JAPAN INTERNATIONAL COOPERATION AGENCY

THE MINISTRY OF INDUSTRY, MINES AND ENERGY
THE ROYAL GOVERNMENT OF CAMBODIA

THE STUDY ON

WATER SUPPLY SYSTEM

FOR SIEM REAP REGION

IN CAMBODIA

FINAL REPORT

Vol. I EXECUTIVE SUMMARY

JUNE 2000

NIPPON KOEI CO., LTD.

NIHON SUIDO CONSULTANTS CO., LTD.

LIST OF REPORTS

Vol. I	**EXECUTIVE SUMMARY**
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Exchange Rate Applied

1.00 US$= 3,800 Riels = 120.00 Yen

(as of June 1999)

PREFACE

In response to a request from the Royal Government of Cambodia, the Government of Japan decided to conduct the Study on Water Supply System for Siem Reap Region in Cambodia and entrusted the Study to the Japan International Cooperation Agency (JICA).

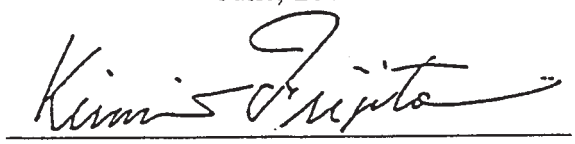
JICA selected and dispatched a Study Team headed by Mr. Osamu TAKAHASHI, joint venture of Japanese consulting firms of Nippon Koei Co., Ltd. and Nippon Suido Consultants Co., Ltd. to the Kingdom of Cambodia, six times between December 1996 to June 2000. In addition, JICA set up an advisory committee headed by Ms. Keiko Yamamoto, Institute for International Cooperation JICA, between December 1996 and June 2000, which examined the Study from specialist and technical points of view.

The Study Team held discussions with the officials concerned of the Royal Government of Cambodia, and conducted field surveys at the Study area. Upon returning to Japan, the Study Team conducted further studies and prepared the final report.

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

Finally, I wish to express my sincere appreciation to the officials concerned of the Royal Government of Cambodia for their close cooperation extended to the Study Team.

June, 2000



Kimio Fujita
President
Japan International Cooperation Agency

June, 2000

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

Dear Sir,

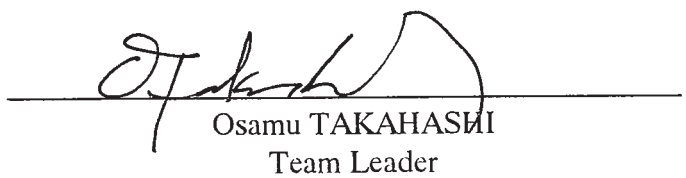
LETTER OF TRANSMITTAL

It is with great pleasure that we submit to you the Final Report of the Study on Water Supply System for Siem Reap Region in Cambodia completed by the Study Team with cooperative efforts of the Ministry of Industry, Mine and Energy (MIME) and other parties concerned. The report has been prepared for the Royal Government of Cambodia in implementing the effective water supply system project for Siem Reap Region in Cambodia.

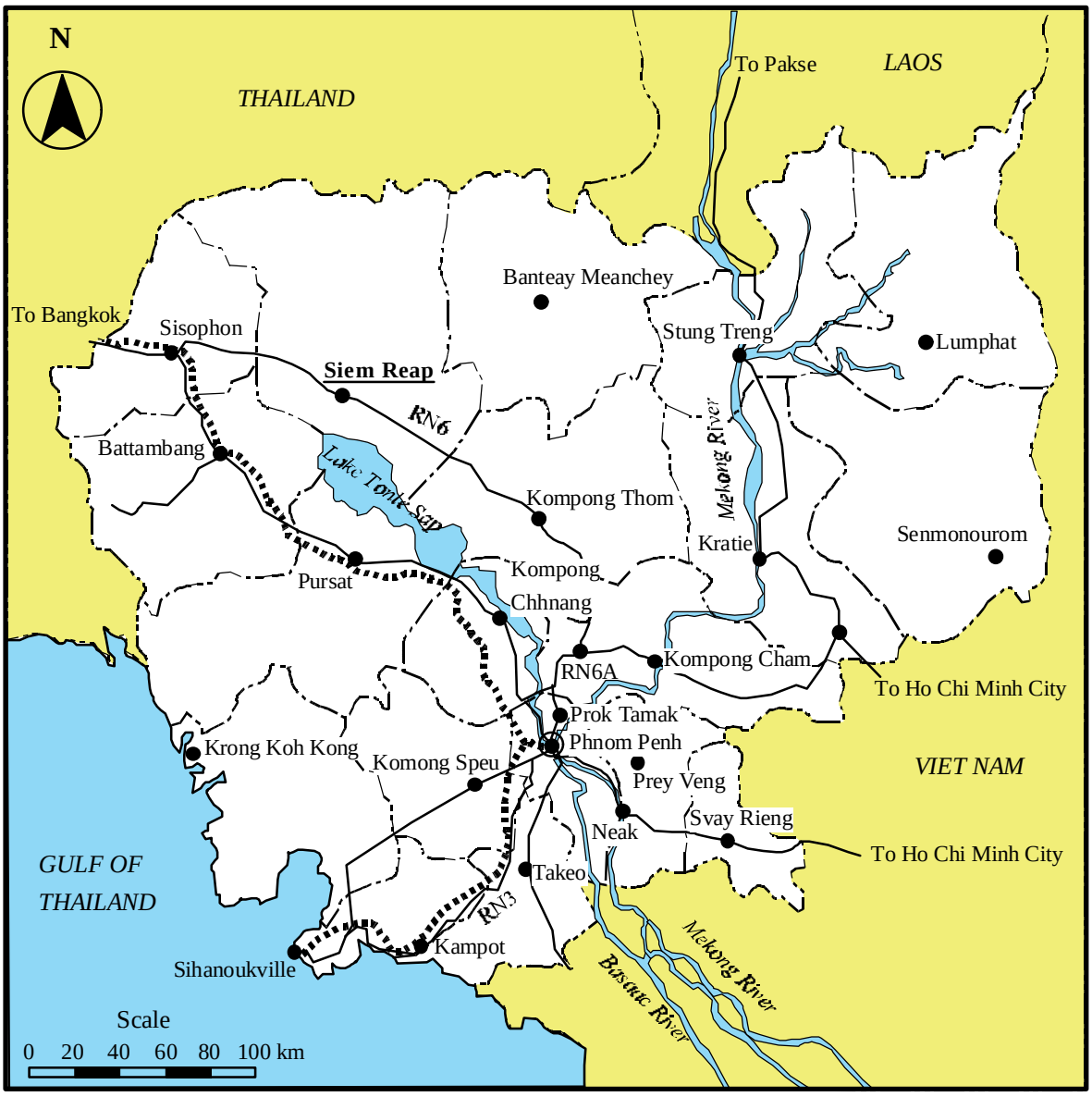
The report consists of four volumes of the Executive Summary, Main Report, Supporting Report, and the Data Book. The Executive Summary presents the outline of the study results and the Main Report gives all the study results regarding the plan for water supply system. The Supporting Report describes more detail results with data for the Study. The Data Book compiles useful reference data relevant to the Study.

Taking this opportunity, on behalf of the Study Team, I would like to express my heartfelt gratitude to the personnel from JICA, Advisory Committee, Ministry of Foreign Affaires, Ministry of Health and Welfare, Embassy of Japan in Cambodia and JICA Phnom Penh Office and Cambodian officials from Steering Committee comprised of relevant government agencies who extended their kind assistance and cooperation for the entire study period to the Study Team. The Study Team hopes that the results of this Study contribute to the future implementation of the water supply project in Siem Reap Region in Cambodia.

Yours faithfully,



Osamu TAKAHASHI
Team Leader
The Study on Water Supply System
for Siem Reap Region
in Cambodia



LEGEND

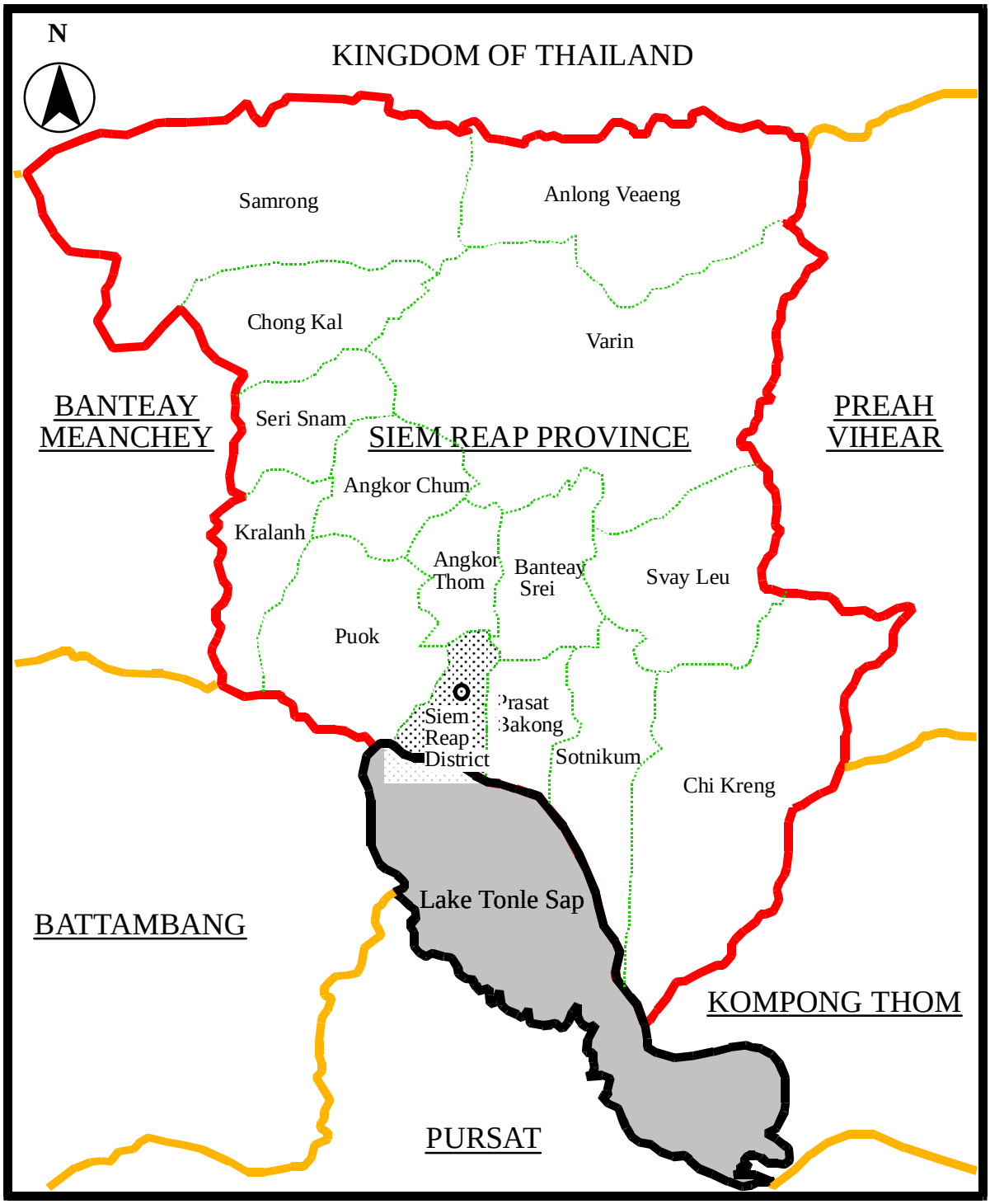
- Capital
- Capital of Province
- National Road
- National Bounderies
- Provincial Bounderies
- Railway

