study on priority project(s) has been conducted. Reports were presented at the times indicated as below.

Overall Study Flow



I2. PRESENT CONDITIONS AND RESULTS OF BASIC STUDIES

2.1 Related Studies and Projects

Of the related studies and projects for the drainage improvement and flood control in the Municipality of Phnom Penh and related areas, major ones are listed with their duration of activities in Figure I2-1.

City of Paris

City of Paris has conducted technical assistance, capacity building to the personnel of the BAU (Bureau des Affaires Urbaines) of Municipality of Phnom Penh, and supply of some equipment. Funds are provided by City of Paris and also by EU. Major studies are the following:

(1) Diagnostic du Reseau D'Assainissement

City of Paris - ADITEM - Agence DESAIX has conducted "Diagnostic Du Reseau D'Assainissement", a study on Phnom Penh City drainage, in 1994-95. The final report was submitted in December 1995. The study consists of the digitalization of all pipes of 80cm diameter and above, diagnostic of the systems and the identification of an immediate improvement program.

In relation to the study, the City of Paris, through ADITEM, donated pumps and equipment (not new) for rehabilitation of pumping stations. The City of Paris and French Government also funded dredging and pipe cleaning equipment

(2) E.E.C. Institutional Support to the Reconstruction of Phnom Penh (Bureau of Urban Affairs - BAU)

The Physical Planning Office of the City of Paris (APUR) provided a technical and institutional support to BAU for regional planning, urbanism and construction from 1995 to 1996, and extended to 1997.

Under the technical and institutional support, BAU initiated a number of rehabilitation projects now operational, rehabilitation of the drainage system, rehabilitation of the main street network. BAU also conducted technical and socioeconomic surveys, aerial survey of the town in December 1992. They also initiated sector studies in town such as "the rehabilitation of the Boeng Salang area"

(3) Phnom Penh Skeleton Development Plan

BAU conducted the study on Phnom Penh Skeleton Development Plan during the extension phase of E.E.C. Institutional Support in 1997. The aim of the plan is to address all crucial issues on the future of the capital city, mainly environmental constraints and main infrastructures for transport. As a first and immediate target, it aimed to make available to investors newly developed land, suitable for urban and regional development, properly located according to their intended use, equipped with the basic amenities at an affordable cost, and respectful of the environmental constraints.

(4) Rehabilitation of Boeng Salang Area

CNATUC-BAU conducted under the technical assistance from ECC and APUR a prefeasibility study for the rehabilitation of Boeng Salang Area. The report was submitted in July 1996.

The Boeng Salang area is part of the Tuol Kork administrative district, which totals 125,609 residents. The Boeng Salang catchment area covers an area of 560 ha and the Boeng (lake) has a capacity of 142,000m^3. Objective and components of the study are: Rehabilitation of the Boeng Salang retention basin and its upstream & downstream associated works; Setting up the physical frame of the area; Adoption, or possible creation of intervention structures for the new layout; and, Improving the living condition of the residents A sub-decree for the development of Boeng Salang Area has been prepared, and approved in 1998.

ADB

Asian Development Bank (ADB) has been conducting a variety of studies and projects for the development and rehabilitation of the Municipality of Phnom Penh. These related to the drainage improvement and flood protection are the following:

(1) Cambodia Urban Development Strategy Study, ADB TA No.2281-CAM

PADCO - SAWA - IRIC conducted Cambodia Urban Development Strategy Study as the technical assistance of ADB. The final report has been submitted in March 7, 1996. The counterpart agency was CNATUC. The study is for the entire Cambodia.

Study objectives are: Review, analyze and assess urban issues and problems and their interrelationships; Assess urban development requirements; Prepare a comprehensive urban strategy up to the year 2015; and, Identify investments, actions and projects as part of the strategy.

A total of six Core Strategy Statements were established, and under them, strategies each for short term (1996-1998), medium term (1999-2005), long term (2006-2015) and each for seven strategy component were developed.

(2) Urban Water Supply and Sanitation Project, ADB TA No.2280-CAM

SOGREAH conducted a study on Urban Water Supply and Sanitation Project as a technical assistance of ADB from September 1995 to May 1996. The final report has been submitted in June 1996.

The objectives of the study are the following:

- Carry out a study for the development of an integrated water supply, drainage and sewerage improvement in the cities of Phnom Penh and Sihanoukville.
- Review the requirements for institutional improvement in the sector
- Recommend improvements in the coordination of assistance for water supply and sanitation projects

- Prepare a project (the Project) to improve water supply and sanitation services for the urban poor of Phnom Penh and Sihanoukville, to the preliminary design stage suitable for Bank financing

The study for the Municipality of Phnom Penh is for the area of the city core of approximately 28 km^2. This study is the basis of the project presently implemented under ADB loan No.1468.

(3) Cambodia Urban Environmental Improvement Project, ADB TA No.2689-CAM

ADB - GHD - Worley - WAVE conducted feasibility study and preliminary design on Cambodia Urban Environmental Improvement Project from April to November in 1997. Draft final report in November 1997 is available.

Of the eight components, the flood protection component consists of the following four sub-projects:

- Upgrade and extension of south west levee
- Upgrade of the north west levee
- Upgrade of the Bassac levee
- Tonle Sap bank protection

The drainage component includes the following three sub-projects:

- Pochentong East Drainage sub-project (a new drainage system for high value future development land east of Pochentong airport)
- Boeng Payap Drainage sub-project (a new outlet for the lake and a channel leading to the headwaters of Stung Meanchey)
- Boeng Salang Drainage sub-project (a self-draining path through the lower end of the boeng, increased storage within the boeng and improvements to the outlet structure)

For both flood protection and drainage components, sub-projects are just identified without any master plan or prioritization. The study level is preliminary.

(4) Phnom Penh Water Supply and Drainage Project Part B: Drainage, ADB Loan No. 1468-CAM(SF)

This is the detailed design and implementation for the some of the identified component projects in the Urban Water Supply and Sanitation Project (ADB TA No.2280-CAM). Sheladia - COWI are providing the consulting services. The work started in March 1998 and completion period is 4.5 years after the commencement of the work.

The work include the following:

- Rehabilitation and upgrading of the Boeng Trabek and Toul Sen canals and associated secondary drainage works
- Concrete lining of the old Boeng Trabek main canal and its secondary branches

- Concrete lining of the Toul Sen Canal and its associated combined drainage systems
- Reconstruction at the same place of the Boeng Trabek Pumping Station and Spillway, to provide a maximum pumping discharge of 8 m^3/s

(5) Phnom Penh Water Supply and Drainage Project Part B: Drainage: Institutional Capacity Building Component and the Neighborhood Improvement Program, NORAD co-finance to ADB

The Institutional Capacity Building Component and the Neighborhood Improvement Program are a part of Phnom Penh Water Supply and Drainage Project Part B. Norwegian Agency for Development Cooperation (NORAD) financed as a form of co-finance to ADB Loan No.1468. INTERCONSULT, a consultant company commenced the services in July 1, 1997. Completion of services is expected in June 30 in the year 2000.

Institutional capacity building is for the staff of DPWT to improve the proficiency and technical skills, to develop skills in the use of computer assisted design and other relevant software, and to enhance the overall management capability of DPWT.

Neighborhood improvement program is to establish workable systems for community based solid waste collection services and to establish community organizations that will enable people to participate actively in the improvement and maintenance of sanitation/drainage systems in their own community.

<u>World Bank</u>

The study on Urban Infrastructure Rehabilitation and Management Project has been conducted by World Bank - BCEOM - COWI. The study started in January 1996 and completed in October 1996.

The study for the drainage component is mainly of the review of the existing studies. Proposed World Bank rehabilitation program includes the following with a total cost of US$3.25 million:

- Cleaning Operations
- Pipes Inspection
- Pipes and Manholes Rehabilitation
- Gullies Rehabilitation & Manhole Covers
- Canal Emergency Works (Trabek, etc.)
- Dredging Works (Boeng Trabek, Salang, Tompun
- Pumping Stations

The Short Term Drainage Plan includes:

- Rehabilitation of Underground Drainage Network
- Primary Canals Emergency Works
- Implementation of the Road Drainage Rehabilitation Works
- Dredging Emergency Works

Implementation of the drainage component of the project has not been realized yet, though some components for the road rehabilitation sector are scheduled to be implemented.

2.2 Socioeconomy

2.2.1 Cambodia in Brief

After decades of civil wars, Cambodia started to reconstruct the country in 1993 under a new coalition government with a market economy system. With the assistance of the international community, the Cambodian government has been actively promoting administrative and financial reforms and development of infrastructures. The present socioeconomic condition of Cambodia is, however, characterized by still low level of economic and social standards. Table I2-2 compares the socioeconomic condition in Cambodia with those of neighboring countries.

Cambodia has a population of about 10 million, about double of Laos, but 14 % and 17 % each of those of Vietnam and Thailand. Cambodia is situated between the two populous countries in the east and west. Gross national product (GNP) per capita of Cambodia at US$ 270, according to the World Development Report 1997 by the World Bank, is comparable to Laos and Vietnam with US$ 350 and US$ 240 respectively, all classified as the lowest income economies. Cambodia's GNP per capita at US$ 270 is equivalent to 10 % of Thailand (US$ 2,740), which experienced a remarkable economic growth in the last 10 years. Reflecting the smaller population size and lower per capita income level, the size of economy in terms of GDP (US$ 2,771 million in Cambodia) is about 2 % of Thailand's GDP at US$ 167,156 million.

Cambodia as well as Laos is highly dependent on the agriculture sector with agriculture value added accounting for 51 % of GDP (52 % in Laos), while that in Thailand is only 11 %. Vietnam is less dependent on agriculture with 28 %. The other side of the coin is lower level of industrialization in Cambodia with the manufacturing sector value added accounting for only 6 % of GDP.

In the social aspect, Cambodia still lags behind the other countries. Illiteracy in Cambodia is 35 %, while those in Vietnam and Thailand are 6 %. That in Laos is higher at 43 %. Infant mortality rate is highest in Cambodia at 108 deaths per 1,000 births, while those of other countries are 90 (Laos), 41 (Vietnam) and 35 (Thailand). The rate of schooling is also low in Cambodia compared with the other three countries: only less than half of primary school age children going to school in Cambodia.

Following the economic reforms launched since 1989 aiming at liberalization of prices and international transactions, the Cambodian economy showed a recovery at a fairly high pace. As shown in Table I2-3, GDP growth rates exceeded 7 % per year in 1991 and 1992. After a slowdown from 1993 to 1994, the economy expanded at a high rate at 7.6 % per year in 1995. The growth in 1996 was reduced to 6.5 % per year, still fairly a good performance. This fall in growth rate in 1996 is explained by damages by floods from September to October, leading to drop in crop production. Until 1996, the engine for fast GDP growth were such sectors and sub-sectors as the manufacturing (garment industry with foreign capital and local small scale industries) and the service sector (restaurants, shops, hotels and trade related activities).

In 1997, however, the economic growth is estimated to be down to about 2.0 % as a result of the political crisis in July. While the agriculture sector remained unaffected with a growth rate of 5.2 %, the industry and service sectors were severely affected with growth

rates reduced to 0.6 % and minus 0.4 % respectively. The prospect for 1998 is unfortunately not very bright. The economic crisis started in the second half of 1997 in neighboring Asian countries will inevitably affect the Cambodian economy. Much of the foreign investments, that have been leading the growth of the Cambodian economy in the last several years, originates in the suffering Asian countries such as Malaysia, Hong Kong and South Korea. It is highly possible that the number of investors with sufficient capital to be able to make investment in Cambodia is now much more limited compared with the pre-crisis period. Weakening currencies of these countries and other Asian countries will also adversely affect the number of tourists to Cambodia. Considering these factors, the economic growth in 1998 could remain at the 1997 level.

2.2.2 Phnom Penh City

The major socioeconomic characteristics of Phnom Penh City is presented in the following table:

Socioeconomic Characteristics of Phnom Penh

Item	Values	
Land area	290.06	km^2
Population (registered)	872	thousand
Population (total)	1,000	thousand
Sex composition of population		
- Male	47	%
- Female	53	%
Population density	3,006	persons/km^2 (registered population)
Population growth (1986-1996)	3.2	%/year
Household size	5.7	persons/household
Population under 20 years of age	54	%
Migrants	43	% of total population
Unemployment	6.5	%
Labor force structure		
- Agriculture	13	%
- Industry	14	%
- Service	74	%
Average household expenditure	781	thousand Riel (1993-1994)

Phnom Penh has a registered population of 872 thousand as of March 1998. The actual population including non-registered population is said to be around 1 million. Phnom Penh's population accounted for 7.7 % of the national population in 1996. As is the case in Cambodia, female population accounts for 53 % of the total population, the result of long-lasting civil wars and genocide years. Accordingly, female-headed households account for 28 % of all the households in Phnom Penh, unusually high compared with other Asian countries. The population of Phnom Penh grew at 3.2 % per year since 1986, slightly higher than the national population growth at 3.0 % per year.

The manufacturing value added generated in Phnom Penh accounted for 20 % of the national manufacturing value added in 1993, seeming intuitively low. In 1998, the share should be higher than this, as a result of accelerated foreign direct investments in the manufacturing sector concentrated in Phnom Penh since 1993. As a reflection of the Phnom Penh's role as the industrial and commercial center of Cambodia, the labor force

structure is characterized by a high proportion of the industry and service sectors, both combined accounting for 88 % of the total labor force.