KEY MAP

The Study on Water Supply System for Siem Reap Region in Cambodia

Japan International Cooperation Agency

Location Map of Cambodia



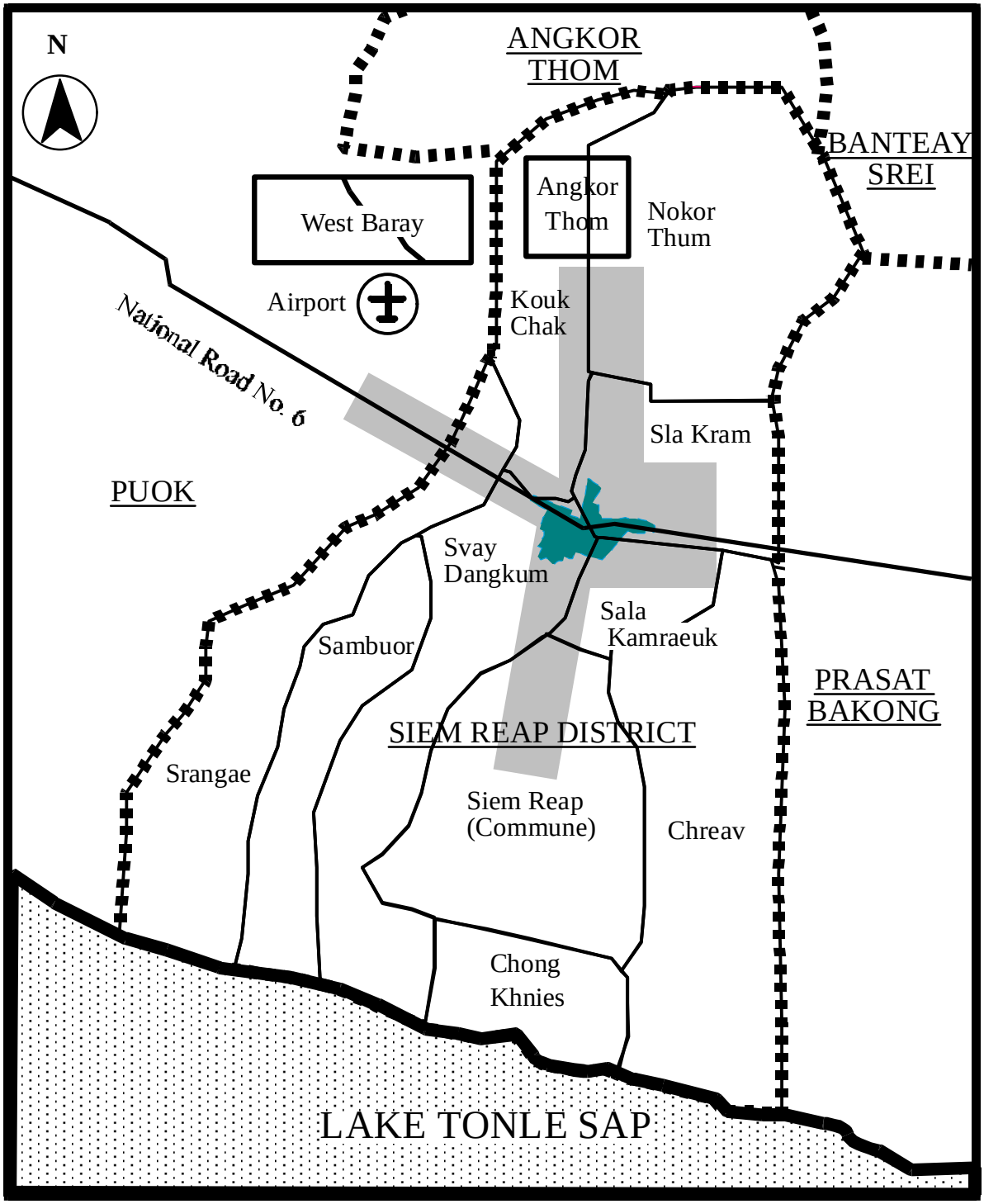
Legend

PURSAT	: Province Name
Svay Leu	: District Name
	: Provincal Boundaries
	: District Boundaries
	: Siem Reap Town

Scale

0 30 60 km

The Study on Water Supply System for Siem Reap Region in Cambodia	**Location Map of Siem Reap Province with District Names**
Japan International Cooperation Agency	



Legend

SIEM REAP : District Name	: Commune Boundaries
Sla Kram: Commune Name	: Social Survey Area
: District Boundaries	: Water Supply Service Area

0 Scale 5 km

The Study on Water Supply System for Siem Reap Region in Cambodia	**Location Map of Study Area with Commune Names**
Japan International Cooperation Agency	

THE STUDY ON WATER SUPPLY SYSTEM FOR SIEM REAP REGION IN CAMBODIA

1. INTRODUCTION

1.1 Background of the Study

The Royal Government of Cambodia (RGC) encourages recovery and development of Siem Reap Town with the financial and technical helps from donor countries. In response to an official request of the RGC, the Japan International Cooperation Agency (JICA) made a contract with the joint venture of Japanese consulting firms of Nippon Koei Co., Ltd. and Nihon Suido Consultants Co., Ltd to carry out the study on "Water Supply System for Siem Reap Region in Cambodia"(the Study).

1.2 Objectives of the Study

The objectives of the Study are categorized in the following four items:

- To evaluate potential of water sources for the water supply system in Siem Reap Region.
- To formulate a Master Plan (M/P) for the water supply in Siem Reap Town.
- To conduct a Feasibility Study (F/S) on priority project identified in the M/P.
- To pursue technology transfer to counterpart personnel in the course of the Study.

1.3 The Study Area

The Study area covers Siem Reap Town and parts of the Lake Tonle Sap, the West Baray (Reservoir) and Siem Reap River Basin.

1.4 The Study Period

The Study period is from December 1996 to June 2000.

1.5 Counterpart

The Ministry of Industry, Mines and Energy, of the Royal Government of Cambodia is the counterpart.

2. FIELD SURVEYS AND RESULTS

2.1 Surveys and Investigations

Topographic Survey, Hydrological Investigation, Geological and Geotechnical Investigation, Hydrogeological Investigation, Water Quality Analysis, Social and Environmental Investigations were carried out in the course of the Study.

2.2 Results of Field Survey

- The catchment of Siem Reap River is about 600 km^2 with a total length of 90 km. The peak discharge in 1997 is estimated around 150 m^3/s. The observed minimum flows at Prasat Keo are 0.80 m^3/s (1997), 0.56 m^3/s (1998).
- The effective capacity of West Baray is estimated 48.6 million m^3 at the elevation of water level of 25.0 m (approx. 19.6 m in Mean Sea Level (MSL)).
- Water quantity of Lake Tonle Sap is not a limiting factor for possible water abstraction.
- The most promising groundwater having good quality could be extracted near WT4 well (between southwest end of West Baray and National Road No.6) from the result of drilling and testing for eight observation wells.
- Eight automatic monitoring units were installed in the area. Among them, the data in front of Angkor Wat (LTb Observation well: Feb. 1998 – Jan. 1999) revealed that the Groundwater Level (GWL) fluctuated 2.3 m. The Land movement in the same unit was recorded as 1.3 mm corresponding to the GWL fluctuation with reversible behavior.

3. WATER SUPPLY MASTER PLAN

3.1 Future Population Forecast

The target year of the Study is 2010. A most probable scenario was set for the population projection in the Siem Reap Region for the various categories such as resident, tourist, and foreign delegation. The projected population in the year 2010 is 53,151 within the service area.

3.2 Service Area

Considering present urban use and potential future growth, the service area and population projection are proposed in two stages. That is, the proposed service area is: 345 ha (Stage 1), 436 ha (Stage 2), and future populations of the service area is: 37,028 (Stage 1), 53,151 (Stage 2), respectively.

3.3 Water Demand

Water Demand is calculated separately for domestic water demand, tourism water demand, and special use demand. Special use includes water demand for hospitals, schools, government office, royal residence, temples, and markets. In 2010, the total net average demand is around 7,700 m^3/day. Unaccounted For Water (UFW) until the target year 2010 is assumed as 15%. For Siem Reap Water Supply System, a peaking factor is assumed as 1.2 for domestic and special water demand. The peak factor for the tourism demand is considered as 1.57. Thus, the gross peak water demand in 2010 comes to 12,000 m^3/day.

3.4 Development Potential of Water Sources

Water availability from the four alternative (Siem Reap River, West Baray, Lake Tonle Sap, Groundwater) sources is assessed.

(1) Groundwater

Excessive groundwater extraction may cause land subsidence in and around the well field including Angkor heritage. In order to find out the allowable maximum groundwater abstraction without any adverse effect, computer simulations were conducted considering different cases for two firms.

1st simulation

1st simulation result is that steady pumping of 14,900 m^3/day in the well field near WT4 cause GWL drawdown of 3 m at the field, and 0.3 m GWL lowering and <1 mm reversible land subsidence in Angkor heritage. The permeability coefficient of $2x10^{-2}$ cm/s, which was obtained from the pumping test of WT4, was used for simulation. For more safety, pumping of 12,000 m^3/day (80% of 14,900 m^3/day) is conservatively settled.

2nd simulation

2nd simulation result is that steady pumping of 12,000 m^3/day by 15 wells in the well field will cause 4 m GWL drawdown in the field, and will not arise < 0.1 m GWL lowering and < 0.1 mm land subsidence in Angkor heritage area. The permeability coefficient of 7×10^{-3} cm/s, which was obtained from two pilot wells drilled at the well field, was adopted for simulation. Therefore, the pumping rate of 12,000 m^3/day is concluded as the most practical and safety plan.

(2) West Baray

Considering the irrigation use, the remainder is around 4.7 millions m^3. If the remainder is available to use, it can provide a water supply of around

12,900 m^3/day.

(3) Siem Reap River

The calculated possible amount of intake becomes 0 m^3/s and accordingly the Siem Reap River option will be completely discarded from water source alternatives.

(4) Lake Tonle Sap

The possible yield from the lake can be considered as unlimited. Due to water level fluctuations, the available intake site is recommended to be located at least 4 km offshore from the existing boat house. The distance from the town center will exceed 19 km. It is impossible to convey the raw water by gravity to the city center. In addition, the water quality is the worst among the four alternatives.

3.5 Comparative Study on Alternative Water Sources

For the selection of the best water source, the following criteria are considered.

- Lower Cost considering both investment cost and Operation and Maintenance (O&M) cost
- Easy Operation and Maintenance
- Less Impact to Angkor heritage
- Reliability
- Stable and Suitable Water Quality
- Flexibility of the System, and
- Less Impact to Environment

Groundwater system is the most economic, recommendable, and promising source for Siem Reap Water Supply System.

3.6 Past and Present Public Water Supply System

(1) Production

Old French System: Established in the 1930s Source: Siem Reap River
American System: Established in the 1960s Source: Siem Reap River
Because of deterioration of raw water quality and facilities, this system was stopped in 1995.
New French System: Established in 1998 Source: Groundwater
Services started from the end of July 1999.

(2) Distribution

The dominant material of the distribution pipeline is Asbest Cement (ACP). Poly Vinyl Chloride (PVC) material was used partly.

Rehabilitation of the existing distribution network is necessary. Around 50% of the existing pipeline should be replaced.

3.7 System Expansion Program on Siem Reap Water Supply

(1) Stage-wised Development Policy

A stage-wised plan is feasible from cost and benefit viewpoints based or the system capacity and water demand prediction.
Increase of water supply capacity is shown in the following table.

Stage	Incremental Capacity (m^3/day)	Total Supply Capacity (m^3/day)
Existing		1,440
Stage 1	8,000	9,440
Stage 2	4,000	12,000

At the end of the Stage 1, the existing system of 1,440 m^3/day capacity may be abandoned. Therefore the total capacity of the Stage 2 will be
9,440 + 4,000 – 1,440 = 12,000 m^3/day.

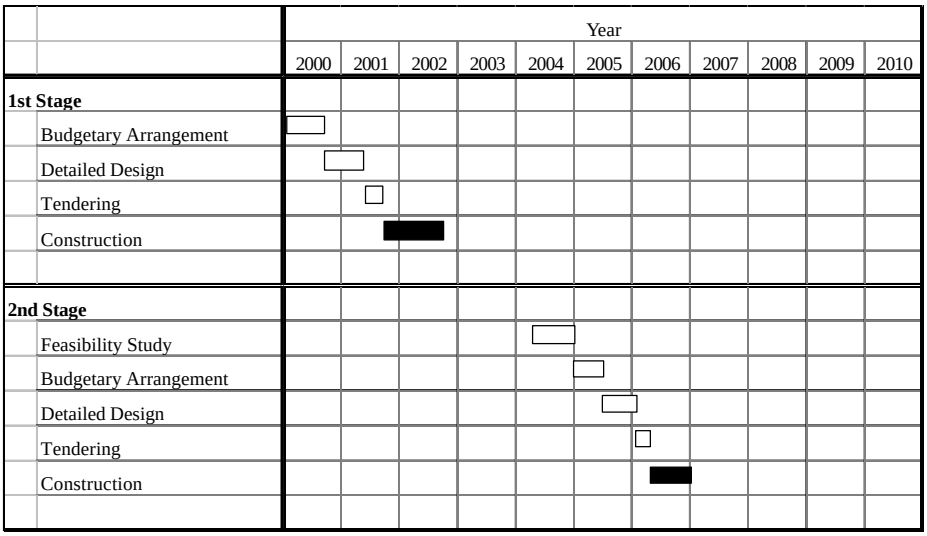
(2) Plan of Water Supply System

- Stage 1 : 10 wells along the National Road No. 6.
- Stage 2 : Additional 5 wells located along the branch road from the National road No.6 to the West Baray.
- Each well capacity : 800 m^3/day. Depth of the wells : 50 m.
- Distribution trunk main : Along the National Road No.6.
- Hotel zone : Bulk water supply system.

3.8 Preliminary Cost Estimates (M/P level)

	Project Cost (US$)	O&M Cost (US$/$m^3$)
Stage 1:	16,192,000	0.135
Stage 2:	2,781,000	0.115
Total	18,973,000	

3.9 Implementation Schedule



3.10 Institutional Development

- At present, the Waterworks is managed by 9 persons and it is comprised of two divisions, namely, administration and technical.
- The numbers of employees for the Waterworks are proposed as 14, 19, and 25 in the year 2002, 2006, and 2010, respectively.
- Three divisions are proposed, namely, administration and finance, customer service, and technical. A detail job description for each position is also proposed.

3.11 Recommendations for Institutional Improvement

- Human resources development. Training program for the employees to be held both domestically and internationally.
- Enactment of the following laws: Water Supply Ordinance, By-law on Business Consignment, Law for Restriction for Groundwater Usage, Law for Water Pollution Control.

3.12 Operation and Management

- Reduction of UFW ratio.
- To supply safe potable water ceaselessly, the following strategy is recommended; Improvement and enhancement of the volition of employees, System of reward, Continuous monitoring for water quality, Inventory management, and Ledger of facilities.

3.13 Economic and Financial Analysis

The project evaluation is conducted from three points of view, i.e, (1) economic aspect, (2) financial aspect, and (3) socioeconomic aspect.

(1) Economic Analysis

Economic Internal Rate of Return (EIRR) 10.5%, B/C 1.04, NPV 0.56 million US$, thus, the project could be viable from the economic point of view, because its EIRR exceeded 10%.

(2) Financial Analysis

- Financial Internal Rate of Return (FIRR) –2.2%, Benefit-Cost Ratio (B/C) 0.34, Net Present Value (NPV) –12.0 million US$;therefore, the project may not be said to be viable.
- The project can be made financially viable by either increasing the water tariff 3.2 times or by covering 81% of the capital investment by subsidy. Both of these two countermeasures could be combined to make it viable.

(3) Socioeconomic Impacts

Construction work for water supply project activates regional economy and create job opportunity.
The total investment cost of 72.1 billion Riels (3,800 Riel = 1 US$) in two stages accounts for 3.4% of the total expenditure of the RGC in 1999.

3.14 Environmental Consideration

(1) Initial Environment Examination (IEE)

- Since there is no Cambodian Law available for the environmental screening, principally JICA format is applied making reference to Asian Development Bank (ADB) and World Bank (WB) guidelines.
- The project will significantly improve the public health condition
- Reduction of water fetching and storing time. Save a great amount of energy for independent water withdrawal and treatment in Hotels.
- Excessive abstraction of groundwater causes lowering of groundwater level and land subsidence.
- Negative impacts for land acquisition and generation of wastewater.

(2) Future Wastewater Disposal Plan

Public hygiene education and the application of simple and effective wastewater disposal method are important. An outline plan is also proposed.

3.15 Evaluation of the Master Plan

(1) Technical Evaluation

- Service area: 345 ha (Stage 1), 436 ha (Stage 2).
  New hotel development area in the northeast part of the Siem Reap Town can be served with sufficient water.
- Domestic Service ratio is planned to increase 65% at the end of the Stage 1 (2006) and 75% of the Stage 2 (2010).
- 95% of hotels, guesthouses and restaurants will be served.
- As system water sources is plural number of wells, water supply will be stable and reliable.
- Having stand-by generator, public power failure will not affect.
- Water quality of the groundwater is confirmed suitable for a water supply source. Abstracted groundwater will be supplied without any treatment except disinfection.
- New water supply system will not require any special technology.

(2) Economic/ Financial Evaluation

- It would be possible to make the project viable by means of subsidy for the 81% of the capital investment costs.
- The combination case of 62% of the subsidy and 50% of hike in water tariff also makes financially viable.
- The available financial sources for the project have to be found in the foreign and local financial markets.
- Since its EIRR exceeds the opportunity cost of capital (10%), the project is viable from the economic point of view.

(3) Environmental Evaluation

- The project will reduce the occurrence of water related diseases to a great extent and improve the economic condition of the town by reduction of diseases.
- The project contributes all tourist-related infrastructures, and regional and national economy.

4. FEASIBILITY STUDY ON PRIORITY PROJECT (F/S)

4.1 Definition of Priority Project for Feasibility Study

The Stage 1 is identified as the priority project for urgent implementation in the M/P. Thus Stage 1 will be covered in the F/S.

The key parameters of the Stage 1 are shown in the following table.

Description	Figures in Year 2006
Population in Service Area	39,244
Service Ratio	65%
Served Population	25,508
Domestic Water Demand (Daily Average)	3,061 m^3/day
Tourism Water Demand (Daily Average)	2,060 m^3/day
Special Water Demand (Daily Average)	156 m^3/day
Total Water Demand (Daily Average)	5,277 m^3/day
Total Water Demand (Daily Maximum)	8,352 m^3/day
Number of Domestic Connection	4,475
Total Number of Connection	4,797

Main work items of the Stage 1 :

Construction of 10 wells, Installation of well connecting pipes, Construction of receiving well, Construction of clear water reservoir, Installation of disinfection facilities, Construction of distribution pumping station, Installation of distribution pipelines, Installation of service mains, Rehabilitation of existing distribution pipeline, replacement of house connections on the rehabilitated pipe.

4.2 Additional Topographic Survey

Route survey of 15 km along pipeline and supplementary surveys were carried out in F/S stage.

4.3 The Project and Its Feasibility Study

(1) Plan of Water Supply Facilities

- 10 wells to be constructed under the Stage 1 along the National Road No.6 with 400 m interval.
- Distribution Center : receiving well, clear water reservoir, disinfection facilities, distribution pumping station and generators.
  Location : the center of the well field.
- Two sets of chlorinators will be installed under Stage 1.
- 7 distribution pumps with two different capacities in Stage 1.
- Disinfected groundwater will be stored in the clear water reservoir.
- Direct pumping method shall be employed for water distribution.
- 8 generators of two different capacities (each 4 sets) in Stage 1.

- Bulk water supply system for the new hotel development area
- Meter District System (MDS), to evaluate the effectiveness of water supply or level of UFW in each district.

(2) Operation and Maintenance

- Periodic maintenance is recommended for the wells once every 5 years.
- Keeping records of water quantity is important for the production facilities.
- Distribution network drawing is important to keep, and network drawings should always be updated.

4.4 Institution and Organization

(1) Institution and Legislation

- RGC has been encouraging that waterworks in the country employs Private Sector Participation (PSP) system.
- Existing legal framework is to be reviewed when PSP is foreseen.

(2) Organization

- The system of three independent divisions namely, Administration and Finance Division, Customer Service Division, and Technical Division is recommended.
- Total employees number will be 19 in total by 2006.

(3) Training

Following training system is proposed:

- Training for every split business hierarchy,
- Training for practical business/subjects,
- Training for specified items,
- Training by dispatching/sending to other places or by invitation of lecturer,
- Training within workshop/working place (on-the-job training), and
- Support for self-study.