Significant proportions of the Phnom Penh's population are migrants from other provinces, recorded at 43 % of the total population. The main reason for moving is related with seeking a job in Phnom Penh. Unemployment in Phnom Penh is high at 6.5 %, while that in Cambodia is 0.9 %. These facts imply that while people move to Phnom Penh looking for job, there are not sufficient job opportunities in Phnom Penh, resulting in a higher unemployment rate. In Phnom Penh, about 6.2 % of the population is regarded as earning below the poverty line (Riel 1,578 per person per day in 1993/1994 in Phnom Penh).

In the absence of regional income data of Phnom Penh, a preliminary effort was made to estimate gross regional domestic product (GRDP) of Phnom Penh. Table I2-4 shows the result. Labor productivity, value added produced by one worker, in each sector in Cambodia is first derived based on the data on gross domestic products and labor force by sector. Assuming the same levels of labor productivity, GRDP of Phnom Penh is estimated based on the sector-wise number of labor force in Phnom Penh and the derived value added per worker in Cambodia for each sector. The following points are clarified:

- The Phnom Penh's GRDP is estimated to be Riel 1,218 billion in 1996, accounting for 15% of the Cambodia's GDP.
- The industrial and service sectors combined account for 97 % of the GRDP, a sharp comparison with Cambodia with both sectors combined accounting for 56 % of GDP and remaining 44 % produced by the agriculture sector.
- GRDP per capita in Phnom Penh is estimated to be US$ 562 per capita in 1996, about 87 % higher than GDP per capita of Cambodia at US$ 301.
- Reflecting the dominant share of the industrial and service sectors, the growth of Phnom Penh's GRDP was remarkable even including the year 1997. An average growth rate of GRDP is estimated to be 8.9 % per year during the 1990 –1997 period.

In reality, it is likely that the Phnom Penh's GRDP is greater than the estimate above, reflecting the possibly higher labor productivity of economic activities in Phnom Penh. With the absence of data concerning the difference in labor productivity, however, the estimate above is used as proxy.

2.2.3 Study Area

The Phnom Penh's city boundary extends beyond the Study Area boundary. Out of the city's total area of 290.06 km^2, 90 km^2 is out of the Study Area. The population in the Study Area is estimated to be about 817 thousand in 1998, both registered and non-registered. Excluding the population in the sub-districts totally outside the Study Area and counting only the portion within the Study Area by area proportion for the sub-districts lying across the city boundary, it is found that about 81.7 % of the Phnom Penh's population lives within the Study Area boundary. These sub-districts are found in Dangkor, Meanchey and Russey Keo districts. The number of households is estimated to be about 143 thousand assuming 5.7 members per household. Figure I2-1 shows the boundaries of Phnom Penh City, Study Area and the districts. Table I2-5 presents

population in the seven districts and those in the sub-districts in the outlying three districts.

2.2.4 Challenges in Socioeconomic Development

Existing Development Plans

A number of challenges await Cambodia in maintaining economic growth and alleviating poverty. As part of the government's effort to manage and promote economic growth in a coherent and efficient manner, a number of documents such as follows have been prepared:

- First Five Year Socio-Economic Development Plan 1996 – 2000 (hereafter SEDP);
- Public Investment Programme, 1996 –1998, 1997-1999 and 1998 – 2000 (hereafter PIP); and
- Policy Framework Paper 1997 - 1999.

In order to clarify the major challenges awaiting the Cambodia's socioeconomic development, SEDP and PIP 1998-2000 as well as a World Bank report entitled "Cambodia, Progress in Recovery and Reform, June 2 1997" (hereafter the WB report) are reviewed. The findings are summarized in the following part.

Major Challenges in Socioeconomic Development

(1) Economic Development Targets

Reflecting the overall good economic performance until 1996, the existing economic development targets and prospect are assumed based on an optimistic view and with the characteristics as a base target for policy formulation. The following are the assumed targets and prospects in the rate of economic growth:

- SEDP : 7.5 % per year between 1996 and 2000
- PIP 1998-2000 : 7.0 % per year between 1998 and 2000
- WB report : 7.1 % per year for 1999 - 2001
  7.6 % per year for 2002 - 2006

These targets will be a basis for establishing a socioeconomic framework for the present study at a later stage. Inflation rate is set at 5 % per year. Reflecting the government policy of achieving a balanced budget, the proportion of government revenue to GDP is assumed to rise from 9.9 % in 1996 to 11.6 % in 2000 and 16.9 % by 2006.

(2) Tight Fiscal and Monetary Policy

The government will continue adopting a tight fiscal and monetary policy to maintain the Cambodian macro-economy in a stable condition and gain momentum in growth. This direction will be sought through implementing various reforms in administration, tax system, legal foundation, and the financial sector structure. The number of civil servants and expenditure on defense and security, accounting for 55 % of the current expenditure in 1997, will be reduced such that more funds become available for other important purposes in tackling poverty and bringing about economic growth. Tax reforms aim at expanding taxation base as well as

improving the tax collection mechanism. This will be an important measure to increase government revenue. An appropriate legal framework provides a secure environment for business activities, an important prerequisite for a market economy. The financial sector reform aims at building a "two-tier system", in which the central bank concentrates on monetary policy and supervising private banks, whereas private banks are engaged in commercial financial transactions. "Dedollarization" would be an important direction in strengthening the central bank's effectiveness in monetary policy.

(3) Public Investment Plan

Public investment plays a vital role in achieving economic growth and improving people's living standard. Physical infrastructure needs to be upgraded such that new investments are attracted and the existing business can operate efficiently. Development of social infrastructure would contribute to upgrading living environment for people.

The Cambodian government prepared the first Public Investment Programme (PIP) in 1995 for the following 1996-1998 three years. Since then the program has been updated every year and the latest version is the Public Investment Programme 1998-2000. Currently, as of June 1998, preparation work is going on for the PIP 1999-2001. The PIPs list up projects and programs, both investment programs and survey programs, and put priority to them depending on their funding status and investment efficiency. Projects and programs need to be processed and included in the PIPs in order to be financed by the national budget. The PIP unit in the Ministry of Planning serves as the secretariat. An inter-ministerial steering committee is set up, chaired by the Ministry of Planning and joined as members by the Ministry of Economy and Finance, Council for the Development of Cambodia, and National Bank of Cambodia. The PIPs include projects and programs which are ongoing, committed and those neither ongoing nor committed but judged to have high priority. Other projects and programs with lower priority are not included in the PIPs. A total of US$ 1.2 billion for three years is estimated in the PIP 1998 – 2000 with the following allocation:

PIP 1998 - 2000

(Unit : US$ million)

Item	1998	1999	2000	Total
Capital Investment	171	268	355	794
Technical Assistance	133	134	139	406
Total	304	402	494	1,200

(4) Private Investment

Most of the envisaged economic growth will be derived from accelerated and expanded activities in the private sector. The government role will be confined to that of a facilitator, improving and developing an environment more favorable for private sector activities. On this basis, the government will implement a number of software and hardware measures such as mentioned above. It is estimated by the

WB report that increased private investment will result in the share of private investment in GDP rising from 14.5 % in 1995 to 18.2 % by the year 2006.

(5) Capacity Building

For promoting Cambodia's development, assistance from abroad will be indispensable for some years to come. In the development process, however, an effort should be continued to internalize skills and technologies. A sustainable development in a long run will be attained only with Cambodian people playing the central role. Strengthening education, from basic education to higher education as well as vocational and technical training will be vital in this regard. SEDP sets forth the following targets in educational development by the year 2000:

(a) 65 % of 12 year-old children complete grade 6 and become functionally literate and numerate. In 1994, only 13 % of primary school children complete grade 5 in five years.
(b) 50 % of 16 year-old girls are enrolled in grade 10. In 1994, there were only 19 % female students at this level.

The PIP 1998-2000 assumes a spending of US$ 56 million per year in the education sector.

2.3 Land Use and City Planning

2.3.1 Present Land Use and Urban Development

Boundaries of the Study Area

The border of the Study Area follows, to a large extent, natural limits or existing infrastructures. The rivers all along its eastern side border the Study Area. The northern limit is the Kop Srov dike, going from the Prek Phnov riverside village to the Kop Srov village. From there it bends towards the south to naturally follow the laterite road which joins the National Road No. 4 at Tmat Pong village.

It then follows the National Road No. 3 down to Sleng village, and from there goes along the existing road towards the east and north, up to Dankouv village. Last, it follows the Boeng Tompun southern dike and the city limit until it meets the river again at the Monivong Bridge.

Phnom Penh City location has been chosen, for symbolic reasons as well as for economic reasons, to be on the western embankment of the Tonle Mekong and Tonle Sap rivers confluent, where the Tonle Bassac defluent immediately separates again from the Mekong, towards the South. The City has developed as a series of folders linked to the river natural embankment, and protected from the river by dike-roads. Due to the very smooth natural relief, inner concentric dikes remaining from successive enlarging of the city, altered this natural relief up to playing a major role in defining the catchment areas borders.

The Present Development Situation

In its present boundaries, Phnom Penh City covers a surface of about 290 km^2. Its population grew from 581,000 inhabitants in 1986 (Statistics Book 1995) to about

872,000 in 1998 (Department of Planning, MPP). This makes it by far the first Cambodian city, with about 7 times more inhabitants than in Battambang, the second one.

As the population grew rapidly with migration in the recent years, the city developed with little planning and control. As a results, "free" surfaces inside the city, like the boengs embankments, have been covered and some of the most easily accessible surroundings have been developed creating new suburbs along the main road axes. This resulted particularly in:

- Squatter problem, bringing degradation of the urban center as well as of the drainage system: settling on canals and boengs, squatters often restricted water flow and retention capacity; settling on the protection dikes, they weakened their banks, increasing the danger of flooding while also limiting the intervention possibilities.
- An unplanned urban development outside the present inner dikes, thus in areas much more exposed to flood risks, and with no consideration for the natural water flow regulation system that used to participate in the city protection, and which balance is severely threatened.

Along with this process of urbanization came uncontrolled land fill, building and impermeabilization; residential or activities areas developed without service, resulting in "urban" areas that lack much of the necessary facilities, and where safety is uncertain.

Present Land Use

The Study Team prepared the present land use map for the Study Area (see Figure I2-2). According to this map, the percentage of the total area that is devoted to each land use category in the present situation is the following:

Category		Description	Area (ha)	Ratio (%)
A	Dense urban center	Big buildings, Chinese compartments, side by side houses	603	3.1
B	Dense residential	Urban villas, buildings with small gardens	1,124	5.7
C	Loose residential	Small villas and buildings, important green spaces or agricultural land	3,012	15.4
D-1	Dense activities	Activities and industries requiring important buildings and infrastructure	287	1.5
D-2	Loose activities	Small-size activities mixed with residential or waste grounds	793	4.1
E	Agricultural land	Rice fields, important vegetable or fruit gardens	11,919	60.9
F	Fish ponds	Ponds devoted to intensive fish breeding	70	0.4
G	Green spaces	Urban green spaces, excluding the gardens surrounding villas in urban residential areas	209	1.1
H	Lakes and ponds	All water-covered surfaces, including rivers and swamps (besides fish ponds)	1,554	7.9
Total Study Area			19,571	100.0

2.3.2 Existing Data and Reports on Urban and Rural Development Plans for Phnom Penh City and Suburbs

Several studies and reports are relevant to the urban and rural development plans for the Phnom Penh City and suburbs.

Cambodia Development Strategy

The Cambodia Development Strategy is outlined in the 1997 CG Paper (Draft version 2.0 by CDC/CRDB). According to this document, the following short-term objectives have been set for all economic activities in Cambodia:

- To develop an outward-oriented, competitive industrial and services sector, through the already ongoing structural reform, and
- To support growth and development through rationalizing and improving the public sector, establishing an efficient banking system, and developing the infrastructure and human resources.

Development strategies are discussed by sector to achieve the objective. (For detail, see Supporting Report).

Cambodia Urban Development Strategy Study (CUDSS), ADB TA No. 2281

The city, designed to accommodate about five hundred thousand people, will have to manage with four times that number in about ten years. Hence this report points out the necessity to control development and create the bases of a good economic development of the city, which will likely follow the model of other southern Asia capital cities in playing the role of an economic engine for the whole country. The report insists on the importance of the location of the future developing industries and the need of a policy to control their development.

The report defines the objectives for the urban development, and towards these objectives the following core strategy statements applied to Phnom Penh:

- The city growth must be anticipated,
- Phnom Penh will be in the vanguard, and a model for the development of other towns,
- While the development will be mainly private and informal, the main role of the government will be to create an enabling environment for efficient and sustainable growth,
- Strategic, selective interventions will have to be made according to the arising opportunities and available capacities.

Cambodia Urban Environmental Improvement Project (CUEIP), ADB TA No. 2689

This posterior study carried on a review and assessment of the CUDSS, and outlined what was considered as key development strategy issues, in the following list:

Based on these issues a number of actions was recommended; most of them concern the institutional or administrative level and give few indications on the trend of development itself. Concerning urban infrastructure development, quite none gives precise recommendation on the location of future activities. The need for developing a sanitary landfill is outlined.

2.3.3 Identified Existing Urban Development Plan for the Future

While no Master Plan yet exists, we tried to foresee the forthcoming urban evolution, based on an observation of the current development trends, on a survey of the existing projects and proposals developed by different concerned services, and on a sector-by-sector analysis of environmental constraints. This sometimes also led us to issue recommendations.

The City's General Development Policy is based on the UNTAC land law ruling land ownership since 1992, and the CNATUC law for urban planning, dated 1994. Following the latter, a "Bureau des Affaires Urbaines" (BAU) is involved in urban planning, while the Municipal Department of Urbanisation and Construction is in charge of Phnom Penh urban development.