4.5 Cost Estimation and Implementation Plan (F/S Level)

(1) Cost Estimation

(Unit: US$)

Item	Foreign Currency	Local Currency	Total of Stage 1
Construction Cost	10,685,000	635,000	11,320,000
Total Project Cost	14,982,000	1,317,000	16,300,000

(2) Annual Operation and Maintenance Costs

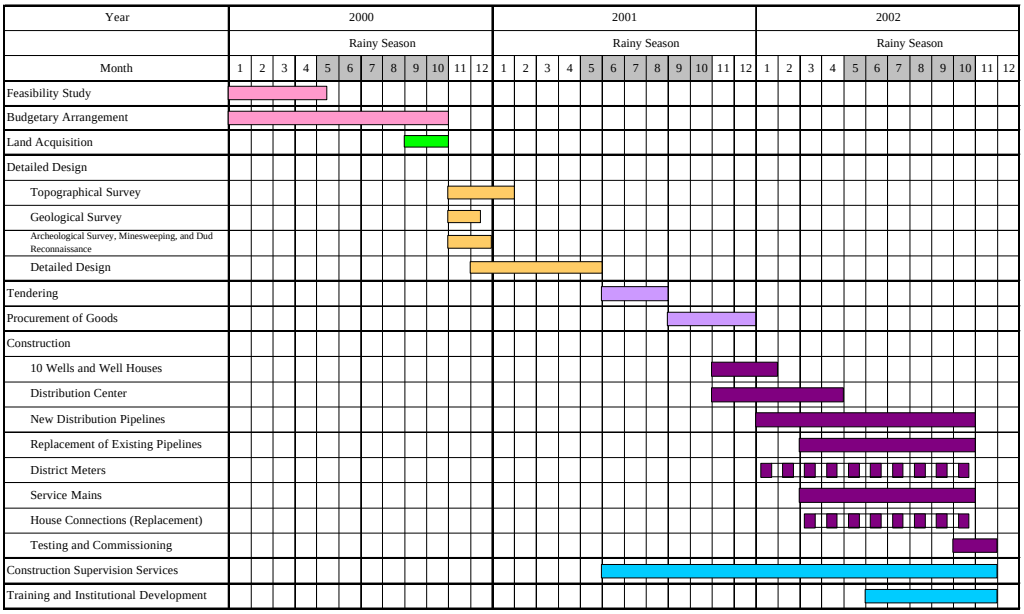
(Unit: US$)

	2002	2003	2004	2005	2006
Annual O&M Cost	278,722	298,363	321,915	338,643	363,531

(3) Implementation Plan

Project implementation plan is shown in the following figure.

Implementation Schedule for Stage 1



Project disbursement for Stage 1 is shown in the following table.

(Unit:US$)

Year	Annual Disbursement	Ratio
2000	591,000	3.6%
2001	7,759,000	47.6%
2002	7,950,000	48.8%
Total	16,300,000	100%

4.6 Economic and Financial Analysis

(1) Economic Analysis

- The Stage 1 cost only is interpreted.
- The evaluation factor: EIRR 9.2%, B/C 0.94, NPV –0.92 million US$.
- The EIRR was slightly lower than the opportunity cost of capital of 10% (the EIRR of the M/P: 10.5%). This is because the facilities include a part of prior investment for the Stage 2. In future, the EIRR is expected to be over 10% after the Stage 2.

(2) Financial Analysis

- The financial evaluation factor: B/C 0.33, NPV –10.98 million US$, and FIRR –2.7%.
  These figures indicate that the project may not be viable.
- Following financial plans are adopted and simulated. Considering the financial situation of consumers and WB guideline for water tariff, financial plan 2 is favored after making various analysis and comparison.
- Financial Plan 1: 30% of the total investment costs is procured from loan of financial organization, 70% from grant of foreign countries and central governments. In addition, the water tariff is set at 50% up from the present one.
- Financial Plan 2: the entire initial investment is procured as grant of foreign countries and central governments. The water tariff is same as the present one.

4.7 Environmental Consideration

Environmental Impact Assessment (EIA) is carried out for Stage 1.

(1) Groundwater Lowering

- It was found that there would be only concentrated drawdown near each well.
- Continuous groundwater monitoring has to be done to check drawdown allowable limits.

(2) Land Subsidence

Based on the results from the pilot well operation, the result of a computer simulation showed that there is no significant land subsidence around the heritage area.

(3) Land Acquisition

A one ha land acquisition is required for the Distribution Center. The center is planned at paddy field to eliminate the impact of resettlement. Proper compensation should be paid for land acquisition.

(4) Wastewater Generation

Proper arrangement for wastewater disposal is essential to get maximum health benefit from a water supply project.

(5) Economic Activity

Easy access to water does, in one hand, benefit the economy by reduced mortality and increase of economic time. Water tariff may put some pressure on personal economic condition.

(6) Cultural Values

With the easy availability of clean water, tourism potential will increase.

(7) Future Water Quality

Area adjacent to the proposed well field is mainly agricultural area. Detail investigation showed that the low coverage of artificial fertilizer and pesticide, and low level of application amount, will not cause possible degradation of water quality in future.

4.8 Conclusions and Recommendations

(1) Conclusions

1) Technical Evaluation

After implementation of the Stage 1 Project, service area will be 345 ha and served population will be 25,500 people in 2006.

No special technologies are required for the construction works of the proposed water supply facilities.

The proposed groundwater based water supply system requires simple operation and maintenance skill. From the results of pumping and quality tests of pilot wells, quality and quantity are confirmed as suitable as a water source.

2) Financial Evaluation

Under the conditions that 30% of the total investment costs is procured from loan of financial organization and 70% from grant of foreign countries and central governments, the water tariff is set to 50% higher than the present rate (Financial Plan 1), the cash balance is expected to return to the black in 17th year (2018). After that the accumulated deficit will reduce and return to break-even in 24th year (2025).

In the case that the entire finance for initial investment is procured as grant from foreign countries and central governments, the water tariff is set at the present water rate (Financial Plan 2), the cash balance will return to the black in 17th year (2018), and the accumulated deficit will return to break-even in 27th year (2028).

From the financial point of view, these two financial plans make this project viable. Considering the water tariff, the Financial Plan 2 is recommended.

3) Environmental Evaluation

Groundwater abstraction may cause the land subsidence. From the results of the pumping tests and groundwater simulation, it is confirmed that the planned groundwater abstraction will not cause any serious land subsidence problem (simulation result: land subsidence is less than 1 mm) around the Angkor heritage area.

4) Overall Evaluation

Considering the technical, Financial and environmental evaluations, the Stage 1 project is judged as a feasible project.

After the implementation of Stage 1, people will be able to access the safe water easily. Water born diseases will be decreased. Tourist-related infrastructure will also be improved.

(2) Recommendations

1) Review of M/P in Future

The present study for the Stage 2 has the time horizon set at the year 2010. It is recommended to review of the study in the year 2006.

2) Continuous Monitoring

Groundwater monitoring should be conducted through the entire service period of the project. The main objective is to ensure the safety of the famous Angkor heritage by monitoring system.

3) Regulation for Restriction of Groundwater Usage

At present, the major source of water in Siem Reap Town is groundwater. To ensure the renewability of the groundwater resources, this use has to be restricted after the operation of the project.

4) Public Relation and Education on Hygienic Life

Hygiene education should be included in the curricula of school.

5) Sanitation and Wastewater Control System

Total benefit from a water supply project can not be obtained completely without a proper wastewater and drainage management system. An immediate attention should be given in order to implement future wastewater disposal plan.

6) Action Required for Project Implementation

The following action should be required for the project implementation:

- Coordination with Central Government
  (Arrangement of external funding)
- Coordination with Local Provincial Government
  (Project implementation and management of Waterworks)
- Arrangement for Acquisition of Land Space Required
  (For timely implementation of the Project)

- Archeological Survey in the Distribution Center
  (For checking the existence of heritages at the construction site)
- Coordination with Phnom Penh Water Supply Authority (PPWSA)
  (Technical and managerial assistance)

THE STUDY ON WATER SUPPLY SYSTEM
FOR SIEM REAP REGION IN CAMBODIA

FINAL REPORT
Vol. I EXECUTIVE SUMMARY

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ABBREVIATIONS

ACP	Asbestos Cement Pipe
ADB	Asian Development Bank
AFD	French Agency for Development
AIDS	Acquired Immune Deficiency Syndrome
APSARA	Authority for the Protection of the Site and the Management of Angkor Region
ASEAN	Association of Southeast Asian Nations
B/C	Benefit-Cost Ratio
BOD	Biochemical Oxygen Demand
CARERE	Cambodian Area Rehabilitation And Re-generation
CAD	Computer Aided Design
CFD	Caisse Francaise de Developpement (French Development Bank)
COD	Chemical Oxygen Demand
CPA	Complementary Package of Activities
CPI	Consumer Price Index
CRF	Capital Recovery Factor
D	Depth
DDT	Dichlorodiphenyl Trichloroethane
Dept.	Department
DFID	Department For International Development, UK
DIP	Ductile cast Iron Pipe
Div.	Division
DO	Dissolved Oxygen
DSR	Debt Service Ratio
DWL	Dynamic Water Level
EC	Electric Conductivity
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EL	Elevation Level
EU	European Union
FAO	Food and Agriculture Organization

FBC	Feed Back Committee
FIRR	Financial Internal Rate of Return
F/S	Feasibility Study
GAD	Gender and Development
GAMS	General Algebraic Modeling System
GDP	Gross Domestic Product
GIS	Geographic Information System
GL	Ground Level
GOJ	Government of Japan
GWL	Ground Water Level
GVA	Gross Value Added
H	Height
HCMC	Health Center Management Committee
HWL	High Water Level
ICP	Inductively Coupled Plasma
ID	Inner Diameter
IDA	International Development Association (The World Bank Group)
IEE	Initial Environment Examinations
IO	International Organizations
IPM	Integrated Pest Management
ISO	International Standards Organization
It/R	Interim Report
IWDA	International Women's Development Agency
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standard
JWWA	Japan Waterwoks Association
L	Length
LAN	Local Area Network
LDC	Least Developed Countries
LPG	Liquefied Petroleum Gas
L.S.	Lump Sum
LWL	Low Water Level
M	Meter

MDS	Meter District System
MIME	Ministry of Industry, Mines and Energy
MOA	Ministry of Agriculture, Forest and Fisheries
MOEF	Ministry of Economy and Finance
MOH	Ministry of Health
MOP	Ministry of Planning
MOT	Ministry of Tourism
M/P	Master Plan
MPA	Minimum Package of Activities
MPN	Most Probable Number
MSL	Mean Sea Level
NGO	Non-government Organization
NPV	Net Present Value
NTU	Nephelometic Turbidity Unit
O&M	Operation and Maintenance
OD	Outer Diameter
ODA	Official Development Assistance
PBML	Provincial Budget Management Law
PDIME	Provincial Department of Industry, Mines and Energy
PE	Poly Ethylene pipe
PPWSA	Phnom Penh Water Supply Authority
PSP	Private Sector Participation
PVC	Poly Vinyl Chloride (pipe)
Q	Quantity, Flow
RC	Reinforced Concrete
RGC	Royal Government of Cambodia
SCNC	Supreme Council for Natural Culture
S/O	Simulation and Optimization
SP	Steel Pipe
SS	Suspended Solid
SWL	Static Water Level
TDS	Total Dissolved Solid
THM	Tri Halo Methane

UFW	Unaccounted For Water
UK	United Kingdom
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFPA	United Nations Population Fund
UNICEF	United Nations Children Fund
UNO	United Nations Organization
UNTAC	United Nations Transition Authority for Cambodia
UNV	United Nations Volunteer
USA	United States of America
US$	US Dollar
VIP	Ventilated Improved Pit
VLF	Very Low Frequency
W	Width
WAC	Women's Association of Cambodia
WB	World Bank
WES	Water and Environmental Sanitation
WFP	World Food Program
WHO	World Health Organization
WID	Women In Development
ZEMP	Zoning and Environment Management Plan (prepared by UNESCO)
ϕ	Diameter

MEASUREMENT UNITS

Extent

cm^2	=	Square centimeters (1.0 cm x 1.0 cm)
m^2	=	Square meters (1.0 m x 1.0 m)
km^2	=	Square kilometers (1.0 km x 1.0 km)
ha	=	Hectares (10,000 m^2)

Volume

cm^3	=	Cubic centimeters (1.0 cm x 1.0 cm x 1.0 cm)
m^3	=	Cubic meters (1.0 m x 1.0 m x 1.0 m)
m^3/day	=	Cubic meters per day
m^3/h	=	Cubic meters per hour
m^3/min	=	Cubic meters per minute
m^3/s	=	Cubic meters per second
l or lit	=	Liter (1,000 cm^3)
lpcd	=	Liter per capita per day

Length

mm	=	Millimeters
cm	=	Centimeters (cm = 10 mm)
m	=	Meters (m= 100 cm)
km	=	Kilometers (km = 1,000 m)

Weight

g	=	Grams
mg	=	Milligrams (1/1,000 g)
mg/l	=	Milligrams per liter
µg/l	=	Micrograms per liter
kg	=	Kilograms (1,000 g)
kg/cm^2	=	Kilograms per square centimeter
t	=	Metric ton (1,000 kg)

Currency

US$	=	United State Dollars
		US$1.0 = J¥120 = R 3,800
J¥	=	Japanese Yen
R	=	Cambodian Riels

Time

s	=	Seconds
min.	=	Minutes (60 s)
h	=	Hours (60 min.)

Energy

kVA	=	Kilovolt Ampere
kW	=	Kilowatt

Others

per/km^2	=	Persons per square kilometer
S/m	=	Siemens per meter
µS/m	=	Micro siemens per meter

CHAPTER 1 INTRODUCTION

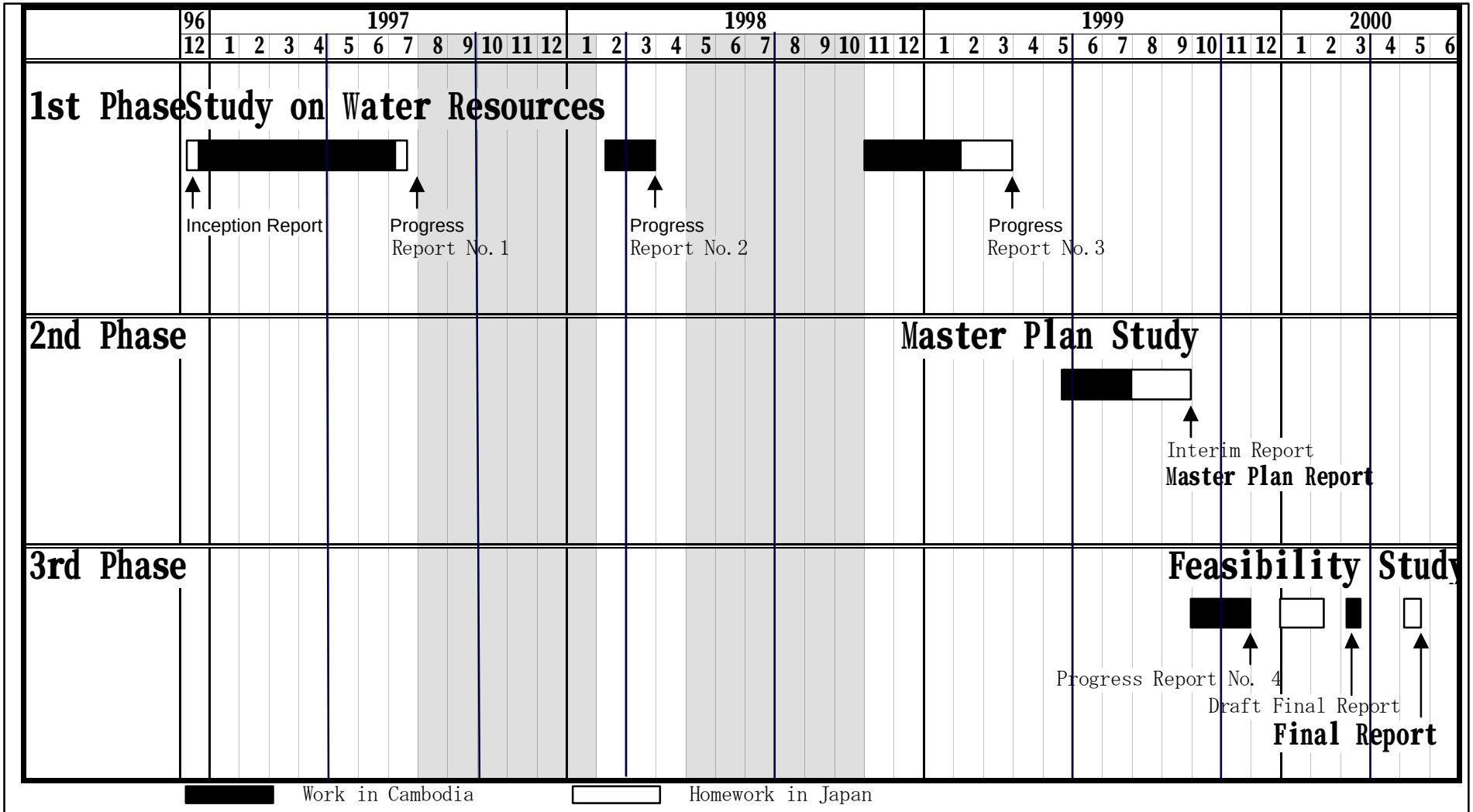
1.1 Background of the Study

The Kingdom of Cambodia occupies 181,035 km^2 in the Indo-China Peninsular and is bordered by three countries, Thailand, Lao PDR, and Vietnam. The total population of the country was 11.43 million in 1998. GDP per capita of the country is US$ 286 in 1998, which is still one of the lowest levels in the world. The restoration of deteriorated infrastructures is considered as the most urgent need in the country. Siem Reap is one of Cambodia's 24 provinces and is located in the northern part of the country. The total area of the province is 10,299 km^2 with a population of 695,485 in 1998. The total population of the Siem Reap District is 103,752 in 1998.

The Siem Reap Town is located 5 km south of the Angkor heritage that is well known as one of the important historical heritages in the world. The Angkor heritage is also recognized as a big potential resource for the tourism development of this area. The Royal Government of Cambodia (RGC) encourages recovery and development of the town with the financial and technical help from donor countries. In this regard, the RGC requested the Government of Japan (GOJ) to carry out a study on 'Integrated Plan for Angkor and Siem Reap Region' in February 1993. In January 1996, the GOJ dispatched a mission to determine what infrastructure in the region most urgently needed to be developed. As a result, the mission concluded that the development of water supply system is the most urgent need in Siem Reap Region.

In response to an official request of the RGC, the GOJ dispatched the Japan International Cooperation Agency (JICA) preparatory study team to Cambodia to discuss the scope of work for a study on 'Water Supply System for Siem Reap Region in Cambodia' (the Study). Both parties discussed the scope of work and reached an agreement in September 1996.

On the basis of the scope of work concluded, JICA made a contract with the joint venture of Japanese consulting firms of Nippon Koei Co., Ltd. and Nihon Suido Consultants Co., Ltd. in December 1996 to carry out the Study. The JICA Study Team organized by experts of the joint venture consultants worked for the Study from December 1996, as shown in Figure 1.1.1.



The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 1.1.1 The Study Schedule**
Japan International Cooperation Agency	

1.2 Objectives of the Study

The objectives of the Study are categorized in the following four items:

1) To evaluate potential of water sources in Siem Reap Region.
2) To formulate a Master Plan (M/P) for the water supply system in the Siem Reap Town.
3) To conduct a Feasibility Study (F/S) on priority project identified in the M/P.
4) To pursue technology transfer to counterpart in the course of the Study.

1.3 Actual Execution of the Study

The Study is divided into three major phases. These are,

- Phase I : Study on Water Resources,
- Phase II : Preparation of M/P, and
- Phase III : Preparation of F/S.

Phase I consisted of the investigation for four probable alternative water sources, namely, groundwater, West Baray (Reservoir), Siem Reap River, and Lake Tonle Sap. Starting with aerial photo interpretation and site reconnaissance, Phase I included extensive topographic survey, well inventory survey, water quality analysis, electrical sounding, core drilling and pumping tests for hydrogeological investigations, geophysical logging and soil tests, hydrological investigations including water balance study, and computer simulation study for groundwater development and land subsidence. This phase also included various social and environmental investigations. These covered review of existing city planning and tourism planning, environmental investigation in both dry and wet seasons, public awareness and water use survey, and study on social relations.

The target of Phase II was to prepare a Master Plan for water supply system in Siem Reap Region up to the year 2010. The work started with water demand projection and preliminary plan for water resources development for four possible alternative sources. The Study recommended groundwater development as the most suitable option for the target year 2010 based on various factors. The Master Plan also included preliminary plans for water supply system, operation and maintenance, institution and organization, cost estimate and financial plan. The Master Plan was rounded up with Initial Environmental Examination (IEE) and future wastewater disposal plan.

Phase III concentrated on the priority project identified in the Master Plan. With the help of additional topographic survey, a Feasibility Study was prepared for the priority project that covers preliminary facilities design, construction plan, financial plan and organizational plan. An Environmental Impact Assessment (EIA) was also carried out to assess any impacts due to project implementation. After making economic, financial, organizational, technical, social and

environmental evaluation, an implementation program for the priority project was prepared.

CHAPTER 2 THE STUDY AREA

2.1 Definition of the Study Area

The Study area covers Siem Reap Town and parts of the Lake Tonle Sap, the West Baray and Siem Reap River Basin. All physical investigations covered the entire Study area. 'Public Awareness and Water Use Survey' conducted by the Study Team covered an area comprising the town center and surroundings.