Main issues and data concerning this future evolution are (Figure I2-3):

About communications, thanks to international co-operation within a few years, the main highways and national roads, as well as the Pochentong international airport will be rehabilitated; the issue of a possible ring road(s) around the city will arise with the increased traffic. The railway network, much damaged, also is progressively rehabilitated. Railways towards Vietnam and Laos would have to be created and a new station would then be absolutely necessary. The inland water port has been improved but in the long-term it should be displaced, possibly downstream on the Tonle Mekong river.

Industry is expected to grow rapidly, essentially by construction and manufacturing. Different locations for these developing industries have been proposed; if not appropriately located they would jeopardise the environment, the long-term economy or the urban heritage. The most recommendable location seems to be downstream on the Tonle Mekong River as already considered at the BAU of PPM.

Agriculture is the first occupation of Cambodian people; it is wishful that this activity remains close to the growing city, especially in the most northern and southern zones of the area of study.

Specific Projects and Proposals include an Urban Development Zone, a bigger international airport, a wholesale market and a Technical Platform.

For each part of the study area, considering the natural and environmental constraints and the existing projects and realisations, we outline the possible orientations of development.

2.3.4 Predicted Land Use for Year 2010

According to UWSSP the Phnom Penh population by 2010 could increase by about 20% for the city core, and 75% for the suburbs. In the inner city, there will probably be a little spread of the dense urban centre, a restructuring of the dense residential areas, and a progressive evolution of loose residential sectors towards the dense residential type. Around the city center, residential zones will probably spread, mainly with a "loose residential" structure.

However, this future will be function of the degree of control by the authorities. We hence assumed two scenarios for the land use in 2010: Development Managed with Appropriate

Control and Infrastructure; and Spontaneous Development with Little Management. Maps of what could be the land use in our Study Area in year 2010, according to each of these two scenarios have been prepared. For the establishment of the master plan, we applied Scenario-1 (Development Managed with Appropriate Control and Infrastructure) as presented in (Figures I2-4)

Category		Area in 1998 (ha)	Areal growth (%)	Area in 2010 (ha)	Ratio to total (%)
A	Dense urban center	603	10	663	3.4
B	Dense residential	1,124	20	1,349	6.9
C	Loose residential	3,012	85	5,572	28.5
D-1	Dense activities	287	50	431	2.2
D-2	Loose activities	793	100	1,586	8.1
E	Agricultural land	11,919	-32	8,130	41.5
F	Fish ponds	70	10	77	0.4
G	Green spaces	209	0	209	1.1
H	Lakes and ponds	1,554	0	1,554	7.9
Total of Study Area		19,571	-	19,571	100

2.4 Meteorology and Hydrology

2.4.1 Study Area, Relevant Rivers and Watersheds

Study Area and Relevant Rivers

The Study Area, with an area of 195.71 km^2, shares a greater part of Municipality of Phnom Penh, the capital of the Kingdom of Cambodia. The area is within longitude 105°45' E to 105°55' E and latitude 12°27' N to 12°40' N, and is in the delta plain of the Mekong river system with low altitudes ranging from 4 to 14 m above the mean sea level.

The Study Area is located on the right bank of three large rivers, Tonle Mekong, Tonle Sap and Tonle Bassac, and moreover it is sandwiched by two rather small rivers which flow from west to east joining to the Mekong river system. One is the Prek Phnov River with a catchment area of approximately 640 km^2, discharging to the Tonle Sap River. The other is the Prek Thnot River with approximately 5,200 km^2 of catchment, flowing into the Tonle Bassac River. Major features of these rivers are tabulated as below:

Major Features of Relevant Rivers

River Name	Catchment Area (km^2)	Stream Length (km)	Average Flow Rate (m^3/sec)
Tonle Mekong	660,000*	4,500*	11,830**
Tonle Sap	84,400*	400*	1,570**
Tonle Bassac	-	300***	
Prek Phnov	640	50	
Prek Thnot	5,200	110	

* Upstream of Phnom Penh.
** At Phnom Penh
*** From Phnom Penh to the sea.

On the other hand, Figure I2-5 shows a three-dimensional view of the Study Area. As can be seen in the figure, the Study Area is obviously classified into three zones. The first is Phnom Penh City Core and an adjoining riverine strip along the Tonle Sap River on a natural levee formed by the Mekong river system. The elevations range from EL. 8 to 11.5 m. The second is a low land in the middle, where the Prek Phnov River probably had flowed from north to south in ancient time, extending with several lakes as its remnants. The elevations are mostly lower than EL. 8 m. The third is the west area, where Pochentong Airport is located, spreading on a little higher flat land sloping down from west to east with elevations from 8 to 14 m. Such hydro-topographic features are clearly presented in Figure I2-6 as profiles across the Study Area.

Watersheds

The Study Area (195.71 km^2) is, as mentioned in the above Clause, limited by the Tonle Sap and Bassac rivers on the east, by the Prek Phnov floodplain to the north, by the Prek Thnot floodplain to the south, and by a hilly area to the west. In view of the topography, hydraulic characteristics and land use, the Study Area can be divided into the following five major watersheds anti-clockwise from the City Core. These five are further partitioned into basins as below (refer to Figure I2-7):

- City Core : C1 to C10 Basins (25.29 km^2)
- Northeast Area : E1 to E4 Basins (40.23 km^2)
- Northwest Area : No subdivision (50.79 km^2)
- Middle Area : M1 to M4 Basins (38.80 km^2)
- South Area : S1 and S2 basins (40.60 km^2)

The land use, topography and hydraulic characteristics of each basin, along with its catchment area, are enumerated in Table I2-6.

2.4.2 Meteorology and Water Levels

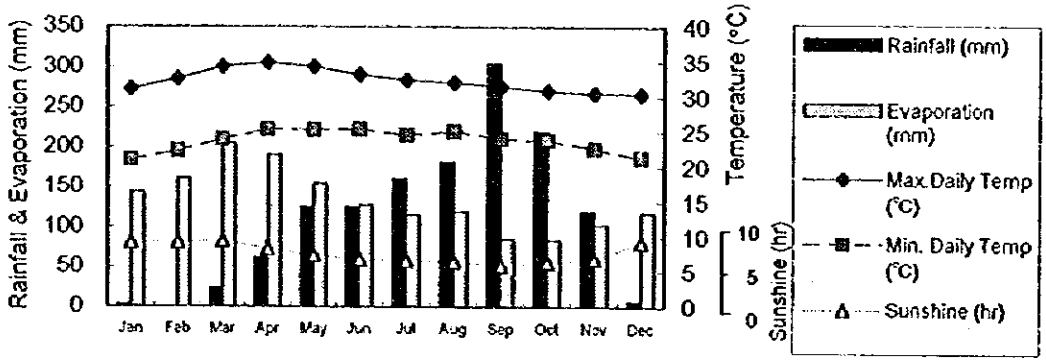
Location of Observation Stations and Available Data

In and around the Study Area exist one meteorological station named Pochentong near Pochentong Airport, two rainfall gauging stations named Bassac and Changvar, and three water level gauging stations at Chaktomuk, Phnom Penh Port and Changvar. All these stations are managed by General Directorate of Irrigation, Meteorology and Hydrology (GDIMH) of Ministry of Agriculture, Forestry and Fisheries (MAFF) as of 1998. The location of the stations is indicated in Figure I2-8.

Meteorology

The Study Area is situated on a part of the Continental Southeast Asia, so that the weather is strongly influenced by the monsoon and a year is clearly divided into the rainy and dry seasons. The rainy season usually lasts from May to November with wet winds from the Siam Gulf (from the south and west), bringing quite large amount of rainfall on the area. The dry season from December to April, on the other hand, is dominated by dry winds blowing from the Continental Shelf (from the north and east). The monthly means of general meteorological items observed at Pochentong Station are given in the following graph:

General Meteorology at Pochentong Station



(1) Rainfall

There are three stations measuring rainfall in and around the Study Area, however most reliable data, with the longest observation period, are obtained from Pochentong Meteorological Station. Records in the other two stations are said to include unreliable data with shorter observation periods. In this case, it is decided that the rainfall data recorded at Pochentong Meteorological Station only be applied to the further hydrological study.

The annual rainfall amounts recorded at Pochentong Meteorological Station from 1981 to 1997 range between 1,092 mm and 1,639 mm and the average is 1,327 mm. About 93 % of the annual rainfall occurs in the rainy season (May to November), 57 % of which concentrates in three months from August to October. On the other hand, the maximum daily rainfall in a year is mostly observed in the three months, ranging from 63 to 137 mm. Together with high water stage of the Tonle Mekong river system appearing in the period, this local rainfall often brings about serious inundation in the Study Area.

(2) Evaporation

The annual evaporation depths recorded from 1981 to 1997 vary between 1,224 mm and 2,145 mm, with a mean of 1,623 mm. These values are larger than the annual rainfall amount. This is because open pan evaporation measurements during the dry season, commonly, give much larger values than those in actual fields. The seasonal variation of evaporation, increasing in the dry season (205 mm in March at

maximum) and decreasing in the rainy season (84 mm in September at minimum), is contrary to the rainfall pattern.

(3) Temperature

The maximum and minimum daily temperatures are 32.4 °C and 23.8 °C on the average from year 1985 to 1997. The temperature is highest at the end of the dry season and lowest at the beginning of the dry season. (In terms of maximum and minimum daily temperatures, about 35 °C and 25 °C in April whilst about 30 °C and 21 °C in December.) The all time daily maximum and minimum were recorded at 40.4 °C in April, 1990 and 15.0 °C in December, 1993.

(4) Humidity

The monthly mean relative humidity, on the average from 1985 to 1997, ranges between 68.2 % in March and 85.8 % in September. The relative humidity, naturally, increases in the rainy season and decreases in the dry season.

(5) Sunshine

The daily sunshine hours range from 9.4 hours in March (the dry season) to 5.9 hours in September (the rainy season).

(6) Atmospheric Pressure

The monthly mean atmospheric pressure hits the peak at December in the dry season and reaches the bottom at June and July in the rainy season.

(7) Wind

Strong winds, whose velocities exceed 10 m/sec, tend to appear in the first half of the rainy season with directions of south, southwest and west mostly.

Water Levels

On the Mekong river system, three water level gauging stations are provided by Department of Hydrology of GDIMH, MAFF. The water level is observed twice a day (7:00 and 19:00). Observations have continued since 1960, except between January, 1975 and June, 1980, at Chaktomuk Water Level Gauging Station. At Phnom Penh Port and Changvar stations, on the other hand, complete records are available from 1993 only. Hence, applied to the further analysis are the data recorded at Chaktomuk Station.

Figure I2-9 depicts seasonal variation of the water level at Chaktomuk Station since 1960. Moreover, Table I2-7 shows the annual highest, mean and lowest water levels at the station, which are EL. 8.83 m, EL. 4.07 m and EL. 0.66 m on average. The all time high water level is EL. 9.96 m in October, 1961, followed by EL. 9.92 m in October, 1996. In addition, noted in the table is that the highest water level in year 1998 is the lowest record since observation started.

In Figure I2-10, the yearly water level variations in the last decade are superimposed by the daily rainfall measured at Pochentong Meteorological Station. The figure suggests high

probability of synchronization between high water level of the Mekong river system and strong local storms in the Study Area. In fact, such synchronization has often resulted in serious inundation over the Study Area.

2.4.3 Flood and Inundation Condition

Flood and Inundation in 1995 and 1996

To clarify the flood and inundation conditions in the recent major flood years, i.e. 1995 and 1996, an interview survey over the Study Area was carried out. Major findings obtained through the survey are:

(a) No overtopping happened along the Outer Ring Dike in both flood years thanks to the flood defense activity by governmental agencies concerned (refer to Table I2-8). So, all the inundation identified through the interview survey was rated as ones caused by local rainfall, except in the South Area where floodwaters from the Mekong river system easily come in and out through openings provided along the Outer Ring Dike.

(b) There is no meaningful difference in the magnitude of inundation between the year 1995 and 1996 (refer to Table I2-9). In this case, the survey prepared a flood and inundation map only for year 1996 that is higher in the water level of the Tonle Mekong by 0.8 m and is a bit larger in the annual rainfall in the Study Area by 226 mm. The map is briefed in Figure I2-11.

(c) At any location, interviews cannot specify exact dates when flood or inundation took place in the year. This infers that the surveyed flood/inundation depths and duration may correspond to the maximal ones occurring some day in the year.

Water levels in the 1995 and 1996 rainy seasons observed at several points in and around the Study Area are delineated in Figures I2-12 and I2-13, respectively where the daily rainfall at Pochentong Station is superimposed. These records include some unreliable data, but they are quite valuable in realizing relative correlation among high water levels at necessary locations.

Field Observation in 1998 Rainy Season

In order to identify actual flood and inundation conditions in the Study Area, a field observation work was realized by the Study Team from Oct. 11 to Oct. 28, 1998. Following are its findings:

First, it should be mentioned that the highest water level of the Tonle Sap River in 1998 rainy season is as low as EL. 6.90 m. This annual maximum water level is the lowest since 1960 compared to the second lowest EL. 7.30 m occurring in 1988. In this case, floodwater barely comes up on the outside slopes of Kop Srov and Tompun dikes, bringing about little damage to the dikes. Through the field investigation of the Study Team, only found as dike deformation are holes on the dike road surfaces which were however observed even in the dry season. Such holes are judged to result from local rainfall on the dikes in previous rainy seasons. No flood defense activity has been taken uncommonly with other years.

Second, with respect to inundation in the Study Area due to local storms, the Study Team experienced 8 times of rains in their stay (16 days in total). The rainfall amount in each rain is less than 20 mm, except a rain starting at midnight and terminating early in the morning on October 20 whose amount reached 63.5 mm. At 8 o'clock in the morning, the Study Team still observed many places of inundation with about 20 cm of depth. This condition was prolonged over the morning. Particularly around the DPWT office, inundation lasted until the evening. Pump facilities, Trabek and Tompun stations, etc., were fully operated, however the effects being limited in their lower reaches, and because of less capacity/clogging of drainage channels and especially sewer pipes, the upper reaches cannot be free from such longtime inundation.

2.4.4 Rainfall Analysis

Premises

Premises for the rainfall analysis are set as follows:

(1) Maximum Annual Rainfall

The maximum annual rainfall for each duration (15 minutes to 4 days) between 1980 and 1997 at Pochentong Meteorological Station are used for the present rainfall analysis. This data has been compiled by Pochentong Station itself using automatic gauging data at 15 minutes intervals.

(2) Area Reduction Factor

In the present study, the area reduction factor is not considered on the conservative side since there are no sufficient data to verify such factor.

(3) Rainfall Duration

Figure I2-14 shows the single rainfall patterns of recent heavy rains causing sever inundation in the Study Area. As can be seen in the figure, all rains terminated within 6 hours. It is hence concluded that the duration of the design rainfall can be 6 hours.

Rainfall Intensity Curves

Rainfall intensity curves have been developed in the following process.

(1) Calculation of Probable Rainfalls

The recurrence probability analysis for various times of duration was made by using two methods, Gumbel and Normal Distribution methods. The results are delineated in Figure I2-15. Gumbel Method gives higher accuracy and safer values for planning, hence its result is applied to the succeeding studies. The values of probable rainfalls, by Gumbel Method, for rainfall duration of 15 minutes to 4 days in return periods of 2, 5, 10, 30 and 50 years are summarized as follows:

Probable Rainfall

Return Period (year)	Hourly Rainfall (mm/hr)	Daily Rainfall (mm/day)
2	44.8	87.8
5	63.2	112.3
10	75.4	128.4
30	93.8	152.9
50	102.2	164.0

(2) Equations to Express Rainfall Intensity-Duration Relation

The following equations are commonly applied to express the relationship between rainfall intensity and its duration:

(a) Talbot Type : $I = a / (T + b)$
(b) Sherman Type : $I = a / T^{n}$
(c) Kuno Type : $I = a / (T^{0.5} + b)$
(d) Horner Type : $I = a \times (T + b)^{n}$

where,

I : Rainfall Intensity (mm/hour)
T : Rainfall Duration Time (min.)
a, b, n : Constants

The constants of the foregoing equations were estimated by the least-square regression analysis on the relation between the probable rainfall intensity and its corresponding rainfall duration. The estimation was made individually for less than 6 hours and for more than 6 hours. The rainfall intensity curves of Horner Type, which was verified to be most in conformity with the actual relation between probable rainfall intensity and duration, are given in Figure I2-16.

Design Hyetograph

Figure I2-17 shows three actual rainfall patterns attained from Pochentong Meteorological Station. These rainfall patterns are characterized by the facts that all rainfalls terminate within 6 hours and the peak of each rainfall appears nearly at the middle of its duration. In this case, the study decided to apply so-called 'Centrally Concentrated Rainfall Pattern' shown on the bottom of Figure I2-17 to the design hyetograph for planning the major drainage facilities such as pumping stations, regulation ponds and drainage mains.

2.4.5 Water Level Analysis

Flow Regime

Based on the water level observation data at Chaktomuk Station, the flow regime of the Mekong river system was analyzed to realize the general annual fluctuation of water level outside the Study Area. The results are shown in the following table:

Flow Regime at Chaktomuk Station

Water Level	Average since 1960 (EL. m)
Annual Highest	8.88
95th day in a year	6.59
185th day in a year	3.38
275th day in a year	1.36
355th day in a year	0.80

Probable High Water Levels

To determine the design high water level along the Tonle Sap and Tonle Bassac rivers, probable high water levels are analyzed by using the data in Table I2-7 that shows the annual highest water levels at Chaktomuk Station since 1960. The analysis results are shown in the table below:

Probable High Water Levels at Chaktomuk Station

Return Period (year)	High Water Level (EL. m)
2	8.9
5	9.4
10	9.7
20	9.9
30	10.0
50	10.1

Note: EL. 9.96 m is the all time high since 1960.

2.4.6 Runoff and Inundation Analysis

Principles

The Master Plan and feasibility studies require the following three sorts of runoff and inundation analyses:

(a) Analysis to estimate the design discharges and volumes of major drainage facilities such as pumping stations, regulation ponds and drainage mains (corresponding to a 5-year return period), where hydrographs in consideration of the retarding effect in the upper reaches are entailed;

(b) Analysis to clarify the inundation conditions, with and without projects, for various return periods of rainfall to estimate the benefits induced by the project implementation; and

(c) Analysis to determine the design size of each pipe in sewer networks (corresponding to a 2-year return period), where peak discharges only are necessitated;

For the third analysis (c), the Rational Formula will be applied according to common practices in the similar type of projects. On the contrary, the first and second analyses can

be made in a single manner, but in such analysis there are several methods. Following are discussions to select a suitable method for the analysis.

The methods of runoff and inundation analysis to be applied to Items (a) and (b) above are generally classified into two types: the one-dimensional analysis and the two-dimensional analysis (usually with unsteady flow calculation). The former is simple, but cannot express the spread of flow in two dimensions on floodplains like the Study Area. For that end, the latter would be superior and could simulate the spreading and gathering flow condition, even if it is a little more sophisticated. It was hence concluded that the runoff and inundation analysis be made by the 'Two-dimensional Unsteady Flow Method' that is one of typical two-dimensional analyses.

Modeling of Study Area

Basically, the analysis covers the whole Study Area (195.71 km^2). However, the following two basins are omitted therefrom as the study results on the protection line (against floods) as discussed in Subsection 3.3.2:

- C6: Bassac Riverside Basin (1.58 km^2), and
- E4: Sap Riverside Basin (1.27 km^2).

Thus, the total area subject to the runoff and inundation analysis is 192.86 km^2. The area is in turn divided into two in response to the study requirement as follows:

- Suburban Area, with an area of 157.99 km^2; and
- City Core (23.71 km^2) including Tompun Basin (11.16 km^2), totaling 34.87 km^2, which requires more detailed examination.

Figures I2-18 and I2-19 present the hydraulic models for the runoff and inundation analysis in the Suburban Area and City Core, respectively. These models have been constructed in the following procedure:

(a) Firstly, in view of the location of major channels, roads, dikes, embankments and other facilities controlling flood flow, the Suburban Area is divided, based on the watershed definition described in Subsection 2.4.1, into 117 blocks with areas of 20 to 460 ha, while the City Core into 77 blocks with areas of 6 to 156 ha;

(b) In order to realize inundation condition, a rating curve (so-called H-V curve) is developed for each block using the topographic maps with a scale of 1/2,000;

(c) The boundary between adjoining two blocks is classified into two conditions in terms of the elevation of the boundary: whether surface runoff can pass through the boundary or not? (However, when a sewer system is provided through the boundary, runoff in sewers is included in the surface runoff discharge);

(d) Along boundaries working as obstruction against flood flow, sluiceways and openings are identified mainly through field investigations;

(e) Pumping stations, regulation ponds and drainage mains are depicted on the plan; and

(f) Finally, 4,860 meshes are superimposed on the Study Area to express a result of the analysis (inundation water depths).

Calculation Cases

The following are the calculation cases of runoff and inundation analysis required for formulating the Master Plan and conducting the feasibility studies:

(a) Case 1 : Year 1996 flood for the verification of the hydrological and hydraulic models and conditions assumed;

(b) Case 2 to 9 : to realize the effect of drainage improvement projects, with rainfall probabilities of 2-, 5-, 10- and 30-year, under with- and without-project conditions; and

(c) Case 10 and 11 : to identify the possibility of flood protection projects, with water level probability of 10- and 30-year, under without-project conditions.

Results of Runoff and Inundation Analysis

(1) Design Discharges and Hydrographs

One purpose of the runoff and inundation analysis is to give the design discharges and volumes of major drainage facilities such as pumping stations, regulation ponds and drainage mains with a design magnitude of 5-year return period. To this end, flow rates and flow directions through every block boundary, and hydrographs at the pumping station sites are estimated through the Two-dimensional Unsteady Flow Method. The results are depicted in figures as follows:

(a) Flow directions and peak discharges of Case 5 in Suburban Area (With-project, R.P. = 5-year): Figure I2-20;
(b) Flow directions and peak discharges of Case 5 in City Core (With-project, R.P. = 5-year): Figure I2-21; and
(c) Design Hydrographs at the Inlets of Tompun, Trabek and Pochentong pumping stations (With-project, R.P. = 5-year): Figure I2-22.

(2) Inundation Analysis

The inundation analysis aims at clarifying the inundation conditions, with and without projects, for various return periods of rainfall or water level to assess the benefits induced by the project implementation. The results are used for the economic evaluation described in Section 4.1.

2.5 Topography and Geology

2.5.1 General Topography and Geology

Topography

The land of Cambodia is composed practically solely of a vast lowland, although it is dotted with small hills and plateaus, and fringed by mountainous areas on its border. The lowland, usually called the central plain, extends with the Tonle Mekong and Sap rivers and their tributaries, and shares extremely important position in terms of population, economy and politics of the country.

The City of Phnom Penh is located at the southern part of the central plain, where the Tonle Mekong and Sap rivers merge on it's western side. The old city area, together with nearby villages and settlements, develops on natural levees which are relatively high land with elevations of 9 to 11 m formed by the two rivers. The rest of the city area is literally low and flat, where there are cultivated lands, grazing lands, lakes/swamps and small to medium streams flowing towards the major rivers.

The Study Area, as a whole, slopes down moderately from west to east and from north to south. The difference between the lowest and highest elevations is approximately 10 m (4 to 14 m). There is a high terrain zone measuring a maximum elevation of 14 m between Prey Key Village and the western part of Pochentong Airport, however no terrain is higher than EL. 14 m within the Study Area. The Boeng Puongpeay area has low elevations of 5 to 6 m, and the Tompun area of 4 m at the lowest point. The remaining area representing most of the Study Area, in general terms, ranges between 7 m and 10 m in elevation.

Geology

The geological structure of the Mekong Delta region, where the Study Area is situated, was formed from Precambrian to Holocene ages. The oldest massif of the region includes granite, gneiss, quartzite and other crystalline rocks considered being of Precambrian to early Paleozoic ages. During Paleozoic Age, areas north and south of this massif were downwarped and a thick series of limestone, sandstone and shale of Ordovician to Carboniferous ages accumulated in the depressed areas.

In the late Carboniferous age, the older Paleozoic sedimentary rocks were metamorphosed, deformed and uplifted during the Hercynian orogeny. Also, during the Hercynian orogeny, large granite plutons with associated dacite dikes invaded the older Paleozoic sedimentary rocks. During and following the Hercynian orogeny, major volcanic activity was recorded in andesite flows and in rhyolite/dacite flows that rise above the deltaic alluvium in the north of the Study Area. The trend coincided with that of the tectonic trough in which the alluvial complex of the Mekong Delta was later deposited.

The northwest-trending tectonic trough, now filled with the Quaternary alluvial complex of the Mekong Delta, began to subside in late Tertiary age, probably along lines of crustal weakness that had developed in the Hercynian orogeny. During Plio-Pleistocene Age, the Old Alluvium was deposited by the Mekong River and its tributaries in a vast deltaic fill. The deltaic fill attained a thickness of 600 m or more along the axis of the trough, but thinned to a featheredge along the massif margins. Concurrent with the early stages of the alluviation, local basaltic eruptions in lava flows and small volcanoes occurred along the northeastern and southwestern (running west of the Study Area) margins of the trough. Along both margins, the Old Alluvium is in places interbedded with and in part overlain by basalt flows. Basalt flows are also interbedded with sand and gravel beds of the Old Alluvium near the Study Area.

Gentle downwarping along the axis of the delta and some uplift of the Old Alluvium along the northeast and the southwest margins has occurred as the trough has subsided and succeedingly Holocene deltaic alluvium was deposited. The Holocene Alluvium, consisting largely of unconsolidated silt and clay with some lenses of sand, blankets virtually the entire delta. The Holocene Alluvium in and around the Study Area has generally a thickness of less than 25 m and thickens to more than 100 m along the seaward

of the delta. The Holocene Alluvium differs from the Old Alluvium in having a generally finer texture, almost no laterite, and a relative abundance of shell and lignite layers. Both the Holocene and the bulk of the Old Alluvium are considered to be of Quaternary Age.

2.5.2 Topographic Mapping

Existing Maps and Aerial Photographs

The following table shows a list of existing topographic maps and aerial photographs for the Study Area:

Item	Scale	Covering Area	Quantity on Project Area	Prepared by	Year	Issued by
Topo. Map	1:2,000	Phnom Penh Area	100	IGN France	1995	Cadastral Dep. Municipality of Phnom Penh
	1:5,000	Ditto	24	Ditto	Ditto	Ditto
	1:10,000	Ditto	9	Ditto	Ditto	Ditto
	1:50,000	Whole Country	2	AMS (US Army Map Service) Viet Nam Army Mapping Agency	1960-1980	AMS (US Army Map Service) Viet Nam Army Mapping Agency
	1:100,000	Ditto	7 (Catchment Area)	Viet Nam Army Mapping Agency	1960-1980	Viet Nam Army Mapping Agency
Aerial Photo	1:10,000	Phnom Penh Area	Approx. 170	IGN France	1993	Cadastral Dep. Municipality of Phnom Penh
	1:25,000	Mekong River Basin Area	34	FINNMAP	1992-1993	Cambodia National Mekong Committee

Mapping in this Study

Mapping was carried out in this Study through ground control survey (refer to Figure I2-23) and photogrammetric digital mapping (refer to Figure I2-24), and produced the following results:

(1) 1:2,000 scale topographic maps with 0.5m-interval contour lines:
   (a) New Mapping Area (see Figure I2-25) : 37 sheets, 1 set
   (b) Existing Map Area (see Figure I2-26) : 66 sheets, 1 set

(2) 1:10,000 scale compiled topographic maps with 0.5m-interval contour lines (see Figure I2-27) : 8 sheets, 1 set

(3) Map Data in CD-ROM : 4 pieces, 1 set

(4) Computation Result and Field Book of Control Survey
   (a) Computation Result : 1 volume, 1 set
   (b) Field Book : 2 volumes, 1 set

2.6 Flood Protection/Drainage Facilities and Measures

2.6.1 Ring Dikes, Roads and Crossings

Ring Dikes

There are two ring dikes called "Outer Ring Dike" and "Inner Ring Dike" (refer to Figure I2-28).