2.2 Natural Conditions

Cambodia has a vast central plain surrounded on three sides by highlands except the southern side. This plain is divided by the Mekong and Bassac Rivers, both of which flow in a southeast direction and enter into the South China Sea through the Mekong Delta in Vietnam. The Tonle Sap River originating from the Lake Tonle Sap joins the Mekong River in Phnom Penh, the capital city of Cambodia. The lake is located about 100 km northwest of Phnom Penh, and has a particular hydrological characteristic that the flow of the Mekong River reverses direction during the wet season. The Siem Reap Town is located on a lake terrace formed by fan deposits about 15 km north from the shore of Lake Tonle Sap. The Siem Reap Town is 314 km from Phnom Penh by road. However, direct distance is around 200 km.

The climate of Cambodia is classified as 'Tropical Monsoon' with definite wet and dry seasons affected by the direction of monsoon. The southwest monsoon prevails in the wet season from May to October. Air temperature is highest in April and lowest in December. In the Siem Reap Town, the average monthly air temperature ranges from 31ºC - 40ºC for the maximum and 14ºC - 24ºC for the minimum. The annual rainfall is 1,400 mm on average and varied from 1,082 mm to 1,773 mm during the last 19 years (1979 - 1998).

2.3 Economic Conditions

The major economic activities in Siem Reap Province are reported as farming 85%, fishing 5%, trading 7%, and service 3%. The per capita annual income of a farmer in rural area, a fisherman in Tonle Sap area and a trader in urban area are estimated by the Provincial Department of Planning as US$ 80, 120 and 150, respectively. The most important agricultural practice is rice cultivation. Another major crop is sesame.

2.4 Siem Reap Town

The town is located 15 km north from the shore of Lake Tonle Sap. The town lies on the flatland at the elevation between 15 and 20 m. Many tourists are visiting the town to see the Angkor heritages, so tourism promotion is important for the town. A number of new hotels are under construction. A significant number of the population is engaged in the tourism sector. The residential area is condensed in an area of 2 km south to north along the Siem Reap River and 1 km east to west along the National Road No.6, located in the central part of the town.

At present, most of the people are using groundwater by employing shallow dug or hand pump well. A large number of these wells are contaminated by poor sanitation and high iron content.

The Siem Reap Town area has insufficient facility for disposal of wastewater. In addition, lack of maintenance of wastewater carrying pipes and canals has compounded the problem extensively. Considering poor water management in the area, some countermeasures for wastewater treatment and improvement of the water environment of the Siem Reap River and the Lake Tonle Sap are important.

2.5 Angkor Heritage

The world famous Angkor Wat heritage consists of the Theravada Buddhism temples constructed from 7th to 15th century during the Khmer Imperial Age. It is said that a few hundreds heritages exist in and around the area of Angkor Thom and Angkor Wat and their surrounding area. The structures of the heritage made by stone ware are now heavily damaged and deteriorated by weathering. The Government of Cambodia wants tourism development and to materialize that, it intends to have infrastructure improvement such as water supply, road and electricity. It is expected that the number of tourists visiting the heritage will rapidly increase. The infrastructure development for the Siem Reap Town is therefore an urgent requirement in order to accept increased tourists.

In the Khmer Imperial Age, it is believed that the Angkor area had a good water environmental condition. These include the North, East, West and Bakong Barays, the moats of Angkor Wat and Angkor Thom, and the ponds of Surah Srang, Preah Khan, Neac Pean and so on. However, most of the barays and ponds are not functioning at present except West Baray and the moats of Angkor Wat and Angkor Thom.

2.6 Potential Water Sources

In the vicinity of the Siem Reap Town, there are four potential water sources. These are Lake Tonle Sap, West Baray, Siem Reap River, and Groundwater.

(1) Lake Tonle Sap

This is the largest lake in Southeast Asia. During the wet season, water flow of the Tonle Sap River is reversed into the lake due to the flood of the Mekong River. It acts as a natural retarding basin. The water surface area varies greatly from 3,000 km^2 in the dry season to 10,000 km^2 in the rainy season. Water levels of the lake fluctuate annually from about EL.11 m in the rainy season and EL. 1-2 m in dry season.

(2) West Baray

The West Baray is located at the west side of the Angkor heritage. It is 8 km long in east-west direction and 2.2 km wide in north-south direction. It was put back into service in 1937 and then enlarged in 1955. The water is diverted by French Weir from the Siem Reap River near Prasat Keo heritage, and conducted in rainy season through Takev Channel of approximately 5 km long (Canal A). A good water management program of the West Baray for irrigation should be established for maximizing the efficiency. Also, the excavation of the land area in the eastern half might be necessary to obtain an additional storage volume for future requirement.

(3) Siem Reap River

The catchment of the river is about 600 km^2. Total length is 90 km Approximate river width is 20 m in the upstream of the river. It stretches near the Angkor heritage. It is said that the river course was artificially changed with the construction of the West Baray, North Baray and the East Baray. There are two weirs in the river. One is 'French Weir' constructed at about 10 km upstream from the town center to divert the river water to the West Baray. The other is called 'Crocodile Weir' constructed for irrigation intake, located downstream of the town.

(4) Groundwater

Groundwater is used for domestic purposes in the Study area by shallow hand pump wells or dug wells. Most of the hotels have their own deep tube wells with purification system. The groundwater in the vicinity of the town contains high iron caused by subsurface laterite layer, and the shallow groundwater is polluted by wastewater due to poor drainage.

CHAPTER 3 SURVEYS AND INVESTIGATIONS

3.1 Topographic Survey

From March to April 1997, the following topographic surveys were carried out by the JICA Study Team:

List of Topographic Survey Work (March-April 1997)

Location	Type of Survey	Quantity	Survey Purpose
Siem Reap River	Longitudinal and Cross section survey	27 km long in total 31 cross sections	To determine the river gradient and river width for the interpretation of the hydrologic study.
West Baray	Cross section survey	9 cross sections(x-x') 2 cross sections(y-y')	To check the storage capacity in the reservoir.
Takav Channel	Longitudinal and Cross section survey	7 km long in total 10 cross sections	To find the intake level, canal capacity to divert the Siem Reap water to the baray.
Level Survey for the selected hydrological measuring points or important structures	Level survey	13 spots including the cross section survey points of 7 locations	To find the elevation at the important gauging stations, hydrological point and existing structures such as bridges and intakes.
Inventory survey of some 100 nos of existing well	Level survey	83 spots from the nearby existing bench mark	To find the elevation of the existing wells for the observation of groundwater fluctuation.
New 8 drilling points	Level survey	8 spots from the nearby existing bench mark	To obtain the elevation for the drilling spots.
Lake Tonle Sap	Level survey	1 spot from the existing bench mark	To confirm the elevation of staff gauging station.
Entire Study Area	Aerial Photograph Interpretation	1992 FINMAP and 1997 JICA	Understanding of present land use, geography and hydrology

The result was used for the preparation of hydrological study, geological interpretation and hydrogeological study.

Additional topographic survey was conducted for the new water supply facilities planned, such as water works and water distribution system in the Feasibility Study Stage (October – November, 1999).

The work done at that time included:

- Topographic mapping survey required for the newly proposed water supply system,
- Route survey along major pipeline, and
- Leveling survey.

3.2 Hydrological Investigation

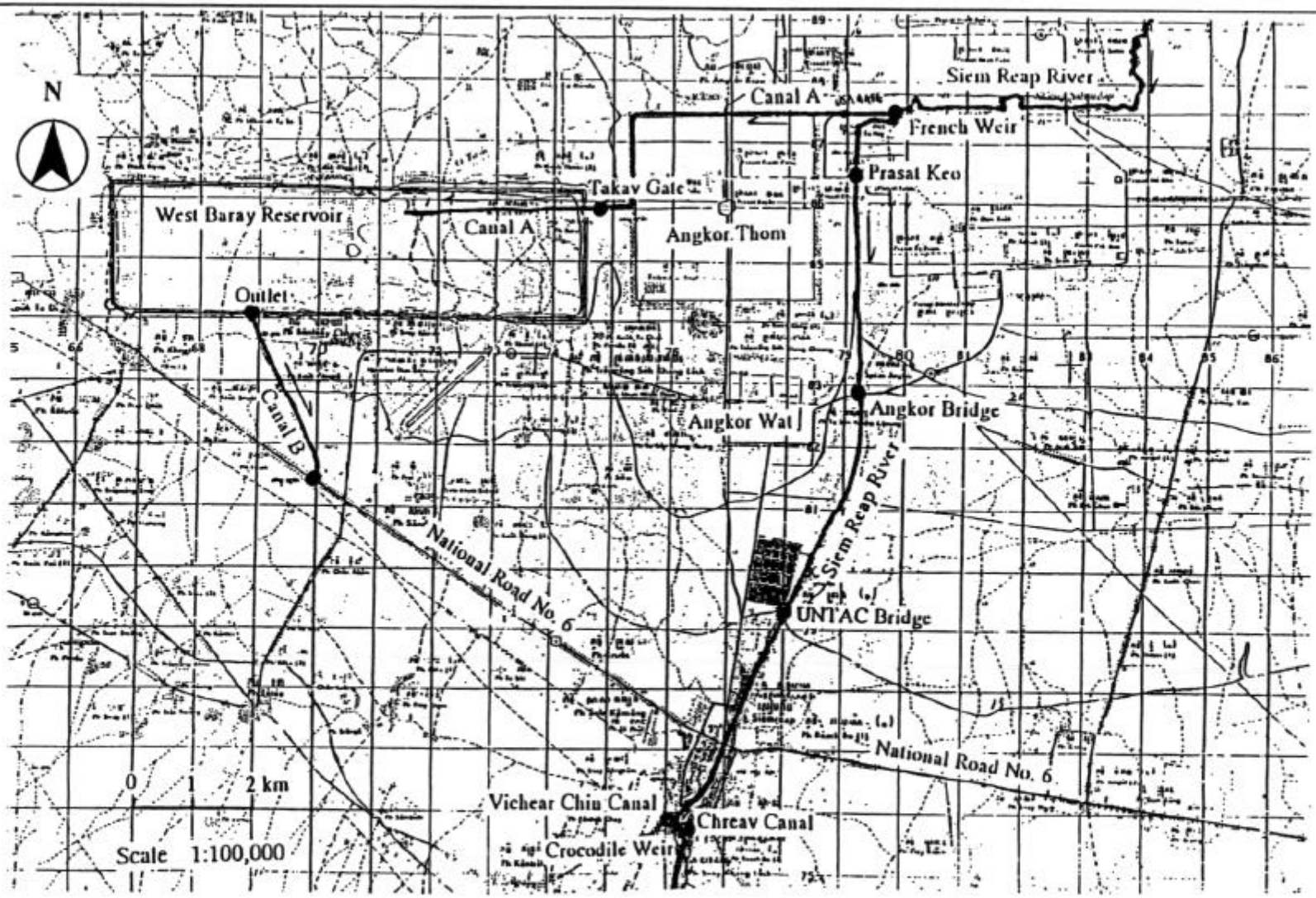
The hydrological investigation was carried out for the following three surface water sources for the purpose of water supply in the Study Area:

1) Siem Reap River;
2) West Baray, and
3) Lake Tonle Sap.