(1) Outer Ring Dike

(a) Tompun Dike and South Section

Tompun Dike starts from the junction with St. 271 (a part of the Inner Ring Dike) ending at NR 303 to protect the inland from the flooding of the Thnot river basin. The total length is 4.4 km. Its crest elevation ranges from 10.0 to 10.7 m in most parts, whilst the lowest elevation is 9.7 m near the junction with NR 303. The height ranges from 4.0 to 6.5 m with a side slope of about 1:2 and the crest width is from 15 to 20 m, of which 5.0 to 7.5 m is utilized as a carriageway. The road surface is not paved and undulated. On both sides of the road are occupied mostly by squatters.

NR 303 starts from the City Core extending to the south. The road length within the Study Area is 4.8 km. The stretch forming the south section is between the junctions with the Tompun Dike and Prey Sar Rd., having a length of 1.8 km. Its crest is about 15 m wide, about 5 m of which is shared by a carriageway surfaced with asphalt. The crest elevation ranges from 9.5 to 9.7 m and the height from 0.5 to 1.3 m.

Prey Sar Rd. runs between NR 303 and NR 3 forming the southern boundary of the Study Area. The length of the road is 11 km. The crest elevation ranges between 9.7 m and 14.2 m ascending from the junction with NR 303 to that with NR 3. Its width is about 3 to 5 m and the height varies from 1.4 to 2.8 m. The road surface is unpaved and uneven.

NR 3 is one of the principle national highways in the country extending from Phnom Penh City to Veal Rinh near Sihanoukville. The total length is 202 km, of which 16.5 km stretch passes in the Study Area. Out of the stretch, 6.6 km forms a part of the South Section. The width ranges from 8 to 10 m, of which about 5 m is utilized as a carriageway with asphalt pavement. The crest elevation ranges between 14.2 m and 12.4 m descending from south to north, and its height ranges from 0.3 to 2.3 m.

(b) West Section and Kop Srov Dike

Prey Pring Dike constructed between NR 3 and NR 4 has a function of protecting Prey Pring Town (a triangle-shaped small town) from flooding in the Thnot river basin. Its length is about 1.2 km. The crest elevation is around 10.6 m and the height ranges from 0.9 to 2.5 m.

Kop Srov Rd., both hilly and dike portions, was constructed in the Lonnol era connecting NR 4 to NR 5 to protect the invasion of Khmer Rouge from the north as well as the flooding in the Phnov river basin. The crest width ranges between 10 m and 12 m. The crest elevation varies from 14.4 to 10.2 m descending from south to north. The height ranges from 1 to 4 m (much higher at the northern part dike section). The side slopes of the road embankment vary from 1:1 to 1:3 depending on its height. The surface is unpaved and uneven, and the carriageway width is about 8 m. The total length of the road is 11 km. At a quarter point from NR 4, a railway crosses perpendicularly to the road.

(c) Sap Upstream Section (NR 5)

NR 5 runs on the right bank of the Tonle Sap River, with a length of 11 km, to prevent floods from entering the land side areas. Its crest elevation is 10.2 to 11.1 m in most parts, while the lowest is 9.9 m. The crest width is about 10 m and the carriageway is about 5 m wide. The road surface is paved with asphalt.

(d) Sap Downstream and Bassac Sections

Since the capital was transferred to Phnom Penh in the 15th century, the city has suffered from flooding caused by the Mekong river system. The riverfront has accordingly been heightened by filling earth and maintained to secure the city. The present land elevation along the riverfront is around 10.0 to 11.5 m. The area facing the Tonle Sap River is a little higher than Bassac Section.

(2) Inner Ring Dike

The Inner Ring Dike separates the City Core from suburbs. Along the dike, there are 7 drainage pumping stations constructed to discharge storm water inside to the outer area. The crest of the Inner Ring Dike is 10 to 12 m wide and its elevation varies between 9.5 m and 11.0 m. The southern part of the dike (St. 271) has relatively higher crest elevations ranging from 10.0 to 10.5 m, which lowers at the western part of the dike (St. 271) around the Salang area at 9.2 to 9.8 m and again rises in the Tuol Kork area (St. 598) at 11.0 m. The northern part's crest elevations are between 9.5 m and 10.7 m.

Roads

The present road network in the City Core had been developed during the French protectorate era, and is formed as a grid system centering the Grand Market. The roads in the City Core are basically numbered using uneven numbers for the roads running in the east-west direction and even numbers for those running in the north-south direction. The main north-south roads are Norodom Blvd., Monivong Blvd., Sivutha Blvd. and Issarak St. Major roads running in the east-west direction are Pochentong St., Kampuchea Krom St., Sivutha Blvd. and Issarak St. These roads are paved with asphalt and maintained in good condition. However, other minor roads are unpaved, or paved but damaged in places (although some are repaired by overlaying).

Other than the above-mentioned main roads in the City Core, the following three roads play an important role in the Study Area:

- BOT Road;
- Khmuonb Road; and
- NR 4.

Crossings

Most of roads and railways in the Study Area are constructed by filling earth and their formation levels are usually some meters higher than the surroundings. Drainage basins are thus defined. The site reconnaissance in this study identified such drainage culverts, flood gates and bridges crossing under roads and railways as shown in Figure I2-28.

2.6.2 Pumping Stations

There are 10 pumping stations in the Study Area. The locations and major features of the pumping stations are shown in Figure I2-29 and Table I2-10.

Principal Pumping Stations

(1) Trabek Pumping Station

Trabek Pumping Station covers a catchment area of 10.63 km^2 equivalent to 40% of the City Core area. The storm water through the sewer network, Trabek Channel and Toul Sen Channel are conveyed to the pumping station. The storm water are stored in Boeng Trabek before discharged by pumps over the Outer Ring Dike, where there is the function of retention as well as purification. It is reported that the original storage volume of the lake is about 520,000m^3. Many squatters have settled on lands around the lake and roads across the lake. These facts suggest that the lake surface has reduced and accordingly the storage function has decreased. Also, sedimentation aggravates the storage function.

The pumping station was constructed in 1960. Eight (8) units of pump equipment are housed in the station. All pumps are of the horizontal-shaft centrifugal motor-driven type. The capacity of each pump was originally 2,350 m^3/hr, but has decreased to 1,900 m^3/hr, totaling 15,200 m^3/hr (specific pump capacity: 0.40 $m^3/sec/km^2$ = 15,200 m^3/hr/10.63 km^2).

At present, the improvement/rehabilitation of the pumping station, together with Trabek and Toul Sen channels, is being undertaken by ADB, called "Phnom Penh Water Supply and Drainage Project, Part B: Drainage, ADB Loan No. 1468 (ADB Trabek Project)" , and will be completed by 2002.

(2) Tompun Pumping Station

Runoff led to Tompun Pumping Station are of the storm water from Tompun's own catchment (11.16 km^2) and water pumped by Tum Nup Toek, Salang and Toek Laak pumping stations (3 pumping station's catchment area is 6.31 km^2 in total). All

runoff is collected through Meanchey Channel to the pumping station, the total catchment area being 17.47 km^2 at the station site.

The water collected through Meanchey Channel is once stored in Boeng Tompun before discharged by the pumping station to the outside of the Study Area. The lake's figure is not precisely defined and its storage capacity is gradually decreasing due to land reclamation and sedimentation.

Firstly, a pumping station had been constructed in 1969-70 but it had collapsed. In 1972, the existing pumping station was built and several units of pump equipment (numbers unknown), having a capacity of 2,500 m^3/hr each of the vertical-shaft axial-flow motor-driven type, were installed. Among them, 4 units are still operated, however their capacity has decreased to 2,300 m^3/hr.

Then, 2 units of the vertical-shaft centrifugal motor-driven pump equipment, which were donated from the city of Paris, were installed in 1995. The equipment has a capacity of 720 m^3/hr each. Other than the above, 5 units of diesel-engine-driven pump equipment were additionally installed in 1998. The equipment has a capacity of 2,100 m^3/hr each and is of the vertical-shaft axial-flow type. As a result, Tompun Pumping Station, presently, has a capacity of 21,140 m^3/hr in total (the specific pumping capacity: 0.34 $m^3/sec/km^2$).

Moreover, the installation of 2 units of pump equipment, having a capacity of 2,100m^3/hr each, is planned. The contract of the supply and installation of the equipment has already been made.

Intermediate Pumping Stations

(1) Tum Nup Toek Pumping Station

Tum Nup Toek Pumping Station drains the runoff from an area of only 0.68 km^2 around Khmero-Russian Hospital. The runoff is collected through side ditches and pipe culverts, most of which are however choked and filled up with earth. The collected runoff is stored in a small pond adjacent to the pumping station and is pumped out to Meanchey Channel.

Formerly, Khmero Russian Hospital Pumping Station was constructed to discharge storm water in this area. However, this pumping station was abandoned. Instead, the existing Tum Nup Toek Pumping Station was newly constructed in 1995 by the grant aid of the city of Paris. Two (2) units of pump equipment, with a capacity of 900 m^3/hr each, are housed in the station. The equipment is secondhand and of the horizontal-shaft centrifugal motor-driven type.

(2) Salang Pumping Station

The runoff from Salang Basin (5.53 km^2) is collected through the sewer network and open channels. Before being pumped out, the collected water is stored in Boeng Salang and then discharged into Meanchey Channel. Boeng Salang is of a long and narrow shape and the width is quite reduced like a channel in some locations. It is

reported that the pond surface has an area of 1.42 ha. The perimeter of the lake has been occupied by squatters.

This pumping station was constructed in 1970 and 3 units of the vertical-shaft axial-flow pumps are installed. Each pump is driven by a diesel engine and have a capacity of 2,100 m^3/hr. Two (2) units of the vertical-shaft centrifugal pump equipment, which were donated from the city of Paris, were additionally installed. These pumps have a capacity of 720 m^3/hr each. The pumps are normally driven by motors, while in power failure case they are operated by diesel engines.

Since the water level in the discharge side (Meanchey Channel side) is normally lower than the lake water level, the storm water collected in Boeng Salang can be discharged by gravity. For this purpose, one culvert of Ø 600 mm pipe is located just beside the pumping station, however this pipe is clogged with sediment/debris. The other culvert is located 100m south of the station along St. 271. This culvert is of 2-lane Ø1,000 mm pipes with gates (now out of order) at the downstream side and with gate slots at the upstream side.

(3) Toek Laak Pumping Station

The pumping station was constructed and 2 units of pump were installed in 1962. The pumping capacity was formerly 150 m^3/hr each. At present, the pumps are replaced by 2 units of the vertical-shaft axial-flow diesel engine-driven pump having a capacity of 300 m^3/hr each.

The pumping station covers a small catchment area of 10 ha. The water is collected through side ditches. The existing side ditches are choked up with wastes and sludge due to the lack of maintenance, which results in inundation over the catchment. The inundation water flows into the adjacent Salang Basin.

(4) Olympic Stadium Pumping Station

The pumping station is located in the Olympic Stadium compound. The compound had been furnished with a sanitation complex consisting of a wastewater treatment plant, retention ponds and the pumping station. However, the whole complex is now under no operation.

The pumping station was constructed in 1965 and 3 units of pump equipment are installed. The original pumping capacity is 1,700 m^3/hr each of the vertical-shaft axial-flow motor-driven type. However, the pumps are at present out of order due to the lack of spare parts such as electric cables and transformers.

The runoff from the catchment is stored in small ponds and used to be pumped up to Toul Sen Channel. Presently, the water collected in the ponds is drained through the existing pipe culvert (Ø800 mm x 5 lanes) crossing under Sivutha Blvd. to Toul Sen Channel by gravity.

Local Pumping Stations

(1) Tuol Kork I Pumping Station

The pumping station was constructed in 1970 and a unit of the vertical-shaft axial-flow pump is installed. The capacity is originally 2,500 m^3/hr, but has decreased to 2,100 m^3/hr at present. Two Ø 600 mm pipes are installed just beside the station to allow gravity flow.

The runoff from the catchment is collected in a pond located just upstream of the pumping station (beside Phnom Penh University near the railway). The pond used to function as a retarding basin, however the entire surface of the pond is now covered with aquatic plants (water hyacinth).

(2) Tuol Kork II Pumping Station

This pumping station was constructed in 1970, at the same time as Tuol Kork I, with a unit of the vertical-shaft axial-flow pump. The capacity has also decreased to 2,100 m^3/hr. One Ø 600 mm pipe is installed to secure gravity flow. It is planned to install 2 units of pumps to supplement the existing pump capacity. The contract therefor has already been made, however the date of supply and installation has not yet fixed.

(3) Tuol Kork III Pumping Station

This pumping station was also constructed at the same time as Tuol Kork I and II. However, the pump equipment installed was completely destroyed and no pump equipment is housed in the station. In the dry season, wastewater from the catchment is drained through Ø1,000 mm pipe installed through the Inner Ring Dike, while the runoff during storm flows into nearby Tuol Kork I Basin.

(4) Poungpeay Pumping Station

The pumping station is located in the northeastern part of the Study Area. The purpose of the pumping station is supposed to drain inundation water around the station to Boeng Poungpeay. However, it appears that the pumping station has been abandoned (although detailed information is unavailable).

2.6.3 Drainage Channels and Sewer Network

Drainage Channels

Major drainage open channels in the City Core are Trabek, Toul Sen and Salang channels. These channels are in many parts clogged with debris and sediments. As a result, the flow capacities are remarkably restricted. The channels have been, from time to time, cleaned up by DPWT using their own equipment and by subcontracting with local firms, however the problems have not greatly been solved. It is reported that the clogging ratio is 70 to 80 % of the original flow areas. In addition, there are several drainage open channel systems in the Tuol Kork, Tompun and Pochentong East areas. Major existing drainage channels are delineated in Figure I2-29.

(1) Trabek and Toul Sen Channels

Trabek Channel is located along St. 105, the secondary road in parallel with Monivong Blvd., and is about 1.7 km long with widths of 3 to 5 m. Some portions are occupied by squatters with the surface covered by slabs. The channel crosses small streets running in the east-west direction, where 2-lane Ø 1,500 mm pipe culverts are installed. The flow capacity of the channel is limited by such pipe culverts.

Toul Sen Channel consists of Toul Sen East and West. Toul Sen East Channel connects to Trabek Channel from the right and the length is about 520 m. The Toul Sen West Channel was formerly of an open channel over the whole stretch, however a major part of the open channel was replaced by 2 lanes of sewer pipes with a diameter of Ø1,000 mm each. At present, the middle part only remains as an open channel with a length of 470 m.

(2) Salang Channel

Salang Channel consists of two channels running in parallel, which are the west channel along St. 261 and the east channel along St. 257. Both channels connect into Boeng Salang. The west channel is about 300 m long and the east about 430 m. The widths of both channels are 2 to 3 m and they are choked up due to the lack of cleaning and maintenance works. Another open channel is between the two lakes of Boeng Salang, however the channel was recently replaced by pipes at some locations.

(3) Tuol Kork Channels

In the Toul Kork area, there were main drainage channels on both sides of St. 315 and 289. The channels are gradually buried and replaced with Ø1,000 mm concrete pipes and several parts only remain as open channels with widths of 2 to 3 m.

(4) Meanchey Channel

Outside the City Core, Meanchey Channel has a great role to drain storm water in the Tompun catchment. The channel is aligned along the southwest perimeter of the Inner Ring Dike, collecting the outflow from Salang, Toek Laak and Tum Nup Toek pumping stations and Tompun Basin, then finally connects to Boeng Tompun. In the upstream stretch of the catchment (just south of NR 3), the channel was replaced with pipes. The channel width gradually increases to the downstream direction, ranging from about 2 to 30 m.

(5) Pochentong East Area

In the eastern part of Pochentong Airport, which is under developing as factory lots, residential and school zones, etc., open ditches are constructed on both sides of inner roads running lengthwise and crosswise. At the intersections of the inner roads, several pipe culverts, having diameters of 600 to 800 mm, are provided.

A drainage channel has just been constructed to drain storm water from Pochentong Airport. The channel is of a trapezoidal section, 2.5 m wide and 2.5 m deep. For

several road crossings, Ø600 mm and Ø800 mm pipes are installed. No revetment or protection works are applied to the channel slopes at present due to budgetary constraint.

Sewer Network

Sewers had been constructed until the end of 1960s with city development. During this period, numerous channels and ditches were filled up and converted to sewer pipes. This formed mostly the existing sewer network of the combined system over the City Core, except the Tuol Kork area and Bassac riverfront, having a total length of nearly 200 km. The sewer network is now managed by DPWT, while the need of increasing the drainage capacity to cope with the latest rapid urbanization has not been fulfilled.

Data exactly showing the present sewer pipe's features, such as the invert levels, longitudinal gradients, manhole locations, etc., are not well documented or registered. The sewers are mainly circle-shaped concrete pipes ranging 300 to 1,500 mm in diameter and the longitudinal gradients range from 1/500 to 1/2,000. The pipes are buried, with coverings of 0.5 to 3 m, on one side in narrow to medium streets and on both sides in wide streets. The present sewerage network system in the City Core identified by diameter is tabulated below (see Figure I2-30):

Existing Sewers

Diameter (mm)	Length (m)
Ø1,500	6,765
Ø1,000	27,585
Ø 800	17,595
Ø 600	130,493
Ø 500	1,298
Ø 300	10,838
Total	194,573

A greater part of sewer pipes are choked with sediment and solid waste generated mainly by inhabitants neighboring. The choke rate is reported as 50 to 90 % of their original flow capacities and especially sewers in the Daun Penh North area (around Wat Phnom) are totally choked up. DPWT is making effort to clean up such pipes, however it is not effectively conducted due to lack of equipment and budget.

Along the riverfront of the Sap and Bassac rivers, sewer outfalls are found at 17 locations. Some are completely broken and the other are clogged with sediment and wastes. It is planned to install pump facility at 3 outfalls. A pump pit has been constructed at each location, however pump equipment itself not yet being installed.

2.6.4 Operation and Maintenance of Facilities

Flood Protection Facilities

No operation and maintenance manuals for flood protection facilities have been prepared. Organization in charge of the maintenance of the dike is Road and Bridge Division of DPWT.

Periodical maintenance work has not been conducted though rainfall and seepage have heavily damaged dikes, especially Kop Srov Dike. Along the Tonle Sap River, soil carried and deposited by the river water in front of revetments has been removed from time to time. However, it is said that this work is to borrow soil for land reclamation.

Sewer System

Drainage and Sewage Division of DPWT is in charge of the operation and maintenance of sewer system in the Municipality of Phnom Penh. Operation and maintenance manual for the sewer system does not exist. Periodical dredging is conducted in the rainy season at seven points of canals of Salang, Toul Sen West, Toul Sen East and Trabek. Excavators and trucks of DPWT are used for the work. Cleaning of sewer pipe is also conducted. It is not periodical and according to the availability of budget for purchasing fuel.

Weekly Report and Monthly Report are submitted from the Director of DSD to the DPWT and MPP. They include the work quantity for concrete works, cleaning of pipe by manpower, cleaning of pipes by vacuum truck, dredging, and maintenance work for pumping stations.

Drainage Pumping Stations

Drainage and Sewage Division of DPWT is in charge of the operation and maintenance of drainage pumping stations in the Municipality of Phnom Penh. Major repair of the electromechanical equipment is conducted mainly in the dry season. Daily operation record includes number of installed pumps, water level at pumping stations, operation start time and end time, number of pumps working, number of pumps broken, and electricity stop hours in each day. A form sheet for daily record of a week is filed.

Equipment owned by DPWT

DPWT has been making effort, using equipment for cleaning and maintenance, to secure the existing sewer networks and drainage open channels. These cleaning and maintenance equipment owned by DPWT is listed in Table I2-11.

2.6.5 Non-physical Measures

Flood Forecasting/Warning and Flood Defense Activity

(1) Decree, Regulations and Procedures

Any basic law on measures against disaster has not been established in Cambodia. Actual administrative flow for measures against disaster in the historical experience is the following according to the record in the 1996 flooding.

(a) Letter from the Minister of Interior to the Governor of the MPP

Referring to a report on May 21, 1996 of Committee in charge of Disaster, a letter has been issued by the Minister of Interior to the Governor of the Municipality of Phnom Penh and governors of all cities and provinces on July 17, 1996 telling that "to be more prepared and protective to any disaster which arise in this year". More concrete suggestions are:

- To inform the residence living in the area that may have danger from any kind of disaster to be more careful to protect it successful.
- The authorities of every level have to consider and keep an eye on every condition to protect disaster that may happen in any case.
- As long as there is disaster, in the city/province, it should be reported to the Ministry of Interior about the size of damage, assistance of province/city.

Accomplishment of the above is requested to be conducted through close cooperation with competent ministry and the people in region. Copies of the letter are sent to the following persons and organizations.

- Cabinet of Samdec Krom Preah, 1st Prime Minister
- Cabinet of Samdec, 2nd Prime Minister
- Council of Ministers
- Directorate in charge of Disaster

(b) Declaration Issued by the MPP

Receiving the letter from the Minister of Interior, the Municipality of Phnom Penh issued "Declaration on the Appointment of Committee and Sub-Committee to Protect Flood" on August 1, 1996.

In the declaration, the committee and sub-committee have been established with their roles.

(i) Article 1: A mixed Committee to protect flood has been established consisting of one Chief (Governor of MPP), four Vice-Chiefs, one Permanent Member and 25 Members.

(ii) Article 2: A total of four Sub-Committees to protect flood has been formulated.

(iii) Article 3: The role of Committee and Sub-Committees are defined. The Committee has to stay permanently at the Municipality to solve every flooding matter. The Sub-Committees role is to stay permanently and facilitate in accordance to the Committee.

(iv) Article 4: This Committee has to set up a permanent assistance group to stay at Phnom Penh City Hall that made up of three sections.

(c) Declaration to the Residents in the Critical Area

On September 27, when the water level of the Tonle Mekong came up to W.L. of 10.37m, an urgent declaration has been issued to the residents in the critical area for flooding. An official water level to announce the emergency case is W.L. 10.50m. The declaration is issued to call for all people who are living in

the critical area to be aware of this disaster so that everyone may prepare oneself ready to keep preserve and escape from it on time.

(2) Activities of the Committee and Sub-Committees for Flood Protection

A report on flood protection activities has been submitted from the Governor of the MPP to Co-Minister in charge of Council of Ministers, Co-Minister in charge of Ministry of Interior and Secretary General in charge of Disaster.

- On August 8, 1996 had the meeting among Committee and Sub-Committee to provide duty to the Department of Agriculture, MPP is to take responsible for northern part of Phnom Penh, the Department of Public Works and Transport, MPP is to take responsible for southern part as well as to build 18,400 m dam started from Monivong bridge until road leading to Kop Srov dam.
- Making the announcement to people in Phnom Penh to be aware of flood and be ready to protect it in some case that may arise. MPP had also advised the government institutions to safeguard 24 hours in 24 hours.
- On September 9, 1996 wrote a letter to request budget amount Riel 214,505,506 from National Committee in charge of disaster.
- On September 23, 1996 had the meeting again among the Committee and Sub-Committees to make emergency plan due to water level of Mekong River reaches the maximum height enough to broadcast an announcement.
- Had written letters to private company for machinery to protect flood.
- Had written letters to the Ministry of Public Works and Transport to help warn the ship, motor boat not to drive fast along the river, which causes harmful or damages to river bank and newly built dam.
- Had written letters to three districts surrounding the city to prepare boat to help people.
- Had written letters to every ministry, secretariat, department, district to safeguard at its own place which divided by MPP.

(3) Flood Defense Works in 1996 Flood

The first phase of flood defense was concentrated on two areas, namely, Chbar Ampov in Meanchey District and Chroy Chang Var District in Russey Keo District.

In Meanchey District, the local authorities built Chbar Ampov Dam but the level of Tonle Mekong was too strong to break it at 8:00 on September 28, 1996, therefore the flood covered all over the vegetable market of Chbar Ampov.

In Russey Keo District, a dam was built along the Tonle Mekong from Svay Chrom to Kbal Chroy, however the flood of Tonle Mekong broke through this dam at 24:00 on September 29, 1996 and then it flooded all over Sangkat Chroy Chang Var and Sangkat Prek Tasek.

The second phase, from September 29, concentrated the works in the following three locations:

(a) Kop Srov Dam: A total of 92 trucks of land that covered along Kop Srov dam to stop the seepage through seepage hole "dragon hold" was filled and also sacks of soil are put on the slope of the dam. Machinery was introduced to fill the seepage hole.
(b) Along national road starting from Monivong bridge to Prek Phnov: A total of 30 trucks of soil was put to cover the low land areas.
(c) Boeng Tompun Dam: A total of 119 trucks of soil was put along Boeng Tompun dam to stop seepage through seepage hole ("dragon hold") and sacks of soil were put on the slope of the dam.

Management of Flood Prone Area

Management of flood prone areas generally comprises two aspects: namely, zoning control, and building and development control. Although the CNATUC Law has been established to plan and control land use, building and development, it is not effectively functioning. A land use master plan that should be prepared by CATUC has not been prepared.

2.7 Organization and Institution

2.7.1 Organizations

Organizational structure, staffing, financial aspects, etc. of the organizations related to the present study have been reviewed as follows:

National Level

The Council of Ministers is the Royal Government of the Kingdom of Cambodia. The Council of Ministers is led by one Prime Minister assisted by Deputy Prime Ministers and by Senior Ministers, Ministers, and Secretaries of State as members. There presently is a total of 26 ministries as shown in Figure I2-???. Of the ministries and institutions, function of those related to the present study are discussed hereunder.

Ministry of Economy and Finance (MEF) is responsible for preparation of the national budget. This includes estimating the total expected government revenues for the coming year, establish budgetary priorities and activities within the constraints imposed by available revenues and borrowing limit including grants. MEF will also play a key role in programming the Public Investment Program (PIP) with the Ministry of Planning (MOP) who is responsible for economic and social development and statistic practice of the country. In the process of selecting appropriate projects for capital investment, MEF works with line ministries and the MOP to prepare the annual investment budget.