(1) Hydrological Condition of Siem Reap River

The tropical climate, occurring over Cambodia is characterized by two seasonal monsoons: the southwest monsoon (the rainy season) and the northeast monsoon (the dry season). Annual rainfall varies between 1,100 mm-1,800 mm, with an average of 1,418 mm (average in 19 years from 1979 to 1998). About 88% of annual rainfall (1,248 mm) falls during the rainy season from May to October. The climate in the Study Area is modified by the local topography, dominated by Lake Tonle Sap and the Kulen Mountains. Breezes reinforced over the lake are forced upwards due to the presence of Kulen Mountains and, on cooling, induce showers in the rainy season. The mean daily temperature varies only slightly between a high of 29.9ºC in April to a low of 24.5ºC in December. Average relative humidity ranges from 70% in March to 86% in September. The annual pan evaporation is 1,542 mm.

The Siem Reap River is the only permanent stream in Siem Reap Region (Refer to Figure 3.2.1). The French Weir constructed in 1937 is located in the northeastern part of the heritage area. An artificial canal (Canal A) constructed in 1939 diverts flow from just upstream of the weir and stores the rainy season flow in the West Baray. The river then flows through Siem Reap Town southward and it eventually discharges into Lake Tonle Sap downstream of Phnom Krom.



The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 3.2.1 Location of Hydrometry Points**
Japan International Cooperation Agency	

The Study Team has installed several stream gauges along the Siem Reap River and has conducted intensive hydrometry not only along the river but also on irrigation canals since 1997. The water level of the West Baray has also been measured frequently by the Study Team to supplement the data by the Hydrology Office in Siem Reap, MOA (Hydrology Office). The rating curves are prepared at Prasat Keo and the Angkor Bridge by using the hydrometry records of 1997 and 1998.

The peak discharge at the UNTAC bridge in September 30, 1997 is roughly estimated around 150 m^3/s. The flow gradually decreases from the end of the rainy season in November and reaches annual minimum value at the end of the dry season in April and May. The observed minimum flows at Prasat Keo in 1997 and 1998 are 0.80 m^3/s and 0.56 m^3/s, respectively. The observed minimum flow in 1998 at the French Weir and the Angkor bridge are found to be 0.65 m^3/s and 0.81 m^3/s, respectively.

It is essential to estimate the extended flow regime for 10 years of the Siem Reap River to analyze the availability of raw water. This was done based on the hydrographs at Prasat Keo, inflow hydrograph to the West Baray, and rainfall pattern.

(2) Hydrological Condition of West Baray

The bathometric survey of the baray was carried out by the Study Team in March 1997 and the contour map was prepared by using the survey result. The height, area and volume curve of the reservoir was prepared based on the contour. The effective capacity is estimated 48.6 million m^3 at present average water level of 25.0 m (approx. 19.6 m, MSL). The dead storage below the outlet gate is estimated only around 0.2 million m^3.

The preliminary water balance review of the baray is conducted based on the rising and falling curves of the reservoir water level of the baray (hydrograph) since 1992. The storage by rainfall and loss by evaporation are also taken into account. The supplied amount of water for irrigation is 32.0 million m^3 on average. It accounts for 66% of the total effective capacity. Around 6% of effective capacity are lost by evaporation during the dry (irrigation) season.

The remainder of irrigation use reaches 8.1 million m^3 on average, which is equivalent to 22,100 m^3/day for 12 months. The uncharged capacity also reaches 5.4 millions m^3 on average, which is equivalent 14,800 m^3/day for 12 months. More water resources can be produced from the present reservoir by introducing an effective integrated reservoir operation.

(3) Hydrological Condition of Lake Tonle Sap

This is the largest lake in Southeast Asia. Thus, water quantity is not a limiting factor for possible water abstraction. Water level will be the crucial factor in such case. In the Study Area, the daily water level of the lake has been measured continuously by Fisherman's Office in Siem Reap, MOA since May 1996. The probable maximum and minimum levels are analyzed as follows:

Probable Water Level of Lake Tonle Sap

Return Period	Maximum Water Level (m, MSL)	Minimum Water Level (m, MSL)
2-year	9.23	1.05
5-year	9.69	0.84
10-year	9.94	0.75
20-year	10.15	0.68

3.3 Geological and Geotechnical Investigation

(1) Geophysical Prospecting

Electric sounding had been carried out for a total of 103 spots in the Phase I. Resistivity of alluvial deposits ranges 50 - 3,000 ohm/m for the northeast area and 50 - 1,000 ohm/m for the south area. This reflects containing of groundwater. Resistivity by electric logging is correlative with the sounding results. Resistivity of diluvial deposits ranging 74 - 1,900 ohm/m for coarse sand is found in the north side, and 20 - 400 ohm/m for medium to fine sand is found in the southern side. Resistivity of Pliocene clay stone ranging 10 - 200 ohm/m by the electric sounding, and 5 - 20 ohm/m by the logging were also found in certain areas. In addition, basement rocks include shale, sandstone and silt stone, rhyolitic tuff, tuff breccia, granodiorite, and andesite dyke.

VLF electromagnetic prospecting of a total of 123 spots was carried out in the vicinity of the south area along the envisaged former river course to clarify an expected large quantity of good quality groundwater with low iron content. Average resistivity value of alluvial and diluvial sand layer is 20 ohm/m. Resistivity value higher than 20 ohm/m indicates the existence of former river traces. The area having the resistivity value less than 10 ohm/m may be occupied by contaminated groundwater with iron, and/or by unfavorable layer containing much clayey materials or finer particles than that of clean coarse sand of the former river deposits. The area stretching from the junction of road No.6 and airport road until 2 km east of WT4 shows an indication of the former river course.

(2) Geology

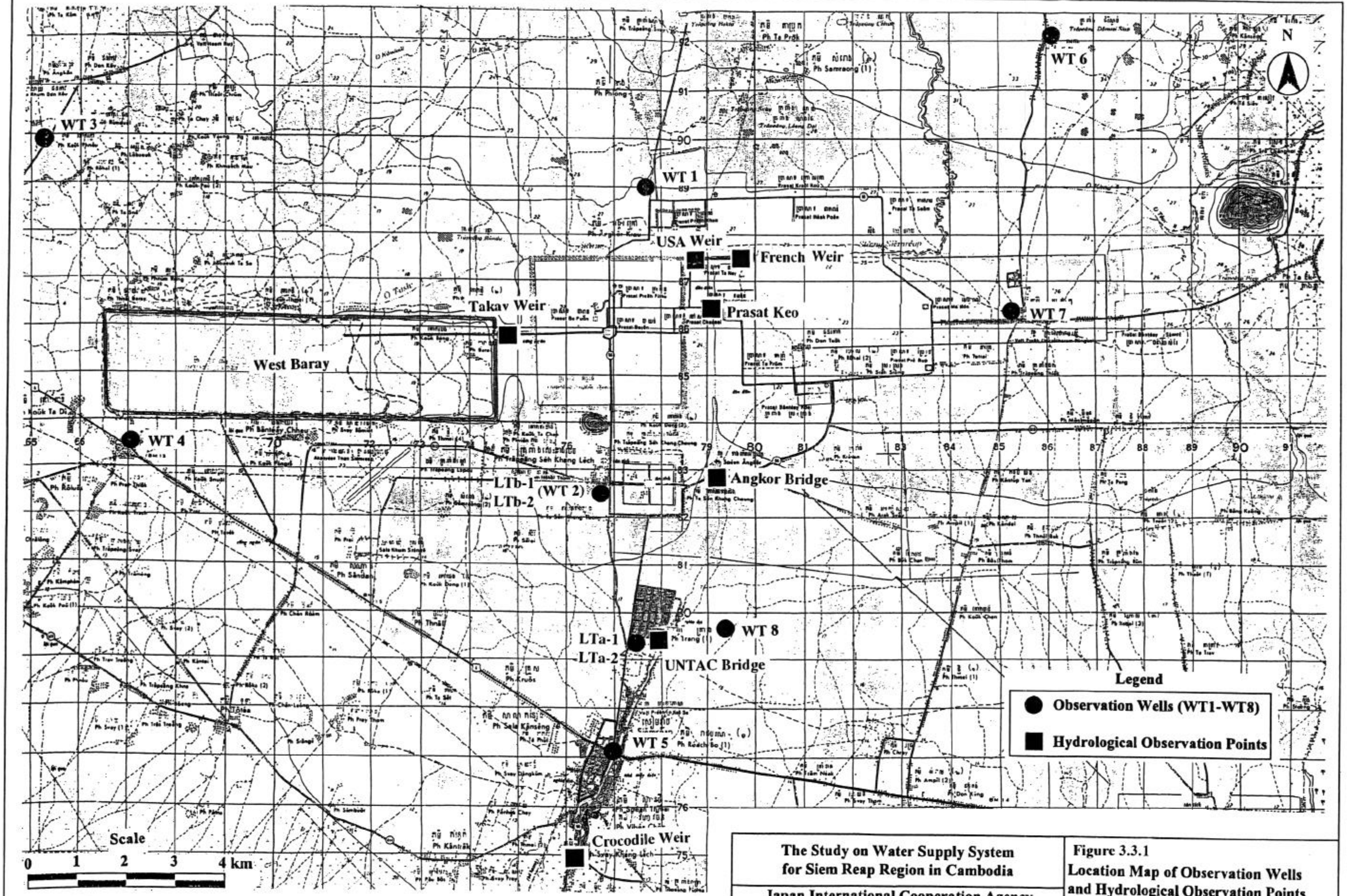
The Study area is composed of the Alluvial fan deposits, Diluvial deposits, Pleistocene sediments, Pliocene clay stone, Mesozoic sedimentary rocks and Paleogene volcanic rocks in descending order.

As shown in Figure 3.3.1, eight core drillings (WT1 to WT8) were carried out in 1997. The results were completely and effectively utilized for the simulation modeling. In total, 14 exploratory and observation wells were established. In the same locations of the core drilling except with WT1 and WT2, 6 observation wells were constructed for groundwater level monitoring. Two land subsidence monitoring stations, LTa and LTb, were established to monitor land subsidence and groundwater levels, each having two wells. For pumping tests, another four wells were constructed. The table below shows the dimension of the drilled holes.