Any request for foreign assistance is first sent from a respective ministry to the Council for the Development of Cambodia (CDC). The CDC accordingly check upon discussions with relevant agencies the conformity of the subject request to the national plan, and decide adoption/dismissal, and give priority for the adopted ones. When the request for the foreign assistance is approved, it is sent to the Ministry of Foreign Affairs and International Cooperation (MFAIC), the agency responsible for foreign assistance.

CNATUC (Comité National de l'Aménagement du Territoire, d'Urbanisme et de Construction = National Committee for Country Planning, Urbanization and Construction)

was created by "Law on the Country Planning, Urbanization and Construction (CNATUC Law)" that was adopted by the National Assembly on May 24, 1994. The objective of the law is to promote the organization and embellishment of the urban and rural areas throughout the country with the purpose of assuring the development of the country.

CATUC of the Municipality of Phnom Penh, though not yet organized in reality, is designated to draw up own development master plans for the reorganization and development of the municipality. CATUC is also responsible to establish land use master plans that clearly indicate the areas to be allocated for national defense, agriculture, commerce, industry, handicraft, culture, tourism, religion and administrative and public facilities.

Agencies related to river and water are Ministry of Public Works and Transport (MPWT), Ministry of Water Resources and Meteorology (MWRM) and Cambodia National Mekong Committee.

Sub-Decree No. 14 dated on March 3, 1998 has newly declared the duty and organization of the Ministry of Public Works and Transport (MPWT). The tasks of the MPWT include those related to infrastructure e.g. roads, bridges, ports, railways and waterways. A part of the duty has been transferred to the Ministry of Urbanization and Construction that has been created under the new government in December 1998. River and water related duties are covered by Department of Inland Waterway. In each province, there is Department of Public Works and Transport and responsible for development and maintenance of infrastructure facilities in each province. DPWT in each province is controlled by the MPWT.

The Ministry of Water Resources and Meteorology has been newly created with the establishment of the new government in 1998. The former body is the General Directorate of Irrigation, Meteorology and Hydrology (GDIMH) of the Ministry of Agriculture, Forestry and Fisheries (MAFF). The tasks and duties of the MWRM is still not clear, the former GDIMH included duties related to water resources, irrigation systems, meteorology and hydrology.

Another organization related to the river is Cambodia National Mekong Committee. It is the Cambodian organization under the Mekong River Commission. The National Mekong Committee does coordination of relevant agencies and investigation on the Mekong River including its tributaries.

Ministry of the Environment (MOE) has been established in July 1993. The MOE has a broad mandate to protect Cambodia's natural resources and to prevent environmental degradation. Department of Environment is the organization in the Municipality of Phnom Penh responsible for environmental matter.

<u>Municipality of Phnom Penh (MPP)</u>

Organizational structure of Municipality of Phnom Penh is presented in Figure I2-???. Municipal Court, Special Regional Military and Municipal Police are under the direct control of the First Vice Governor. All the other functions of the Municipality are under the Deputy Chief of Cabinet or directly under the Chief of Cabinet. There are a total of 18 line ministry institutions.

All the line ministry departments are under the control of both Vice Governors of the Municipality and the respective Ministers. However due to its strong independence of the Phnom Penh Municipality, each department is strongly influenced by the Municipality. Of the line ministry departments, Department of Public Works and Transport (DPWT) is the agency responsible for flood control and urban drainage of the Municipality.

The organization related to urban planning is BAU (Bureau des Affaires Urbaines). BAUs are the implementing arm of the CATUC and the BAU for Phnom Penh is only the active one at present. The BAU is in charge of inter-sectorial coordination and urban planning in Phnom Penh. Department of Urbanization and Construction is a department under the Municipality of Phnom Penh. It is directly under the Chief of Cabinet and controlled by no line ministries. This department is participated in city planning and land use in the Municipality of Phnom Penh.

There are seven Khans in the Municipality, four (Don Penh, Tuol Kork, 7 Makara, Chamkarmon) inside the inner dike and three (Dang Kor, Meanchey, Russey Keo) outside. Khan is divided into Sangkat. Sangkat is usually with 1,000 to 2,000 families. In total, there are 76 sangkats.

There is a total of 11,241 staffs in the Municipality as of May 1998. The Municipality of Phnom Penh is as dependent on the national budgeting process as the provincial government. The Municipality does not have the legal authority to raise revenue or make expenditures at its own discretion. Budget for the Line Ministry Institution is decided and allocated by each ministry.

Budget of Municipality of Phnom Penh

Unit: Million Riel

Item	1994	1995	1996	1997
Salaries & Indemnities	8,425	8,852	8,423	8,452
Operational Expenditure and Small Repairs	3,724	1,720	2,338	2,081
Public Administration and Subsidies	342	1,381	2,159	2,615
Social & Cultural Expenditure	4,194	4,679	7,280	6,022
Capital Expenditure	907	455	1,985	481
Total	17,593	17,099	22,185	19,651

Of the total budget, salaries and indemnities share approximately 50%. This is a large burden for the Municipality that lacks the resources to address even the most basic infrastructure. On the contrary, the budget allocated to the capital expenditure is very small at 5% in 1994 and it reduced to 2.7% in 1995.

The execution of a project is explained with the case of the "Phnom Penh Water Supply and Drainage Project, Part B: Drainage, ADB Loan 1468". In this case, the MPP is the Executing Agency. The Executing Agency is responsible for project implementation and coordination. Under the MPP as the Executing Agency, DPWT is the implementing body. Drainage and Sewerage Division is specifically responsible for the implementation of the drainage component.

Department of Public Works and Transport (DPWT), MPP

Department of Public Works and Transport (DPWT) is responsible for development, operation and management of infrastructures in the Municipality. The DPWT of MPP is the largest of the provincial level Public Works Departments. The DPWT is under the dual supervision of Ministry of Public Works and Transport (MPWT) and of the Vice Governor of the MPP in charge of infrastructure.

The organizational structure of the DPWT is presented in Figure I2-???. Officials of the DPWT are appointed by the MPWT. All funds for salaries, materials and equipment come from the MPWT. The Ministry, based on annual plans prepares all investment budgets, the recurrent budget, and the operation budget. Technical advice and guidance are also given by the MPWT. There is, however, considerable influence from the MPP due to primarily to the independent role played by the Municipality prior to 1993. Urban drainage and flood control in the Municipality of Phnom Penh is under the jurisdiction of Drainage and Sewerage Division of the DPWT.

There is a total of 1,308 staffs as of May 1998. Of these, 626 are full-time staffs and 682 are part-time staffs. The budget for the past five years are as follows:

Budget of DPWT

Unit: Million Riel

Item	1994	1995	1996	1997
Salaries & Indemnities	673.00	535.70	673.00	750.00
Operational Expenditure and Small Repairs	115.00	120.00	115.00	85.00
Public Administration and Subsidies	0.00	0.00	0.00	0.00
Social & Cultural Expenditure	7.50	8.40	7.50	20.00
Capital Expenditure	1,384.70	1,335.94	249.31	668.80
Total	2,180.20	2,000.04	1,044.81	1,523.80

Drainage and Sewerage Division (DSD), DPWT, MPP

The organizational chart of the Drainage and Sewerage Division (DSD) is presented in Figure I2-3. The Drainage and Sewerage Division (DSD) manages the maintenance and operations of the combined drainage and sewerage system (sewers, open channels, retarding ponds and pumping stations). Activities of the DSD include the following:

- Planning and programming of maintenance work on the system
- Operation and maintenance of pumping stations
- Production and laying of drain and sewer pipes
- Supervising work performed by contractors

There are five subdivisions each headed by a Deputy Director. There is a total of 257 staffs as of May 1998. Of these, 118 are full-time and 137 are part-time. In the case of the implementation of projects related to drainage and sewerage, e.g. Phnom Penh Water Supply and Drainage Project, Part B: Drainage financed by ADB Loan 1468 and co-financed by NORAD, it is managed by PMU (see next article).

The budgets for the past five years are as follows:

Budget of DPWT

Unit: Thousand Riel

Item	1993	1994	1995	1996	1997
Salaries & Indemnities	70,335	80,415	78,891	70,002	61,126
Public Administration and Subsidies	62,100	62,100	62,100	62,100	62,100
Social & Cultural Expenditure			1,053	2,450	755
Capital Expenditure	114,957	132,368	115,981	38,091	263,168
Total of the above	247,392	274,883	258,025	172,644	387,149
Operation and Maintenance Work	No data	928,600	1,545,300	1,057,000	1,012,700

Project Management Unit (PMU), DPWT, MPP

Project Management Unit has been established to assist DPWT of MPP in the drainage component of the ADB Project (Loan 1468) in 1996 as an organization responsible for the implementation of foreign assisted projects. The PMU is under DPWT of Municipality of Phnom Penh. It has the following organizational structure. PMU coordinates and manages all activities related to the project implementation.

2.7.2 LAWS AND REGULATIONS

Water Law and River Law

There is no law on water, its use and its management in Cambodia. Since there is a plenty of water in and around the area of living and production activities, the necessity of law to control the use of water has been recognized not so indispensable. However, in accordance with the progress of development, a law on water, its use and its management seems to be needed. Ministry of Water Resources and Meteorology has started establishment of a law on river and water.

Drainage and Sewerage

At present, no law regulates domestic or industrial wastewater disposal to rivers or to sewerage systems. There is no law that control the quality of domestic or industrial wastewater discharged to rivers or to sewerage systems. Declaration states the connection to sewer. Drainage and Sewerage Division visits the site upon request from households and issue authorization to the connection to sewers. Connection without the license is strictly prohibited.

In the Municipality of Phnom Penh, sewerage fee of 10% of water bill is collected from water users from 1997. The collected sewerage fee is paid from PPWSA to the account of MPP.

Law on Water Supply

Supply and consumption of potable water is declared by a decree, (Council of Ministers, No. 32, December 31, 1987). Phnom Penh Water Supply Authority (PPWSA) is defined in this decree.

"Declaration on the Charge of Water Connection" (Municipality of Phnom Penh, No. 178) is approved on October 22, 1997. According to the declaration, the house connection

from the public main pipes to the water meters is the duty of PPWSA when the consumer pays the subscription charges.

All consumers of PPWSA must pay deposits for water consumption stipulated in sub-decree No. 32 dated December 31, 1987 and in the notice of Phnom Penh Municipality No. 633 dated November 3, 1993.

Urban Planning and Development

The National Assembly adopted "Law on the Country Planning, Urbanization and Construction" on May 24, 1994. The law is called as CNATUC Law. The objective of the law is to promote the organization and embellishment of the urban and rural areas throughout the country with the purpose of assuring the development of this country. The law is based on the ownership titles as provided in the present Land Law.

The Land Law is established in 1992 under UNTAC. The Government of Cambodia does not recognize any form of land ownership or land rights predating 1979. Both private and communal property rights exist in Cambodia. The 1992 Land Law recognizes the following rights; proprietorship, temporary possession, authorization to cultivate land, franchise, usufruct, right of use and stay, succession, easement, and secured loan on real estate and mortgage. Land proprietorship (freehold tenure) is only applicable to residential land. Land Acquisition Law is presently under process.

"Sub-decree on Construction Permit" essentially serves as a site-specific control on new construction to ensure all future development meets appropriate standards. It establishes basic guidelines to control and limit development in urban areas as per the CNATUC legislation. Land observation is conducted by sub-district (sangkat) and commune (phums) under the Municipality of Phnom Penh

Environment

Law on Environmental Protection and Natural Resources Management (EPNRM) was established in 1996. The purpose is; to protect and promote environmental quality and public health; to assess the environmental impacts of all proposed projects prior to the issuance of the decision by the Government; and to ensure the rational and sustainable conservation, development, management and, use of the natural resources of the country; etc.

Royal Decree on the Protection of Natural Areas, November 1, 1993 declares the responsibility for the protection of natural areas. The Secretariat of Environment is responsible for managing and supervising the development and protection of natural areas. The decree declares Natural Parks, Wildlife Preserves, Protected scenic view areas, and Multi purposed areas.

The Creation and Designation of Natural Areas Sub-Decree, 1996 designated a system of national parks, wildlife sanctuaries, protected landscapes and multi-use management areas (MMAs). No MMAs are as yet designated in or around Phnom Penh City.

The Environmental Impact Assessment Sub-decree is still in draft form, awaiting approval by the Council of Ministers. It supports the EPNRM law by providing implementing regulations associated with environmental impact assessment.

Technical Regulations and Guidelines

Technical regulations and guidelines, and design criteria have poorly been prepared. In the case of technical assistance from foreign countries, it is common to apply technical regulations and guidelines of the donor countries.

2.8 Environment

2.8.1 Natural Environment

Topography and Basic Layout of Phnom Penh

Phnom Penh is located on a flat alluvial plain at the western bank of the confluence of the Tonle Mekong and the Tonle Sap rivers. Natural embankments along the western side of the Tonle Sap and Tonle Bassac rivers are relatively high with elevations at around 10 m. Low-lying land behind of these embankments is not filled by urbanization, and presents a series of lakes and ponds interconnected by streams and canals. Further west, at roughly 5 to 7 km from the river, the land slowly begins to rise; thus the system of lakes and ponds receives the runoff from the higher land as well as that of the embankments and the urbanized area

The town center is located on the west bank of the Tonle Sap river just north of its confluence with the Tonle Mekong and Tonle Bassac.

Hydro-geology

Phnom Penh lies on young and old alluvium deposits, which overlay weathered rock and clay at a depth of 30 to 50 meters with hard crystalline rock at the base. As far as is known, there are no artesian aquifers and practically no groundwater.