Well Dimension and Monitoring Purpose

Well No	Depth (m)	Screen Depth(m)	Purpose	Materials
WT1	89.3	Abandoned		
WT2	95	61.38-73.20	Pumping test with LTb-1	PVC6"
WT3	80	20.38-32.20	GWL monitoring	PVC6"
WT4	80	13.38-25.20	GWL monitoring	PVC6"
WT5	100	42.38-54.20	GWL monitoring	PVC6"
WT6	80	13.38-25.20	GWL monitoring	PVC6"
WT7	80	44.38-56.20	GWL monitoring	PVC6"
WT8	95	67.38-79.20	GWL monitoring	PVC6"
WT9	40	26.38-39.20	Pumping test with LTa-2	PVC 6"
WT10	40	27.38-39.20	Pumping test with LTb-2	PVC 6"
WT11	80	61.38-73.20	Pumping test with LTa-1	PVC 6"
Lta-1	80	63.62-71.90	Land subsidence monitoring	100A,STPG
Lta-2	40	26.61-34.90	Land subsidence monitoring	100A,STPG
LTb-1	73	64.61-72.90	Land subsidence monitoring	100A,STPG
LTb-2	40	31.61-39.90	Land subsidence monitoring	100A,STPG

Note: Screen length is equally 12 m



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 3.3.1 Location Map of Observation Wells and Hydrological Observation Points
Japan International Cooperation Agency	

3.4 Hydrogeological Investigation

(1) Simultaneous Groundwater Measurement

A total of 96 existing wells were selected in Phase I, January 1997, for the groundwater level monitoring. Elevations for the 83 wells were surveyed in 1997 and 1998. Based on level survey data, groundwater contour maps were prepared. From the results of four years observation, it can be said that there is no notable difference in the seasonal fluctuation. This means that groundwater withdraw at present does not exceed the recharging quantity.

(2) Pumping Test

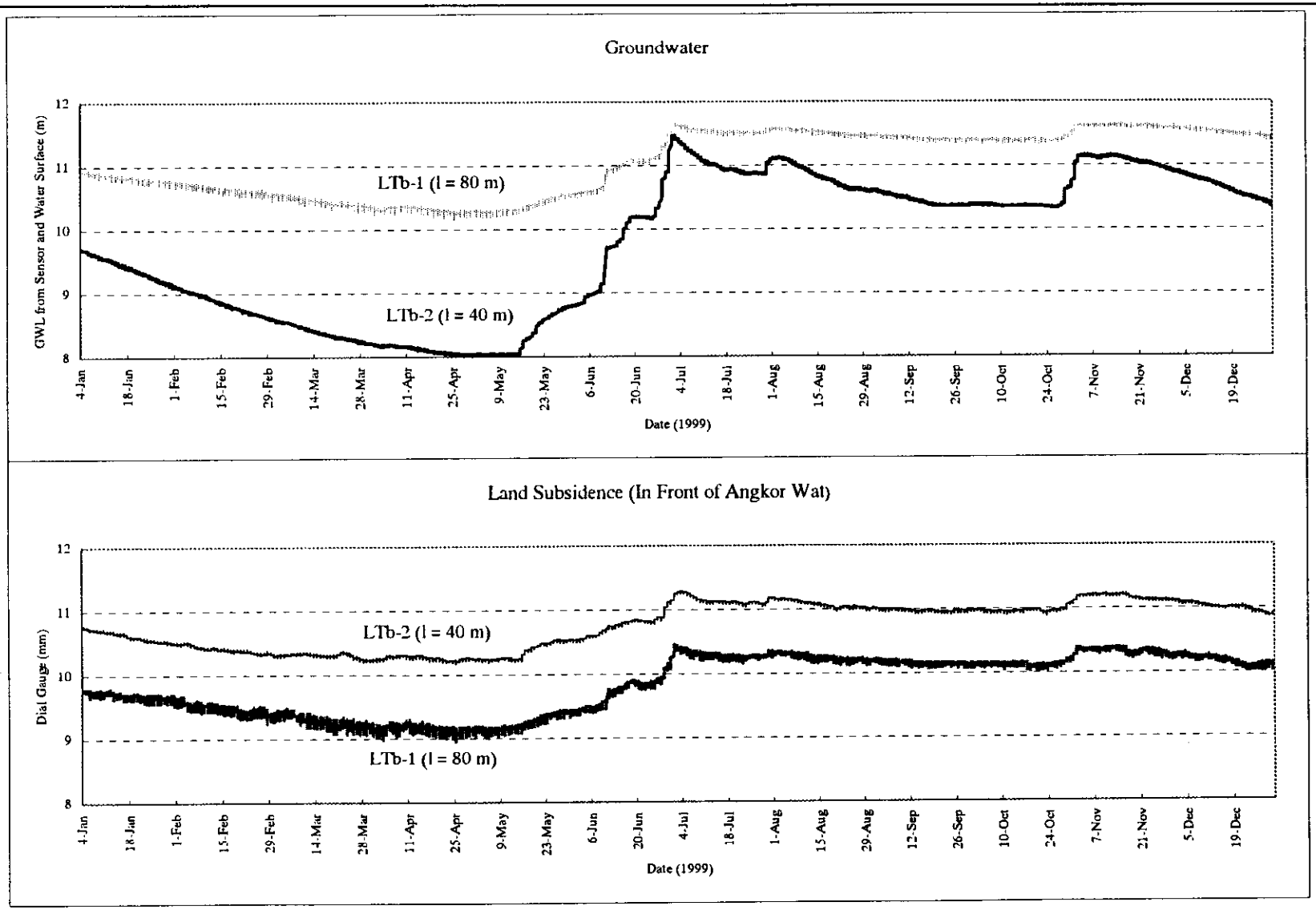
In total, 10 pumping tests were conducted in the course of the Study. The result reveals that the wells of WT4, LTa-2 and LTb-2 installed in alluvial and diluvial sand layer have a good capacity. Also WT5 and WT6 wells are second good performance group of wells. It is judged that the area near WT4 well can yield more than 444 liters/min.

(3) Monitoring of Groundwater Level and Land Settlement

A total of eight automatic monitoring units were installed at the eight locations. Almost all units had been recording well from February 1998 to present. This was used for an interpolation of the monthly simultaneous data of the existing wells. The two sets of monitoring units for upper aquifer and deeper aquifer had been installed at the teacher's training school (LTa) and in front of Angkor Wat (LTb), respectively. The data from these stations was used for simulation model. The records of the LTb-1 and LTb-2 installed in front of Angkor Wat were effectively used in this Study for the relation between land movement and GWL fluctuation. The data from February 1998 to the end of January 1999 reveal that the natural GWL fluctuation of 2.3 m was occurred. The land movement in the same period was recorded as 1.3 mm corresponding to the GWL fluctuation and it was found that the land movement is reversible. The record is shown in Figure 3.4.1.

3.5 Water Quality

Water quality of the four alternative sources are discussed here in order to find out required treatment facilities for each of the water sources. For the planning of future treatment plant facilities, present water quality is assumed to prevail. Measures should be planned in order to improve or at least maintain the present water quality for all possible sources.



The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 3.4.1 GWL Fluctuation and Settlement in front of Angkor Wat**
Japan International Cooperation Agency	

Groundwater quality for the existing wells was measured in 1997 both in wet and dry season. Temperature, pH, and Electric Conductivity (EC) were measured in-situ for the existing wells. Water qualities of the existing wells were again checked in February 1998. Hence, it became clear that most promising groundwater could be extracted near WT4 well, regular analysis of WT4 water has been carried out approximately once per month. Water quality of West Baray, Siem Reap River at Angkor Bridge, and Lake Tonle Sap near the boat station was also tested nearly once per month.

Main findings of the tested result are as follows;

(i) groundwater is acidic in nature, (ii) iron content is highest in the river water, (iii) water of Tonle Sap is the most polluted one among four alternatives and influenced by Mekong River, (iv) groundwater is not contaminated by organic contents, (v) water quality of West Baray is not varied by season, (vi) the river water is highly polluted by organic matters, (vii) the formation potential of Tri-Halo-Methane is very low in the groundwater, and (viii) turbidity is negligible in the groundwater.

It can be said that groundwater is the best among the four alternatives from the water quality point of view. Water treatment is necessary for the other three water sources if they are taken as drinking water source.

3.6 Social and Environmental Investigations

(1) Existing Urban Development and Tourism Plan

The Siem Reap Town is the administrative center of the province and important urban center. The town is also the focus for the region's economy and a major station for inter-regional transport and exchange. The immediate proximity of the Angkor archaeological site makes it the most important pole for tourism in the country.

Detail investigation of urban development and tourism plan was conducted by the Study Team. Firstly, the existing situation was analyzed in detail. Then, information on all proposed and ongoing projects were complied.

Investigations were conducted covering the present land use of the town, the development trends, the demographic plans, tourist attractions, tourism activities, proposed site capacity, and detail information on tourism and transportation. It is estimated that the number of visits, both domestic and international, to Siem Reap will be in the range between 250,000 and 500,000 per year in 2001, rising to 1,000,000 per year in 2006 (APSARA-UNESCO, 1996).

For the proposed and ongoing projects in urban planning, the Royal Decree of 1994, which defines the perimeter of protection of the Region was studied in detail. General strategies for the urban development as proposed by APSARA-UNESCO report was also analyzed. A related zoning sub-decree, serving to demarcate a hotel district in the town, was adopted by the Government in October 1995. In this area, about 20 hotels of four to five stars with 200 - 250 rooms are planned to be constructed in next 10 years.

A series of studies concerning tourism development at Angkor has been carried out over the past few years. According to the study named 'Tourism Development Strategy for Siem Reap' (July 1996), there would be 380,000 tourists visiting Angkor in 2001. An another study carried by the Ministry of Public Works and Transport states that the total number of visitor to Siem Reap will be around 400,000 and out of which around 350,000 will be foreigners in the year 2005 (Etude des aeroports du Cambodge, December, 1994). Also, the JICA Study Team critically reviewed tourism and transport development strategies.

(2) Social Survey

Under this Study, detail investigations on social sector were conducted. It was divided into three types of investigations: investigation on general social structure, investigation on Women in Development (WID) and Gender And Development (GAD) aspects, and a questionnaire survey on 'Public Awareness and Water Use'.

In the general social structure investigation, adequate considerations were given to society and life, living standard, education sector, health sector, and mine injury. Based on this study, critical constraints were identified and agenda for social sector was proposed. Finally social impact of water supply system was investigated.

Under the WID and GAD aspects, life of Cambodian women, their social status, access to health and education, programs for women, and situation of children were investigated. Finally, impact of water supply project on women and children were reviewed.

A public awareness and water use survey was conducted by JICA Study Team in February 1998. The objectives of the survey are to appreciate and to evaluate the knowledge and attitudes of the people of the town and its immediate vicinities in terms of water sources and use as well as sanitation awareness and behavior. This survey also focuses on willingness to use and pay for piped water supply system in addition to some key features of social and gender aspects. The results of this survey are considered as a key criterion for formulating a long-term water supply development plan in the Study Area.

(3) Environmental Investigation

Environmental investigations were carried out to grasp the current situation in water sources, water supply, water use, sanitary condition and social relation. Similar kinds of investigation were carried out both in dry and wet season to understand the seasonal difference on various aspects. Findings of these investigations are complied for Initial Environmental Examination (IEE) and Environmental Impact Assessment (EIA).

This investigation concerns with the environmental characteristics in the project area. These include the area's physical and ecological conditions, laws and regulations related with environment, water quality, water and sanitary related infrastructure and system, environmental management, the major features of human and economic development and quality of life values. These factors contain both the elements that determine the nature of the Siem Reap Water Supply Project and those that may be affected by the project.