Urban Infrastructure and Environment

Some important characteristics of the existing infrastructure in Phnom Penh are as follows:

Surface water drainage has a fundamental influence on the water environment in the city. Three kinds of drainage elements, namely drainage networks, storage basins and pumping stations are general from upstream to downstream. The drainage networks are not functioning well due to clogging and collects a small part of the storm water. Its major part flowing onto the street surface and resulting in frequent flooding during the rainy season. The problem of storage basins mainly lies with their progressive filling by silts and other solids. The banks of the basins are progressively being colonized by squatters, which worsens the situation. The pumping stations, the final element of the drainage system, do not operate satisfactorily because of their old age, the lack of spare parts, and shortages in electrical or thermal energy supply.

Combined systems for sewage and surface water are applied in Phnom Penh City. Domestic wastewater is held on plot in septic tanks. Overflow effluent from the septic

tank runs through pipes into the combined system that also collects surface water runoff. Outside the inner dike, in the peri-urban area, there is virtually no sewerage system. All domestic wastewater is either disposed off on-site (septic tanks or pit latrines) or in the very common case of embankment housing on stilts, via privies in which all wastes are directly dropped into the lake, pond or stream. It has been determined that most industries do not have any specific treatment system and divert their wastewater directly to the nearest drain, river or lake. A few neutralize the wastewater before discharge.

Thirty percent of total households in Phnom Penh have piped water or water from the PPWSA. Almost 44% purchase water for drinking and cooking purposes. The piped water supply as well as water from wells is used for bathing, washing and watering plants. Water distribution system is in a poor state of repair with high leakage rates. Only the four central districts of the seven in the city receive more or less continuous supplies. Rest of the city supply is limited to a few hours per day due to insufficient electrical supply to operate pumps. The networks in the three outer districts are no longer supplied due to limited capacity. Private water sellers are common who buy water from the waterworks and deliver to unconnected households. The status, however, is steadily being improved by the projects implemented under the Japan's grant aid program and under a loan from ADB.

The large number of unsealed roads in Phnom Penh results in grit being washed into the drains and sewers. This blocks all but the largest diameter drainpipes.

Central area of Phnom Penh is served by semi-regular curbside pick-up of household solid wastes. The system requires residents to deposit waste at communal collection points in their vicinity. The waste is collected from these points and transported to the municipal dumpsite. The communal collection points are generally in unconfined areas within the road reserves. Waste is often poorly packaged and not picked up properly. As a result, debris is scattered by animals, scavengers or the wind, and consequently fails to be collected. There is no more sufficient capacity in the existing dumping site. Garbage or urban solid waste collection is inefficient in the peri-urban area and in squatter settlements scattered all over and contributes to drainage pipe blockages.

Market places particularly are very poorly drained resulting in unsanitary working and shopping conditions in the wet season. The walkways between the stalls are often flooded and muddy with decaying organic matter spread on the ground. Such unhygienic conditions pose significant health risks.

There is no industrial park or delineated industrial zone in Phnom Penh. Industry has tended to locate logically where it can function best. Historically, and until today, most manufacturing and warehousing has located along the embankments of Tonle Sap north of town or the Tonle Bassac south of town. Smaller industries, workshops, and artisan establishments are common in Phnom Penh and represent considerable production capacity and employment generation. These tend to concentrate on the radial highways heading out of town or along the outer dike embankments, especially the southwest arc.

One area of industrial concentration is along and beside the access road to the current city landfill located in Sanghat Stung Meanchey. Factories, recycling sheds, and warehouses are all found in this area, mixed with housing. It is also seen that medium and large lot factories and warehouses are being set out on apparent random fashion, practically

anywhere along a vast arc of land west of the presently urbanized area. There seems to be a degree of concentration in three locations, namely, along the Boeng Tompun embankment, north and south of the Pochentong road, and around the airport in Chan Chao Sanghat.

Water and Benthic Material Quality

Water quality data of Tonle Mekong, Tonle Sap and Tonle Bassac are available, but no data are available concerning water quality in the drains, canals, and lakes. No data are available concerning benthic material deposits. Water and benthic quality survey has, accordingly, been conducted in the Study. Twenty locations (see Figure I2-34) at the concerned rivers, channels, lakes and groundwater wells were selected for water and benthic material quality sampling. Water sampling was conducted two times in dry season and two times in rainy season. Benthic material sampling is one time in dry season. Table I2-12 presents a descriptive summary of the results along with general site description and water utilization near each site.

Only the groundwater wells exhibit good water quality (station 18 to 20). All lakes and drainage channels have very poor quality due to direct discharge of sewage and garbage into them. This is clear from the extremely high values of COD, SS and Fecal Coliform Counts at all these locations (Stations 6 to 17). The rivers (Stations 1 to 5) also seem polluted by untreated sewage to a lesser degree.

As for the benthic material quality, the average concentration of contaminants was calculated for each category of water-body as shown in Table I2-13. It is clear that lake/swamp, especially Boeng Kak and Boeng Tompun lakes that collect wastewater from northern and southern sections of Phnom Penh municipality, show relatively higher concentration of pollutants, e.g., Cd, CNN, Pb, Cr^{+6} and organic phosphorus. These findings correlated well with water quality data. These lakes serve as an oxidation pond for the city. Thus, deposition of metals and other contaminants can be found in these lakes.

Table I2-14 presents results of leaching analysis. The results show that the status is not so critical especially when the dredged material is properly filled in dumping site. Some more sampling and leaching test is required to conclude, it is recommended that the site selection for safe land disposal of dredged sediment deposits from various water bodies needs to be carefully done.

Flora and Fauna

There is no information concerning terrestrial flora and fauna within the study area. The study area consists of the central urbanized areas and the peri-urban rural suburbs where paddy cultivation is common, and there are a number of lakes or Boengs and natural drainage canals. Aquatic plants and weeds especially water hyacinth, water lily, and duckweed is common. The water hyacinth proliferation is very significant in all drainage channels and marshy areas near lakes. It can be concluded that there are no valuable floral species in the study area.

There are also no reports or information concerning important fauna like migratory birds in the various water bodies or other terrestrial fauna in the study area. Aquatic faunal

species especially different kinds of fish are common in various water bodies and the rivers. Most fish species in the Tonle Mekong, Tonle Sap and Tonle Bassac rivers, as well as in the natural lakes are well adapted to a widely fluctuating water level, and have a wide tolerance for temperature, pH, DO and other environmental parameters.

2.8.2 Social Environment

Social environment aspects concern human settlements and their various inter-related characteristics. A summary is presented below.

Demography and Urbanization

It is estimated that the population of the Phnom Penh Municipality is approximately one million in 1998 including both registered and non-registered population. Of these, about 60% live in the four central districts within the inner-dyke, while the remaining 40% are in the three districts outside the inner-dyke. Assuming the population growth rate to be 3.2% per annum until 2010, the estimated population in 2010 is around 1,450,000. It is expected that Phnom Penh will maintain its primate city status in Cambodia. In 1993, Phnom Penh contained over 41% of all Cambodia's industrial establishments.

Land Tenure

The Land Titles Department in the Municipality of Phnom Penh has made a start in registering properties of the central district of Phnom Penh, but this is not expected to be completed until end 1998. Cadastral mapping is also in progress. Before properties can be properly registered on a cadastral map, the Council of Ministers must approve a parcel map. The unusual history of land ownership in Cambodia with the lack of clarity in the 1992 Land Law has resulted in a large number of land ownership conflicts.

Today, practically all urban land, and particularly vacant land on the city fringes are under private control. This private control can take many forms of possession and ownership, but the result is that, for any land development scheme, Government must purchase or expropriate land or impose development restrictions. While the right to own private property was only re-established in 1989, the purchase and sale of land today in Cambodia is relatively unrestricted. The price of urban property varies greatly depending on location. A substantial amount of residential expansion is occurring on the periphery of lakes or "Boengs" inside the dike in Phnom Penh. In particular, new construction is readily visible in Boengs Slang, Trabek, and Tompun.

Urban Housing

Six types of houses are observed in Phnom Penh: Detached Concrete Villa, Chinese Row Housing, Hybrid Wood Villa, Stilted Khmer Wood House, Stilted Bamboo Wood House, and Thatch Tin House – each ranging in cost, prevalence and characteristics. The Stilted Khmer Wood House is found mixed in with other housing in linear strip development and on spontaneous urban fringes. The Stilted Bamboo/Wood House is prevalent in linear strip developments, in spontaneous fringe areas, and in squatter communities. The Thatch/ Tin House can only be built on ground where there is no flooding. It is commonly found in squatter areas along embankments, and as a "starter" shelter in urban fringe areas.

Urban Social Profiles

The main secondary source of information has been the results as reported in the Socio-Economic Survey of Cambodia (1993-94) conducted by the National Institute of Statistics.

(1) Urban Household

Average household size in Phnom Penh is 5.9 person per household and percent of female headed households is 25.8%. Adult literacy is 91.8% in male and 63.3% in female. Employment rate is 93.9%.

(2) Urban Family Incomes

The mean and median urban family household income is reported to be 781,200 Riel/month and 562,000 Riel/ month respectively in Phnom Penh.

(3) The Urban Poor and Disadvantaged

Women significantly outnumber men in Cambodia. In Phnom Penh, 29% of all heads of households are women. Women play a very important role in the urban economy of Cambodia.

It is estimated that there are 120,000 to 150,000 squatters in Phnom Penh. They are mostly food sellers, small traders, cyclo drivers, construction workers, and petty manufacturers. The majority of squatters are located close to work opportunities. Squatters occupy land owned by the government, although there is disagreement over the legal status of many areas.

Minority Ethnic Groups include the following. The Muslim Cham – mainly lower income communities can be found on the outskirts of Phnom Penh (Russey Keo and Chruoy Chang WA). People of Vietnamese origin can be found in the low-income areas of Russey Keo and Srok Meanchey, mostly along the riverbanks. Their status is precarious, given past anti-Vietnamese feelings. The minority Chinese community is the ethnic group, which is most integrated and assimilated with the majority Khmers.

Seasonal migration to Phnom Penh is thought to be high from the rural areas. It is suggested that as many as 150,000 peasants come to Phnom Penh to seek casual employment during the dry season and between planting/transplanting and harvesting of the rice crop.

(4) Health

Water and sanitation related diseases are the leading cause of mortality and morbidity among the Phnom Penh populace especially children aged 5 years or below. Presence of uncovered storage tanks and water jars, improper sewage and solid waste disposal, poor and cramped living conditions, lack of proper hygiene practices, use of unsafe water, and poor state of urban infrastructure especially drainage, all contribute to creating ideal breeding grounds for vector carrying insects like mosquitoes

Resettlement Issues

A questionnaire survey was carried out concerning various resettlement issues. Results of the survey are as follows:

(1) Social and Economic Characteristics

Average household size is 4.25 persons. Major occupation of respondents is trading (32.4%) followed by wage earning, government employee and taxi driving (26.2%, 18.3% and 11.3%, respectively). A total of 37% of respondents report having a supplementary occupation. The proportion of employed to unemployed members in a household is 1:1.64. It was found that from the interviews there is not much difference in the level of family earning of each group. The average household annual income is US$ 1,309. The average commuting distance for employed persons is about 3.3 km.

(2) Information on Assets Owned by the Family

All households possess a plot of land for house and residence. The average residential area is 365m^2/household. About 61% of respondents have some sort of land ownership certificate. Almost half the respondents in Boeng Trabek and Boeng Salang have no land holding certificate as their houses are built over swamps that are public lands. The average value of houses is US$ 7,329. Among assets owned by families, motorcycle (62.4%), television set (48.3%) and radio (17%) are most common followed by bicycle and power generator.

(3) Information on Migration

In the past 10 years, about 2/3 of respondents have never moved. The remaining 1/3rd of the population has migrated to Phnom Penh within the last 10 years (about 59% from within the districts of Phnom Penh and 38.4% from other provinces).

(4) Perception of Existing Living Conditions

The reasons cited commonly for living in present location are good neighbors, close to school, close to work place and available infrastructure/electricity. Perceived problems are inadequate/ no water supply, annual flooding, odor from polluted water, excessive mosquitoes/insects, and excessive garbage. Majority (92%) of the respondents had never heard of the drainage improvement and flood control project. The project is felt to be necessary by all respondents as it may contribute to alleviating existing environmental problems.

(5) Attitude to Relocation

More than half the respondents (56%) showed their cooperation to relocate while 19.4% disagreed and 24.7% gave no opinion. Communities around Boeng Tompun, Boeng Salang and Boeng Trabek are willing to cooperate especially since their houses are built on public lands and are prone to natural hazards like flooding. Significant reason for cooperation is the expectation of being provided better housing, improved environmental conditions and water availability. The communities expect to be provided as part of the relocation assistance package new

residential land, provision of funds for relocation of houses and assets to new place, and provision of supporting facilities at new place.

Present Condition of Water Use

In order to supplement available secondary data, a questionnaire survey was carried out to know the present condition of water use. These samples were within those who could also be affected by necessary temporary or permanent resettlement.

It was seen that there are four main sources of water for drinking/ cooking namely, deep well (25%), water supply from private vendors (50%), city water supply system (19%), and water from shallow wells (5.9%). Comparing water consumers in central urban area and the peri-urban area, the main water source for residents in the urban area is from private vendors while residents in sub-urban area utilize groundwater as their main source. The average water consumption is 8,352 liters per household per month. The water consumption in urban area is higher than in sub-urban area (10,300 and 6,850 liters/household/month, respectively). The average expense is 7.43 US$/month/household. This figure is higher for urban area as compared to sub-urban area. The willingness to pay for water supply maintenance is 0.85 US$/$m^3$ on the average.